Gulfstream®

A GENERAL DYNAMICS COMPANY

DETAIL TOOL 20

REVISION APPROVAL

REV LTR	REVISED BY	APPROVED BY	DATE	REV LTR	REVISED BY	APPROVED BY	DATE
B	Thomas Reimer	Steve Richie	08/12/13				

REVISION BLOCK

Revision Applicability:

Unless it is expressly indicated, the data in these revisions is not retroactive to parts, assemblies, installations, procedures, or processes that have been previously approved. Group Leads are required to review the revised material to determine the immediate impact it may have on the functions/processes within their group.

Rev	Section	Description Of Change	Retro-active
B	510	Added information to Drill Hole Color Code section.	NO

REVIEW BLOCK

The following area is used for periodic reviews of the SD20 document by designated personnel. The Documentation Group will review the comments and/or suggestions and may incorporate the information into the next revision of the document.

Date	Reviewer(s)	COMMENTS OR SUGGESTIONS

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Appendix

Section I

STANDARD DATA FOR SHEET METAL FABRICATION

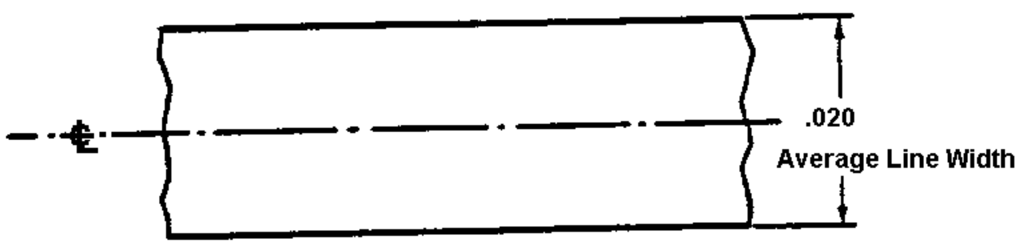
Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

LAYOUT

1.0 **Measurement Techniques:**

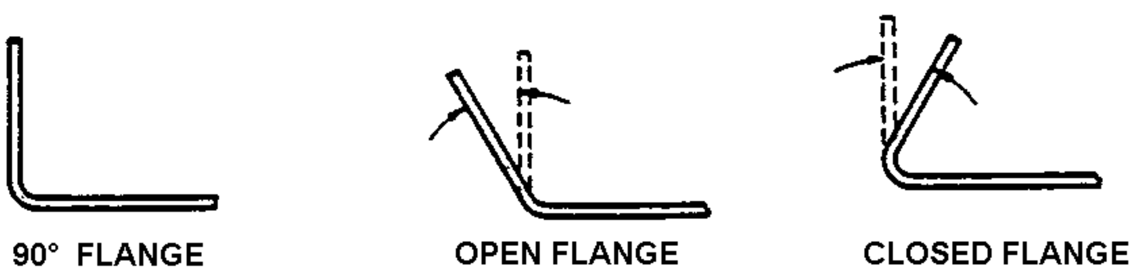
- Work-piece sizes are determined by Photo Lofts, Engineering White Masters, Electronic Models, Flexible White Masters, and measurements given on an Engineering print.

- Measurements made by using lines on PL's, EWM's, and FWM's shall be taken from the center of the line to reduce the possibility of introducing errors from varying line widths.



2.0 **Flanges:**

- Flanges are bent 90° to the body of the part unless specified otherwise. A flange bent less than 90° is said to be open.

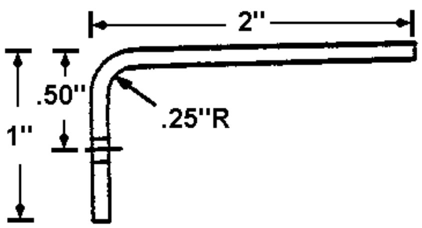


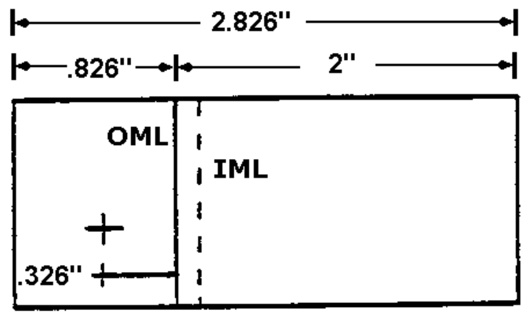
Example: A flange bent 60° is "open 30°"; a flange bent 120° is "closed 30°". Particular attention should be paid to the angle involved. By custom, in the Bend Allowance Charts, the angle referred to as the bent-up angle, is the angle through which the material is actually bent. In the Bend Deduction Charts, the angle referred to is the enclosed angle, which is the supplement of the bent-up angle.

3.0 Locating Holes on Flat Patterns:

- When locating holes on a flat pattern, which are not shown on the flat pattern, but appear on the formed part, the following procedure should be used:

Distance from OML to hole - Bend Deduction = Flat Pattern Hole Distance

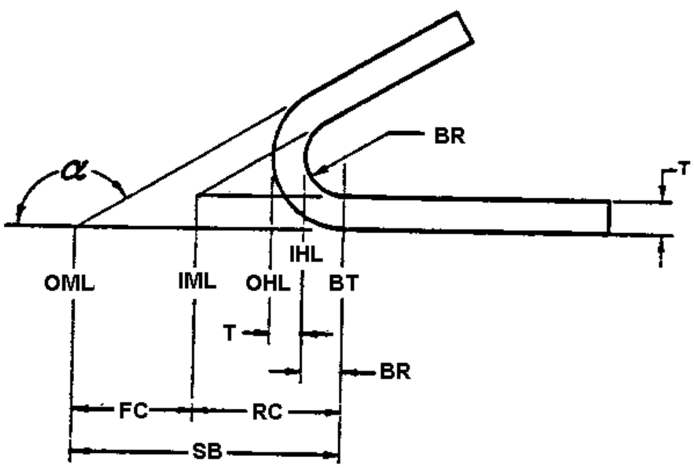




Hole Locations on Drawing	**Flat Pattern**
.050" Material	.500" (Hole Distance on Drawing)
.174" Bend Deduction	.174" (Bend Deduction)
	.326" (OML to Hole Distance on Flat Pattern)

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

FORMING ANGLES and BENDS in SHEET METAL



T	**=**	**Material Thickness**
FC	**=**	**Form Correction**
IML	**=**	**Inside Mold Line**
OML	**=**	**Outside Mold Line**
OHL	**=**	**Outside Heel Line**
IHL	**=**	**Inside Heel Line**
BT	**=**	**Bend Tangent**
BR	**=**	**Bend Radius**
RC	**=**	**Radius Correction**
SB	**=**	**Set Back**
α	**=**	**Degree of Bend**

Since the material thickness, bend radius, and degree of bend are always given, the other values may be easily found.

$$FC = T \times \tan \frac{\text{(degrees of bend)}}{2} = \text{distance from IML to OML}$$

$$RC = BR \times \tan \frac{\text{(degrees of bend)}}{2} = \text{distance from IML to BT}$$

$$SB = (BR + T) \times \tan \frac{\text{(degrees of bend)}}{2} = \text{distance from OML to BT}$$

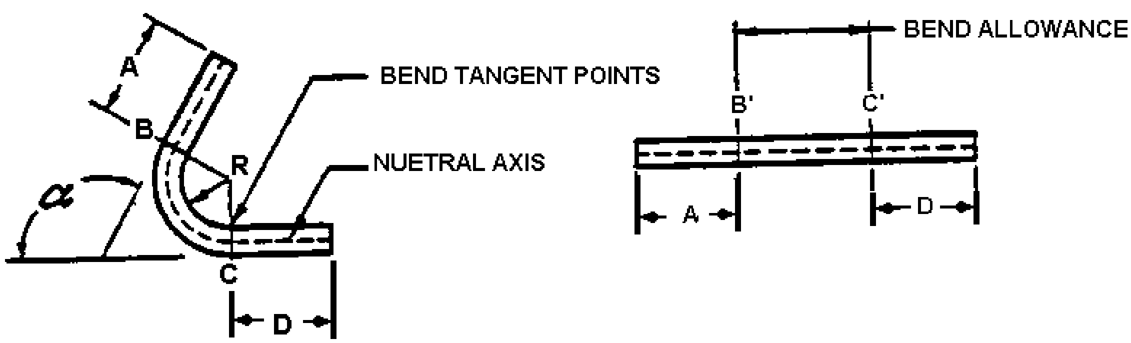
Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

FLAT PATTERN DEVELOPMENT

- The length of sheet metal from the beginning to the end of a bend, measured along the neutral axis (a line near the center where the metal is neither stretched nor compressed) is the bend allowance. To develop the flat pattern of a part, this length of arc must be found.

- There are three principal methods used to find this length of arc:
  Use bend allowance when bend tangents are known, use bend deduction when the outside mold point is known, and use of an electronic model.

Bend Allowance:



- Bend allowance is the distance along the neutral axis between bend tangents, and is based on the formula:

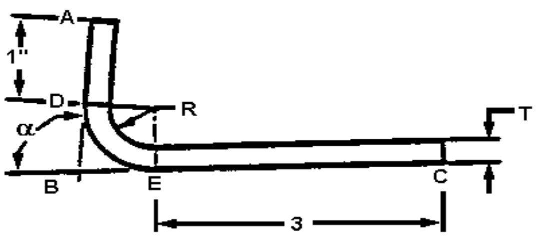
  Bend Allowance = (.01743R + .0078T) α

  Where,
  R = inside radius of bend
  T = part thickness
  α = number of degrees of bend

- Tables of bend allowance will be found in Appendix 1. These values are for 1 degree of bend, and must be multiplied by the number of degrees of bend to find the bend allowance.

Example 1:

Developing a Flat Pattern Using Bend Allowance



BEND RADIUS	=	$^{3}/_{16}$"
ANGLE α	=	5° Closed
MATERIAL	=	.063" Thick

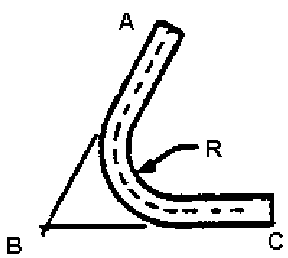
AD = 1"
EC = 3"

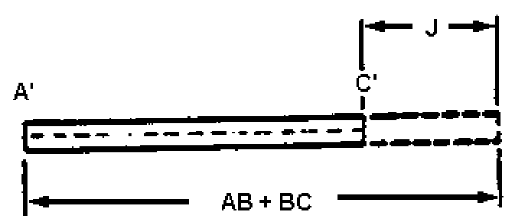
Bend allowance (from chart) for $^{3}/_{16}$" BR, .063" material.

Bend Radius 95°	=	.00377 x 95	=	.358"				
Developed Length	=	AD	+	CE	+	Bend Allowance,		
or,		1"	+	3"	+	.358"	=	4.358"

Bend Deduction:

- The method for finding the flat pattern length of a part is to use the bend deduction chart. The advantage to the bend deduction method is that bend tangent points are not necessary.



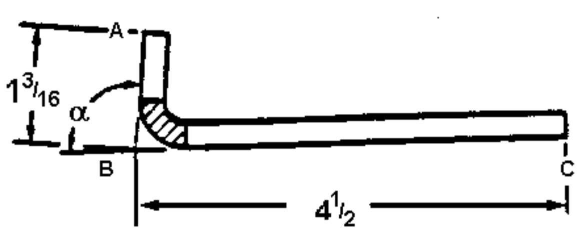


- The length of the flat pattern AC is AB (plus) BC (minus) J, where "J" is the bend deduction value read from the chart (Appendix 3) and point "B" is the outside mold point of the bend. To use the chart, lay a straightedge from bend radius (top of chart) to part thickness (bottom of chart). Read across from degrees of bend. The intersection with the straightedge shows bend deduction value "J" (slanting lines).

Note: These same values are also available in the Bend Deduction and Bend Allowance booklet.

Example 2:

Developing a Flat Pattern Using Bend Deduction:



BEND RADIUS = $^3/_{16}$"
ANGLE α = 5° Closed
MATERIAL = .063" Thick

Developed length = AB + BC - J

From the bend deduction chart,

"J" for .063", 5° closed, BR $^3/_{16}$" = .190"

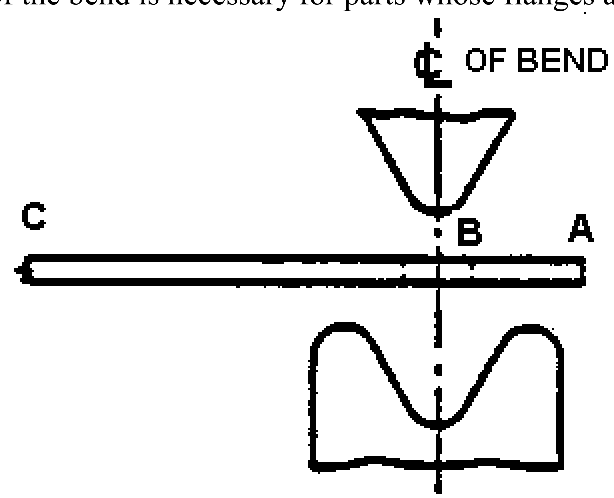
Developed length = AB + BC - J

= $1^3/_{16}$" + 4 $^1/_2$" - .190"

= 1.1875" + 4.500" - .190" = 5.4975"

Center of Bend:

- AB minus $^1/_2$ "J" or BC minus $^1/_2$ "J" gives the distance from the end of either flange to the center of the bend. The center of the bend is necessary for parts whose flanges are formed in a press brake.



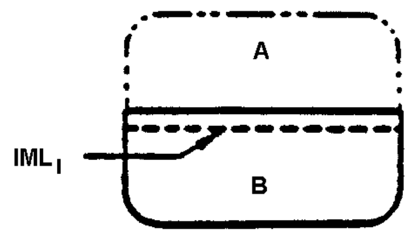
Electronic Model:

- Once the 3D model is established, use the "analysis" function in CADAM/CATIA to determine the length of arc on the total length of the part.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MOLD LINE REVERSAL

- Usually, the web or body of a part is held in position and the flange is bent. Sometimes it is desirable to hold the flange and bend the web. In the following illustration, A is the flat pattern of the flange and B is the web.

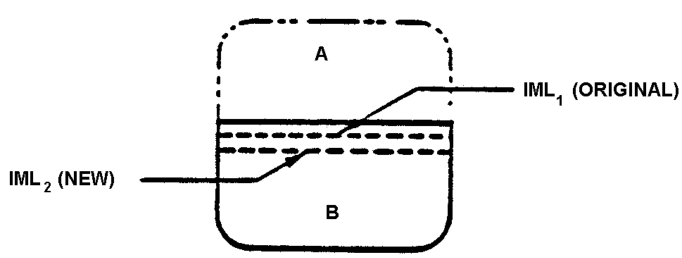


- To hold the flange and bend the web will require a new inside mold line differing from the one shown. This new inside mold line can be found when the original mold line is straight. Curved mold lines require other consideration, covered below.

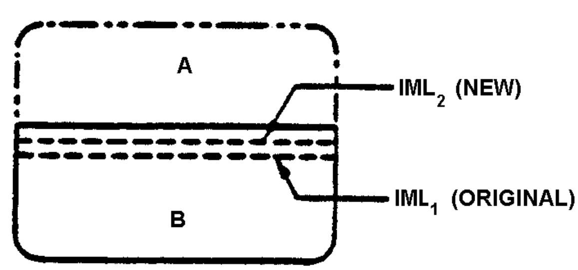
The following method may be used to locate this new mold line:

FC	=	Form Correction	=	Distance from IML to OML (Appendix 9)
J	=	Bend Deduction (Appendix 3 or Bend Deduction booklet)		
D	=	Distance from original IML to new IMLD	=	.2 FC - J

If "D" is negative, the new IML is measured in the direction opposite the flange, ie: mold lines overlap

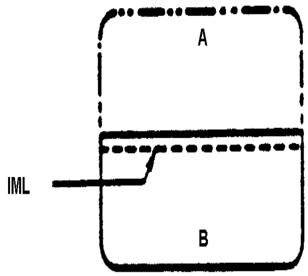


If "D" is positive, the new mold line (IML_2) is measured in the flange direction, i.e.: the mold lines <u>do not</u> overlap.



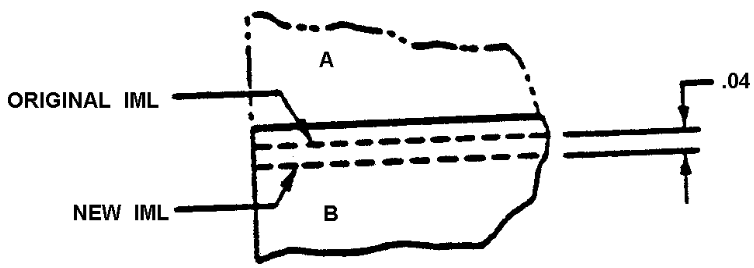
Distance "D" is measured from , and parallel to, the original mold line.

Example:



BEND RADIUS	=	$^{1}/_{8}$"
ANGLE α	=	10° closed
T	=	.040" thick
FC	=	Form Correction
J	=	Bend Deduction

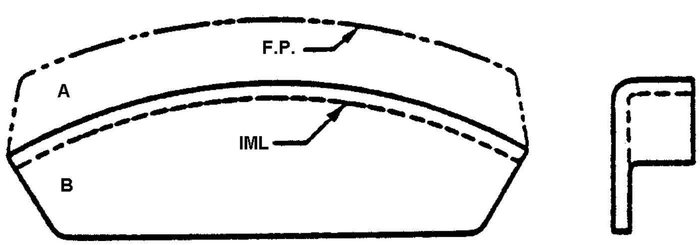
FC (from Appendix 9) = .0477"
J (from Appendix 3 or Booklet) = .144"
D = 2FC - J = 2(.0477") - .144" = .096" - .144" = -.048"



Since "D" is negative, it is measured away from the flange (A).

Curved Mold Lines:

- For any part with a curved inside mold line, such as illustrated below:



It can be seen that it would be practically impossible to form, except by holding the flat web "B" and bending the flange (A). No switching or reversal of mold lines should be attempted, since the top of the block would then be curved.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

SPRINGBACK (Radius and Mold Line Correction)

- When sheet metal is bent or formed, allowance is usually made for springback. To accomplish this, the material is bent past the desired angle.

- Templates for forming tools (PBT, FDT, HBT, etc.) do not allow for springback. The springback allowance must be developed into the forming tool.

- Three events happen in bending:
  1- Springback changes the bend angle.
  2 - The mold line moves.
  3 - The radius of the part changes.

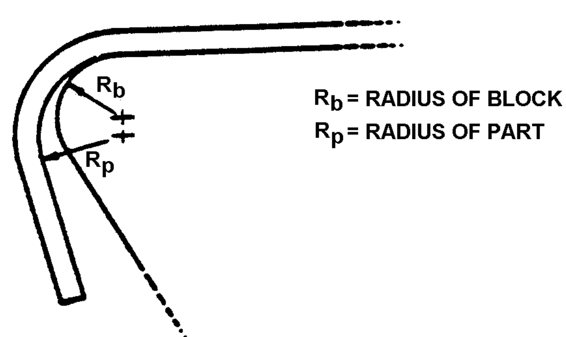
Springback Development in Press Blocks:

- Springback must be developed for forming tools. There is no formula to match all conditions. Appendix 10-1 to 10-13 gives typical values of springback for certain materials and conditions. It is based on rubber press forming and 90° straight-line bends. A list of correction factors are provided for angles from 0° - 135° in Appendix 10-14.

- The values are not accurate for all forming conditions. They represent an average of many trials. Springback for bent or curved bends must be developed for each individual case.

Press Block Radius Correction:

- Angles with springback above a few degrees cause the part to come off the forming tool with a larger radius than the tool.



- The block radius must be reduced to maintain the correct part radius. The corrected block radius, $R_{b,}$ is found by multiplying the part radius, R_b, by the ratio of the angles of the part (P) to the angle of the block (B), or

$$\mathbf{R_b = \frac{P}{B}\ R_p}$$

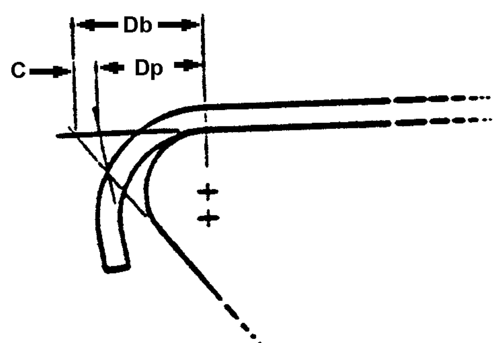
Example: A part with bend radius $^1/_4$" 20° closed bend (P = 110°), with 10° springback (B = 120°). The block radius should be:

$$\mathbf{R_b = \frac{110°}{120°}\ (.250) = .230}$$

(use $^{15}/_{64}$)

<u>Mold Line Correction:</u>

- Angles of springback above a few degrees combined with closed angels may result in a significant change in the mold line position, C.



- The mold line of the block may have to be extended beyond the mold line of the part, so that the springback will return the part to the designed mold point and maintain the correct flange length.

- "C" is the difference between the radius correction distances for the part and the block.

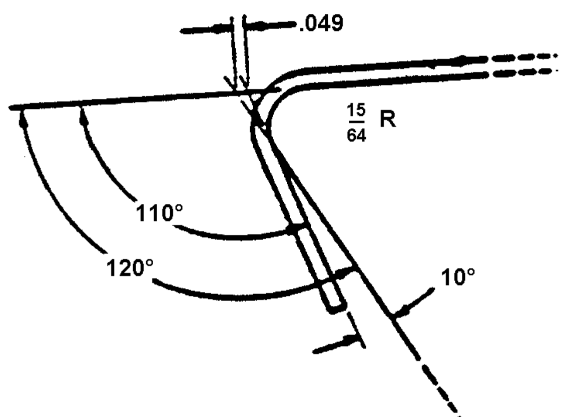
Example: Using the dimension in the above example, the distance from inside mold line to bend tangent, is taken from Appendix 8.

D_p (part), 20° closed, $^1/_4$ B.R. = .357"

D_b (block), 30° closed, $^{15}/_{64}$ B.R. = .406"

Distance C = D_b - D_p = .049"

The mold point of the press block should be .049" outside the mold point of the part, the radius of the block should be $^{15}/_{64}$", and the block angle is 120°.



Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

GENERAL/MISCELLANEOUS

1.0 **Production Holes Drilling:**

- Any tool fabricated for drilling production holes shall be made to accept a standard drill guide, unless otherwise specified. Sizes shall be:

Diameter in Template	Diameter to Drill
# 10	# 50, # 40, # 30
$^1/_4$"	# 21, # 10
$^5/_{16}$"	$^1/_4$"

- For holes other than those listed, drill a # 30 pilot hole at the location and open to size with a secondary operation. Holes between $^1/_4$" and 1" in diameter may be pierced or opened to size from the pilot holes as specified by Manufacturing Engineering. When the hole is in excess of 1" diameter, it will be routed, unless the tolerance will not permit; then Manufacturing Engineering will specify how it will be done. "Steel stamp the hole size at each hole or with the tool code (if all holes are same size)" (for DU, DT, DST, DSU).

2.0 **Size Limitations:**

2.1 Press Blocks:

- No press block shall exceed 5" vertical height, above the base or table, for rubber forming over male tooling.

2.2 Router Templates and Jigs:

	Minimum	Maximum
CBT	None	9" x 14"
URT	1" x 12"	12" x 48"
DRB	5" x 12"	36" x 72"
ROJ	10 $^1/_2$" x 10 $^1/_2$"	36" x 72"

- When used for stringers, the tool may be 144" long. This tool will be used on a pin router and have no setback.

3.0 Locating Templates (DU, DT, DST, SDU, PT, SRT, SCT, STT):

Note: Locating templates can be generated from electronic models and NC machining. Reference the appropriate sections in Section III of this manual for detailed information.

- These tools will generally require specific directions of Manufacturing Engineering for fabrication. They may be used by Production, as defined by Manufacturing Engineering, for the purpose of locating holes, joggles, brakes, shear lines, and parts in assembly material. For flat parts, .125" aluminum alloy will be used. Curved or formed parts may be fabricated from .125" fiberglass lay-up, or as defined by Manufacturing Engineering. Flat, curved, or formed parts may also be machined using electronic models and NC machining.

3.1 Brake Template (BT)

- The template will reflect the location of the brake, the bend radius, and the degree of the bend if other than 90°. The angle will be stated in degrees open or closed. No call out of an angle for a 90° bend will be required.

3.2 Drill Template (DU, DT)

- The template is used to locate the part to be drilled and guide the drill for drilling. A drill template may be used on flat and formed parts. The code DU will be used for flat templates and DT for formed templates. Flat templates may be structured to match peripheral trim of the part for location, or may be made with bank pins to position work piece. If pins are used, then scribe trim lines to reflect position of work piece on template. Formed templates will have bank points by nesting, pins, rails, or utilization of existing holes in the part for pin-up to locate for drilling. Any tooling holes and/or coordinated holes will have full size template bushings.

3.3 Drill and Scribe Template (DST, DSU)

- A template used to scribe trim lines, locate hole pattern, and guide the drill on parts to be drilled. Parts will be trimmed on the band saw following drill and scribe. The code DSU will be used for flat parts and DST for formed parts. Follow the same guidelines as DU and DT to locate.

3.4 Joggle Location Template (JLT)

- The template will be used to locate joggles. The application may be for flats, angles, tees, or channels (formed or extruded), and will be specified:

3.4.1 *Request Material:*

- Material to be the same as that for Production's part.
- Cut size to be the same as part size when ready for joggle.

3.4.2 *Layout:*

(may be NC machined - reference Section III for detailed information)

- Paint the surface with layout fluid.
- Scribe the station locations per the drawing.
- Scribe joggle locations per dimensioned drawings, mylar, electronic master, or ME instructions (as required).
- Scribe lines to reflect top and side locations for critical end of joggle (each scribe line should have a # 50 hole drilled at both ends).
- Identify banking end.

3.4.3 *Identify:*

- Steel stamp

3.5 Punch Template (PT):

- The template will be used in conjunction with punch press type operation for the purpose of single hole locations using an individual punch set up to fabricate the part. The template shall reflect location and diameter or type hole.

3.6 Shear Template (SRT):

- The template will be used as a guide for close tolerance shear size when fractional dimension tolerances are not permissible per Engineering dimensions.

3.7 Scribe and Trim Template (SCT, STT):

- A template used to apply trim lines on parts that will be trimmed on a band saw. The code SCT is used for flat templates and STT will be used for formed parts. Use the same procedure for location as DU and DT.

Section II

STANDARD DATA FOR DETAIL TOOLS

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

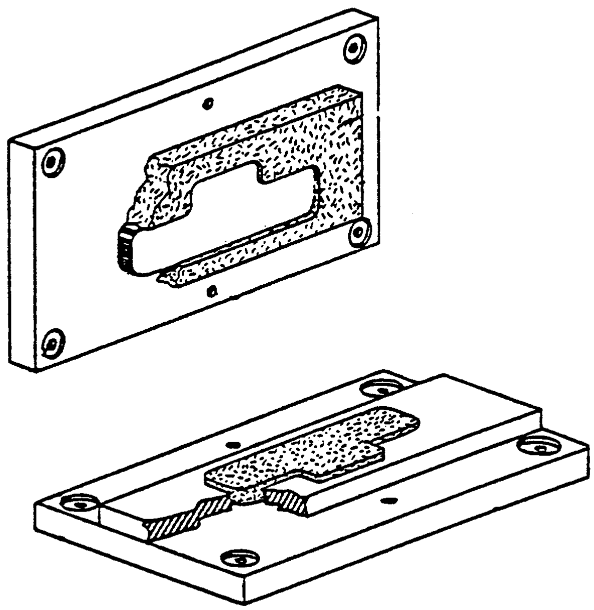
TOOL STEEL PANCAKE DIE (BD, BPD)

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition and Scope:**

- The Pancake Blanking Die is one in which the work-piece does not drop through the die but is stripped from the die with cork. The material used in the die and punch is air hardening tool steel.

- This die is restricted to the steel and steel alloys, and thicknesses that are listed under Tonnage Factors (see table in paragraph 2.6).



2.0 **General**

2.1 Types of Dies:

SD20.14-1 Blanking Die:

- for parts with no holes and no edge slots less than 0.300" wide

SD20.14-3 Compound Blank and Pierce Die:

- for parts with no webs or slots less than 0.300" wide and no more than 1 hole per square inch average

SD20.14-5 Progressive Blank and Pierce Die:

- for all parts not categorized in -1 or -3

2.2 Shear Tonnage Calculation:

- The shearing force required to die cut a work-piece is determined by a simple formula using a tonnage factor listed in "Tonnage Calculation Information" (table in paragraph 2.5).

  T = Perimeter (include all holes) x Tonnage factor

2.3 Die Set Selection:

- The correct die set number for -1 and -3 dies is determined by adding 1.500" (+ 000" / - .250") to each side of the part outline (length and width) and choosing the die stock size nearest the total dimensions (reference the "Die Stock and Die Set Chart" in paragraph 2.9).

- For -5 dies in which the first stage contains holes of .250" diameter or less, the edge of the most extreme hole may come within .750" of the die edge. The other sides are treated as in the -1 and -3 dies (reference "Part Layout for Die Set Selection").

2.4 Ordering Information:

Size Class	Width	Length
A	0.300 to 4.000	0.500 to 4.000
B	0.300 to 11.000	4.000 to 11.000

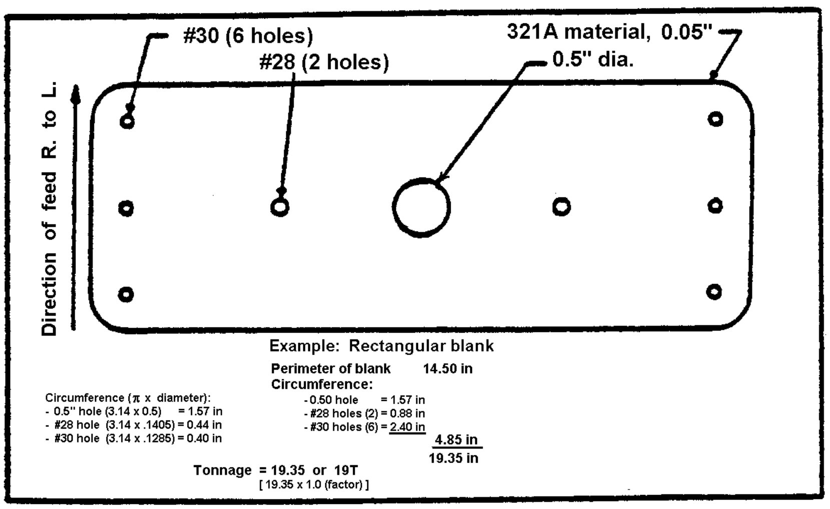
Refer to the following paragraphs for an explanation of how to determine the tonnage and die set number.

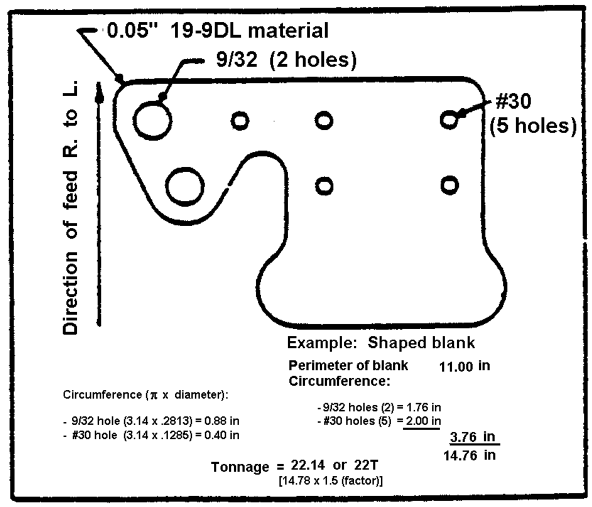
2.5 Tonnage Calculation Information:

Formula: (Perimeter of Blank + Circumference of Holes) x Tonnage Factor = T

Example: Blank and Pierce 2" x 2" piece with a 1" diameter hole, material 19-9DL .062" thick

Solution: (8" + 3.140") x 1.900" = 21.17 = 21T (rounded out to a full number)





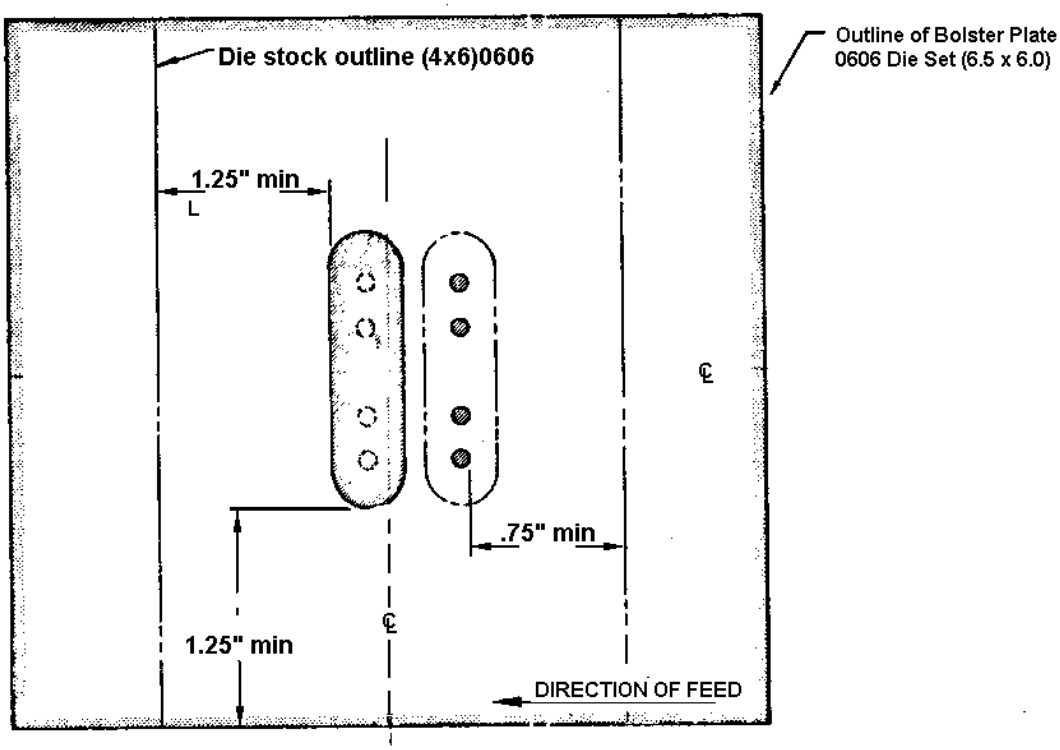
2.6 Tonnage Factors:

Thickness	CMS 4130 ANN	CRES 301A 302A 321A	CRES 19-9DL	CRES 301 $^1/_4$H 302 $^1/_4$ H	CRES 301 $^1/_4$H 302 $^1/_4$ H 17-7PH	CRES 301 FH 302 FH	CFS 1010 1020 ANN
Up to .008	--	.150"	.250"	.250"	.300"	.400"	--
.010"	--	.200"	.300"	.350"	.400"	.500"	--
.013"	--	.250"	.400"	.450"	.500"	.650"	--
.015"	--	.300"	.450"	.500"	.600"	.750"	--
.018"	--	.350"	.550"	.600"	.700"	.900"	--
.025"	.700"	.500"	.750"	.850"	1.000"	1.250"	--
.031"	.820"	.600"	.950"	1.050"	1.250"	1.550"	.600"
.037"	.950"	.750"	1.100"	1.250"	1.500"	1.850"	.750"
.050"	1.350"	1.000"	1.500"	1.700"	1.900"	--	1.000"
.062"	1.600"	1.250"	1.900"	--	--	--	1.250"

2.7 Circumference of Common Holes (3.14" x Diameter):

Hole Dia.	Circumference	Hole Dia.	Circumference	Hole Dia.	Circumference
.063"	0.20"	.25"	0.79"	.6875"	2.16"
.098"	0.31"	.3125"	0.98""	.75"	2.36"
.125"	0.39"	.375"	1.18"	.8125"	2.55"
.1285"	0.40"	.4375"	1.37"	.875"	2.75"
.159"	0.50"	.50"	1.57"	.9375"	2.95"
.1875"	0.59"	.5625"	1.77"	1.0"	3.14"
.1935"	0.61"	.625"	1.96"	--	--

2.8 Part Layout for Die Set Selection:



2.9 Die Stock and Die Set Chart:

Die Stock Size R to L		F to B	Die Set Number
4.25	x	6	0606
6.25	x	8	0808
8.25	x	10	1010
10.00	x	12	1212
13.00	x	8	1509

3.0 **Materials**

3.1 Die and Punch:

- .37 AISI-A6 (7416-4516) for alloy steel
- 50 AISI-A6 (7416-4516) for 17.7 PH

3.2 Bolster Plates:

- TD176 (7416-8062)

3.3 Support Strips:

- .37 x .37 CFS (7416-4216-044)

3.4 Stripper:

- Cork (7416-6511)

3.5 Pierce Punches:

- TD230 (7416-8074)

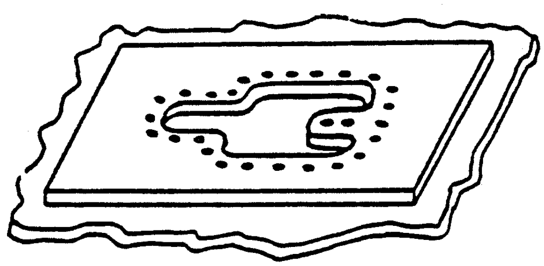
4.0 **Construction**

4.1 Punch:

- Outline, hole location, and hole diameter are determined by the Master Flat Pattern Template (TTH).
- Provide threaded or clearance holes for screws used in fastening the punch to the bolster plate.
- Provide reamed holes with slug clearance when piercing punches are in the die portion (ref: Compound Dies).
- Edge Finish - RMS32 minimum
- Heat-treat the punch to Rc 58-62.

4.2 Die:

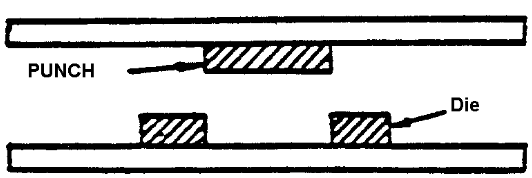
- Outline, hole location, and hole diameter are determined by the TTH. Use .370" thickness for normal parts and .500" when greater strength is needed.
- Match the punch outline and provide clearance according to the gage and type of material.
- Provide threaded or clearance holes for screws, used in fastening the die to the bolster plate.



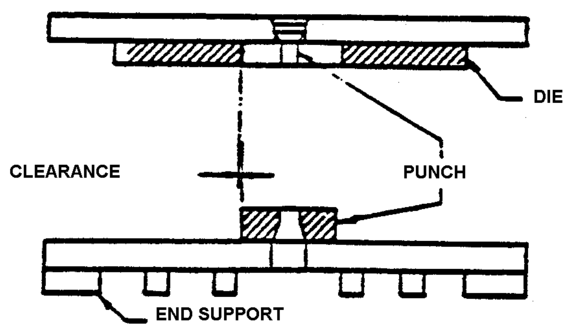
- Provide reamed holes for press fit or piercing punches.
- Heat treat the die to Rc 58-62.

4.3 Assembly:

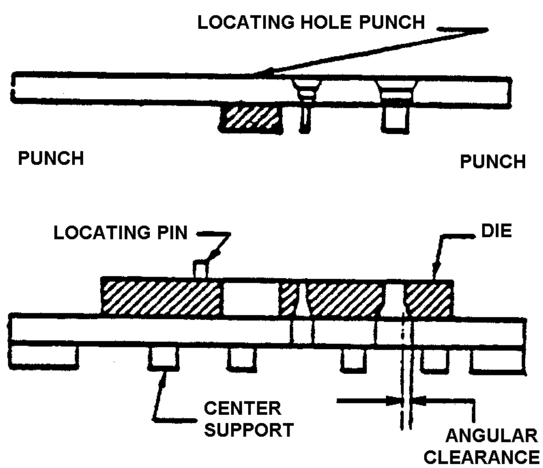
- Fasten the punch and die to the top and bottom plates of the TD176 bolster. Coordinate the location of the die and punch with the standard bolster plate hole pattern.
- Blanking dies have the die punch in the upper plate and the die in the lower.



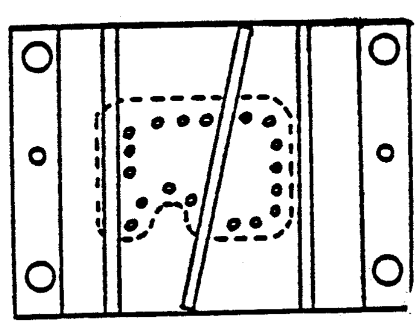
- Compound dies have the die and piercing punches in the upper plate and the punch in the lower.



- Progressive dies have the punch and piercing punches in the upper plate and the die in the lower.



- Weld the support strips under the bottom bolster plate to provide slug clearance where required.
- Grind the face of both die and punch parallel to the bolster plate.



- Fit the cork stripper around the punch and in the die cavity. Use sufficient thickness to strip the work-piece during the tryout.

5.0 **Tolerance**

- Outline - ± .005" in relation to TTH
- Hole Location - ± .002" in relation to TTH
- Hole diameter tolerance is controlled by Engineering loft or drawing callout.

6.0 **Inspection**

- The completed die is inspected by comparing a die-produced tryout part with the TTH, for outline and hole location.
- Hole diameters shall be inspected with measuring tools.

7.0 **Identification**

- Refer to SD20.510, "Tool and Equipment Identification" for specific instructions.
- In addition to the regular inspection process, also stamp the work "FRONT" and the required tons on the edge of both bolster plates viewed by the operator when the die is set up.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

ROUTER JIG (ROJ)

Note: In addition to the information contained in the SD20.107, please adhere to the following criteria when requesting NC data for a ROJ.

- **.375" aluminum will be used unless otherwise specified.**
- **The tool will have a .250" router guide with .030" setback for the remaining .125" of the thickness.**
- **There will be a minimum of two # 30 tooling holes in a neutral area when production holes cannot be used.**
- **The tool will be stamped "DO NOT ROUT" near lightening holes that are input by tooling.**

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

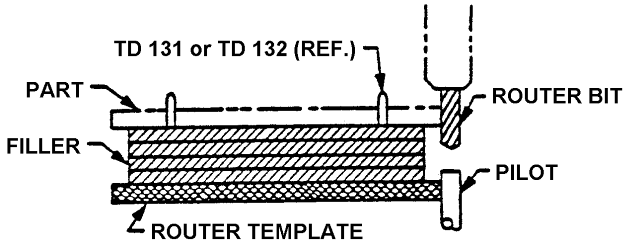
1.0 **Definition:**

- A Router Jig is a flat base router template type tool for holding and guiding a flat or formed work-piece during the routing operations on pin routers (reference Figure 1).

2.0 **Scope:**

- This tool is particularly suited to producing flat parts, but can be used for contoured cross sections which can tolerate a cut edge that is not normal to the face of the part.
- It can be expected to produce work-pieces with good tolerance and edge finish.
- Since this tool does not provide for drilling operations, it is possible to have the drilling done with another tool at a different location.
- For operator safety, the minimum size of the tool is $10^1/_2$" x $10^1/_2$".
- The maximum size is 36" x 72".
- Stringer tools may be 144" long.

Manufacturing Engineering Note: Where the "floating head" router is available, the HRJ is recommended as a preferred substitute for the same applications.



VIEW OF ROJ IN USE

Figure 1

3.0 **Construction:**

3.1 Materials:

3.1.1 *Router Template:*

- Make from $^1/_8$" aluminum alloy sheet, 2024-T3 or 2014-T6 bare.

3.1.2 *Filler:*

- For sizes less than 24" x 24", use $^3/_4$" thick phenolic fiber laminates.
- For larger sizes up to 36" x 72", use $^3/_4$" thick grade A/C exterior plywood.
- For light duty composite and aluminum/honeycomb ROJ's smaller than 36" x 72", use aluminum faced honeycomb panels A89003 (.887") and A89011 (.500").

3.2 Procedure:

3.2.1 *Router Template:*

- Trim router template to outline of the TTH (SD20.113).
- Transfer the pickup-hole pattern from the TTH to the router template.
- Tooling holes shall be # 30 for work-piece thickness up to .125". Greater thickness requires # 10 holes. Work-pieces which contain only # 40 holes shall have # 30 tooling holes added in the work-piece or in tooling ears (SD20.276). Tooling ears are not required in the TTH.

3.2.2 *Filler:*

- Trim filler material .030" ± .015" inside the router template outline, except on internal cuts where distance between cut edges will not permit cutback. Use the router template, located and fastened by the dowels, as the guide for the outline.

CUTTER and PILOT PIN SIZES		
Outline	**Cutter Diameter**	**Pilot Diameter**
Standard	.250"	.250"
Internal Cutouts	**Cutter Diameter**	**Pilot Diameter**
Standard	.250"	.250"

- The first cut in trimming the filler material shall be slightly more than $^1/_2$ the material thickness. The remaining material is removed by turning over the filler and re-pinning the TTH on the opposite side (reference Figure 2).

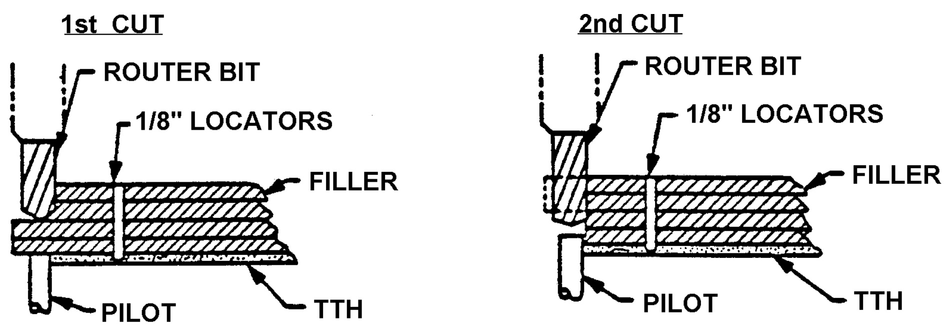


Figure 2

- For routing large internal cutouts, cut a $^1/_2$" wide x $^3/_8$" deep groove in the filler along the cutout outline. The center material shall remain as a support for the part material and locating pins may be placed in this area instead of in tooling ears.

- For added support of formed parts, the filler material shall be contoured as required. Support is only required under the edges that are to be routed (reference Figure 3).

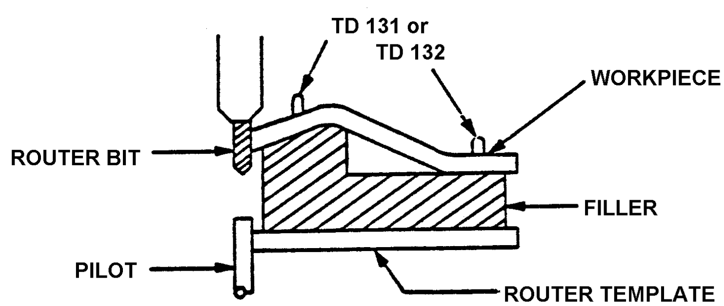


Figure 3

- When routing extruded cross sections, support is required under the surface to be routed. The filler may be trimmed to give support to the edge to be routed (reference Figure 4).

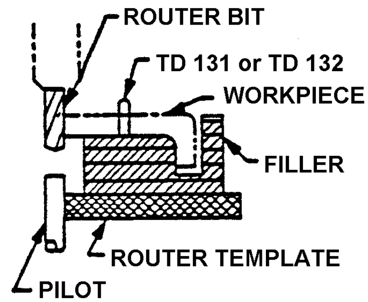


Figure 4

3.2.3 *Work Locations:*

- Pickup pins shall be located along the edge and spaced approximately every six inches. However, there shall be at least three pins for every routed part regardless of size.

- Attach router template with # 6-32 inserts to aluminum faced honeycomb panels, flush with template surface per MEPS 2200-12.

3.2.4 *Assembly (Plywood/Phenolic):*

- Attach the router template to the phenolic filler with $^1/_2$" long # 6-32 flat head machine screws, flush with the router template surface. Use # 6 x $^1/_2$" long flat head wood screws for fastening to the plywood.

4.0 Tolerances:

- Coordinate hole pattern and part outline to the TTH. Tolerance allowed is ± .005" from the TTH on each edge and ± .002" for the hole centers.

Note: All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

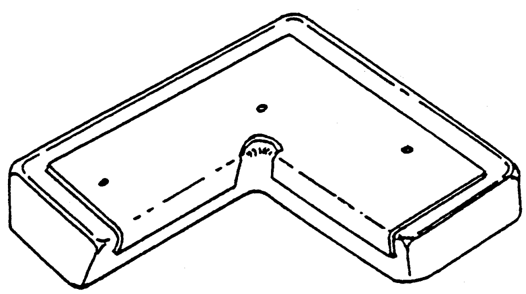
FORM BLOCKS (Rubber Forming) (PB, PBH, WPB, HPB)

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

HPB	**High Pressure Block**	**PB**	**Press Block**
WPB	**Verson Press Block**	**PBH**	**Press and Hammer Block**

1.0 **Definition:**

- The form blocks in this standard are all male forms in the shape of the inside of the required work-piece (part) as determined by a PBT. They require the use of a confined rubber pad under pressure to form the work-piece. This fabrication standard covers the construction features that are common to all the blocks and variations that are restricted to individual types.



1.1 HPB - High Pressure Block:

- Made to form extreme contours and joggles with good definition and a minimum of hand hammering.

1.2 WPB - Verson Press Block:

- Made for "C" size and larger parts in a rubber bladder type forming press (not for closed angles over 30° on block).

1.3 PB - Press Block:

- Made to form parts with simple bends.

1.4 PBH - Press and Hammer Block:

- Same as PB but with 1° springback allowance to permit hand hammering to complete the forming.

2.0 **Tool Size Limits:**

2.1 HPB - High Pressure Block:

- Block Height (max.) = 2" (oblate platen), 3" (round platen).
- Block and Flat Pattern (max.) = $^1/_2$" inside platen outline.

2.2 WPB - Verson Press Block:

- Block Height (max.) = 9".
- Block height shall be as low as possible.
- Use block thickness closest to the maximum flange and bottom of block.
- Block Area (max.) = 1" block 28" x 112" (3" deep tray).
- Subtract 1.500" from the width and length for every .500" increment over 1" in height.
- Blocks with closed angles greater than 30°, including springback, shall not be used on the Verson Press.

2.3 PB - Press Block:

- Block Height (max.) = 4"
- Block Area (max.) = 36" x 72"

2.4 PBH - Press and Hammer Block:

- Block Height (max.) = 4"
- Block Area (max.) = 36" x 72"

3.0 **Tool Ordering:**

- The aluminum and masonite blocks shall be produced in a tool shop.
  Use the standard tool fabrication estimate.

- The steel blocks shall be produced in a tool and die shop.
  Use three times the standard tool fabrication estimate.

4.0 **Materials:**

4.1 Aluminum Parts to be Formed:

4.1.1 *Greater than .063"Thick*

- Any T3 and T6 temper aluminum alloy tool material greater than .063"

4.2.1 *.063" Thick or Less*

- Masonite

4.2 Steel and Titanium Parts:

- Tool Steel, AISI - A6 (GAC7416-4516) in the annealed condition with decarburized surface.

5.0 **Construction (general):**

5.1 Tooling pins shall be added at the discretion of the tool maker or at specific request per tool order.

5.2 Locating Pins (per PBT):

5.2.1 *# 30 Hole in Work-piece:*

- Drill # 31 hole through the block and open up to the # 30 within .120" of the bottom.

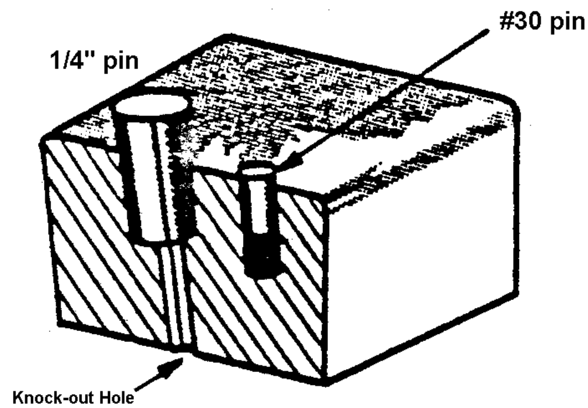
- Press fit .125" diameter CFS pin (rounded on top) flush to the bottom.

5.2.2 *# 40 Hole in Work-piece:*

- Drill # 43 and open to # 40 and install $^{3}/_{32}$" diameter CFS pin (rounded on top) flush to bottom.

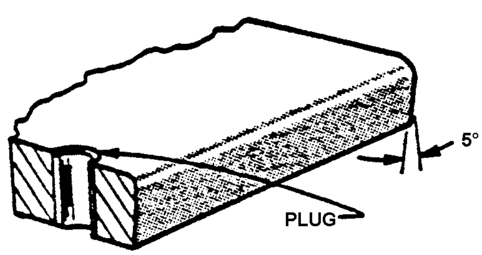
5.2.3 Pins are to project .120" through the part to be formed. Pins are to be no higher than twice the thickness of the material from face of tool.

5.2.4 Blocks over 3" high shall have # 40 and # 30 pins bottomed in a 1" deep hole. Larger diameter pins require a knock-out hole.



5.3 Locating Holes:

- Use locating holes in blocks that form flange angles greater than 5° closed.
- Masonite and plastic form blocks for angles over 5° closed and work-piece over .063" thick require reinforced locating holes.
- Press fit an aluminum alloy plug to be drilled to locating hole diameter.

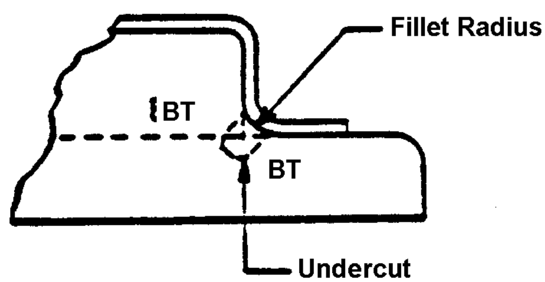


5.4 Outline:

- Scribe mold lines and other details from PBT.
- Overall size of all form blocks shall be kept to the minimum necessary to form the part.
- On sides that do not have a mold line, add approximately $^7/_8$" with a $^3/_4$" radius.
- Blocks over 3" height shall have approximately $^7/_8$" added with a $^3/_4$" radius.

5.5 Fillet Radii:

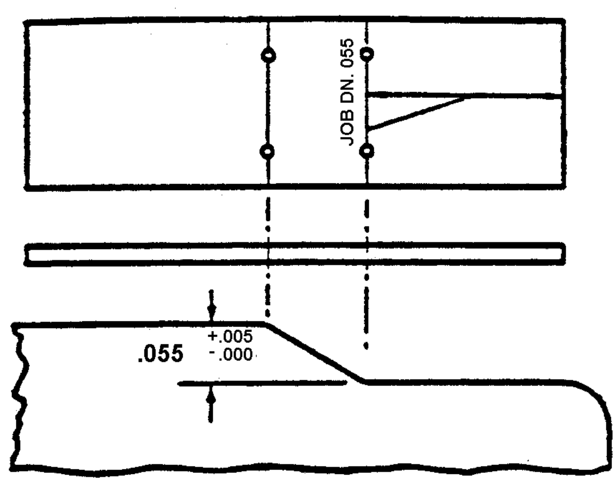
- Fillets are required on the working areas of all form blocks.
- They shall be machined to the required radius whenever possible.
- When necessary, grind a groove in the corner and wipe in an epoxy paste (GAC # 7416-5403-550) to form the radius.



5.6 Joggles:

5.6.1 *Side Joggles*
Per PBT, joggle corrections are already included. The joggle relief, as illustrated in Appendix 7, is required on all forms.

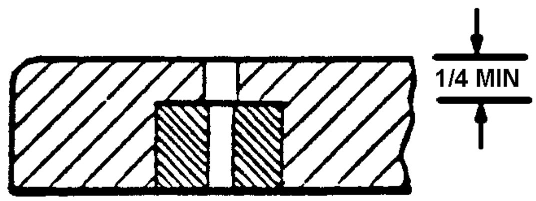
5.6.2 *Top Joggles*
These are scribed on the PBT without correction. Add .003" to the depth when fabricating the block.



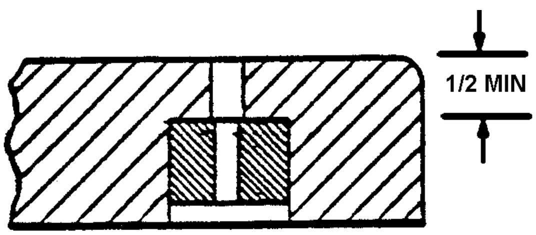
5.7 Bushings:

- Press-fit install all bushings from the bottom of the block.

- When the bushing can be flush with the bottom, a minimum of .250" shall remain between the bushing and the forming surface.



- When the bushing is entirely inside the block, a minimum of .500" shall remain.



5.8 Bases:

- Apply bases only to:

  High, narrow blocks (higher than width)

  Split Blocks

  Horse-shoe shape blocks

  Multiple identical blocks

  Blocks with an insert or dam

- Use $^1/_4$" thick aluminum alloy plate for bases and fasten to the block with $^1/_4$" flat head machine screws.

- The base shall be the same size as the block outline, except add 1" on sides when the flanges are formed.

- Round all edges and corners.

5.9 Nesting:

- When work holes in the PBT do not provide a good failsafe, a nest shall be provided for the outline with approximately $^1/_{32}$" clearance.

- Nests are required for blocks using cover plates.

- Nest will be attached to block (or cover plate) with screws. "DO NOT USE RIVETS".

5.10 Cover Plates:

- Cover plate is always made for HPB, PBH, and HB.

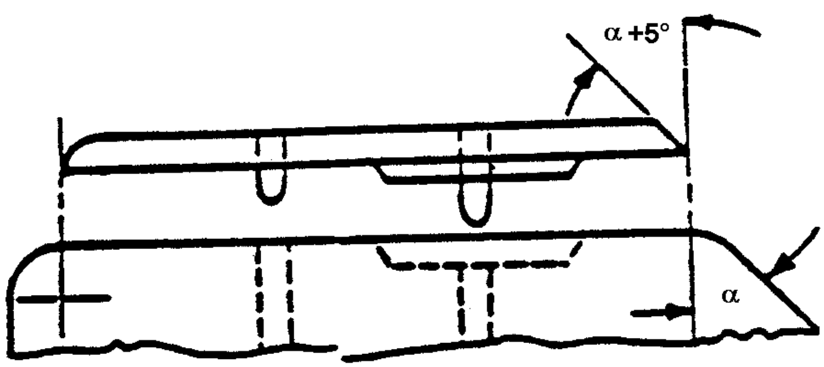
- Cover plate is made for WPB and PB, only if required for proper forming.

- Cover plates shall contain guide pins for alignment. Use $^1/_4$" pins for most blocks. Larger pins shall be used for very large or heavy covers.

- Lightening hole forming plugs (refer to Appendix 11) shall be included in the cover plate, if required.

- The edge of the cover plate shall be at the bend tangent except in high-shrink areas where the edge shall extend over the bend tangent by one part thickness.

- On open angle blocks, relieve the edge of the cover to the bend angle plus 5°.



5.11 Protective Covers:

- Protective covers may be applied only to HPB's and then only upon specific instructions on the tool order.

- These covers are made from any .040" thick "O" temper aluminum alloy. Rough cut outline to TTH, form shape, paint "red" and stamp this Legend.

Example: "cover for 123B00000-11 HPB".

5.12 Forming Dams and Inserts:

- When wrinkles occur on a work-piece "shrink" flange (outside curve), it may be necessary to incorporate a "dam" per SD20.277. The toolmaker shall contact the tool order writer for approval.

- When tearing occurs on a work-piece "stretch" the flange (inside curve), it may be necessary to incorporate an "insert" per SD20.278. The toolmaker shall contact the tool order writer for approval.

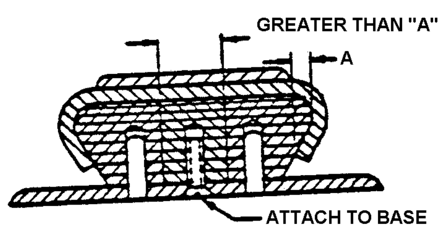
5.13 Lightening Holes:

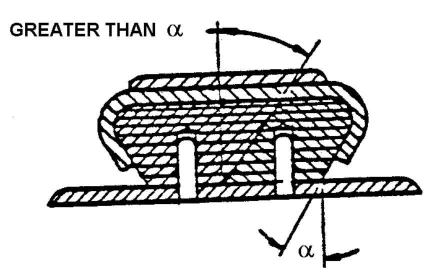
- Correct lightening hole diameters are listed in Appendix 11.

5.14 Split Blocks:

- Parts that lock on the form block when formed, require that the block be split or pieced.

- Two methods of splitting form blocks are acceptable as illustrated.





- Split the blocks before cutting the contour. The removable section(s) shall be slip-fit on dowel pins mounted in the base.

5.15 Rework:

- Holes or gouges shall be filled with epoxy paste (reference Metalset A3 or A4 GAC # 7416-5403-400 or 7416-5441-565). No unplugged holes are permitted.

- Rework that requires the addition of block material shall automatically require the fabrication of a new block. No welding on form blocks is permitted.

- Rework of elongated pin holes require an "0" size plug, re-drilled to proper size.

5.16 Finish:

- Non-working edges shall retain their saw-cut finish.

- Working surfaces including bend radii shall be smooth (approximately RMS 63 surface finish) and free of irregularities.

6.0 **Tolerances:**

6.1 Bend Radius:

3 pl. decimal: ± .005"

2 pl. decimal: ± .015"

6.2 Mold Lines:

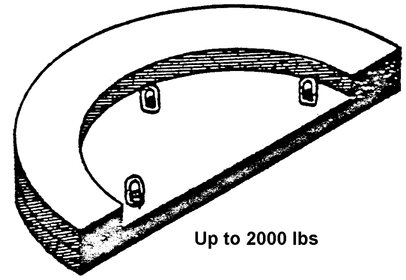
to PBT: ± .005"

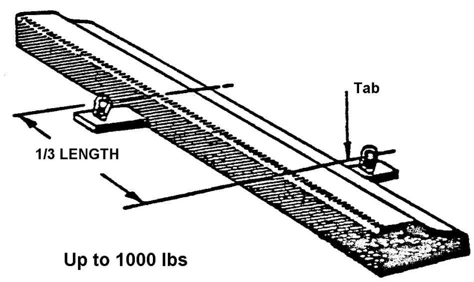
6.3 Flange and other Angles:

$\pm {}^{1}/_{2}°$

7.0 **Lifting Provisions:**

- TD115-102 lifting eyes are required on all form blocks over 100 pounds.
- Threaded hole for eye is $^5/_8$" - 11" x 1" deep.
- Locate lifting eyes as suggested in this illustration.
- Blocks shall be balanced with only minor tipping.
- Lifting eyes are removed during forming and the threaded hole is covered with a $^1/_2$" diameter clevis bolt (reference AN28) during forming.





8.0 **Identification:**

- Identify in accordance with SD20.510. Stamp the base and cover plate, if applicable.
- Single blocks that form both left and right hand parts shall be stamped to show which side forms each dash number.
- All flange angles, including 90°, shall be stamped on the bottom of the block located by the PBT and approximately $^1/_2$" back from the edge. Any tool with a base plate shall have angles identified on the base.

  Flange angles derived from MUF's and not from the PBT, shall have the following note stamped on the bottom:

  DEVELOPED FLANGE ANGLES HAMMER PART TO BLOCK

  "Free" flanges per PBT shall be identified by stamping "FF" with a $^3/_{16}$" metal stamp on the bottom of the block as located by the PBT. "Free" flanges are those that do not mate with other parts.

  Identify all air passage flanges by stamping with metal stamps "Air Passsage" near the flange.

- All joggle depths shall be stamped on the bottom of the block, determined by the PBT and approximately $^1/_2$" back from the edge. Any tool with a base plate shall have joggle depth identified on the base.

- All blocks are to have their ends painted according to the press designated for use as follows:

  Lake Erie ------------ Red

  Williams/White ---- Green

  Verson --------------- Blue

  Wood ----------------- Yellow

9.0 **Inspection:**

- Tool Inspection checks tools per SD20 Manual, tooling, tools, and tool order.
  Buy-off or reject on inspection card only (not on tool).
- Tool shall be submitted to the Production foreman (or designee) with inspection card.
- Production forms part within two hits (preferably 2 parts).
- First article parts submitted to Production Quality Control.
- Quality Control inspects parts. Buy-off or reject on inspection card.
- Inspection card forwarded to Production foreman (or designee) for signature.
- Inspection card and tool returned to steel stamp (by QC) and close out.

Note: **If at any point, the tool is rejected, it will be returned to tool inspection, who will tag the tool and describe the problem. The toolmaker will rework the tool and the process will begin again. Should the Production foreman (or designee) disapprove of the tool order (even though it forms a good part), he must contact the person who wrote the order to negotiate a change.**

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MASTER FLAT PATTERN TEMPLATE (TTH),
MASTER FLAT PATTERN TEMPLATE, SELLERS (TTS)

Note: In addition to the information contained in SD20.113, please adhere to the following criteria when requesting data for a TTH.

- **The originator is to provide a full size Engineering mylar for inspection purposes. NC Programming is to provide a full size mylar if the flat pattern has to be developed.**
- **Add targets to any NC developed mylar.**

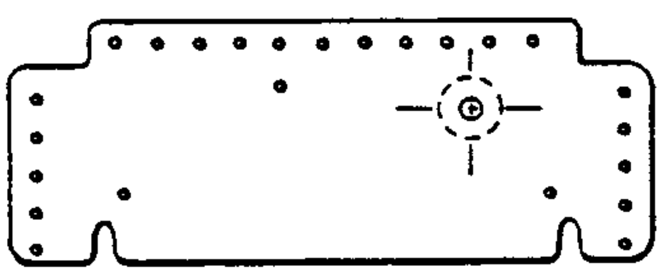
Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition and Scope:**

- A Master Flat Pattern Template is made to the exact outline and hole pattern of an Engineering part.
  This standard describes three types of TTH's:

TTH	Description
SD20.113-1	Used as a master for all template type tools except router templates.
SD20.113-3	Used as a master for flat router tools.
SD20.113-5	Used as a master for punch and die tools. Also for fabrication for TTS.

Note: This standard shall apply to all Gulfstream TTH's and TTS's, except when otherwise specified in the tool fabrication instructions.



1.1 Ordering Information:

- SD20.113-1 shall be ordered when one of the following conditions applies:
  - Part size is oversize
  - Holes are added that are not on loft
  - Flat pattern or hole location is shop-developed
  - Part is coordinated with other parts
  - Part category is I & R (Interchangeable or Replaceable)
  - Closer tolerance holes in part
  - Other requirements deemed valid by the Manufacturing Engineer

- SD20.113-3 or -5 shall be ordered whenever a flat router or punch and die tool is ordered.

2.0 Equipment:

- Aluminum Alloy, 2024-T3 or 2014-T6, .063" thick

- Template stock (aluminum) with the part outline photographically reproduced (etched) on one side, shall be used when available.

3.0 Construction SD20.113-1:

3.1 Outline:

- Cut and file the outline to the lofted line.

Note: On all exterior surface skins, cut and file to + .015" - .000" unless tool order instructions specify otherwise.

- Outlines that are not lofted shall be determined by Engineering dimensions, including bend corrections and hole locations.

- Tooling ears shall be included in the outline when required by the tool order instructions. SD20.276, Tooling Ears Standard, shall be used as first preference.

3.2 Hole:

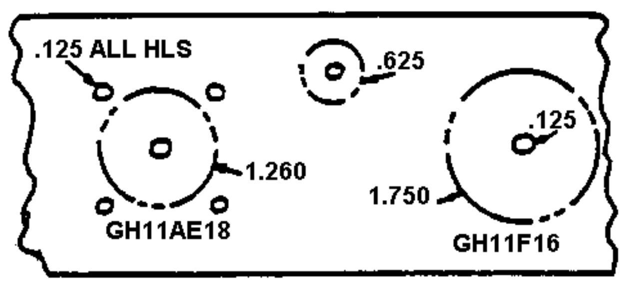
- Drill a # 30 (.1285") diameter hole at all hole centers except at locations of holes smaller than # 30. For holes less than # 30, use # 40 holes (.093") regardless of actual hole size. Hole size shall be stamped next to each hole except when a large number of holes are the same size.

Examples: ALL HOLES # 30 EXCEPT AS SHN
ALL HOLES .250"

- When required by the tool order instructions, specific hole markings may be omitted.

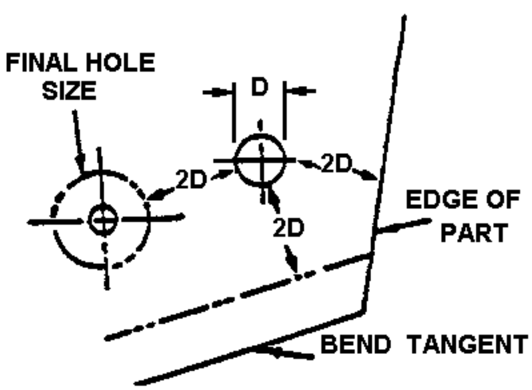
- Standard holes and hole patterns (reference GAH11AE, GAH11Y, etc.) shall have all holes that are shown. Holes and hole patterns shall be identified by stamping the full callout and all hole sizes (reference GH11Y and GH11AE).

- Holes larger than .500" shall have the full outline scribed on the template. (Not necessary if the line is lofted.).



- Tooling holes and their sizes shall be added when specified by the tool order or loft to locate the part on subsequent tools such as form blocks.

- Tooling holes shall be located in a neutral area. Location shall be no less than two times the tooling hole diameter from the edge of the hole to the edge of the template, another hole edge, or a bend tangent, as shown below.

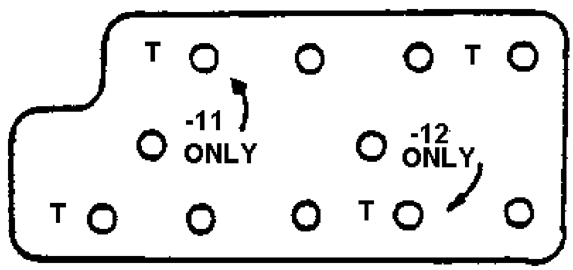


- Production holes shall be used as tooling holes, only when it is impossible or impractical to add separate holes.

- Holes for tooling pickup, either tooling or production, shall be stamped with the letter "T".

- Holes used for coordinating the part with another part or MTD, shall be stamped with the letter "C".

- Tooling holes shall be fail-safe when used for forming left and right hand parts with unequal outline or hole pattern.



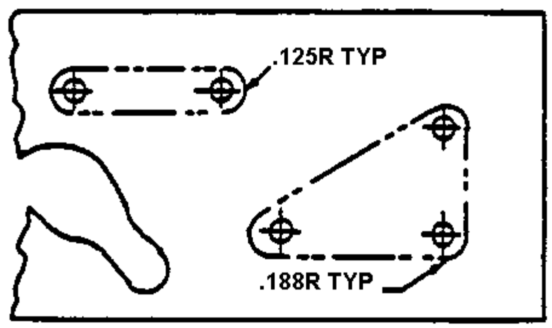
Fool-proofing holes shall be identified with the dash numbers of the finished part they are located in (reference -1 only, etc.). Only the uncommon hole is marked.

- For storage, a .250" square hole may be added for hanging purposes. These holes are added only when required and shall be located in a neutral area of the template. They are identified with the letter "H".

3.3 Internal Cutouts:

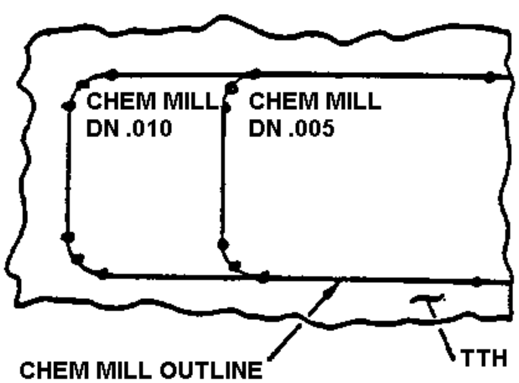
- Straight-sided cutouts with single radius corners shall be scribed on the template with a .125" hole at the center of each radius. The size of each radius shall be identified by stamping.

- Irregular sided cutouts shall be cut out and not scribed unless the tool order gives specific instructions to the contrary.



3.4 Chem-Mill Areas:

- Chem-mill areas shall have .070" diameter holes drilled on the outline(s) to permit the transfer of the line to a subsequent tool such as a chem-mill MAT (Masking Template).



Chem-mill areas shall be identified with the depth and direction (up or down) (reference "Chem-Mill DN .015").

- Parts that are Alclad on one side only shall have the clad side identified (reference "Clad This Side").

4.0 Construction SD20.113-3:

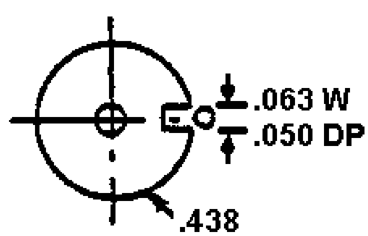
4.1 Outline and Hole Pattern:

- The -3 outline and hole requirements shall be the same as the -1 except:
  - All holes over .500" diameter and all internal cutouts of any size or shape shall be cut out unless otherwise specified. (This feature is required to permit the template to be used as the master for flat router tools.)

5.0 Construction SD20.113-5:

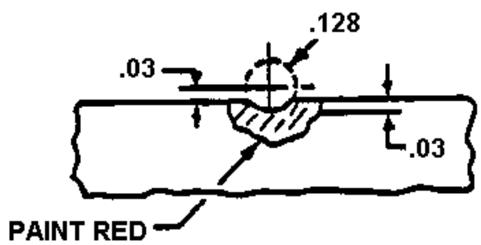
5.1 Outline and Hole Pattern:

- The -5 outline and hole requirements shall be the same as the -1 except:
  - External and internal corners shall have a radius for .010" to .020" unless a larger radius is called-out.
  - Hole diameters that are less than the work-piece thickness cannot be pierced. They shall be drilled to .070" diameter and stamped "PP" to indicate they are not to be included in the die.
  - Holes with keys or key-ways shall be located with a .125" center hole and a .070" hole on the center line above the key-way. Scribe the hole outline and key-way and stamp all necessary dimensions adjacent to the hole.



- Tooling ears shall be avoided in blanked parts. Notches are preferred if tooling holes are not available inside the outline.

Note: Reference only for existing TTH not to be incorporated on new TTH's.



5.2 General:

- Full size pierced holes may be used for structural fasteners as follows:
  - Maximum work-piece thickness shall be .065"
  - Maximum hole diameter shall be .188"
- Holes in parts that exceed the above limits may be pierced .030" undersize for further fabrication to full size.

6.0 **Tolerance:**

6.1 Outline:

- Within ± .005" of the lofted hole or Engineering dimension

6.2 Hole Location:

- Within ± .005" of the lofted hole or Engineering dimension
- Within ± .002" of any coordinating hole

7.0 **Identification:**

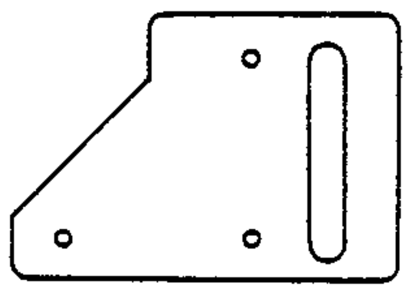
- Tool identification shall be done per SD20.510: "Tool and Equipment Identification Standard".

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

GRIND CHECK TEMPLATE (GCT)

Note: **Alternate Manufacturing Method:**

This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.



1.0 **Definition and Scope:**

- A Grind Check Template is a flat pattern template used to check the filed or ground edge of nibbled parts.

2.0 **Construction:**

2.1 Material:

- Make from .063" aluminum alloy, 2024-T4 or 2014-T6.

2.2 Outline:

- Coordinate with TTH. Cut and file the cutouts and slots as indicated on TTH.

2.3 Hole Pattern:

- Locate tooling holes from TTH. Holes shall be # 30 unless otherwise specified. Stamp the hole size if other than # 30.

2.4 Tolerance:

- Tolerance on hole pattern and outline is ± .005" from TTH.

3.0 **Identification:**

- Per SD20.510: "Tool and Equipment Identification"

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

PUNCH AND NIBBLE TEMPLATE (PNT)

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 Definition and Scope:

- This tool consists of two templates:
  - A punch template is used as a pattern for shearing the part material and also to transfer-punch the hole pattern to the part.
  - A nibble template is used as a guide for the nibbling machine to profile the part.
- A PNT is used for parts made of steel when they can neither be routed nor blanked. Minimum size of PNT (single or multiple part) is $3^1/_2$" x 1".

2.0 Construction:

2.1 Punch Template:

- *Material:*
  - .125" thick 2024-T3 or 2014-T6 aluminum
- *Outline:*
  - Make rectangular, $^1/_4$" larger than nibble template outline.
- Holes:
  - Obtain hole pattern from TTH or electronic model. All holes in the template shall be # 30 for transfer punching the parts. Holes to locate slot ends are stamped with diameter equal to the slot width. Hole location tolerance is ± .005" with respect to TTH.

Note: For manual manufacture of PNT, use a CPNT for template, follow same as N/C nibble or router using CTTH information (reference Section III).

2.2 Nibble Template:

- *Material:*

  - $^1/_4$" thick CRS plate

- *Outline:*

  - Outline shall be .015" larger than TTH outline with + .010"/ -.005" tolerance. Slots shall not be included in PNT unless specified on the tool order. Minimum width of slot is $^1/_4$".

- *Pick-Up Pins:*

  - Use a minimum of two pick-up pins per template. Make pins $^1/_8$" diameter CRS unless otherwise specified. Drill holes for press fit of pick-up pins. Countersink on side only to $^1/_8$" depth. Insert pins so that they do not protrude more than the thickness of the work-piece. Braze the pin on the countersunk side and grind flush.

- *Multiple Templates:*

  - May be made by adding a strap. Locate straps on a straight edge. Strap should have a minimum width of $^3/_4$" and a minimum length of $^3/_4$". Pick-up pins may be added in the strap.

3.0 **Identification:**

- Per SD20.510: "Tool and Equipment Identification"

Note: All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

PRESS BLOCK and HAMMER BLOCK TEMPLATE (PBT, HBT)

1.0 **Definition and Scope:**

- A Press Block Template and a Hammer Block Template are flat patterns cut to the inside mold lines (IML) for formed parts, and are used to locate the mold lines of the form block. Manufacturing Engineering shall order as many templates as required to clearly indicate the bend lines. Auxiliary templates, showing cross sections, shall also be ordered when necessary.

2.0 **Construction:**

2.1 Material:

- Make from .063" thick 2025-T4 or 2014-T6 aluminum alloy. If template is less than $^{1}/_{2}$" wide at any location, make from .125" thick sheet.

2.2 Tolerance:

- + .010"/ - .000" with respect to loft mold lines.

2.3 Outline:

- On flanged sides, cut the templates to the inside mold line of the part as shown on the loft.
- Usually, the web or body of a part is held and the flange is bent. When it is desirable to hold the flange and bend the web, the IML is changed (reference SD20.4 of this manual).
- Unless otherwise noted, templates for blocks with top contours, slopes, or joggles shall be projected from a plane parallel to the base (reference Figure 1).

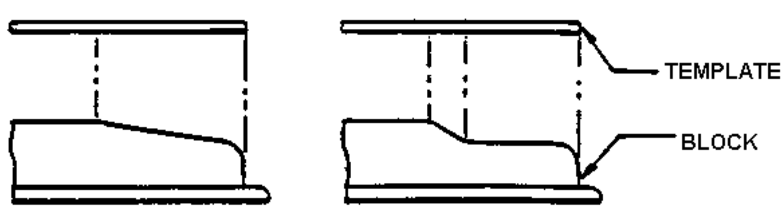


Figure 1

- If so ordered, templates may be contoured to facilitate construction of the block (reference Figure 2).

Figure 2

2.4 Tooling Holes:

- Use # 30 holes, when possible. # 10 holes may be used for material over .063" thick.
- Where possible, a minimum of three holes shall be used.
- For parts made on Blank and Pierce Dies, where holes may be made full size and used for tooling holes, the template holes shall be drilled to size accordingly. Stamp the hole size next to each hole.
- Work holes, centers for flanged holes, and # 50 holes for IML's or joggles are the only holes to be in the template. Tooling holes and notches are located per the TTH. No work holes are permitted in joggled areas.
- Where "shown" and "opposite" parts are included on the same template, and minor differences occur (hole pattern, flat pattern cutouts, etc.), drill two fool-proofing holes in the template and identify each hole with proper dash number (reference Figure 3). Nesting may be used as a failsafe, if a work hole cannot be added.

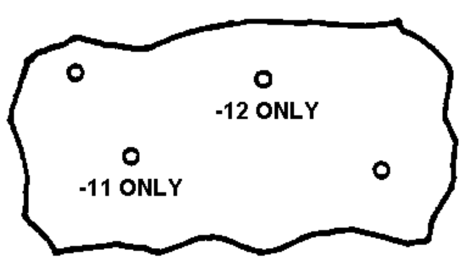


Figure 3

2.5 Joggles:

- The length of a joggle shown on a loft is the dimension "E" shown in Figure 4 and represents the projected distance between tangent points of radii. To obtain the correct placement of a joggle, the inside mold line of the joggle shown on the template is located by using Appendix 7.

  Make all corrections from the critical end of the joggle which is the end closest to the mating part. Measure back "G" then "F" as determined from Appendix 7.

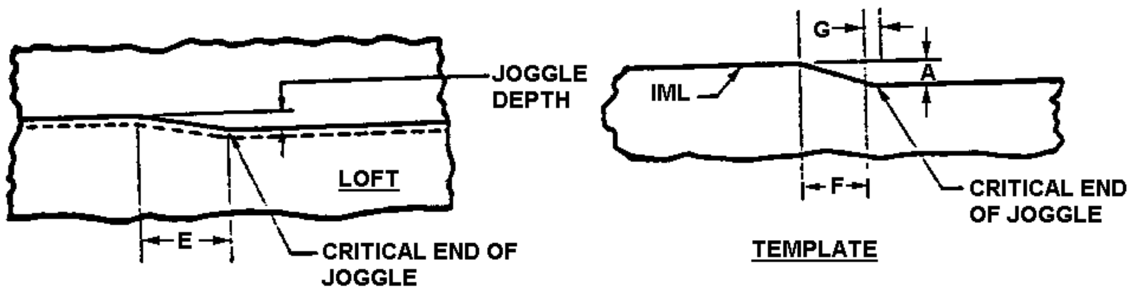


Figure 4

- Indicate the beginning, end, and slant of a joggle with scribed lines to the inside mold point (reference Figure 5).

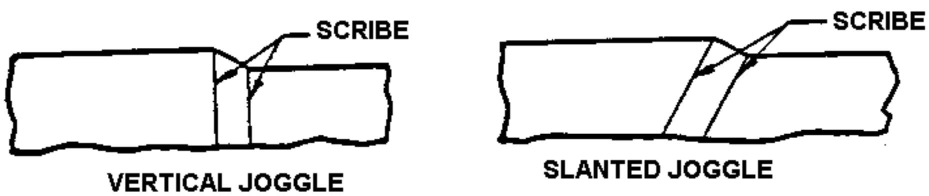


Figure 5

- Joggles depths for various angles (open or closed flanges) are shown in Appendix 15.

- Top joggle depths shall be indicated on the template as shown on the Engineering drawing (reference Figure 6).

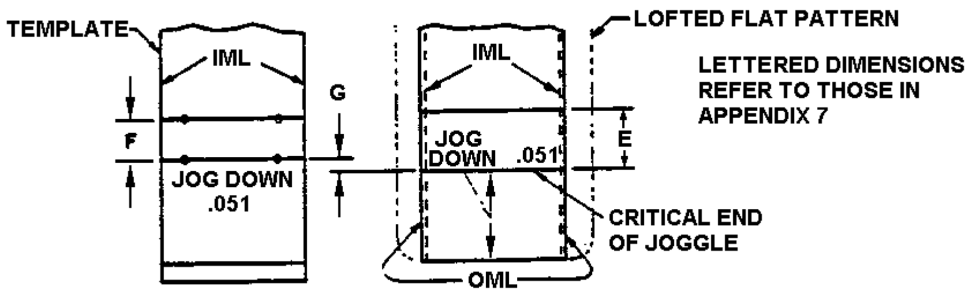


Figure 6

Scribe the IML of the joggle and drill two # 50 holes on each line. Stamp the depth and direction of top joggles in the joggle area (reference Figure 6).

- Joggle relief is required on all form blocks to prevent creasing of joggle during forming.

2.6 Flanges and Bends:

- Stamp the direction of a bend as "UP" or "DN" in the applicable area. If all bends are in the same direction, a note in the title block area, "ALL UP" or "ALL DN" is sufficient. Stamp the degrees of bend open or closed, as shown (reference Figure 7).

  When a flange is "free", and does not mate with other parts, it is identified with the letter "FF" next to the angle callout (reference Figure 7).

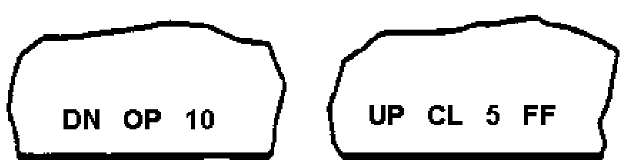


Figure 7

- Do not use degree symbol (°).
- For a varying angle bend, indicate the known angle points with a $^1/_2$" scribed line and call out the number of degrees as open or closed (see Figure 8).

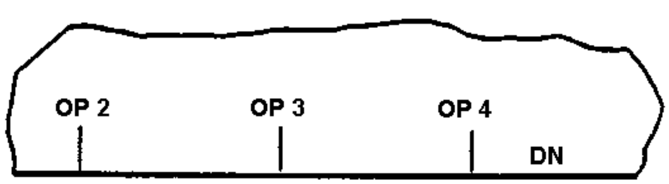


Figure 8

- For top bends, show the IML with a scribe line and two # 50 holes on the line. Stamp the degrees as open or closed (reference Figure 9).

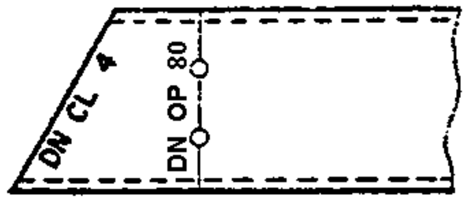


Figure 9

- For multiple bends, make separate templates for each set of IML's with a scribed sketch of the cross section on the first template (reference Figure 10).

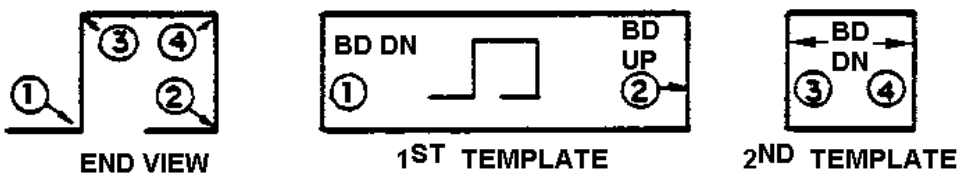


Figure 10

2.7 Flanged Cutouts and Lightening Holes:

- For simple shaped flanged cutouts with bend lines, there are arcs connected by tangents. Locate the center of the arcs with .312" diameter holes. Stamp the radius of each and scribe the tangents (IML or BEND) to the arcs (reference Figure 11).

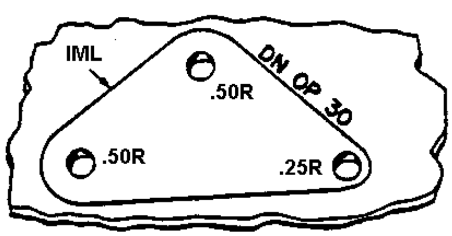


Figure 11

- For complex flanged cutouts, cut the template to the IML of the flanges (reference Figure 12).

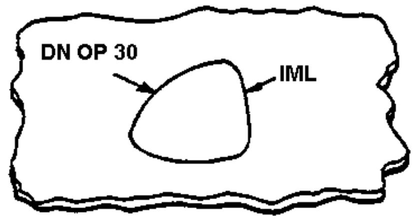


Figure 12

2.8 Lightening Holes:

- Locate center of standard lightening holes with .312" diameter holes. Stamp required GAH11F number (reference Figure 13).

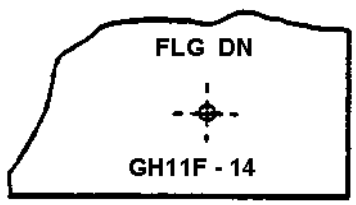


Figure 13

- For non-standard lightening holes, locate the center and scribe the IML as below. Stamp the hole diameter and the bend angle (reference Figure 14).

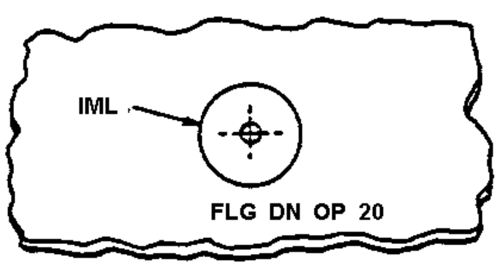


Figure 14

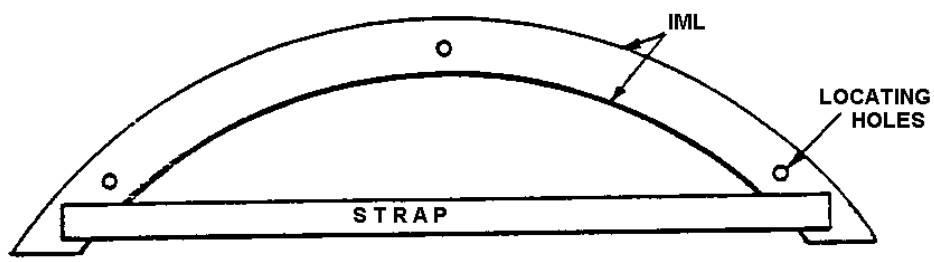


Figure 15

2.9 Straps:

- For narrow and curved templates that may warp or lose contour, the template should include a strap joining the ends and strengthening the template. Straps shall be fastened to the PBT with screws and dowels to permit removal when required. Avoid straps that interfere with mold lines, if possible. Scribe the part outline. The strap shall be labeled "STRAP" in large inked or painted letters (reference Figure 15).

2.10 Narrow Templates:

- Narrow templates may be deformed by side pressure when used on a shaper machine. To prevent this condition, IML's which are less than $^3/_4$" apart and more than 12" long, need a separate template for each IML. These templates shall be coordinated to each other and shall be labeled "1 of 2" and "2 of 2".

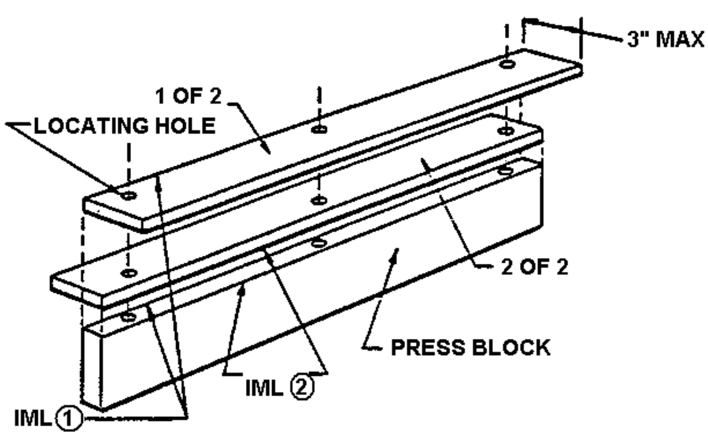
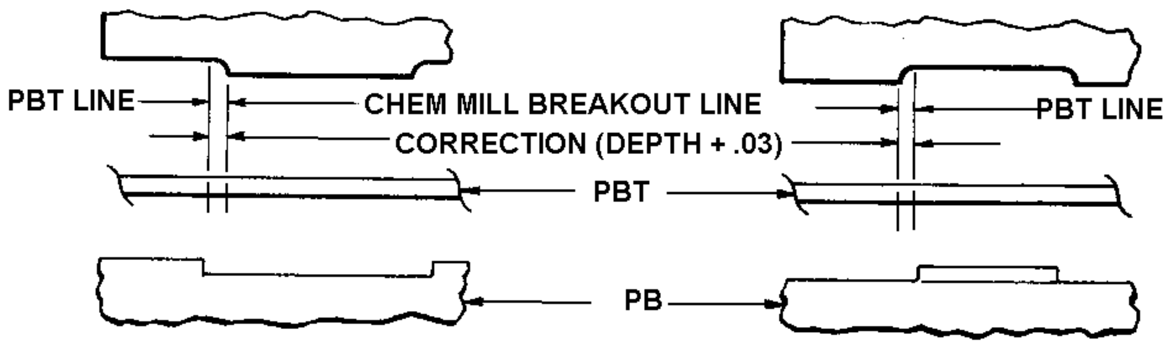


Figure 16

2.11 Chemical Milling Outline:

- Show the outline of all chemically milled areas with a corrected line on the PBT for parts that are etched before forming. The amount of the correction is the sum of the etch depth plus a .030" inch constant. Apply the correction to the proper side of the breakout line as shown in the sketch below. Drill # 50 holes along the scribed outline and stamp the size and direction of the outlined area. (i.e. ".040 DN" or ".050 UP").



2.12 Bead Outlines:

- The bead outline shown on an Engineering drawing represents the point of tangency of the radii. Drill a # 50 hole on the center-line, at the ends of each bead.

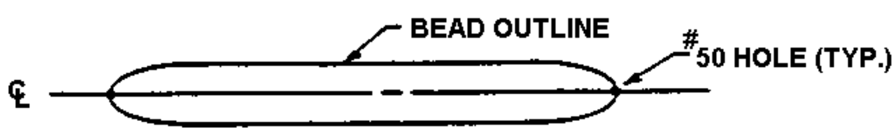


Figure 17

Note: To construct a press block, follow the procedure described in appendix 16.

2.13 Jig Index Holes:

- The PBT may become the master of the Jig Index Hole locations if the holes are to be drilled from the form block. Locations are made within ± .005" of the nearest reference WL and BL locations on the loft and are drilled full size.

3.0 **Identification:**

- Identify per SD20.510 with information in Table 1.
- To avoid deformation of template, stamp all information prior to cutting IML. Use Vibra-etch for all information added after cutting IML.

IDENTIFICATION REQUIREMENTS for PBT and HBT

TEMPLATE FOR:	FACE SIDE	UNDER SIDE
A. "Shown" part only, view flange down on loft. B. "Opposite" part only, view of "shown" part flange up on loft.	Tool Number Bend Radius Forming Direction Scribe Top Joggle Scribe Side Joggle Top Joggle Depth Side Joggle Depth Top Joggle Direction Scribe Known Bend Points Degree of Bend OP or CL Scribe and Stamp "PE" (Part Extremities)	Nothing
A. "Shown" part only, view flange up on loft. B. "Opposite" part only, view of "shown" part flange down on loft.	Tool Number Bend Radius Forming Direction Top Joggle Direction	Scribe Top Joggle Scribe Side Joggle Scribe Known Bend Points Degree of Bend OP or CL Top Joggle Depth Scribe and Stamp "PE" (Part Extremities)
Both "shown" part and its opposite. Formed either up or down.	Tool Number Bend Radius Forming Direction Scribe Top Joggle Scribe Side Joggle Top Joggle Depth Side Joggle Depth Top Joggle Direction Degree of Bend OP or CL Scribe Known Bend Points Scribe and Stamp "PE" (Part Extremities)	Scribe Top Joggle Scribe Side Joggle Scribe Known Bend Points Degree of Bend OP or CL Scribe and Stamp "PE" (Part Extremities)

Table 1

Note: All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

FORM and SCRIBE TEMPLATE (PST)

1.0 **Definition and Scope:**

- A PST is a tool that conforms to the shape of the part and is used for scribing trim lines and locating holes. It is primarily used for the thin gage parts when a PNT or a Blanking die is suitable.

2.0 **Material:**

2.1 Flat Tools:

- Use .125" thick aluminum alloy (2024-T351 (T4) or 2014-T651 (T6)).

2.2 Formed Tools:

- Thinner gage aluminum (2024-T351 or 2014-T651) may be used, however, hole areas shall be built up to a thickness of .125" ± .020".

3.0 **Holes:**

- All holes shall be # 10 diameter for use with a # 10 transfer punch or a drill guide, depending on the work-piece material.

4.0 **Tolerance:**

- All scribe edges shall be within ± .005" of the TTH or TTR trim.

5.0 **Identification:**

- Per SD20.510 Tool and Equipment Identification

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

AIR PUNCH TEMPLATE (APT)

1.0 **Definition:**

- The Air Punch Template is a nesting tool used for low production punching operations on the Air Operated Punch M 7683. It is particularly suited to punching stainless steel, chrome-moly steel, and titanium. On short production runs, it can be used as a substitute for gang punching operations.

2.0 **Scope:**
There are three types of Air Punch Templates:

2.1 SD-133:

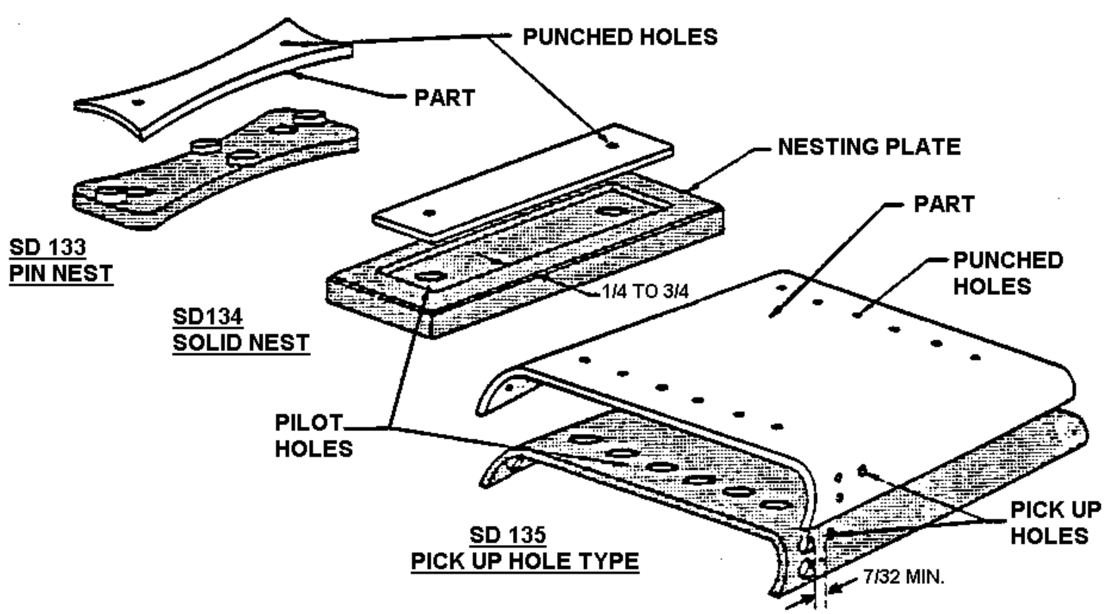
- Pin nest type for flat pattern parts only. This type is typically used for irregularly shaped parts where tooling holes and ears cannot be used. Maximum length is unlimited.

2.2 SD-134:

- Solid nest type for flat pattern parts only. This type is usually made for parts with straight edges where tooling holes and ears cannot be used. Maximum length is unlimited.

2.3 SD-135:

- Pickup-hole type for either flat or formed parts.



3.0 **Construction:**

3.1 Material:

3.1.1 *Flat Templates:*

- Should be made from .125" thick 2024-T3 or 2014-T6 aluminum.

3.1.2 *Nesting Plates:*

- Should be made from .125" thick 2024-T3 or 2014-T6 aluminum.

3.1.3 *Formed Templates:*

- Should be made from .125" thick 2025-O aluminum and heat-treated after forming.

  Templates used to make production hole sizes from $^{17}/_{64}$" to $^{5}/_{16}$" should be made from .190" thick aluminum.

3.2 Contour:

- Contour should be obtained by over-pressing, if possible.

3.3 Outline:

3.3.1 *SD-133:*

- Cut $^{5}/_{8}$" ± $^{1}/_{8}$" outside part outline.

3.3.2 *SD-134:*

- Cut $^{1}/_{4}$" to $^{3}/_{4}$" outside part outline.

3.3.3 *SD-135:*

- Unless otherwise specified, make net trim $^{1}/_{4}$" outside TTH or TTR outline.

3.4 Holes:

3.4.1 *Pattern:*

- Obtain hole pattern from TTH, TTR, or WM.

3.4.2 *Pilot Holes:*

- Pilot holes must be in a flat section of template. (i.e. not on bend lines, etc.)

  Center-to-center distance must be greater than the pilot hole diameter, unless otherwise specified.

Part Hole Size	**Template Hole Size**
# 40 to $^{5}/_{32}$"	.375"
$^{11}/_{64}$" to $^{1}/_{4}$"	.500"
$^{17}/_{64}$" to $^{5}/_{16}$"	.750"

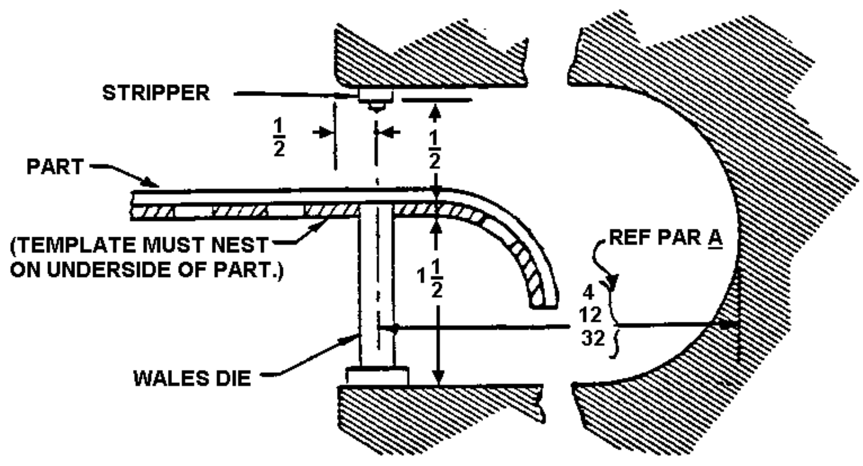
3.4.3 *Pick-Up Holes:*

- A # 30 pickup hole is required for every two feet of template length; minimum of two pickup holes is required for each template.
- For long parts, which require clamping to the template with skin fasteners, the minimum distance between edges of pickup holes and pilot holes shall be $^{7}/_{32}$".

3.5 Tolerances:

- Pilot hole diameters + .005"
  - .000"
- Pilot hole centers ± .005" with respect to TTH or TTR.

4.0 Machine Clearances and Capacity:



- Methods Engineers should investigate the current location of the machine having the required throat size when assigning an APT to a production department.
- Punch and die life will be extended if the punch diameter is not less than the thickness of the material to be punched.
- Normal capacity is $^1/_4$" diameter holes in .250" aluminum and .125" steel or titanium.

5.0 Identification:

- Per SD20.510

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

SETBACK ROUTER JIG (SRJ)

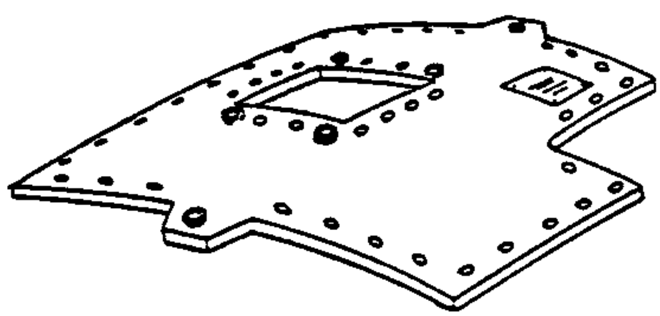
1.0 Definition and Scope:

1.1 A Setback Router Jig is a template type tool used for hand routing and drilling of contoured aluminum alloy work-pieces. This tool shall generally be applied to the "outside" surface of the work-piece, but may be applied to the inside surface, if required. The tool edge is set back from the work-piece edge to compensate for the router guide thickness.

1.2 Two types of SRJ's are described in this standard:

- SD-20.136-1:
  For contoured skins to be trimmed and drilled with hand-held machine tools.

- SD-20.136-2:
  For extruded or rolled cross section work-pieces which may be hand-held for trimming on a table-less router machine. Holes are included for hand drilling operations.



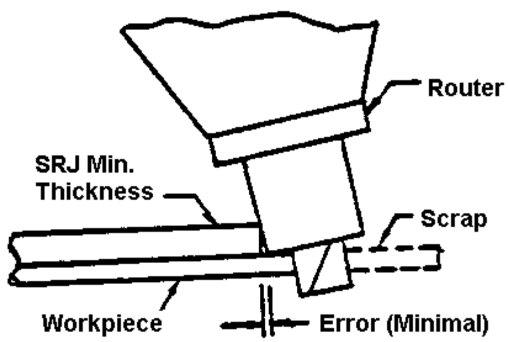
2.0 Materials:

- Fiberglass Laminate:
  - Laminating Resin:
    * Abrasive resistant
    * Room temperature system
  - Fiberglass Cloth:
- Bushings:
  - Knurled Embedment
  - Template Bushings

3.0 **Construction:**

3.1 Laminate:

- Contour is obtained from the MUF, TTR, Form Block, or electronic model.
- Thickness .190" ± .030". Heavier construction only when required for bushing retention (reference 5.3).



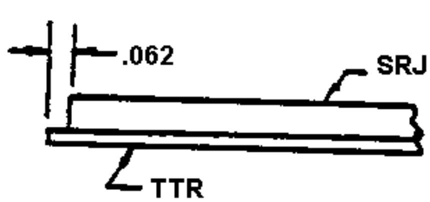
- Upper surface of laminate shall be free of bumps and abrupt changes in elevation for a distance of .750" from the tool edge.

3.2 Over-presses of aluminum alloys may be used for economy, if they are available. Their contour shall be obtained from the DHD, the DHR, or the SD. They shall be made of .094" to .125" thick, heat-treated material.

4.0 **Outline:**

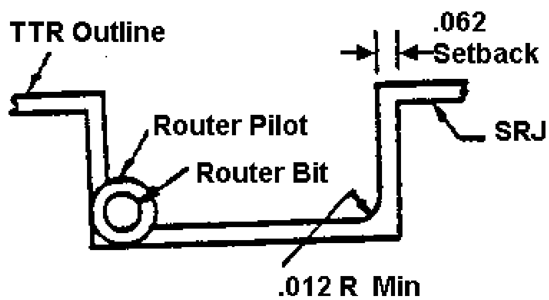
4.1 Trim Edges:

- The outline shall be obtained from the MUF, the WM, TTR, or electronic model. Trim is normal to contour unless otherwise specified. The trim edges of the tool on perimeter, slots, holes, etc. shall be set back .062".



4.2 Cutouts:

- The minimum work-piece corner radius is .125" due to router cutter diameter. Inside corners of the SRJ may omit the radius, if the work-piece radius is .125" or less.



4.3 Holes:

- Include all full size holes over $^1/_2$" diameter in the work-piece.

4.4 Slots:

- Minimum slot width shall be $^1/_2$" in the work-piece.

4.5 Excess Material:

- If excess material is required for the final fitting of the part, it shall be added only when it is added to the master template. This excess shall not be noted on the tool.

4.6 Tooling ears shall be added as specified by Engineering when they are included in the TTR outline.

5.0 **Drilled Holes:**

5.1 Hole Patterns:

- The hole pattern location shall be obtained from the TTR or electronic model.

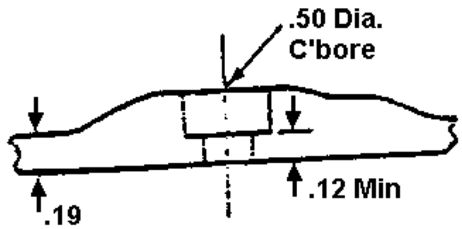
5.2 Drill Guide Holes:

- Holes for standard drill guides are preferred over bushed holes and shall be used whenever possible.

- The SRJ shall be drilled to accommodate standard drill guides (ST511, ST512, & ST513).

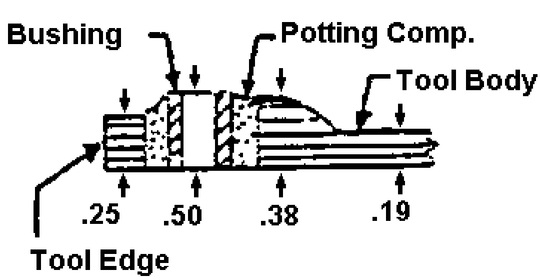
Drill Diameter	SRJ Holes Diameter
# 40 (.098")	# 10 (.1935")
# 30 (.128")	# 10 (.1935")
# 21 (.159")	.250"
# 10 (.1935")	.313"

Note: When an area of a fiberglass tool exceeds the .190" thickness, the drill guide holes in that area shall be counterbored .500" diameter to provide clearance for template fasteners and drill guides.



5.3 Drill Bushings:

- Bushings shall be used for interchangeable hole patterns and for full size holes other than the sizes listed in 5.2.
- Embedment Bushings (7416-1240 series) are used in fiberglass tools; refer to SD20.166 for instructions.
- Use .500" length bushings, except shorter when used for pickup purposes.
- Build-up areas of bushing application as illustrated.



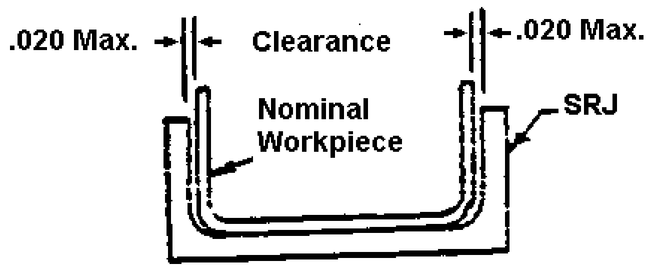
- Template Bushings are used in metal tools.
- Install with Liquid Lock Compound.

5.4 Air Punch Guide Holes:

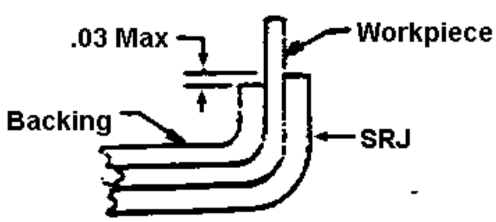
- .375" diameter guide holes may be added if specified by the tool order instructions.

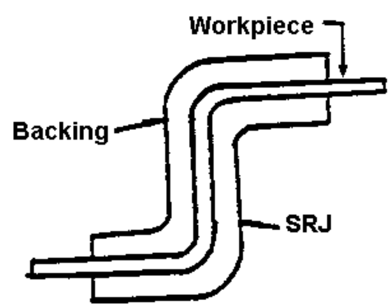
6.0 **Nesting:**

6.1 Channel or box sections shall have clearance, not to exceed .020" on either side, to permit nesting of oversize parts in outside contour tools and undersize contour tools. Avoid 100% nest, particularly where the forming of the work-piece may be marginal.



6.2 SRJ's for workpieces of .032" or less in thickness, when a HF has not been included, require extra stiffening for rigidity. When there is no HF to support the work-piece, a backing equal to or greater than the SRJ thickness shall be required. The backing shall fit the inside of the work-piece and be trimmed to match the SRJ with a tolerance of + .000" - .030". The SRJ and work-piece are clamped together with router clamps during routing operations.





6.3 All SRJ's for Zee sections shall include a work-piece backing. The backing shall be made as described in 6.2, except end trims shall match the SRJ, so that the router may be guided on either edge (SRJ or the backing). Identify which is the SRJ and which is the backing.

7.0 **Chem-Mill Provisions:**

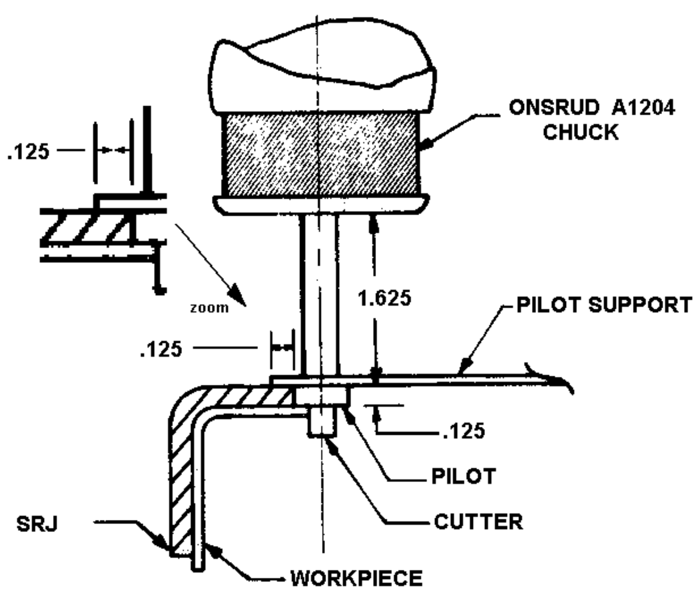
7.1 For pre-chem-mill work-pieces, preliminary SRJ's shall have tooling holes coordinated to the TTR and/or the MAT.

7.2 Hang holes for suspending the chem-mill work-piece shall be added in the excess material around the perimeter. These holes do not appear in the TTR. Use $^3/_8$" ID embedment bushings.

7.3 Tools for chem-mill work-pieces shall have their trim established 1.500" ± .060" outside the final trim (the excessive material does not appear on the TTH).

8.0 **Construction, SD-20.136-2:**

8.1 Construction features and requirements shall be the same as those that apply to SD-20.135-1. The following additional information shall be used as required.



8.2 A flat template or a series of flat templates is the most practical type of construction and shall be used whenever possible. If necessary, a rolled section, an extruded section, or a fiberglass laminate may be used.

9.0 **Tolerance:**

9.1 Setback edges (.0620") shall have a tolerance of ± .005" in relation to the TTR. Hole diameters and their location shall have a tolerance of ± .002" with respect to the TTR/electronic model.

9.2 Edges and holes shall have a surface finish of RMS 32, approximately.

9.3 Scribe a line $^{1}/_{8}$" inside the tool edge as a tool wear indicator.

10.0 **Identification:**

10.1 Refer to SD20.510: "Tool and Equipment Identification" for specific instructions.

Note: All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

SAW FIXTURE (SF)

1.0 Definition and Scope:

1.1 A SF is a device used to locate and support a straight saw-cut operation in a formed work-piece.

1.2 Two types of Saw Fixtures:

- SD 137-1:

  A Saw Fixture used on a base for making a saw-cut parallel to the base of the fixture.

- SD 137-3:

  A Saw Fixture used to locate the position of a straight cut to be made by a band-saw. This tool shall be ordered when the work-piece contains compound curves in more than one plane.

2.0 Construction of SD 137-1:

2.1 Material:

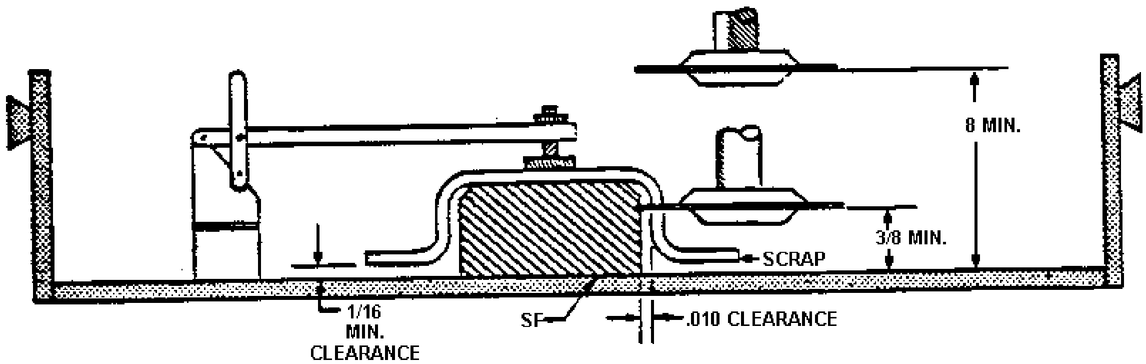
- Use Masonite, aluminum alloy, or metal filled epoxies (i.e. Metalset, etc.).

2.2 Outline:

- Shape to the inside form of the work-piece. Avoid 100% nesting (reference Figure 1).
- Allow approximately .010" clearance around all sides. Use sheet wax as a spacer when casting.
- Metal filled epoxies may be cast into the TTR/electronic model or a sample formed part, capped or dammed with clay where necessary.
- IML's may be obtained from forming tool templates (i.e. PBT, HBT, HDT, etc.) or electronic model.
- When the form is larger than approximately 100 square inches in area, use only bosses and banking points mounted on a base (reference Figure 5).

2.3 Size Limitations:

- Maximum width of a work-piece between clamps is 30 inches, including scrap (excess scrap may be pre-trimmed if necessary).
- Maximum length is unlimited. Other limitations are shown in the sketch below.



Cross Section of Universal Base with Typical SF

Figure 1

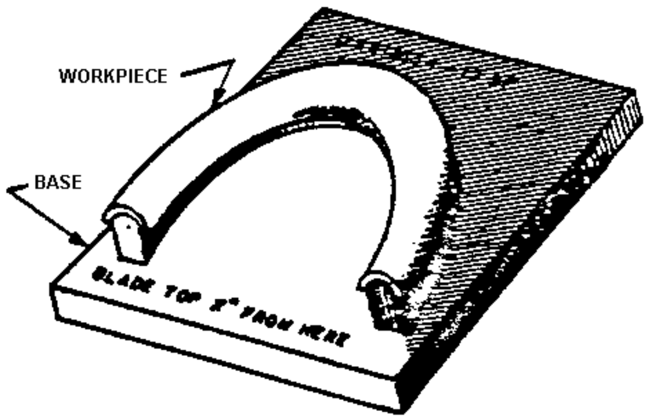
2.4 Mounting:

- Add two standard lock-screws on the underside of the SF to match the standard key holes in the base (reference Figure 3).
- Add a $^1/_2$" thick Masonite base if the tool is not large enough to accommodate the 4" center-to-center distance between the lock screws (reference Figure 2).
- Fasten the Masonite base to the tool "Form" with flat head machine screws.

2.5 Tolerance:

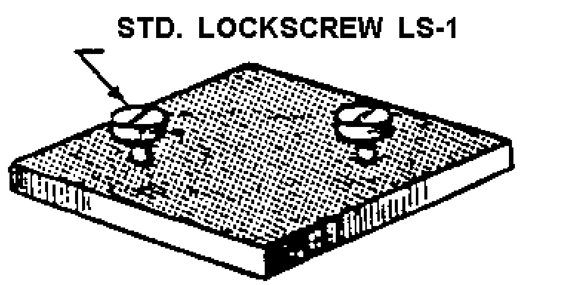
- Tolerance is governed by the Engineering tolerance on the finished part. For inspection of the tool, a work-piece trimmed on the SF shall be used.

2.6 Typical Tools:



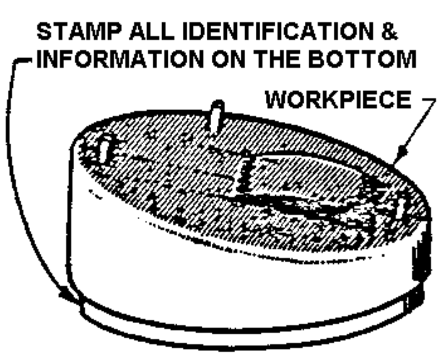
Typical Tool for Work-piece (less than 5" length or width)

Figure 2



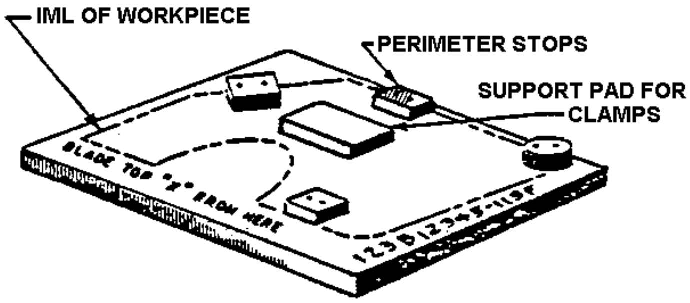
Typical View Underside of SF

Figure 3



Tool Oriented to Workpiece

Figure 4



Typical Tool for Work-piece of More than 100 Sq. In.

Figure 5

2.7 Identification:

- Height of the cutter from the top of the base of the SF shall be clearly marked on the tool. The callout shall read "BLADE TOP X FROM HERE", as shown in Figures 2 and 5.

- Stamp standard tool identification as per SD20.510. Locate in areas shown above.

3.0 Construction of SD 137-3:

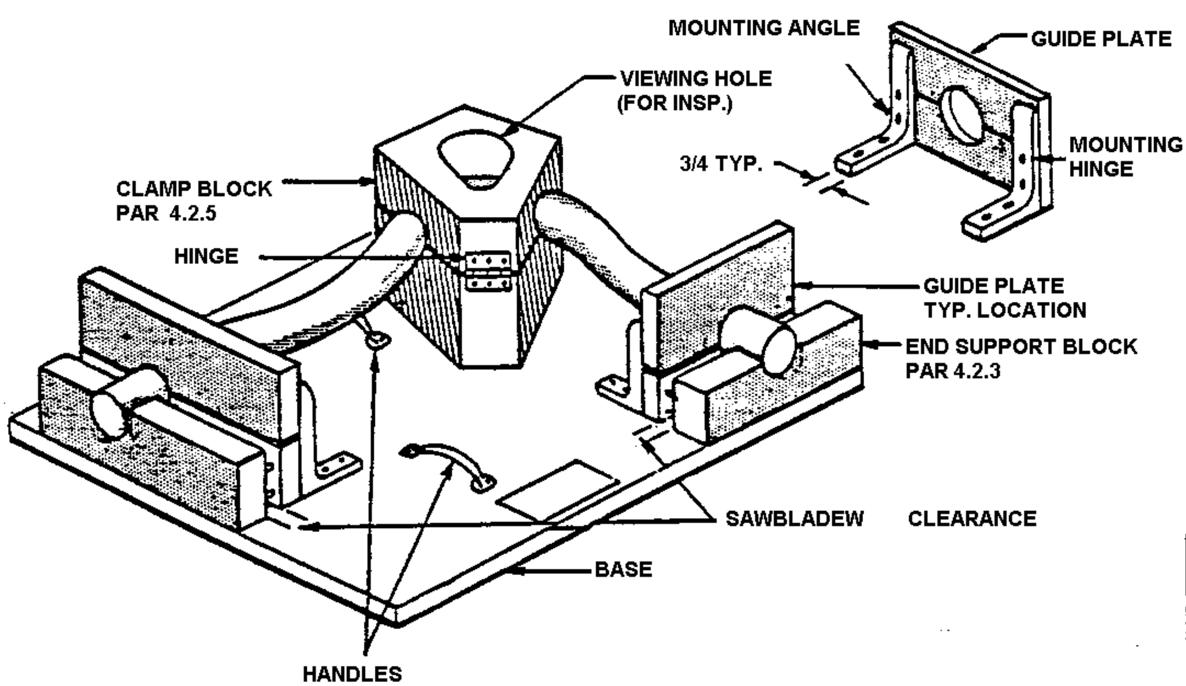


Figure 6

3.1 Material:

- *Base:*

  $^3/_8$" thick aluminum alloy, 2014-T651 (T6), 2024-T351 (T4), or 7075-T651 (T6).

- *Guide Plates:*

  $^1/_2$" thick "Hard Coated" aluminum alloy (6061-T6 or 7075-T6).

- *Support Blocks:*

  Masonite, Richlite, or metal filled epoxies (i.e., Metalset, etc.)

- *Clamp Block Latch:*

  Tension latch

- *Clamp Block Hinge:*

  Use a commercial steel butt hinge (size as required) or aluminum alloy aircraft hinge (cut to required size).

- *Guide Plate Mounting Hinge and Angle:*

  Use aluminum extruded angle cut to .750" lengths (reference Figure 6).

- *Handles:*

  Use suitable size door pulls.

3.2 Procedures:

- Establish the position in which the formed workpiece is to be held during the sawing operations.

- Cast, or cut, local support blocks to hold the work-piece in the required position.

- For better orientation, it may be necessary to support the work-piece in the excess area (reference Figure 6).

- To assure proper nesting, provide a visual inspection cut-out in clamp blocks located in critical areas (reference Figure 6).

- A toggle clamp may be used in place of a clamping block when it will locate and hold the work-piece properly during the sawing operation.

- Hinged guide plates, used to guide the band-saw blade, shall be positioned inboard of the saw-cut (reference Figure 6).

3.3 Fastening:

- Use $^1/_4$-20 FH machine screw, through the base, to secure the support blocks.

- Use $^1/_4$-20 allen bolts threaded into the base to secure the guide plate hinge and mounting angles.

3.4 Handles:

- Handles shall be located so that the saw operator may apply even pressure with both hands while using the SF. Do not locate handles inline with the band-saw blade.

- Use FH machine screws to attach handles to the base.

3.5 Tolerance:

- Tolerance is governed by the Engineering tolerance on the finished part. For inspection of the tool, a work-piece trimmed on the SF shall be used.

3.6 Identification:

- Stamp standard tool identification on the base as per SD20.510.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MASKING TEMPLATE (MAT)
MASKING TEMPLATE (MATP)

1.0 **Definition and Scope:**

A Masking Template is used for scribing the outline of a chem-mill pocket to permit removal of the maskant in preparation for etching of the pocket.

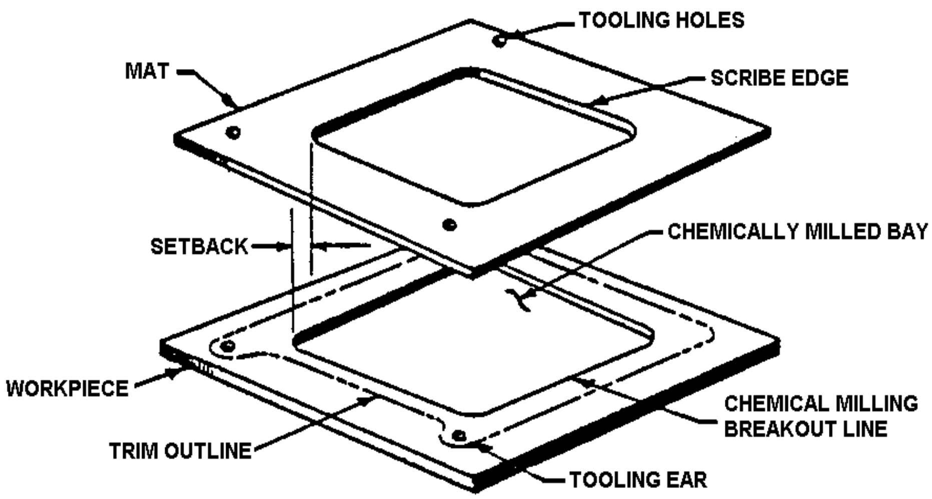


Figure 1

Note: The instructions in this tool fabrication standard shall be applied to flat or formed "MAT" templates regardless of the template material. Specific features of each mat, such as location and amount of setback, are shown on the chem-mill sketch accompanying the tool order.

2.0 **Materials:**

2.1 Flat Templates:

- .064" Aluminum Alloy (2024-T3 or 2014-T6)

2.2 Formed Templates:

- .040" Aluminum Alloy (2024 or 2014) over-press heat-treated and aged

Note: Fiberglass laminates do not give economical tool life and should be avoided as a masking template unless metal-scribing edges can be incorporated.

3.0 **Construction:**

3.1 Outline:

- The template shall be made to permit uninterrupted scribing and eliminate or reduce the need to connect interrupted scribe lines.

- The overall size of the MAT is the same as the rough trim tool. However, large templates with only small, localized chem-mill areas are not economical and should be positioned by tooling holes in the part. Local flat templates can be beneficial in reducing the need for formed templates.

- The actual scribing cutouts and the calculated "setbacks" are always shown on the tooling sketch made for each template. Individual construction techniques shall be incorporated as required using the guidelines established in this standard. The template shall be designed to protect the area to be stripped (see paragraph 7).

- The TTH or TTR is used for the outline of the chem-mill area with the setback added by the toolmaker (see paragraph 7).

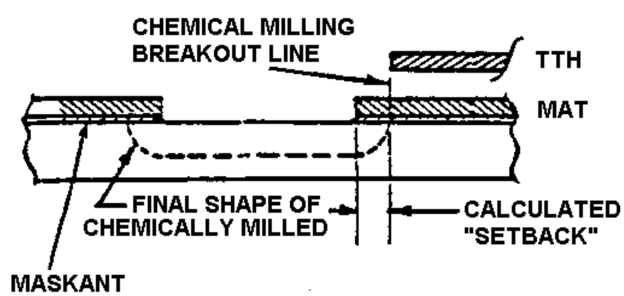


Figure 2

- Where chem-milling extends to the finished trim line of a part, the scribe edge of the template extends .380" beyond the net trim line, and the outer edge shall be .500" beyond that line.

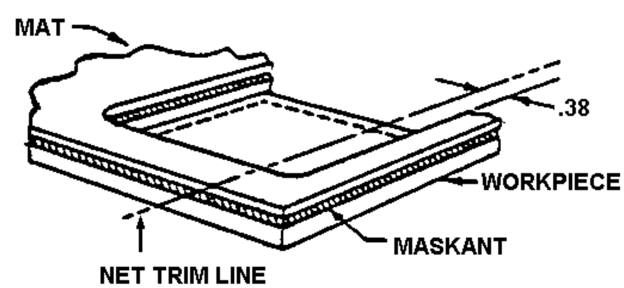


Figure 3

- Corner Radii at Adjacent Cuts:

  Corner radius "setback" shall not be less than the smallest calculated "setback" of an adjacent side not greater than the largest "setback".

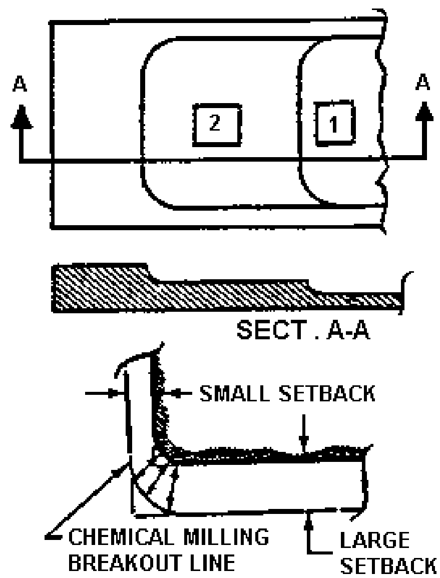


Figure 4

- All scribing edges shall be draw-filed smooth and free of nicks to RMS 32-63.

- Edges on the inside of the template that are not used in scribing (reference paragraph 3.2) shall be left with rough saw-cut edge.

3.2 Straps:

- Straps shall be used to support large cutout areas to prevent template distortion. They are also used to position a local feature within a larger chem-mill area. Reference Figure 6.

- Unless otherwise specified, the strap location shall be determined by the toolmaker. Reference Figure 6.
  The basic rule is:
  "Only use a minimum of straps to reduce the need for joining the interrupted scribe line".

- Apply straps to straight lines whenever possible, using a minimum corner radius. Straps applied to curved lines required an added scribe window to provide additional scribing. Reference Figure 6.

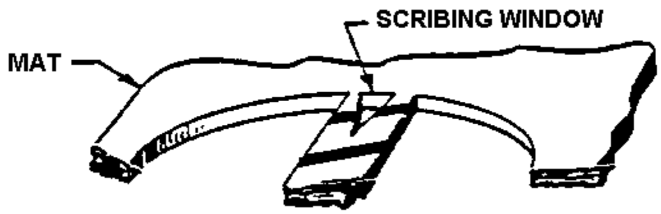


Figure 5

- Spot areas within a larger area, shall be located by straps, but the straps shall not occupy more than 10% of the perimeter. When the straps use more than 10% of the template, make a local template.

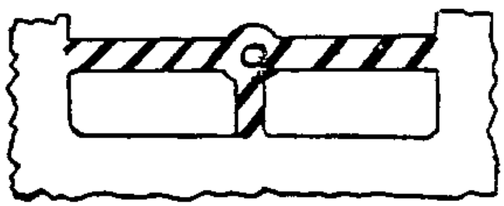


Figure 6

- Straps shall be marked over their entire length with 0.200" red stripes.

4.0 **Tooling Holes:**

- Tooling holes shall be # 30 diameter for most parts, but shall be .250" for large parts such as structural panels. They shall be spaced to permit a failsafe application of the MAT to the work-piece. The location shall be taken from the TTH or TTR, but if a choice is available, the location shall be established as shown in the sketches.

(For Formed Parts)

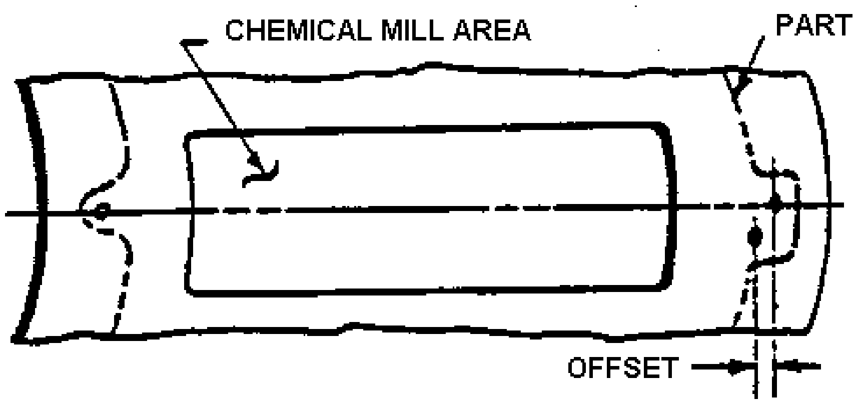


Figure 7

(For Flat Parts)

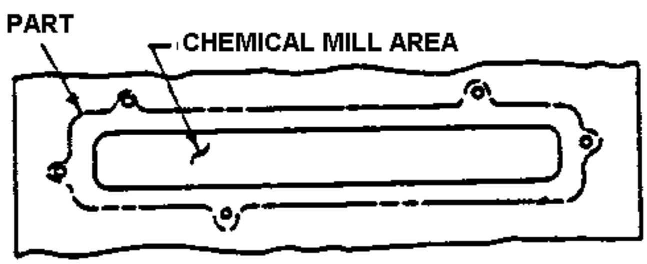


Figure 8

- Marking holes of .500" to 1" diameter shall be inserted in all red-painted areas to permit marking of an area that is to be stripped.

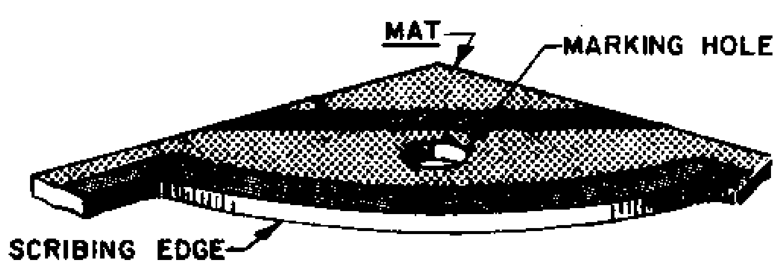


Figure 9

- Inspection sight holes shall be incorporated in the MAT for contoured work-pieces where the depth of cut is .040" or greater. At least two holes per edge are necessary to inspect the breakout line.

5.0 **Color Coding:**

- Color-coding is applied to the edges of MAT's to indicate the sequence of stripping of the maskant. The following chart shall be used to provide this sequence. The colors are applied to the side facing the workman when the template is being used. Apply the color coding to both sides if the one template is used for right and left hand parts.

Color Code Chart

Operation Number	Border Color	Bar Color
1	Black	
2	Orange	
3	Yellow	
4	Green	
5	Blue	
6	Purple	
7	White	
8	White	Black
9	White	Orange
10	White	Yellow
11	White	Green
12	White	Blue
13	White	Purple
14	Orange	Black
15	Orange	Yellow
16	Orange	Green
17	Orange	Blue
18	Orange	Purple
19	Yellow	Black
20	Yellow	Green
21	Yellow	Blue
22	Yellow	Purple
23	Green	Black
24	Green	Blue
25	Green	Purple
26	Blue	Black
27	Blue	Purple
28	Purple	Black

Note: Red is used for straps and areas from which the maskant is to be stripped after a primary depth has been reached.

6.0 Identification:

- Per SD20.510
- The side which is to face the operator should be identified as "THIS SIDE UP". When both sides are used, then each side should be further identified with "THIS SIDE UP" (Part Dash No.).

Example: Side one is used for -1 part number and side two is used for -2 part number for the opposite side.

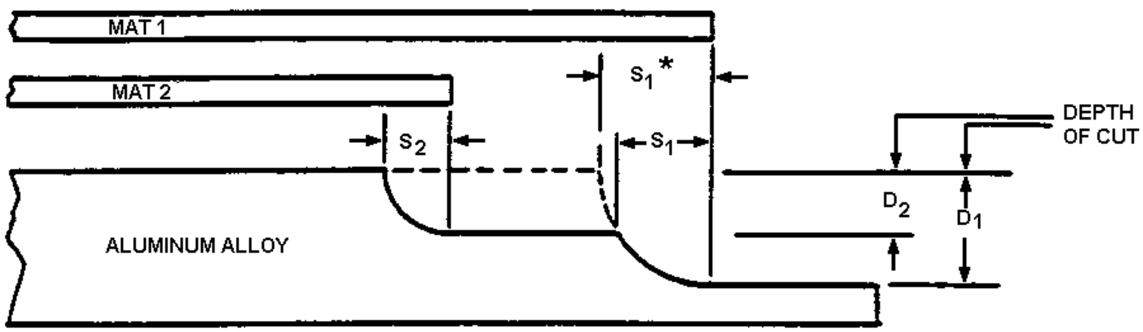
7.0 Effect of Chem-Mill Cuts on Template Design:

7.1 Setback for Step Etching:

- Because etching of the work-piece is not only down but sideways, it will be necessary to compensate for this side etching in order to bring the final outline to the required point (reference Figure 10).
- Template "setback" is obtained by multiplying the required depth by the undercut ratio.

Example: .050" (depth of cut) x .900" (undercut ratio) = .045" (setback of template)

7.2 Template Setback for Adjacent Depths of Cut:



S_1 = Setback for first operation

S_2 = Setback for second operation

D_1 = Depth of etching from first and second operation

D_2 = Depth of etching from second operation

$S_2 = UD_2$ where U = the undercut ratio for the material obtained from the chart (paragraph 7.5)

$S_1^* = UD_1$

Substituting in the formula for an elipse yields.

$S_1 = \sqrt{(UD_1)^2 - (UD_2)^2}$

For 7075-T6 and 2024-T4 alloys, S_1 values may be obtained from the graph. An example is also illustrated.

Figure 10

7.3 Template Setback for Alclad Alloys:

- Alclad alloys are clad stripped locally $^1/_{16}$" larger than the break-out line for etch depths of .040"` or more for conventional parts and for all etch depths when interchangeability is involved - no setback is applied. Etching of the pocket in the stripped area is then treated in the conventional manner.

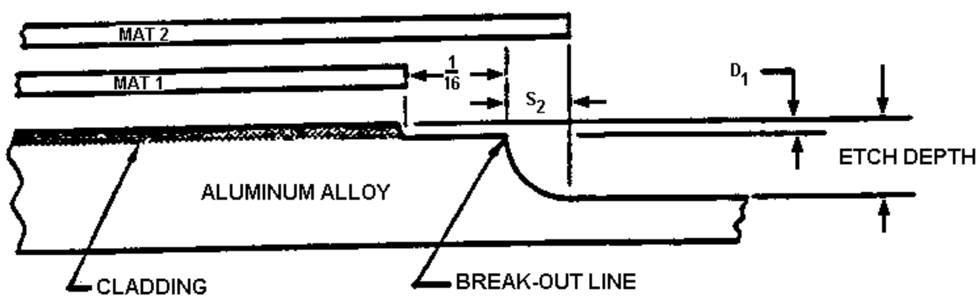


Figure 11

7.4 Break-out Line Tolerance Application of Setback:

- For depths of cut .040" or less, break-out line tolerance is ± $^1/_{16}$". No setback is required when determining setbacks for these etches.

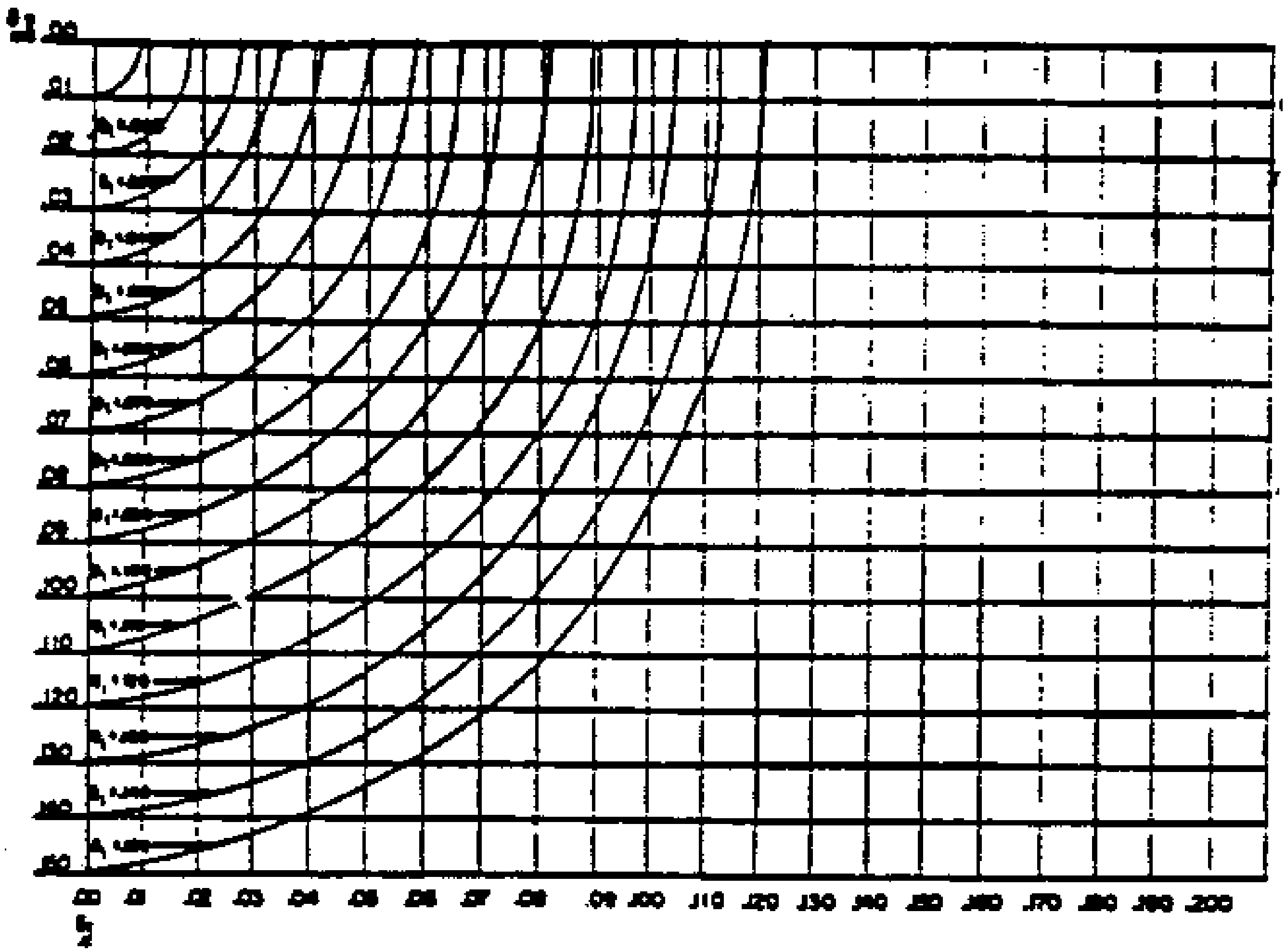
- For depths of cut greater than .040", break-out line tolerance is ± $^1/_{32}$".

7.5 Undercut Ratios for Aluminum Sheet and Plate Stock:

ALLOY (BARE)	PERP. TO GRAIN	PARALLEL TO GRAIN	DIAGONAL TO GRAIN	AVERAGE RATIO	MAX DEPTH
2014-O	1:1.37	1:1.33	1:1.26	1:1.32	.200"
2014-T6	1:1.25	1:1.20	1:1.15	1:1.20	.300"
2024-O	1:1.69	1:1.77	1:1.67	1:1.71	.200"
2024-T3 (PLATE)	1:1.42	1:1.22	1:1.30	1:1.31	.250"
2024-T4 (SHEET)	1:1.30	1:1.26	1:1.26	1:1.27	.150"
2024-T4	1:0.96	1:0.93	1:0.98	1:0.96	.400"
2024-T36	1:1.04	1:0.96	1:0.95	1:0.98	.250"
2024-T81	1:0.70	1:0.92	1:0.74	1:0.80	.150"
2024-T86	1:0.96	1:1.06	1:0.97	1:1.00	.250"
2219-O	1:1.55	1:1.66	1:1.58	1:1.60	.250"
2219-T62	1:1.20	1:1.22	1:1.14	1:1.19	.300"
2219-T81	1:1.50	1:1.19	1:1.26	1:1.32	.090"
2219-T87	1:1.32	1:1.11	1:1.19	1.1.20	.140"
6061-O	1:1.97	1:1.51	1:1.59	1:1.69	.100"
6061 -T4 & T6	1:1.55	1:1.24	1:1.32	1:1.37	.100"
7075-O	1:1.13	1:1.17	1:1.13	1:1.14	.400"
7075-T6	1:1.09	1:1.06	1:1.03	1:1.06	.400"
7075-T6 1/2 SEALANT GROOVE	------	------	------	1:0.80	.065"

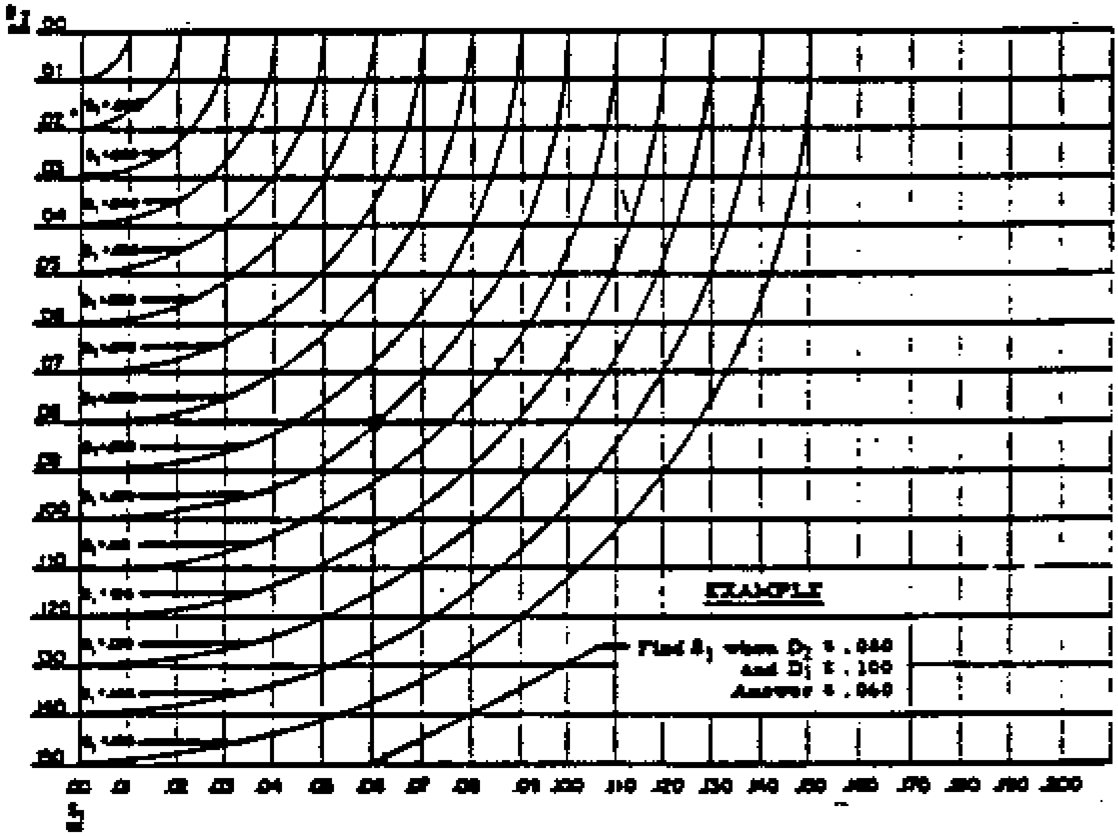
- The average values shown above shall be used for depths of cuts up to and including the maximum limits indicated. For deeper cuts, the directional values must be used in order to maintain "Breakout" tolerances. Where it becomes necessary to confine the chemical milling to a given grain direction, the face of the template, (i.e.. SDT) shall give the grain direction.

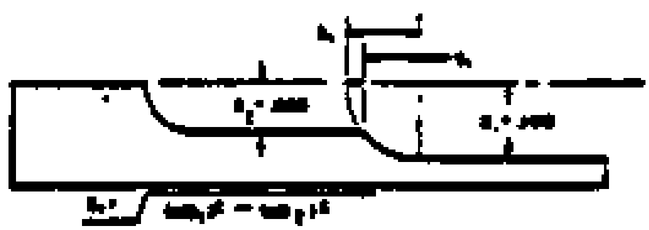
- For cuts of .040" or less in depth, it is necessary to apply the undercut ratio for template "setback" because of the ± .063" tolerance on the "breakout line". However, it shall be necessary to review the effect of this tolerance upon the requirements of the surrounding area, as in the case of $^1/_2$" or smaller lands between pockets and when trim cuts are required tangent to "chem-milled" edges.



Graph for Obtaining "S" for 2024-T81 Bare Aluminum
Adjacent Chemical Milling Cuts Undercut Ratio 0.080
(reference Figure 10)

Figure 12





Graph for Obtaining "S" for 7075-T6, 2024-T5, 2024-T36, 2024-T86 Bare Aluminum Adjacent Chemical Milling Cuts Undercut Ratio 1.06
(reference Figure 10)

Figures 13 & 14

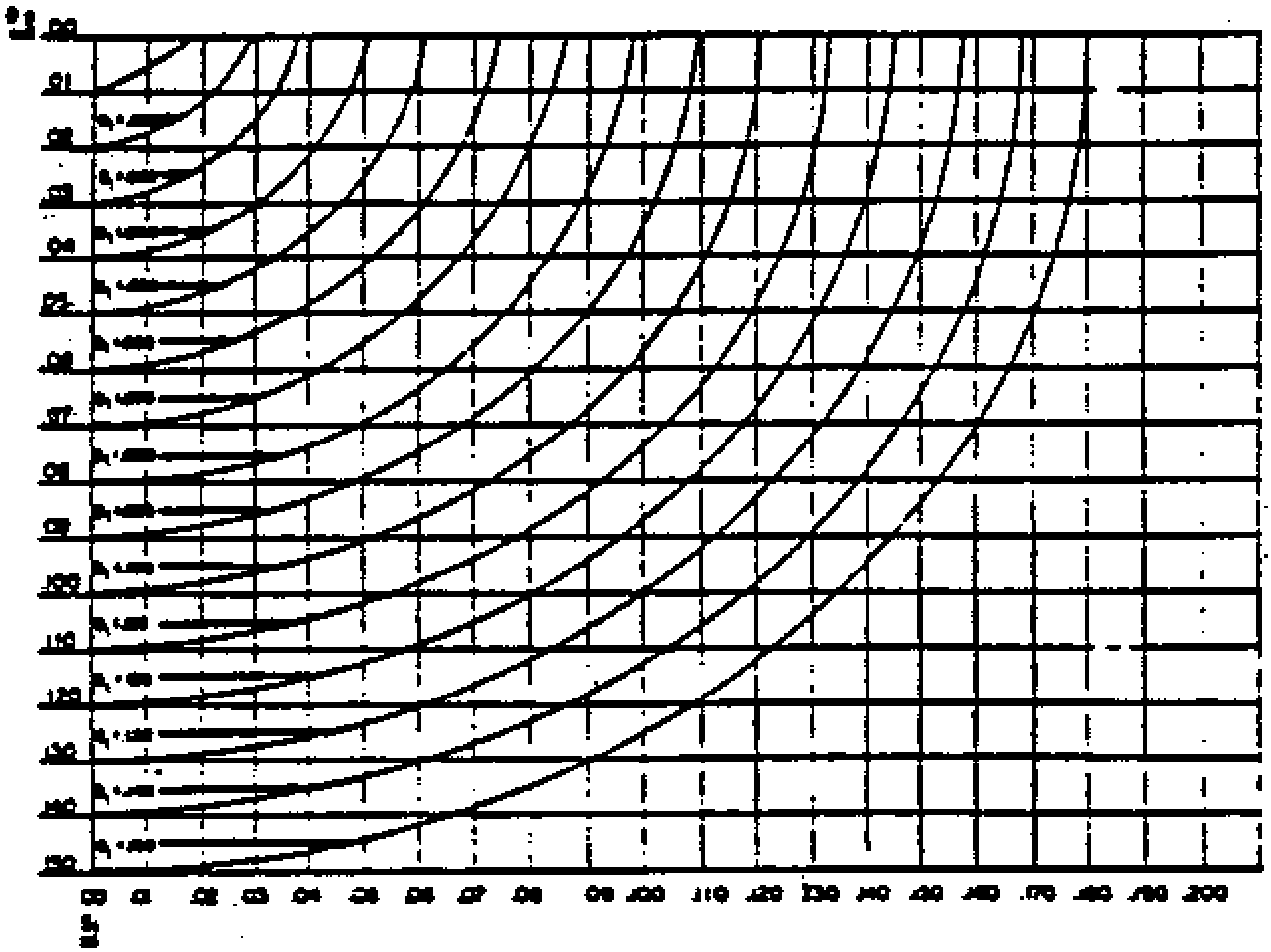
S_1 = (Actual) Setback for D_1 Depth of cut using Graph or Formula in figure 10 above

S_1* = (False) Setback obtained by multiplying Undercut Ratio by Depth of cut.
S_1* = .100" x 1.060" = .106"

D_1 = Deepest Cut .100"

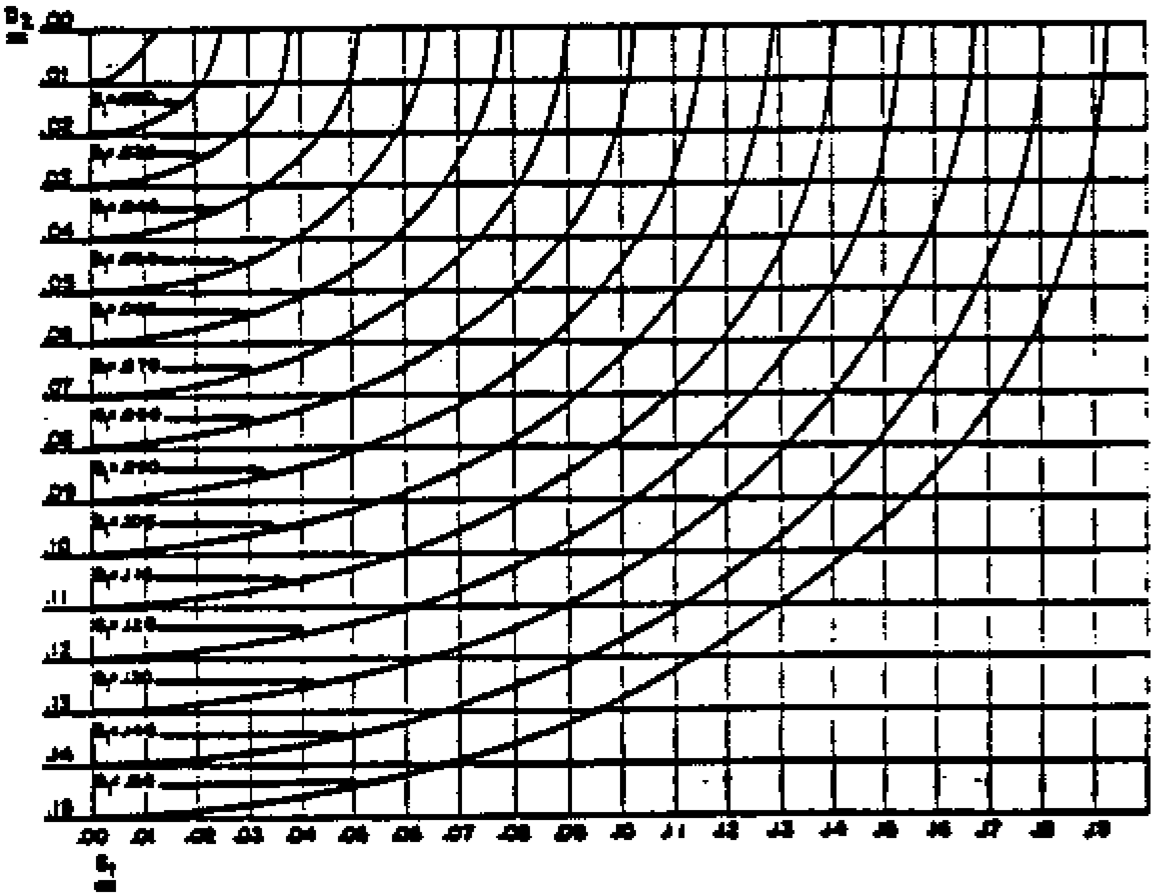
D_2 = Shallow Cut .080"

U = Undercut Ratio 1.060" (reference Figure 10)



Graph for Obtaining "S" for 2014-T6, 2219-T62, 2219-T87 Bare Aluminum Adjacent Chemical Milling Cuts Undercut Ratio 1.20
(reference Figure 10)

Figure 15



Graph for Obtaining "S" for 2024-T3 (plate), 2024-T4 (sheet) Bare Aluminum Adjacent Chemical Milling Cuts Undercut Ratio 1.29
(reference Figure 10)

Figure 16

8.0 **Masking Template (Primer) (MATP):**

8.1 Purpose and Scope:

- A masking template primer is used to distinguish the various types of templates required for use in the priming of components that specifically require designated areas to be free of primer for the purpose of electrical bonding and lightning protection. To provide general instructions on how these tools are constructed.

8.2 Types(1):

8.2.1 *Defined:*

- This version of the MATP tool is the most common of MATP's because it is generally used for small parts (A or B size) and requires only a small section of the component to be masked. It is also used because of the location of the primer free area.

- When the MATP goes to the paint shop, it will be used as a visual aid to show all locations to be masked. Masking tape is used to mask parts because it is inexpensive and it adheres to the components.

8.2.2 *Construction:*

- This MATP is to show locations where primer is to be omitted for the GAB17G spec., as illustrated per the drawing.

- If available, obtain a sample part from stock (the sample part number will be called out on the tool order). If one is not available, manufacture as sample part.

- Remove the hardware (if any) and strip finish at locations to be free of primer, per drawing.

- Cut slots in MATP so that the tool will not be mistaken as a detail part.

- Paint the tool red except for locations to be free of primer.

- Identify as _______________ -___________MATP, the "P" is to identify as part.

Note: Besides making a MATP tool for visual aid, it may also be helpful to make flat metal templates of each area to be masked. Since the masking tape is trimmed with a razor blade, the metal templates will provide a safer method to trim the masking tape.

8.3 Type (2):

8.3.1 *Defined:*

- This method of MATP tool is made to cover the area that shall be free of primer on the part.
- During the prime process, the MATP is placed on the part and held in place with clecos. This method is favorable when the part is large, such as a skin or doubler, and the area to be masked is fairly large.

8.3.2 *Construction:*

- The MATP will be made from a metal loft (if possible) of the section that shows the area to be free of primer. If a metal loft cannot be obtained, then the MATP will have to be shop developed. After a pattern is obtained, holes will need to be added that will coordinate the MATP with the part. If there is only one area to be covered on the part, only one MATP would be required. But, if there are multiple locations to be covered on the part, several MATP patterns will be required. These patterns could be made into one piece if the locations are close enough and could be held together by metal straps. If the areas to be masked are too far apart, then separate MATP tools will be required. When the MATP is complete, it should be identified accordingly. If there are more than one MATP, each section should be identified and tied together for storage.

8.4 Type (3):

8.4.1 *Defined:*

- This type of MATP has been used for medium to large sized flat parts and is used when several areas need to be masked on the same part. These MATP tools consist of metal templates to trim the masking tape to the correct pattern and a locating template to locate each area to be masked.

8.4.2 *Construction:*

- This type of MATP may require two metal lofts. The first loft will be used to make all of the patterns to trim the masking tape per metal loft and GAB17G spec. The second loft will be used to locate each section on the part to be masked and it will be constructed by trimming the MATP to the same periphery as the part and making full size cutouts at each location to place the masking tape inside. To locate the MATP itself on the part, holes will need to be added to the MATP to cleco it to the part. If the part has cutouts, the toolmaker could cut the exact size of the cutout from the first loft and use this piece to place on the bottom of the locating template where the cutout would be when the template is placed on the part. By using the second method, the locating template when placed on the part, locates itself rather than having to cleco the template to the part. This method should also reduce the time to mask the parts.

- After all trim templates and locating templates are complete they should be identified and tied together for storage.

Note: All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

WHITE MASTERS (WM)

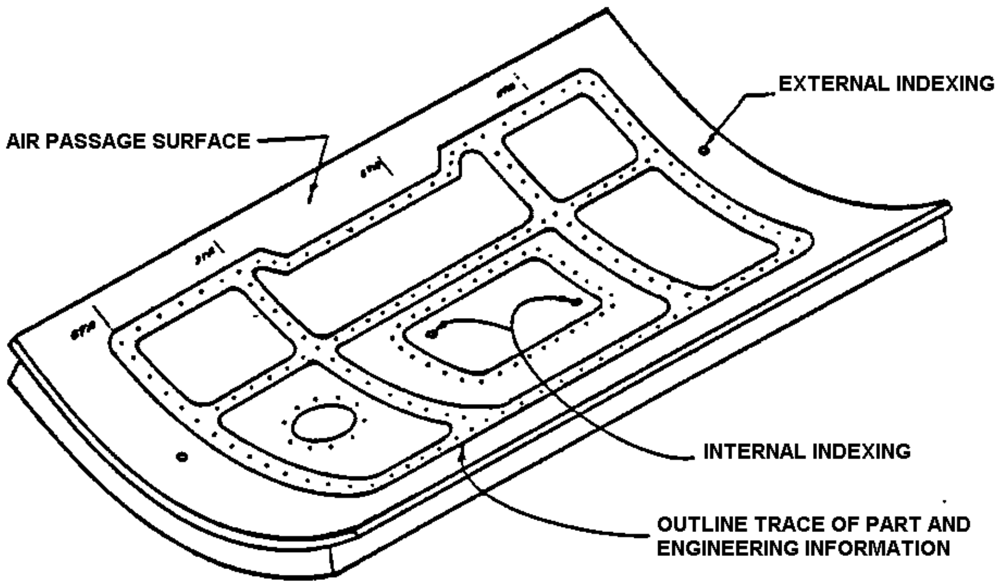


Figure 1

1.0 Definition:

- A White Master is a fiberglass reinforced plastic laminate with plywood or cellular cellulose acetate stiffening. Formed against a mockup surface, or a model surface, it provides the compound curvatures and surface that cannot be drawn in flat pattern for photographic reproduction of Engineering lines. The reference lines scribed on the surface of the mockup are transferred to the White Master and appear as raised lines.

2.0 Scope:

- Information inscribed on the surface of the White Master, such as location of rivets, screws, bolts, skin trim, chem-mill lines or cutouts and parts in relation to each other, together with indexing for coordination, provides the Engineering information required to control and manufacture the tooling to make the parts shown.

- Used in place of photographed lofts, the White Master supersedes all other Engineering (reference information Figure 1).

- There are three types of White Masters designated as follows:

SD139-1:

- Reinforced laminate .120" thick, laid up to mockup air passage surface. Confined to Engineering information at air passage (reference Figure 2).

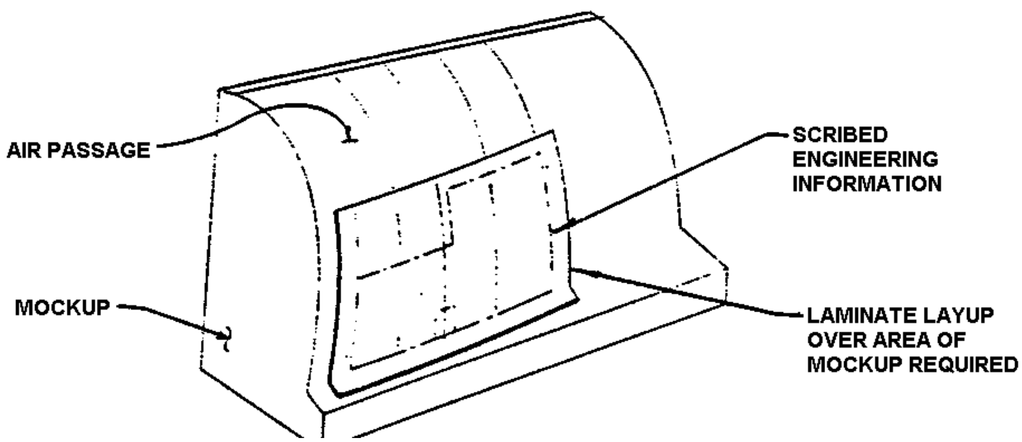


Figure 2

SD139-3:

- Reinforced laminate .250" thick, laid up to mockup air passage surface, together with wood base, serves to support "inner surface White Master". This type is used where honeycomb core inner surface information is required.

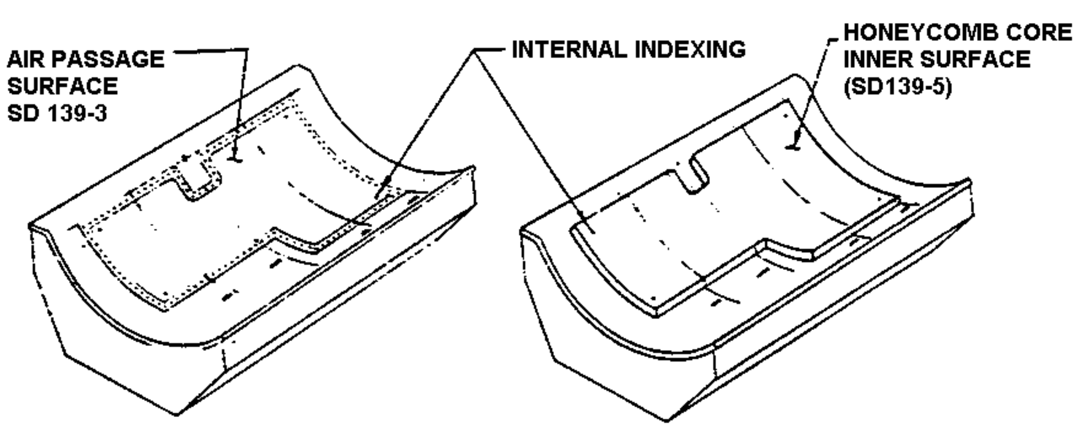


Figure 3

SD139-5:

- Reinforced laminate .250" thick, laid up in shop support cast off of honeycomb master (TTB) or equivalent. This type masters the inboard surface of core, skin, and edge member surfaces. Made to locate in SD139-3 by internal indexing (reference Figures 3, 8, 9, & 10).

3.0 Construction SD139-1 ($^1/_8$" Laminate) SD139-3 ($^1/_4$" Laminate):

3.1 Preparation of Mock-Up:

- Apply three coats of separator (liquid soap) to mockup per standard shop practice.
- Apply parting agent, per standard shop practice.
- Apply two heavy coats of clear coat, per standard shop practice.
- Apply one or two brush coats of polyvinyl, per standard shop practice.
- Apply three coats of Wax, per standard shop practice. Buff smooth after each coat.

3.2 Fabrication of White Master:

- Brush on surface coat per standard shop practice.

  Smooth on resin and hardener. Allow two hours tacking time (approximately).

- Lay-up fiberglass cloth with resin and hardener per standard shop practice. Lay-up should be a minimum of five outside of skin time.
- Insert $^1/_4$" ID x $^1/_2$" LG knurled bushing (reference Figure 4).
- Reinforce with $^3/_4$" plywood around the perimeter of lay-up. Approximately 2" outside of skin trim to clear part configuration (reference figure 5).

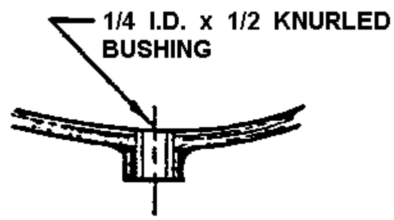


Figure 4

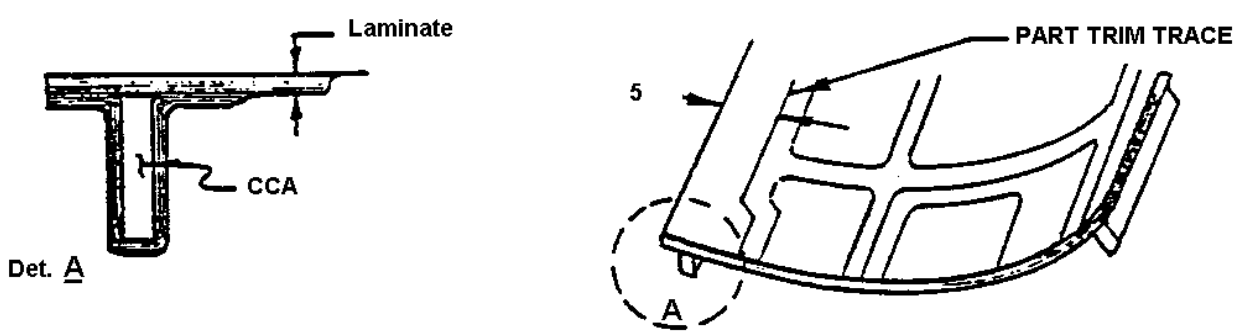


Figure 5

- Apply 3 layers of cloth and resin covering strux to approximately 3" inside of strux (reference Figure 5, Detail A).

- Clean and trim 1" minimum outside of base. Round all corners.

3.3 Preparation for Drawing on White Master:

- Wash the surface with a GAC approved thinner. Rewash with thinners.

- Spray with three coats of primer.

- After the drawing (White Master) is complete, spray two coats of an approved protective coating. The use of clear laquer is continued on white masters fabricated prior to the change in protective coating materials.

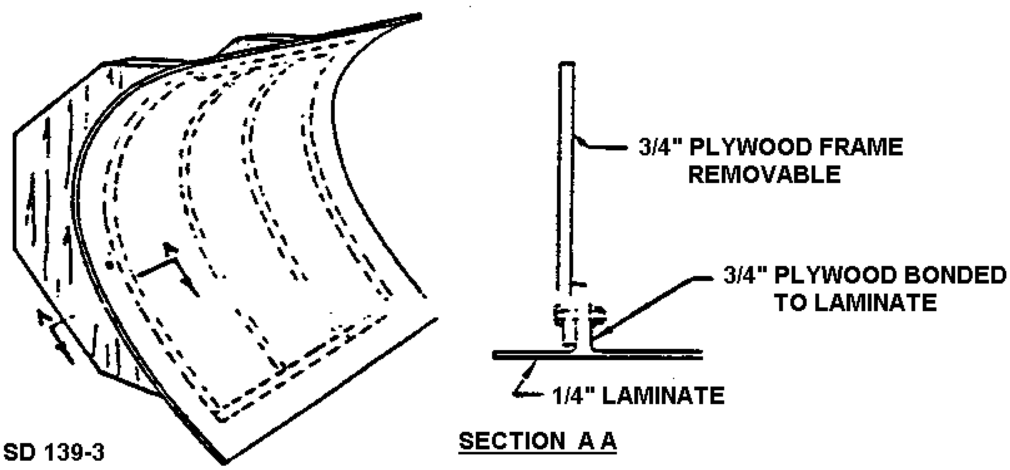


Figure 6

Note: Variations of the end product and sequence of operations are at the discretion of the Engineer (reference Figure 6).

3.4 Base:

- Base for White Master, if required, may be assembled with $^3/_4$" plywood as shown in Figure 7. Contour to be obtained from Master Contour Templates (MCT) or equivalent (add variable) (reference Figure 7).

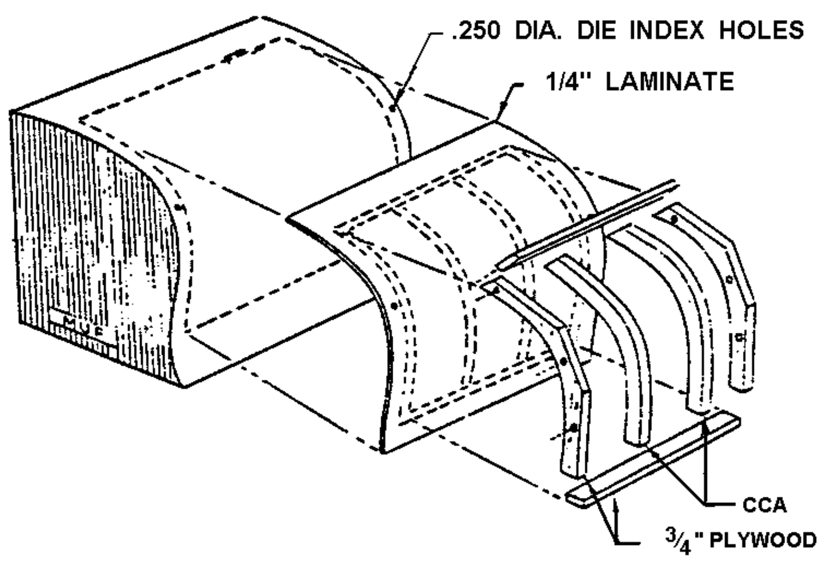


Figure 7

--

4.0 Construction SD139.5:

- The materials and methods of fabricating an inner skin white master, differs mainly in the support tools and the sequence of operations to arrive at the inner required surface plane.

Example: To develop an inner skin white master of the inboard surface plane of honeycomb core, the following support tools and operations are required.

4.1 Support Tools:

- An edge member master Jig Master (TTB) together with a honeycomb bonding fixture machining model, (reference Figure 8) coordinated by indexes are used as the mold to cast a plaster cover or to lay up a $^1/_4$" thick laminate cover (reference Figure 9).

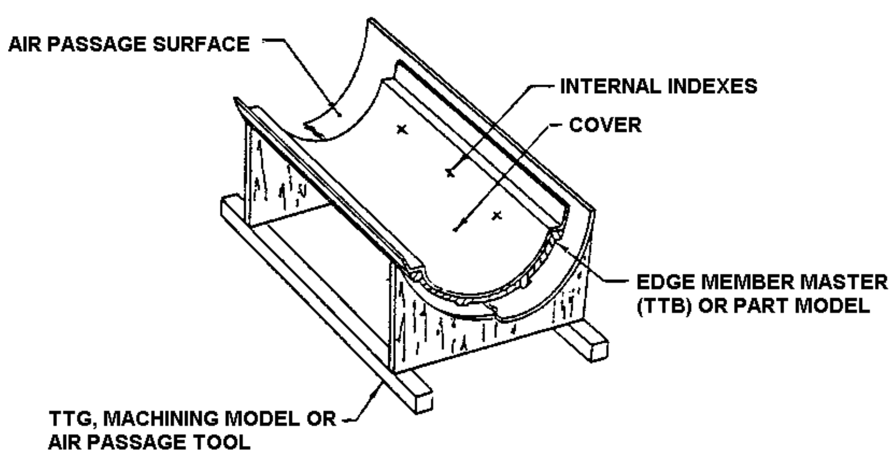


Figure 8

- The indexing system and pertinent information is transferred to the cover. Stiffening may be added to prevent warping or cracking.

- Inspect inside surfaces of cover and smooth where required.

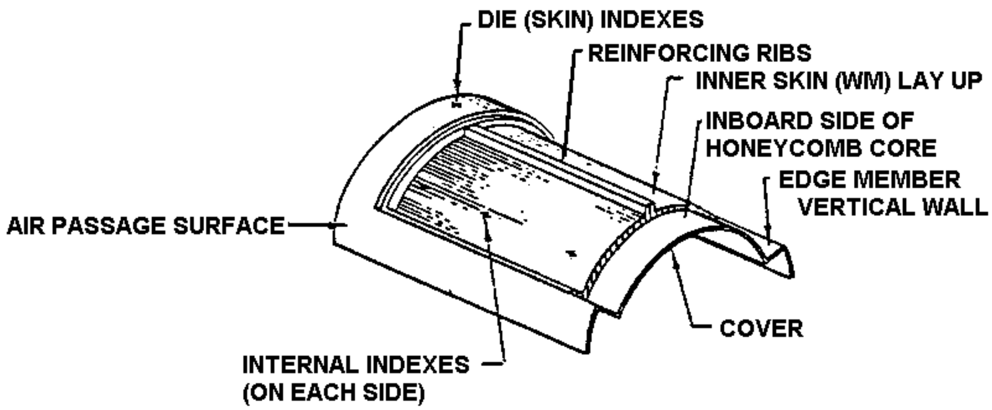


Figure 9

4.2 Preparation of Cover:

- Apply three coats of separator (liquid soap) to mock-up.
- Apply parting agent per standard shop practice.
- Apply two heavy coats of clear coat.
- Apply one or two brush coats of polyvinyl.
- Apply three coats of wax. Buff smooth after each coat.

4.3 Laminate Construction:

- Brush on surface coat.

  Smooth on resin and hardener. Allow two hours tacking time (approximately).

- Lay-up fiberglass cloth with resin and hardener to an approximate thickness of $^1/_4$".
- Reinforce perimeter with 1" CCA and cover with fiberglass cloth and resin to thickness required to bring up to air passage surface (reference Figure 10).

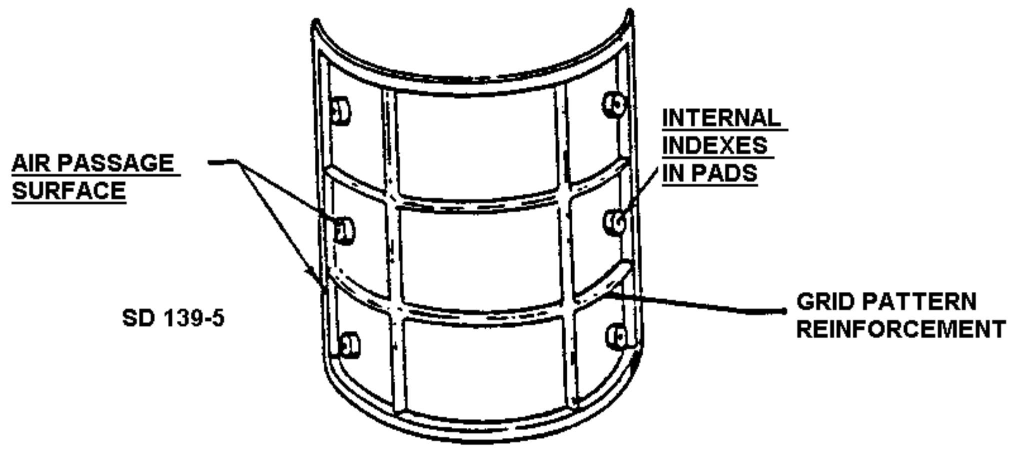


Figure 10

4.4 Reinforcement:

- Reinforce internal index areas with 3" diameter CCA and cover also with laminate to A/P surface (reference Figure 11).
- Reinforce in grid pattern short of A/P surface, with CCA and cover with laminate (reference Figure 11).
- Pot $^{1}/_{4}$" ID x $^{1}/_{2}$" LG knurled bushing in all index holes.
- Remove from cover, clean, and trim as required.

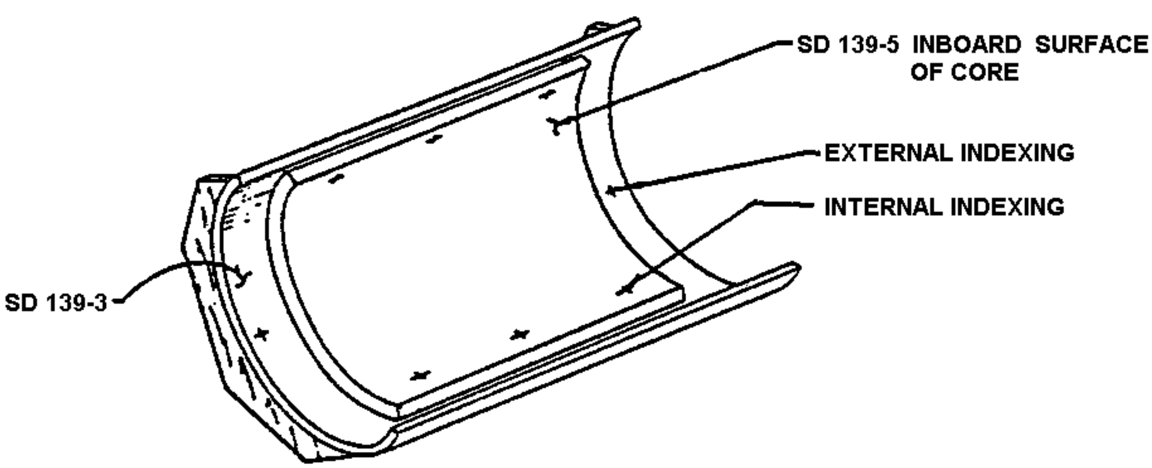


Figure 11

Note: All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

DRIVMATIC MASKING TEMPLATE (MTD)

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 Definition:

- A Drivmatic Masking Template is a flat pattern template used for stenciling hole locations for drivematic operation. Template is aligned over coordination holes on part, then paint is sprayed to mark hole location.

2.0 Material:

- Aluminum alloy, 2024-T3, .040" thick. If template thickness must be greater, such as with chem-milled part, all spray dot holes in "sandwiched" area will be counterbored .500" diameter to a depth which leaves .040" material thickness at the spray hole (reference Figure 1).

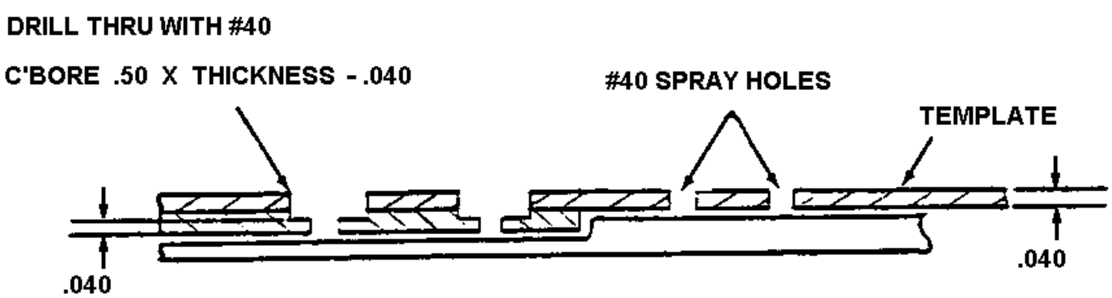


Figure 1

3.0 Construction:

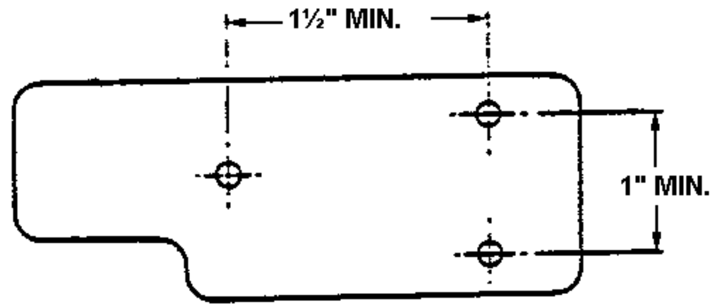
- All spray holes will be # 40 diameter.
- All coordination holes will be # 30, except in cases where the final size is smaller. In this event, # 40 holes shall be used and marked "C" to differentiate from the spray holes. Coordinating holes shall be controlled by use of a Master Flat Pattern Template (TTH) or Record Template (TTR) as appropriate. An adequate number of coordination holes must be provided to assure full contact of template to the part to be sprayed. This is necessary to achieve a well-defined dot.
- A failsafe must be provided, when required, to ensure proper orientation of MTD to the part.
- Consider the configuration of the part when it is sprayed. Is it formed? Is it assembled?
- All MTD's shall have a minimum of 1" overhang wherever possible to protect detail parts from over-spray. It is acceptable to over-spray in areas where it is inconvenient or impractical to protect the part. Generally, flat or rolled parts can be fully protected, while with formed parts protection may be limited.

4.0 Identification:

- Per SD20.510: "Tool and Equipment Identification"
- Identify on template whether the top or bottom of the part is to be sprayed.

UNIVERSAL ROUTER TEMPLATE (URT)

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.



1.0 **Definition:**

- The URT (used for a very limited run of production parts) is a flat template used for drilling hole patterns and cutting outline from a flat sheet. It is attached to the universal router jig, ST 888 and used on the pin router.

2.0 **Material:**

- The URT can be used for part sizes from 1" to 12" x 48". Maximum pin distance on the jig is $18^3/_4$" x 68". Parts are first stack drilled, then routed. Minimum width slot to be routed is $^1/_4$". This tool should not be ordered to make production parts. Use a CBT or DRB (used for long term production parts) unless the tool is for a limited number of parts.

3.0 **Construction:**

3.1 Material:

- Construct from $^1/_8$" aluminum alloy, 2024-T3 or 2014-T6.

3.2 Tolerance:

- Tolerance of ± .005" is allowed on outline and hole location. For $^1/_4$" wide slots, the slot in the template must be .250" + .015"/-.000".

3.3 Outline:

- Obtain template outline from the TTH or electronic model. If template is only for # 40 holes in part, ears must be added to mount on router jig. Tooling holes in ears will be # 30.

3.4 Tooling Holes:

- A minimum of three sufficiently spaced tooling holes must be provided. Tooling holes shall be drilled # 10 in the template. Minimum spacing for tooling holes is 1" between holes on the same jig rail and $1^1/_2$" between holes on adjacent rails. Minimum edge distance for locating a hole is $^5/_{16}$".

3.5 Production Holes:

- Shall be drilled to accommodate standard drill guides. Drill # 10 for production hole sizes # 50, # 40, # 30; drill $^1/_4$" for a # 10 hole and $^5/_{16}$" for $^1/_4$" hole. Paint holes with standard color code, except for # 30 holes, where no coding is necessary.

4.0 **Identification:**

- Stamp standard tool identification data, per SD20.510. When templates are larger than 5" x 5", encircle information with orange dye ring.
- Paint one corner red on both sides. This will facilitate locating the drilled stock on the jig.

DRILL and ROUTER BOARD (DRB)

Note: In addition to the information contained in SD20.153, please adhere to the following criteria when requesting data for a DRB.

- **.375" thick aluminum will be used unless otherwise specified.**
- **The tool will have a .250" thick router guide with .030" setback for the remaining .125".**
- **There will be a minimum of two # 30 tooling holes in a neutral area when production holes cannot be used. Identify these holes as T/H.**
- **The tool will be stamped "DO NOT ROUT" near lightening holes and lightening cutouts input by tooling.**
- **The board is to be flat within .010" unless otherwise specified.**
- **The size of the router board will determine if the board is to be made from MIC-6 aluminum or 6061-T6 aluminum.**
- **The tool is to be made to the net periphery.**

Note: In addition to the information contained in SD20.153, please adhere to the following criteria when requesting data for a DRB2.

- **The tool will be fabricated from .375" thick aluminum unless otherwise specified.**
- **The tool will have a .250" thick router guide with .030" setback for the remaining .125".**
- **There will be a minimum of two # 30 tooling holes coordinated to the DRB and ROJ marked as T/H.**
- **The periphery of this tool is to be .125" larger than the periphery routed by the DRB.**
- **Lightening holes and cutouts are to be steel stamped "DO NOT ROUT THIS AREA".**
- **The tool is to be flat within .010" unless otherwise specified.**
- **The size of the router board will determine if the board is to be made from MIC-6 aluminum or 6061-T6 aluminum.**
- **The tool is to be made to the net periphery in the areas to be routed only.**
- **The tool is to be .125" oversize in areas not to be routed.**

Note: <u>Alternate Manufacturing Method:</u>
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition:**

- The Drill and Router Board (DRB) consists of two parts:

  A - A separate flat pattern drill template

  B - A router board made from a phenolic laminate on aluminum honeycomb.

- The two-part tool would be used for most drill and route requirements.

- It can also be a one-part combination drill and route tool, made with aluminum honeycomb.

  The one-part tool would be used for aluminum honeycomb drill and route requirements.

- Both tools are used on a pin router machine.

2.0 **Scope:**

- There are three types of router boards:

  SD151 (Multiple Type):

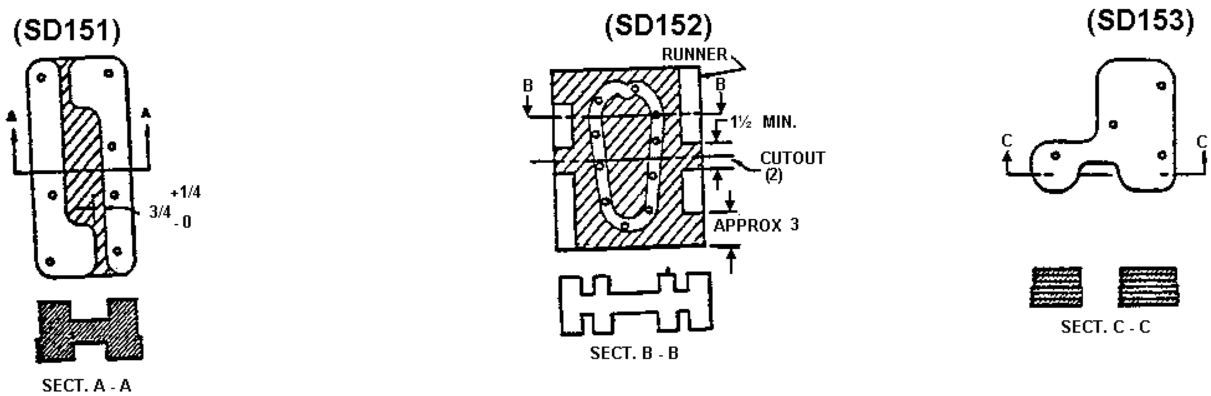
  For long narrow pieces where two, or more (when specified), are made on the same router board. The minimum distance between parts shall be $^3/_4$" (+ $^1/_4$", - 0").
  That is, between $^3/_4$" and 1” but no less than $^3/_4$".

  SD152 (Box Type):

  For narrow parts that the single type (SD153) would not provide the router-operator with a safe holding area and the multiple type (SD151) would be impractical.

  SD153 (Single Type):

  Used for parts over 5" x 12".



Drill and Router Boards

Figure 1

3.0 **Construction:**

3.1 Drill Template:

- Make from .125" thick aluminum alloy (2024-T3) and it will have the same dimensions as shear size.

- Obtain the hole pattern from the Master Flat Pattern Template (TTH). Drill all holes to accommodate standard drill guides for the different production hole sizes. "Steel stamp hole size at each hole or with tool code (if all holes are same size)", for the Drill and Router Board (DRB).

TEMPLATE HOLE	**WORKPIECE HOLE**
# 10	# 50, # 40, # 30
$^{1}/_{4}$"	# 21, # 10
$^{5}/_{16}$"	$^{1}/_{4}$"

- For hole diameters between $^{1}/_{4}$" and $^{1}/_{2}$", the work-piece shall be pilot drilled # 30.

- Holes $^{1}/_{2}$" diameter or larger shall be routed full size.

- Trim to a square or rectangular pattern to match shear size specified by Manufacturing Engineering. Scribe part outline on the drill template. If practical, drill template may be routed to outline of router board by the using department at their option.

3.2 Router Board:

3.2.1 *Material:*

- Make from phenolic laminate or honeycomb with the required thickness below:
  - Multiple (SD20.151) and Box type (SD20.152), 1" thick.
  - Single type (SD20.153), $^3/_4$" thick (refer to section 3.2.5 for the exception).
  - Selection of the material (i.e.: phenolic laminate or honeycomb) will be entered on the work order by the initiator.

3.2.2 *Size Limitations:*

Maximum: 36" x 160"

Minimum: 5" x 12" (overlap with DRB)

3.2.3 *Locating Drill:*

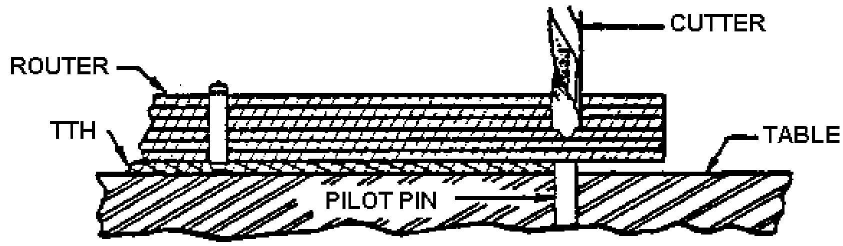
- For parts over 1" wide, add locating provision at approximately 9" - 12" along the perimeter.
- For parts less than 1" wide, space the locators at approximately every 6". There shall be at least three pins for every routed part regardless of size.

  Select the required holes, then use the drill template (part A) as a guide to drill 3.1 mm holes through the router board. Press ($^1/_8$" x $^3/_4$") locating pins into the holes of a Single type router board (SD153) and ($^1/_8$" x 1") pins for the Multiple (SD151) and Box type (SD152) router boards.

3.2.4 *Outline:*

- First Cut:

  Use the TTH as a router plate, then route a $^3/_8$" ± $^1/_{32}$" deep cut using the proper pilots and cutters shown in Table 1 (see figure 2). When 1" thick material is used, remove all the material in non-working areas to a depth of $^3/_8$" (reference section 3.2.5).



First Cut

Figure 2

CUTTER and PILOT PIN SIZES			
	Cutter Diameter First Cut	**Pilot Diameter First Cut**	**Pilot Diameter Second Cut**
Outline			
Standard	$^5/_{16}$"	.310"	.250"
$^1/_4$" Slots and $^1/_8$" Radii	$^1/_4$"	.247"	.218"
Internal Cutouts			
Standard	$^5/_{16}$"	.301"	.250"
$^1/_4$" Slots and $^1/_8$" Radii	$^1/_4$"	.238"	.218"

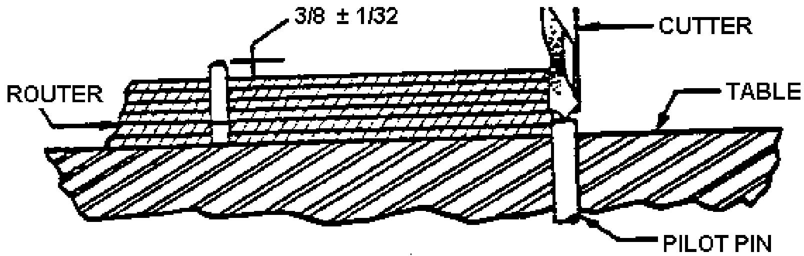
Table 1

When the proper pilots and cutters are used, the router board will have the following characteristics:

- Outline conforms to TTH.
- Hole diameters will be .018" oversize (the TTH will overlap cutouts .009" on edges).

* Second Cut:

  Turn the router board over, then use the First Cut as a guide to route a $^3/_8$" deep cut, using the proper pilots and cutters shown in Table 1 (see Figure 3). When one inch material is used, remove all the material in non-working *internal* areas to a depth of $^3/_8$" (refer to section 3.2.5 for the exceptions). The remaining web is used to hold the Multiple and Box type router board together. Lower the cutter sufficiently (approximately an additional $^1/_4$") to remove the excess material on the outside of the basic Multiple type router board (see Figure 1).



Second Cut

Figure 3

When the proper pilots and cutters are used, the router board will have the following characteristics:

- Outline will be $^{1}/_{32}$" inside the first cut.

- Hole diameters will be $^{1}/_{16}$" oversize with respect to the first cut and will overlap the cut-outs $^{1}/_{32}$" on the edge.

3.2.5 *Cutouts:*

- When large internal cutouts are to be made, use one inch thick material for the Single type (SD153) router board. Cut a $^{1}/_{2}$" wide by $^{3}/_{8}$" deep groove in the router board along the cutout outline. The center material shall remain as a support for the part material. When suitable, locating pins may be placed in this area instead of adding external ears.

- Box type runners shall have a three-inch section removed from the upper right and lower left end of each runner, with respect to the cutter. In addition, when a router board is over 48" in length, a $1^{1}/_{2}$" (minimum) slot shall be cut through each runner about the centerline of the DRB.

3.2.6 *Ears:*

- Locate ears on straight rather than contoured edges (if possible). When square corners are required on the part, locate ears on these corners.

3.2.7 *Pick-up Pins and Bushings:*

- Remove locating pins and press TD131 pins in # 4 diameter holes. For materials of .016" or less, substitute TD132 bushings (in place of the TD131 pick-up pins), press fitted into # 4 holes drilled through the router board.

3.2.8 *Tolerance:* (see figure 4)

- First Cut:

  ± .005" with respect to the TTH.

- Second Cut:

  ± $^{1}/_{64}$" with respect to the First Cut edge.

- Routed surface edges shall have a finish of approximately RMS-63.

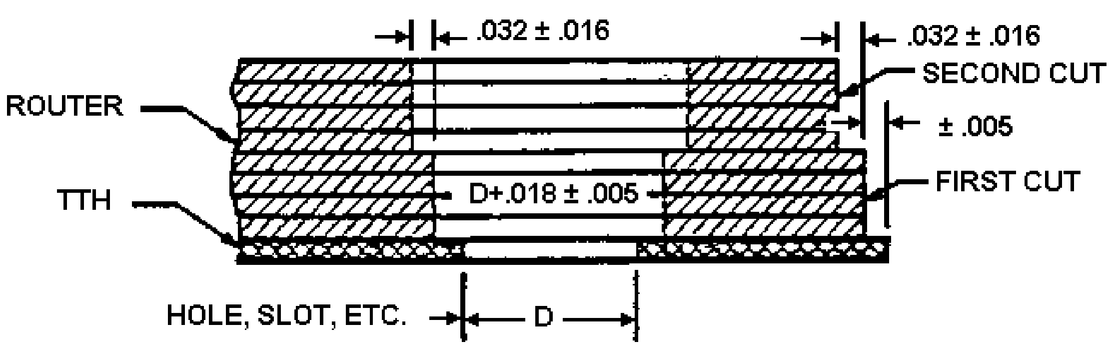


Figure 4

3.2.9 *Identification:*

- Scribe the part outline on the drill template.
- Stamp both the drill template and the router board. Stamp the drill template inside the part outline. Each item shall be stamped with the tool code "DRB".

- Corresponding corners of the drill template and the router board may be painted or identified in some other way to facilitate locating the drilled stock on the router board in the proper position.

- Comply with SD20.150.

3.2.10 *Thumb Screw System:*

- Determine which delron holes are to be used as tool holes by selecting $^{11}/_{32}$" or $^{5}/_{16}$" diameter delron holes spaced so as to provide equal clamping pressure on the work-piece (reference TTH).

- Route a $^{1}/_{8}$" thick aluminum base plate to match the TTH.

- Cut a $^{1}/_{2}$" thick aluminum honeycomb panel to a size slightly larger than or matching the base plate.

- Bond the aluminum honeycomb panel to the base plate with EC2216 adhesive or equivalent.

- Fabricate $^{3}/_{4}$" to 1" diameter x $^{1}/_{2}$" thick aluminum plugs for each tool hole location.

- Counterbore the honeycomb at the tool hole locations and bond the aluminum plug in place using EC2216 adhesive or equivalent.

- Route the core cutback or crush the core around the periphery of the panel and edge fill with 615 corfil or equivalent.

- Route the periphery of the honeycomb panel. Undercut the panel to $^{1}/_{32}$" to $^{1}/_{16}$" less than the base plate.

- Drill and tap the aluminum plugs at the tooling hole locations to 10-32.

- Assemble the appropriate $^{11}/_{32}$" or $^{5}/_{16}$" delron to a 10-32 thumb screw.

3.3 Drill and Router Board Combination:

3.3.1 *Material:*

- Make from .500" thick aluminum honeycomb and .125" thick aluminum alloy (2024-T3). Tool is to be net to the periphery of the desired part.
- Reference requirements are identical to paragraph 3.1 except all holes are to be full size to the drawing where possible.
- For hole diameters between $^1/_4$" and $^1/_2$", the work-piece shall be pilot drilled # 30.
- Holes $^1/_2$" in diameter or larger shall be routed full size.
- Trim the aluminum honeycomb periphery and cutouts with the required setback.
- Drill and counterbore the drill bushing locations in the honeycomb to 1" diameter.
- Route the core cutback of the periphery and cutouts, and the periphery and interior drill bushing locations, .125".
- Edge fill.
- Bond the aluminum honeycomb into the base plate.
- Manufacture the appropriate size ST905-327 tool pins.

PNEUMATIC ROUTER BOX TEMPLATE (CBT)

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition:**

- The CBT is a template used for routing the outline and drilling the hole pattern in the flat pattern parts. It is attached to the Pneumatic Router Box and used on the Pin Router.

2.0 **Scope:**

- SD20-160:

  The CBT can be used for part sizes to 9" x 16" maximum size for CBT's. Parts are first routed, then stack drilled. Maximum thickness of the material to be cut is to be routed in $^{1}/_{2}$" increments or maximum thickness.

- SD20-161:

  Narrow parts - $^{3}/_{16}$" x 3" to $^{3}/_{16}$" to 8" - may be routed by mounting the template on a base. No drilling is done with this tool.

- SD20-162:

  Long parts - to a maximum of 16". No drilling is done with this tool.

3.0 **Construction:**

3.1 Material:

Make the template from $^{1}/_{8}$" aluminum alloy, 2024-T3 or 2014-T6.

3.2 Outline:

Obtain the template outline from the TTH or loft line.

3.3 Tolerance:

± .010" with respect to the loft line on the outline and hole location.

4.0 **Tooling Holes:**

4.1 To eliminate unnecessary resetting of the material clamping bars, templates shall be centered approximately with the center line of the base of the Router Box. This will permit grouping of the templates so that parts falling into the strip size may be routed at the same clamping bar setting. Use tooling holes as required to contain template.

4.2 Tooling Hole Placement for Standard Alignment Bars - SD160:

The following hole patterns shall be centered in the CBT approximately along its major axis.

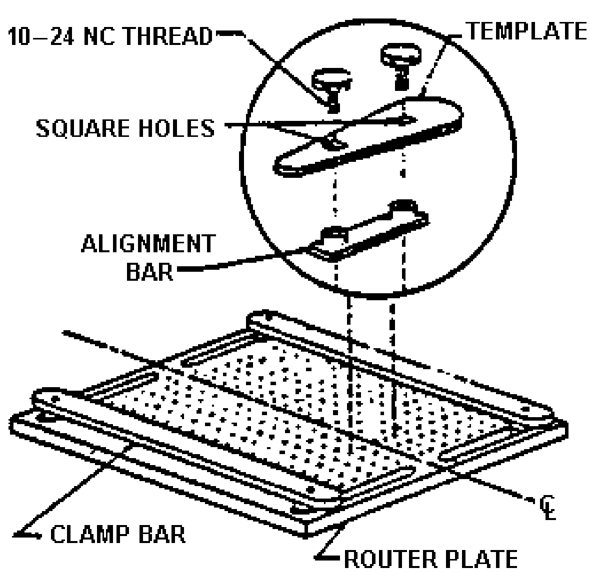


Figure 1

4.2.1 *CBT's $^{3}/_{8}$" x $2^{1}/_{2}$" and Larger:*

This shall have two 192" square punched tooling holes. Use a tooling hole spacing of 2, 4, 6, 8, or 10" to coincide with the length of the standard alignment bars.

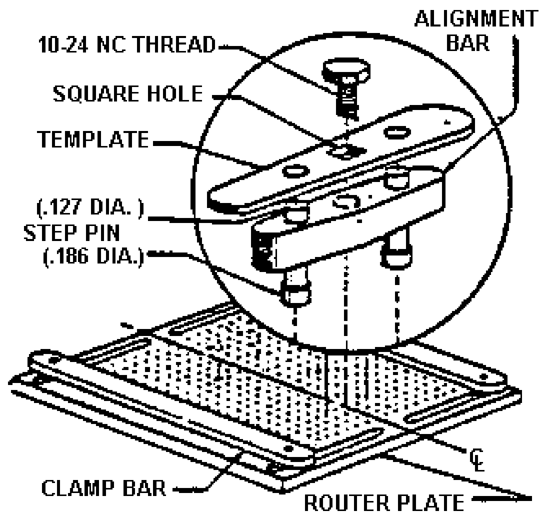


Figure 2

4.2.2 *CBT's $^{3}/_{8}$" x $1^{1}/_{2}$" to $^{3}/_{8}$" x $2^{1}/_{2}$":*

When there is no hole conflict with the production part, the CBT shall have two one-inch spaced # 30 guide holes and one .192" square tooling hole at its center (Figure 2).

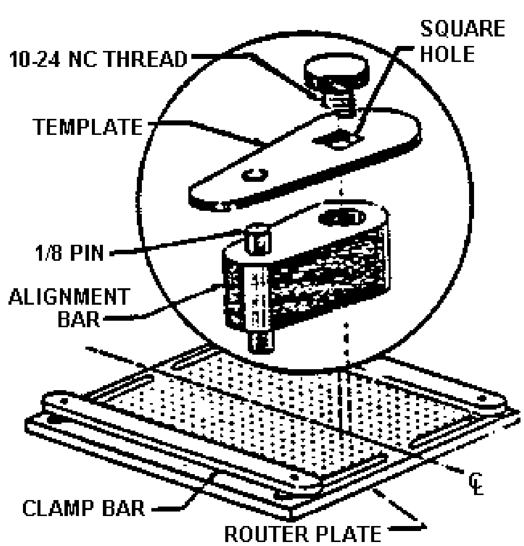


Figure 3

4.2.3 *CBT's $^3/_8$" x $^{13}/_{16}$" to $^3/_8$" x $1^1/_2$":*

This shall have one # 30 hole and one square tooling hole $^1/_2$" apart (Figure 3).

4.2.4 *CBT's $^3/_8$" x $^1/_2$" to $^3/_8$" x $^3/_{16}$":*

This shall have one # 30 hole $^7/_{32}$" apart (Figure 3).

4.3 SD161 - Narrow CBT's Requiring a Base Plate:

4.3.1 *For Bases up to 15 $^1/_2$" x 17":*

Parts as narrow as $^3/_{16}$" may be routed by mounting the templates on a rectangular base. The base shall extend approximately $^1/_2$" beyond the outline of the template. Use the 1" grid pattern to locate one tooling hole in the area of each corner of the rectangular base (Figure 4).

The template is fastened to the base plate with FH rivets.

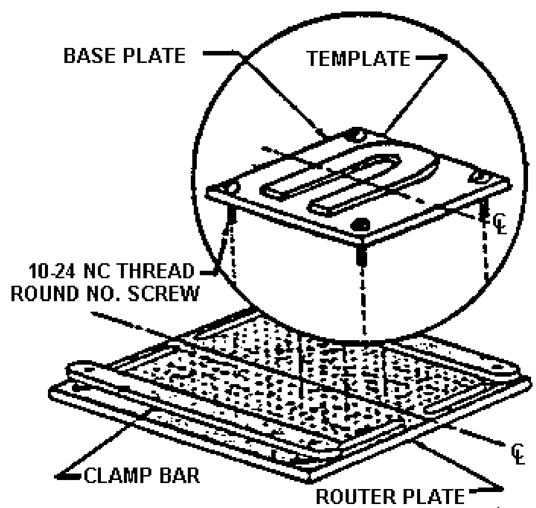


Figure 4

4.4 SD162 - Long CBT's Requiring a Base Plate:

- The template is fastened to a base plate which contains square pick-ups spaced to 6" internals. The holes match one side of a special universal jig with air clamps. FH rivets are used for joining the template to the base.

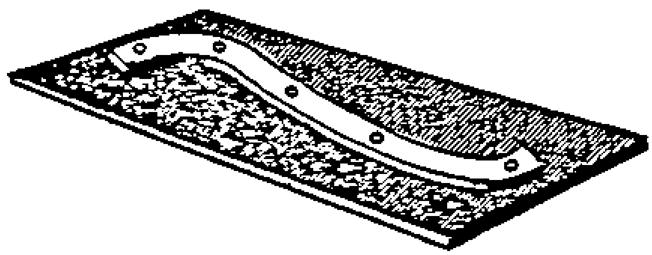


Figure 5

5.0 **Production Holes:**

CBT's shall be drilled to accommodate standard drill guides as follows:

Part Hole Size	Template Hole Size
# 60, # 50, # 40, # 30, 1/8"	# 10
# 10, # 21	1/4"
1/4"	5/16"
1/4" up to 1/2"	# 10 (to pilot drill # 30)
1/2" and larger	Routed full size

"Steel" stamp hole size at each hole or with tool code (if all holes are the same size) for CBT.

6.0 **Identification:**

Stamp standard tool identification data per SD20.510: "Tool and Equipment Identification".

RECORD TEMPLATE (TTR)

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

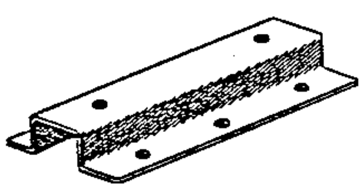
1.0 **Definition:**

- A Record Template is a master template, other than flat pattern, which records the functional operation of the parent tool(s).

2.0 **Scope:**

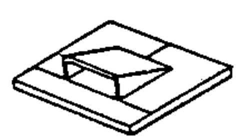
- The TTR master is a stage of fabrication and therefore may represent a semi-finished or a finished work piece. TTR's may also be assemblies of a number of formed work-pieces used to master banking points on jigs or fixtures. The code applies to all masters which are not perfectly flat and includes formed sheet metal, rolled cross sections, and extrusions. For flat sheet metal masters, refer to SD113, 130 (TTH).

ROLLED SHEET METAL



FORMED SHEET

WELDED ASSEMBLEY



3.0 **Construction:**

3.1 Material:

- Made of the same material and thickness as the work-piece, or may be made of a substitute material, such as a fiberglass laminate to reduce tooling lead-time. Fiberglass is used only upon specific request of the tool order. Laminates have only one smooth surface and are not the same thickness as the metal they simulate. This may cause errors on related tools if no compensation is made.

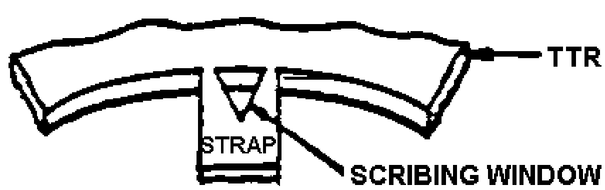
3.2 Outline:

- Trim to outline indicated on Loft or White Master or to Engineering Print dimension. Excess material may be added to the net trim line when specified by the tool order. Interchangeable outlines require coordination with the mating master.

Note: **On all exterior surface skins, trim to + .015"/- .000" to electronic model, unless otherwise noted on the tool order.**

- Ears are added to the trim when necessary to engage index holes outside of the final trim (reference SD20.276, Tooling Ears).

- Straps are kept to retain rigidity of the TTR when large areas are removed from the template. Straps which must be applied to curved edges, shall have scribe windows to reduce the length of the unmarked edge.



- Nominal chem-mill lines are defined by scribe window cutouts (reference Sketch) when an interchangeable fit is required. Chem-mill lines on regular parts require only scribing (reference to SD20.138 (MAT)). No more than two scribe windows are required for each straight line since gaps may be spanned with a scale.

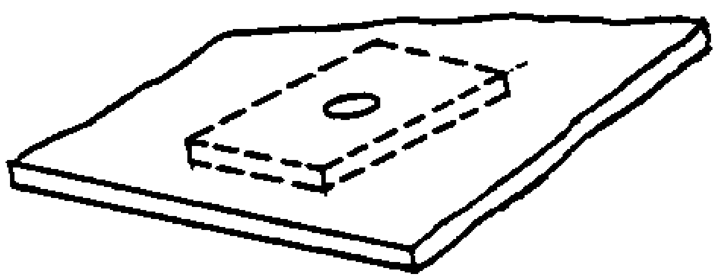
3.3 Hole Pattern:

- The TTR shall contain all the holes which the parent tool(s) drills. Final part hole sizes larger than # 40 and less than $^1/_2$" shall be drilled # 30, holes # 40 and smaller should be drilled # 40. Stamp or inscribe the final hole size in these cases. Holes larger than $^1/_2$" shall be cut full size. All holes for interchangeable hole patterns shall be full size and require coordination with the mating master.

- Production holes other than interchangeable holes may be used as tooling holes only when it is impossible or impractical to add separate tooling holes or ears.

- Failsafe holes are required whenever the contour or shape does not guarantee a difference between right and left hand parts.

- Imbedded aluminum alloy plates (.040" x $1^1/_2$" x $1^1/_2$", 2024-T3) shall be used to reinforce index holes in fiberglass laminate TTR's. Relocation of index holes in these masters shall be done with potted bushings.



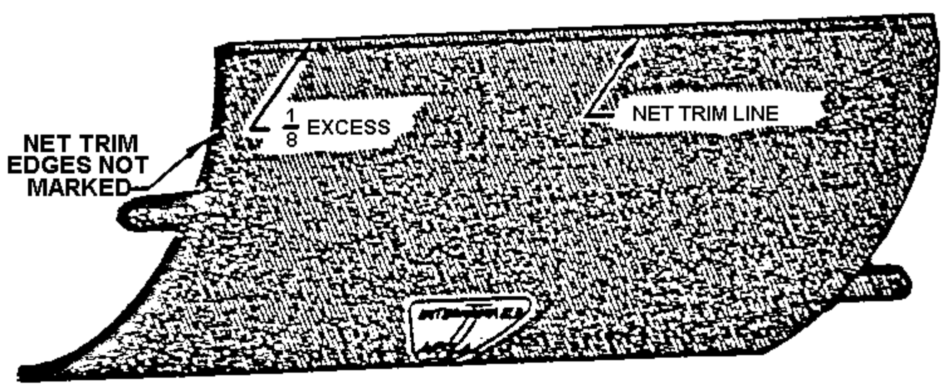
4.0 **Tolerance:**

- Tolerance shall be ± .005" in relation to Loft or WM lines and Engineering dimensions and ± $^1/_2$ degree on angles.

- Formed contours shall be within ± .010" of the WM if one exists, or the form block if there is no WM.

5.0 **Identification - All TTR's to be Painted Red Complete:**

- Stamp or engrave standard tool identification, per SD20.510.
- Add the parent tool code(s) to the tool number (reference 128 B 12345-11 TTR, SRJ).
- Tooling holes and production holes used as tooling holes shall be painted white and stamped with a "T".
- Stamp or paint trims and excesses only where there are deviations from finished outlines. In these cases, also mark the net trim line.
- Paint straps white and stamp or engrave the work "Strap".



STRIPPIT PUNCH TEMPLATE (SPT)

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition:**

- The SPT is a flat pattern template used to position a work-piece for piercing, notching, or slotting. Each location will have identification of the punch to be used.

2.0 **Scope:**

- This template will be used on a brake with standard strippit holders. It is held in position by fit of the hole diameter, at each location in the SPT, over a die button in the holder, at each punch location. All holes will be punched simultaneously with one stroke of the ram. Round or shaped holes may be done also. Holes must be in a straight line within 1" for the application.

3.0 **Construction:**

3.1 Make from .125" thick 4130 sheet to coincide with standing height of die button above the top of frame. Bank points shall be established for one end and one edge to locate work on the template. Holes to fit die buttons will have dimensional locations from banks. Minimum pitch is $^3/_4$" for one set up. Closed spacing will require two tools or two stages to do. Scribe net peripheral trim lines as work-piece would be against banks to punching. Holes shall be as follows:

DIAMETER IN TEMPLATE	TO PIERCE IN PART
.4925" + .003" - .000"	.0937" to .3125"
.9375" + .005" - .000"	.3125" to .3750"
1.6255"+ .005" - .000"	.3750" to 1.0000"
2.6255" + .005" - .000"	1.0000" to 2.0000"
Route Full size	Over 2.0000"

3.2 Holes:

Locate holes from the TTH or electronic model. All pilot holes shall be .250" diameter, countersink 90° x $^{5}/_{16}$" diameter to act as a lead for the machine stylus. The countersink shall not extend more than .032" into the material.

3.3 Banking Edges:

The longer side of a SPT shall be referred to as the "primary banking edge".

When looking down at a SPT, the secondary banking edge (short side) shall be to the left of the primary edge.

When added material is necessary, it shall be added to the primary edge only. Select, as the primary edge, the side that requires the latest added material.

3.4 Outline:

Size - Minimum: 1" x 7"

Maximum: Transverse side 30

Longitudinal side 30 to last hole or 43 to end of template.

3.5 Added Material:

- *Holes 1 $^{1}/_{4}$" Diameter orLess in the Part:*

  Add 1$^{1}/_{2}$" to the primary banking edge of the SPT when the nearest hole centers are less than 1$^{1}/_{2}$" from the edge.

  Material shall not be added when there are at least two locations where the hole centers (less than 1$^{1}/_{2}$" from the primary banking edge) are spaced at least 4" apart.

  Material shall not be added when the end holes (less than 1$^{1}/_{2}$" from the primary banking edge) are centered at least 2" from the ends.

- *Holes Over 1 $^{1}/_{4}$" Diameter in the Part:*

  Add 3$^{1}/_{2}$" to the primary banking edge of the SPT when the nearest hole centers are less than 3$^{1}/_{2}$" from the edge.

Material shall not be added when there are at least two locations where the hole centers (less than $3^1/_2$" inches from the primary banking edge) are spaced at least 7" apart.

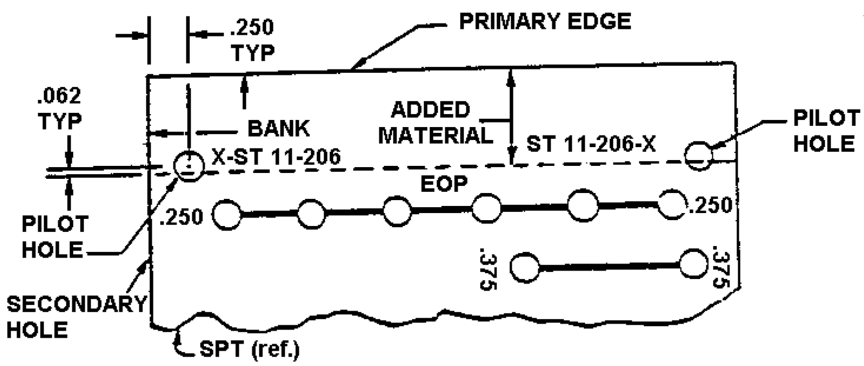
- *Holes - Other Than Round:*

  Add $3^1/_2$" to the primary banking edge of the SPT when the nearest hole centers are less than $3^1/_2$" from the edge.

3.6 Shear Locating Notches:

The material that has been added to the primary banking edge of the SPT shall be removed from the work-piece after it has been punched. When the finished edge of the work-piece is to be straight, notches shall be provided (at both ends) so that the shear may be accurately located.

Locate two $^1/_4$" diameter pilot holes in the SPT to establish the position of the shear notches.



Strippit Punch Template

Figure 1

Counter sink the two holes 90° x $^5/_{16}$" diameter.

Stamp an "X" inboard of both holes to indicate the direction of the punch.

Stamp the punch number "ST11-206" (.625" x .125") inboard of the X's.

3.7 Tolerances:

Pilot Hole Diameter	+ .005" - .000"
Pilot Hole Center	± .005" with respect to TTH/electronic model.
Outline	± .005" with respect to TTH/electronic model. When template is larger than TTH/electronic model, excess material shall have a tolerance of ± $^{1}/_{16}$".

4.0 **Identification:**

4.1 Stamp standard identification data in lower left corner of template, per SD20.150.

4.2 Stamp "Bank" and two arrows to show how to position template under fixed stops. Stamp in lower left corner (reference Figure 1).

4.3 Holes:

Stamp all round holes with their decimal diameters.

Stamp all irregular holes with the punch and die number and with an "X" in the position shown in the Standard Die Manual. A list of all punches is also available in the Standard Die Manual.

If there are more than two holes of the same type, stamp only the beginning and end holes of each line.

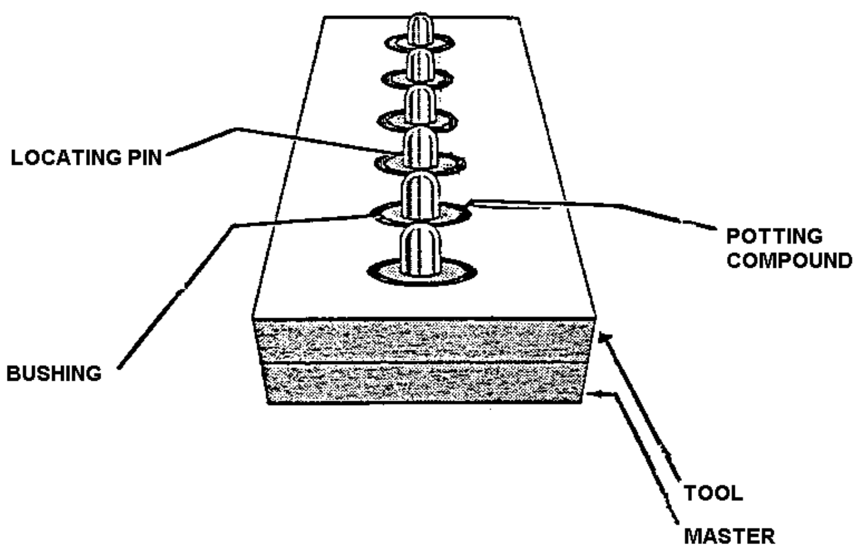
All pilot-hole identification numbers should be stamped to face the operator when the template is mounted on the machine.

POTTING of BUSHINGS with a THERMOSETTING COMPOUND

1.0 Definition and Scope:

- Potting is a method of anchoring bushings in a mastered location in metals, plastics or fiberglass laminates. This is done by inserting the bushing in an oversize hole and surrounding it with a thermosetting resin. Potting provides an inexpensive and accurate means of locating bushings from a master location. Applications include interchangeable hole patterns in non-designed tools and accurate hold locations in designed drill jigs or assembly jigs and fixtures. Accuracy of location is determined by the fit between the hole in the master, the potting pin and the bushing ID. This standard provides the instructions to be followed for uniform potting practices at GAC or for work accomplished at sellers for GAC.

- Potted bushings act as heat sinks. Therefore, bushings with the greatest mass (OD and length) possible shall be used. Thin wall bushings are considered satisfactory if they are used as liners for slip renewable bushings.



2.0 Materials:

- Potting pins and drill rod (reference 5.0 and 7.0).

- Knurled embedment bushings.

- Thermosetting Compounds:

- Paste Wax
- Poly-vinyl chloride sealer, or lacquer (against plaster)
- Chlorothene NU
- Mixing cups (wax free)

3.0 **Method:**

- Drill a pilot hole through the tool material at the hole location.
- Enlarge the pilot hole with a drill or counterbore to make a potting hole. It is preferable to the hole to go completely through the tool material and be .090" larger in diameter than the bushing OD (use a carbide counterbore on fiberglass laminates). Maximum clearance shall be .120" on diameter.
- Rough up and clean the interior of the hole. Dirt, chips, moisture, and oil prevent good adhesion of the potting compound. When possible, in steel, magnesium or aluminum, sandblast the wall of the hole. Alternate methods are to run a rotary file against the wall of the hole, or scarify the walls with a vibrator-engraving tool. No extra hole preparation is necessary in fiberglass.
- Apply paste wax around the hole in the master and on the pickup pin to prevent the potting compound from adhering to the master or the pin.
- Authorized shop personnel shall perform the mixing of the potting compound. The compound shall be mixed only per the following instructions in 4.0 to guarantee the full physical properties that are expected of this material.
- The pouring type compound is used whenever the work is flat. When possible, pour epoxy to approximately $^{3}/_{4}$ of the depth of the hole with the potting pin in place and slide the bushing over the pin and into the hole allowing the epoxy to surround the bushing. Use the troweling grade when there is a possibility of the unset compound oozing out of the hole before it can "set up".
- Prior to inserting bushing, clean with safety solvent Chlorothene NU. Align the bushing in the hole by using potting pins or drill rods when no pins are available.
- Build up the compound around the bushing to give maximum support when the bushing length is greater than the hole depth.
- When potting against a sheet metal master, seat the bushing against the master surface to assure that the hole is normal to it. In all other cases the potting pin controls the attitude of the bushing.

- Allow the potting compound to set at room temperature for a minimum of eight hours before removing the potting pin. This precaution will prevent accidental shifting of the bushing.

4.0 **Mixing Instructions for Thermosetting Compound:**

- Stir the resin and hardener thoroughly, in their original containers using a separate paddle for each. This pre-mixing shall not be omitted.
- Mixing proportions shall be determined by the instructions on the container.
- Mix hardener and resin and stir thoroughly until uniform in color and consistency. This requires from three to five minutes.
- Pour approximately .250" inch of the compound into a small paper cup, which is to be set aside for hardness inspection. Note the tool number, time, and date on the cup. Sellers shall send this sample with the tool (reference 8.0).
- Apply the remainder to the potting holes.

5.0 **Potting Pins:**

- For masters up to .125" thick and having no bushings, potting pins are recommended. Drill rod may be used as a substitute. Use "Select-Fit" in matching the drill rod diameter to the bushing. In some cases, it may be necessary to lightly polish it to get the drill rod to enter the bushing. Polishing should be done carefully keeping in mind the fact that the closer the fit, the more accurate the potting will be.
- For master over .125" thick and containing bushings, closer fits between bushings and pins are required. The tool designer shall specify the potting pins and their tolerance.

6.0 **Tolerance:**

- In non-designed tooling, the final bushing location in relation to the originating master shall be checked by aligning the holes with a checking pin made .001" to .0015" under normal hole diameter.
- In designated tooling, the tool designer shall specify the tolerance required. As a general rule, hole alignment shall be inspected with a checking pin .0005" to .0008" under the potting pin diameter.

7.0 **Tolerance:**

BUSHING (MORSE GAGE)	02 DRILL ROD (STUBS GAGE)	HSS DRILL ROD (MORSE GAGE)
# 40		# 40 (.0980")
# 30		# 30 (.1285")
# 28	9/64 (.1406")	
# 21		# 21 (.1590")
# 19		# 19 (.1660")
# 18		# 18 (.1695")
# 11	# 10 (.1910")	
# 10		# 10 (.1935")
# 7	# 6 (.2010")	

- These comparisons shown above are given to provide a ready reference of the most used hole and drill rod sizes at GAC. Fractional sizes are not shown because there are no conflicting sizes as in the numerical series of sizes.

8.0 **Inspection:**

- Maximum hardness of the potting compound takes place after curing for three to five days. Hardness reading shall not be taken earlier than 24 hours after applications.
- The potting sample shall have a flat and smooth surface free from any air bubbles.
- Readings after 24 hours (minimum values).

  Barcol 935 (70)

  Shore D (66)

- Reading after 72 hours.

  Barcol 935 (88)

  Shore D (83)

TOOLING for INTERCHANGEABLE PARTS
Conventional (Built-Up) Sheet Metal

1.0 **Definition:**

- To be interchangeable, a part must be capable of being readily installed, removed, or replaced without alteration, misalignment, or damage to it or to adjoining parts. No fabricating operations, such as filing, reaming, hammering, or bending are permitted once the part has completed the last operation on production tools (reference MIL-I-8500).

2.0 **Scope:**

- This data is meant to guide the selection and manufacture of detail tooling for built-up sheet metal interchangeable parts and their mating assemblies. The Cover TTH or TTR shall be the control master for all required coordinated tooling (refer to SD20.168 for chemically milled parts detail tooling).

- This standard is separated into four categories, as follows (SD20.167):

  - SD20.167.1 - Flat
  - SD20.167.2 - Formed
  - SD20.167.3 - Hinged Doors (Interchangeable at Hinge Pin)
  - SD20.167.4 - Hinged Doors (Interchangeable at Hinge Fasteners)

- Data is specified for a $^{1}/_{16}$" gap, the most common for interchangeable mating parts. Smaller gaps are required on control surfaces, and larger gaps are permitted on power operated doors and mating removable panels. For these gaps, the ICT and IJ sizes must be adjusted accordingly (the ICT is oversize on each edge by the gap, minus the skin tolerance. The IJ is oversize by half the gap on each edge).

- BPD's are recommended for all covers and doors that are flat or rolled. This recommendation is extended to steel dies when sufficient production, as in wing inspection covers, is indicated.

- Poly-vinyl chloride sealer, or lacquer (against plaster).

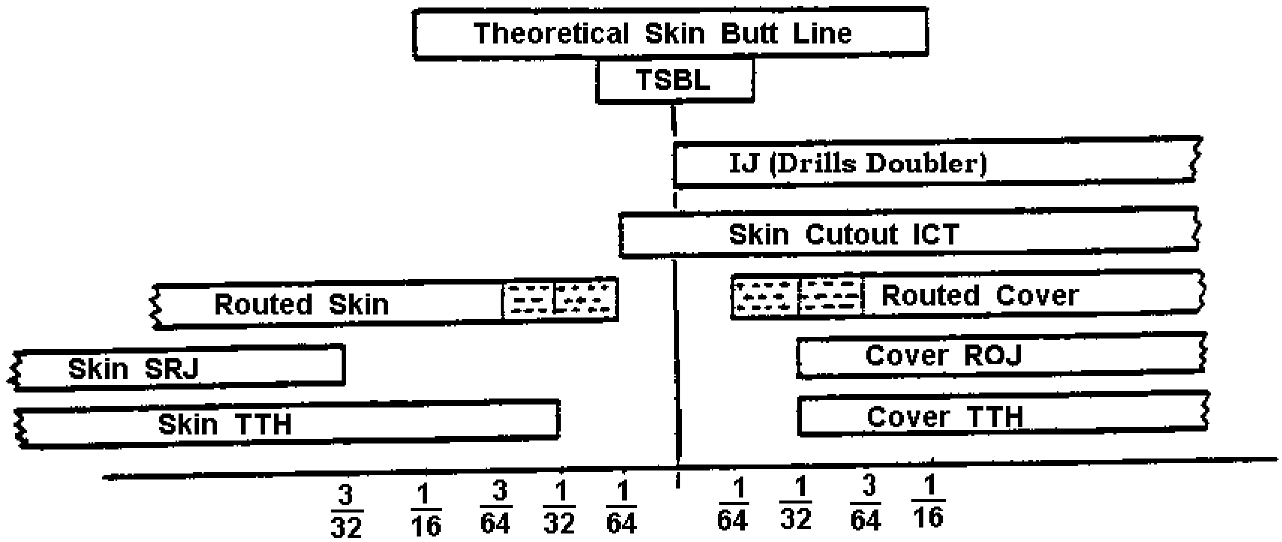
Note: The nature of these parts requires that their tooling be coordinated, fabricated, and finished to the closest tolerances possible.

3.0 **General Information:**

- ICT checks quality of skin cutout, eliminating the possibility of interference areas between the cover and the skin.

- IJ, smaller than ICT and larger than maximum cover, permits skin to "creep" slightly during assembly and allow clearance for cover.

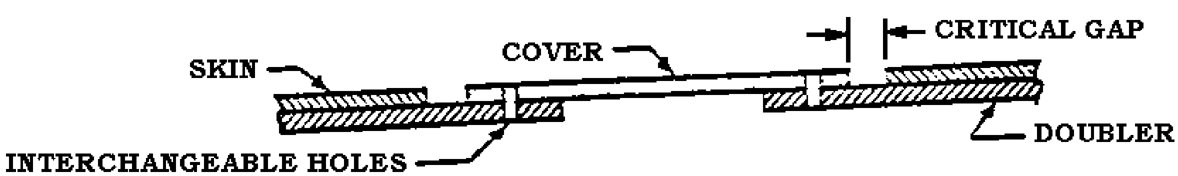
4.0 **Graphic Synopsis:**



THEORETICAL SKIN BUTT LINE

5.0 **Construction:**

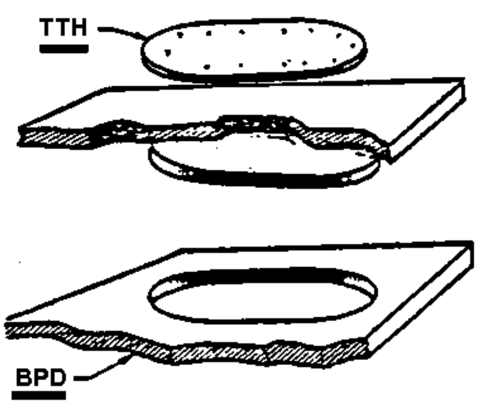
5.1 SD20.167-1 Flat:



(-1) Flat Cover, Skin and Installation

5.1.1 *(-1) Cover Tooling:*

- For parts .065" and less in thickness (and holes of $^3/_{16}$" diameter or less):



TTH Make per loft - provide # 30 holes for punch location and stamp hole size as called out on the tool order (reference SD20.113).

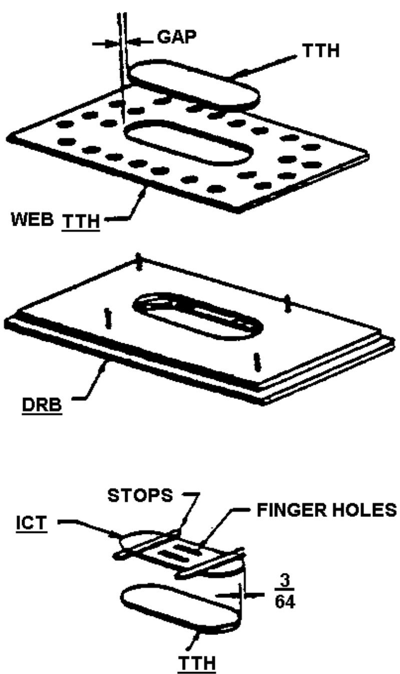
BPD Make per TTH. This tool must produce a finished outline and full size holes.

ICT Not required for die made parts.

<u>(-1) Cover Tooling</u>

- For parts over .065", make a TTH, CBT, and DP using full size bushings in the DP for the interchangeable holes. A male type ICT with holes is required to check size and coordination between outline and holes.

5.1.2 *<u>(-1) Skin Tooling:</u>*



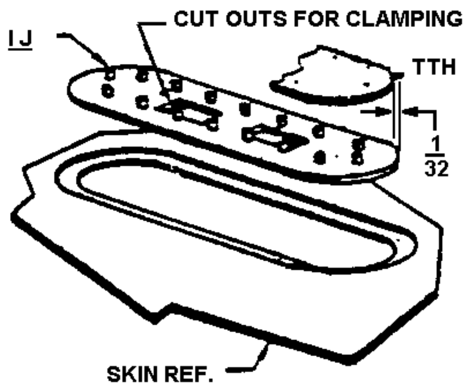
TTH Make per loft and coordinate the hand hole cutout with the cover TTH. Trim the cutout for the required gap clearance on all sides of the cover TTH.

DRB
or
HRJ Make per the TTH (reference SD20.135, SD20.136).

ICT Plug type to check the hand hole cutout for minimum allowable size. Make from .063" aluminum alloy. Trim per the cover TTH, plus $^3/_{64}$" on all sides. Provide handle or finger holes for gripping the template and stops to locate inspection note: "Butt fit to $^1/_{32}$" gap allowed." Stamp "UP" and "FWD" for tool orientation.

<u>(-1) Skin Tooling</u>

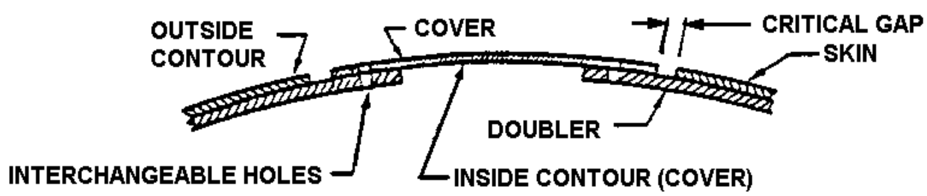
5.1.3 *<u>(-1) Installation Tooling:</u>*



(-1) Installation Tooling

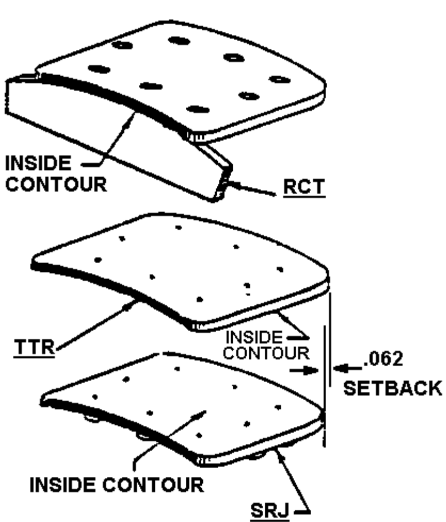
IJ Make from .125" aluminum alloy per cover TTH plus $^{1}/_{32}$" on all sides. Provide full size bushings for the interchangeable holes. Provide cutouts to permit C clamping to the structure. The gap between the IJ and skin cutout must be kept constant on all sides by shimming. Stamp "UP" and "FWD" for tool orientation.

5.2 SD20.167-2 Formed:



(-2) Formed Cover, Skin, and Installation

5.2.1 *(-2) Cover Tooling:*

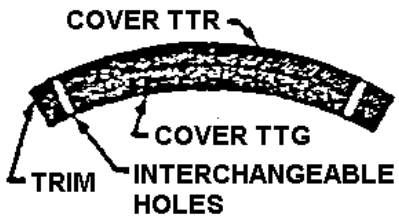


(-2) Cover Tooling

RCT For rolled covers, make male RCT from .063" aluminum alloy - one for constant curvature, two for tapered contour. Cut to air passage minus material thickness. Inspect contour to the appropriate MCT.

TTR Per WM - roll .063" aluminum alloy to contour of cover RCT. Provide full sized holes as specified on the tool order for the interchangeable hole pattern.

SRJ Per WM - Make from .190" aluminum alloy and roll from application to inside contour of part. Provide full size bushings for the interchangeable holes. Provide a .063" back-up plate for drilling parts of .032" or thinner (reference SD20.136).



Shallow rolled covers may be blanked in the flat and rolled or fitted to contour.
The following change in procedure will be required:

TTH & BPD
Per WM or loft. To provide a finished outline and full size holes.

RCT Refer to previous RCT.

TTR Per TTH and rolled to the RCT.

TTG Per TTR. Roll for application to inside of TTR and trim to net outline. Use this TTG for skin coordination in place of the cover SRJ but discount the $^{1}/_{16}$" setback.

5.2.2 *(-2) Skin Tooling:*

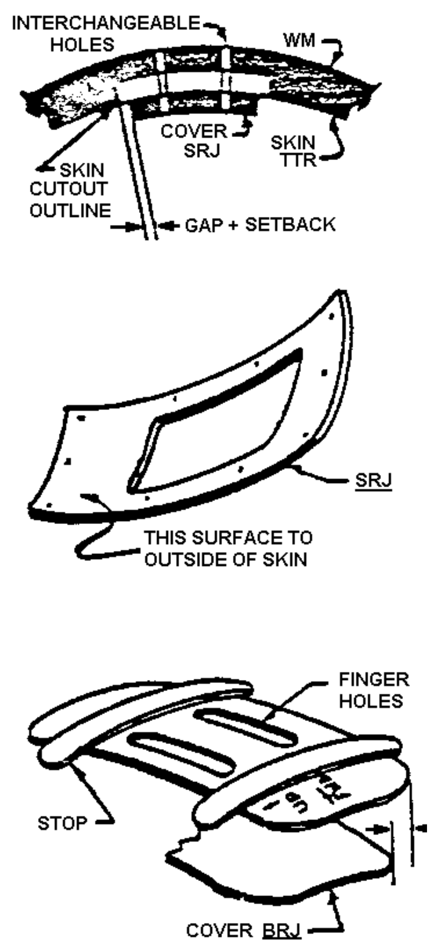
RCT Same as for -2 cover when required for single curvature.

SD Tool design by the die group is required for any compound curve forming operation. Inspect contour to the appropriate MUF or MCT.

TTR Per WM - Use a sample formed piece. Coordinate the hand hole cutout with the cover SRJ (plus $^{1}/_{16}$" because of SRJ setback). Locate the SRJ from the interchangeable hole pattern obtained from WM. Trim the cutout for the required gap clearance on all sides of the cover SRJ.

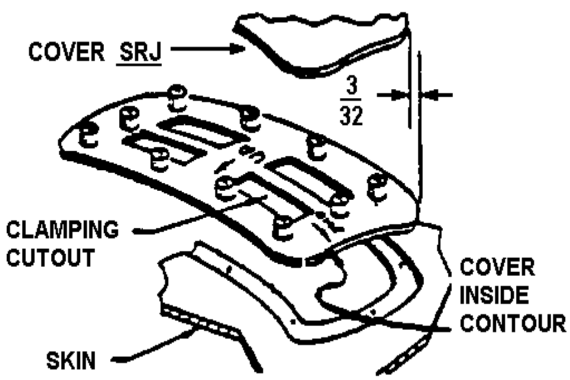
SRJ & HF or HRJ -- Per the TTR - Make SRJ from an overpress or fiberglass layup for application to the outside contour of the skin. Make HRJ from .125" aluminum alloy. Do not include interchangeable hole pattern (reference SD20.136, 20.271, and 20.182).

ICT -- Plug type to check the hand hole cutout for minimum allowable size. Use a sample formed piece (cover) or a fiberglass layup. Trim per the cover SRJ plus $^{7}/_{64}$" on all sides (includes $^{1}/_{16}$" SRJ setback). Provide a handle or finger holes for gripping the template and stops to locate the template flush with the skin. Add inspection note: "Butt fit to $^{1}/_{32}$" gap allowed". Stamp "UP" and "FWD" for tool orientation.



(-2) Skin Tooling

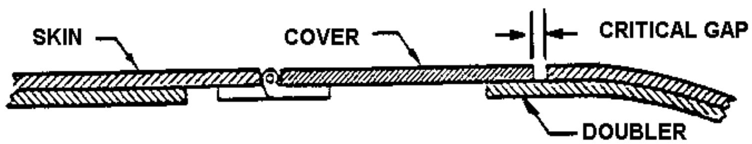
5.2.3 *(-2) Installation Tooling:*



(-2) Installation Tooling

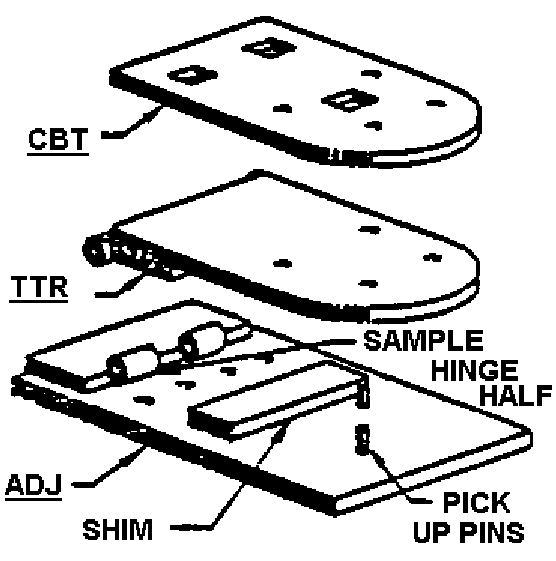
IJ Roll .125" aluminum alloy to contour of cover RCT. Trim per the cover SRJ plus $^{3}/_{32}$" on all sides. Provide full size bushings for interchangeable holes. Provide cutouts to permit C clamping to structure. The gap between the IJ and the skin cutout must be kept constant on all sides by shimming. Stamp "UP" and "FWD" for tool orientation.

5.3 SD20.167-3 Hinged Doors (Interchangeable at Hinge Pin):



(-3) Hinged Doors (Interchangeable at Hinge Pin)

5.3.1 *(-3) Door Tooling:*



(-3) Door Tooling

TTH Make per loft - provide # 30 holes for punch location and stamp hole size as called out on the tool order (reference SD20.113).

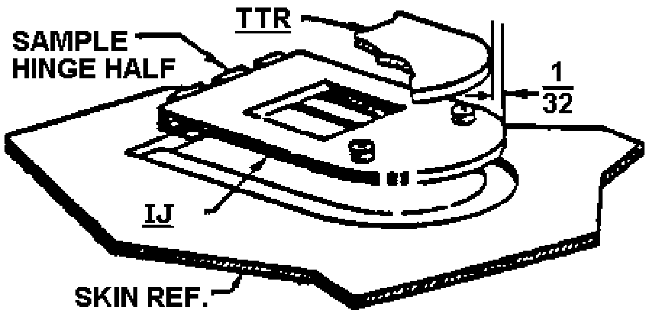
BPD Make per TTH. This tool must produce a finished part.

TTR An assembly of a duplicate door TTH and a hinge half.

ADJ Per TTR for assembling hinge half, door and locking devices. Locate door hinge with a sample hinge half secured to base. Locate door with pickup pins on rivet or latch hole pattern. When no-hole pattern is available, locate door with edge stops on an outlined $^{1}/_{64}$" larger than TTH.

5.3.2 *(-3) Installation Tooling:*

Same as Flat and Rolled (-1).

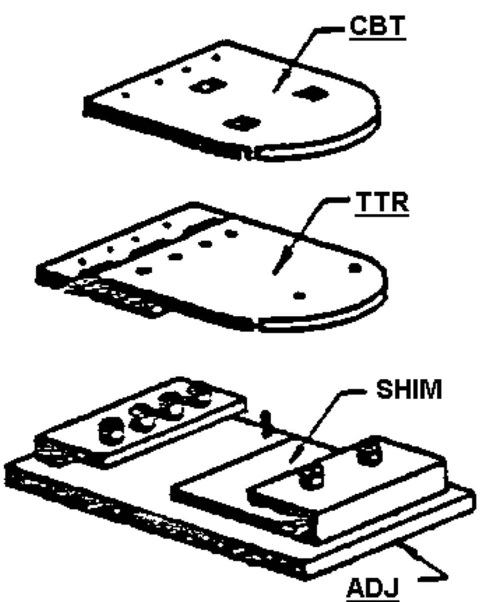


IJ Per the Door TTR plus $^{1}/_{32}$" all around the door outline. Make from .125" aluminum alloy sheet and sample hinge half to locate structure hinge half. Provide bushings for drilling the lock screw receptacle holes, and openings for clamping the IJ to the structure. The gap between the IJ and the skin must be kept constant on all sides by shimming. The fastening rivets on the structure may be located from the skin or the hinge half as required by the installation.

(-3) Installation Tooling

5.4 Hinged Doors (Interchangeable at Hinged Fasteners):

5.4.1 *(-4) Door Tooling:*



TTH Make per loft - Provide # 30 holes for punch location and stamp hole size as called out on the tool order (reference SD20.113).

BPD Make per TTH. This tool must produce a finished part.

TTR An assembly of a duplicate door TTH and both hinge halves. Include full size interchangeable holes.

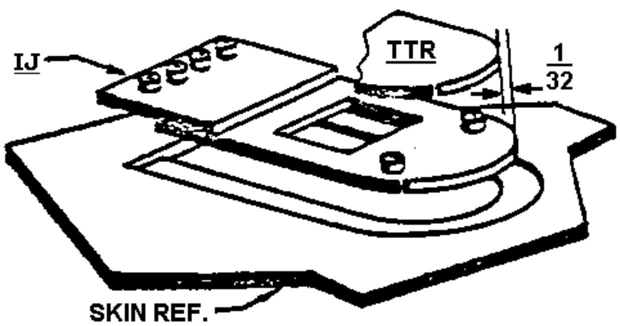
ADJ Per the above TTR for nesting the door and both hinge halves. Provide bushings for the full size interchangeable holes in the hinge half and also for mounting locking screws, if required.

(-4) Door Tooling

5.4.2 *(-4) Skin Tooling:*

Same as Flat (-1).

5.4.3 *(-4) Installation Tooling:*



(-4) Installation Tooling

IJ Per the Door TTR plus $^1/_{32}$" all around the door outline. Make from .125" aluminum alloy sheet (and angle section for bulkhead mounted hinges). Provide full size bushings for drilling the hinge half mounting holes and the lock screw receptacle holes. Provide openings for clamping the IJ to the structure. The gap between the IJ and the skin cutout must be kept constant on all sides by shimming.

TOOLING for INTERCHANGEABLE PARTS

Chemical Milled Parts (smaller font)

1.0 **Definition:**

- To be interchangeable, a part must be capable of being readily installed, removed, or replaced without alteration, misalignment, or damage to parts being installed or to adjoining parts. No fabrication operations, such as cutting, filing, drilling, reaming, hammering, bending, prying, or forcing shall be permitted once the part has completed the last operation on production tools (reference MIL-I-85000).

2.0 **Scope:**

- This data is meant to guide the selection and manufacture of detail tooling for chemically milled covers, doors, and/or skins. The Cover Master Flat Pattern Template (TTH) or the Record Template (TTR) shall be the control master of all coordinated tooling required to make a mating cover or door and skin combination (refer to SD20.167 for conventional (built-up) parts detail tooling).

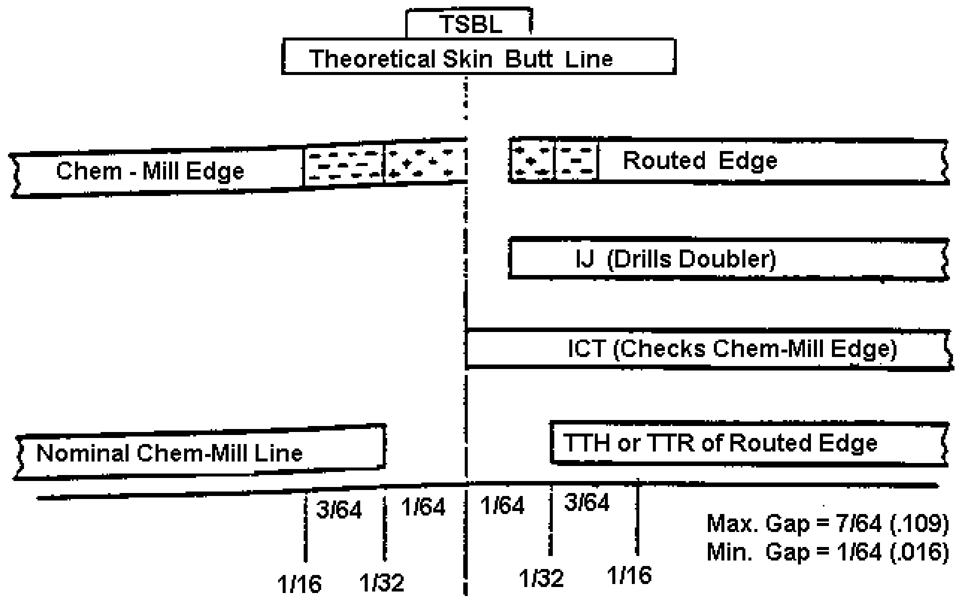
- This standard is separated into six categories, as follows:

  - SD20.168-1 - Flat - No Step in Cover; Step in Skin
  - SD20.168-2 - Flat - Flange in Cover; Step in Skin
  - SD20.168-3 - Flat - Step in Cover; Flange in Skin
  - SD20.168-4 - Formed - No Step in Cover; Step in Skin
  - SD20.168-5 - Formed - Flange in Cover; Step in Skin
  - SD20.168-6 - Formed - Step in Cover; Flange in Skin

- Data is specified for a $^1/_{16}$" gap, the most common for interchangeable mating parts. Larger gaps are permitted on power operated doors and mating removable panels. For these gaps, the ICT and the IJ sizes must be adjusted accordingly (the skin ICT is oversize on each edge by the gap minus the skin tolerance. The IJ is made $^1/_{64}$" smaller than the ICT).

Note: The nature of these parts requires that their tooling be coordinated, fabricated, and finished to the closest tolerances possible.

3.0 Graphic Synopsis:



THEORETICAL SKIN BUTT LINE (TSBL)

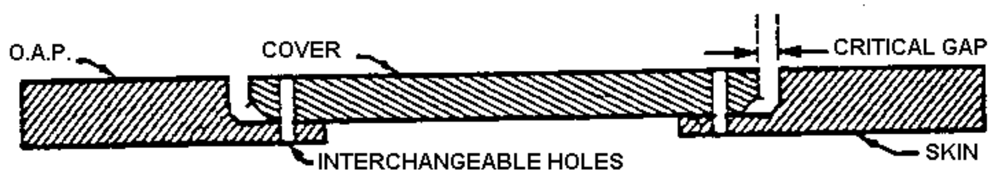
4.0 General Information:

- When the chem-milled member is made of alclad material, the critical edges (the edges forming the critical gap) shall be clad stripped locally. This will eliminate poor line definition and shallow chamfers resulting from etching directly into the alclad.
- Calculated setback shall be applied to all critical edges regardless of the depth of cut. This will give maximum accuracy to the chem-mill breakout line.
- ICT checks quality of skin cutout, eliminating the possibility of interference areas between cover and skin.
- IJ of the same size as maximum cover must conform to the skin cutout if all covers are to fit.
- For in-tolerance gaps, IJ must be shimmed in the skin cutout to locate it on the "Theoretical Skin Butt Line". Otherwise, minimum covers in minimum skins can yield a maximum gap of $^{7}/_{32}$" (.219).
- The nominal size of the critical gap for interchangeable parts is usually $^{1}/_{16}$". For chem-milled parts, this is the minimum nominal gap and the tolerance is $\pm\ ^{3}/_{64}$"; $^{1}/_{64}$"applies to the routed edge, $^{1}/_{32}$" applies to the chem-milled breakout line.

5.0 **Construction:**

5.1 (-1) Flat - No Step in Cover; Step in Skin:

(-1) FLAT - NO STEP IN COVER; STEP IN SKIN

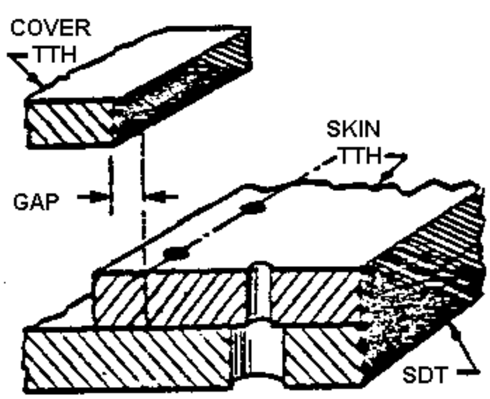


(-1) Flat - No Step in Cover; Step in Skin

5.1.1 *(-1) Cover Tooling:*

Same as SD167-1 Cover Tooling.

5.1.2 *(-1) Skin Tooling:*



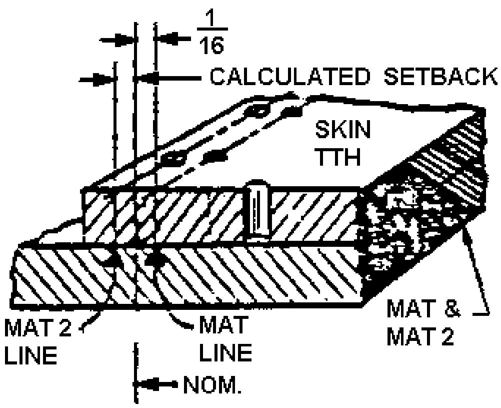
(-1) Skin Tooling

TTH Per the loft. Add full size interchangeable holes as called out on the tool order. Coordinate to the cover TTH. Apply the nominal gap for the chem-mill line. Cut out scribe windows along this line. Cut out the routed opening.

SDT To provide excess material, hang holes, and tooling holes. Coordinate to the skin TTH for tooling holes and chem-mill reference.

MAT For stripping the alclad. Make to a line coordinated to the skin TTH, plus $^{1}/_{16}$".

MAT2 For the chem-mill cut. Shall have the calculated setback for all depths of cut. Coordinate the outline to the skin TTH for bare or clad material.



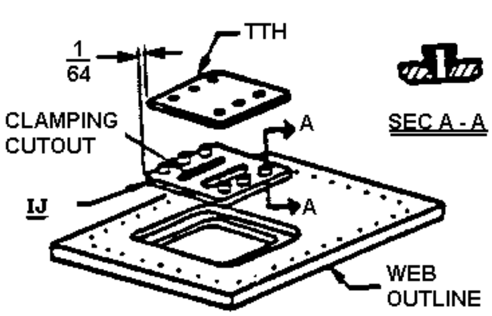
(-1) Skin Tooling (cont.)

ICT Plug type to check the minimum size of the chem-mill opening. Trim the plug to the cover TTH plus $^{1}/_{32}$" on all sides. Provide finger holes for gripping the template. Make of .063" aluminum alloy. Add inspection note: "Butt-fit to $^{1}/_{16}$" gap allowed". Stamp "UP" and "FWD" for tool orientation.

DU Per the skin TTH. Make the DU to drill the work-piece from the side opposite the chem-mill. The work-piece is located on the DU by using the tooling holes. Do not drill the interchangeable holes.

HRJ Per the skin TTH. Make the HRJ (reference SD20.181) to route the work-piece with the chem-milled surface <u>UP</u>. Provide pickup pins (hard dowel) for the tooling holes. Remove the ears as part of the deburring operation.

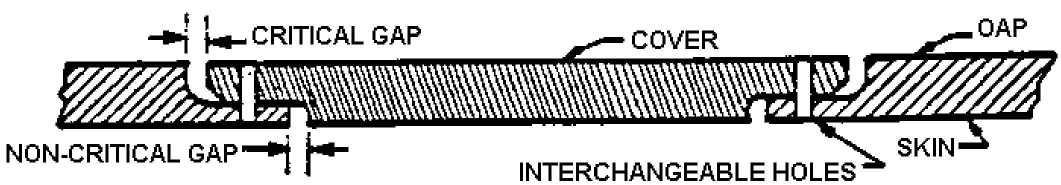
5.1.3 *(-1) Installation Tooling:*



(-1) Installation Tooling

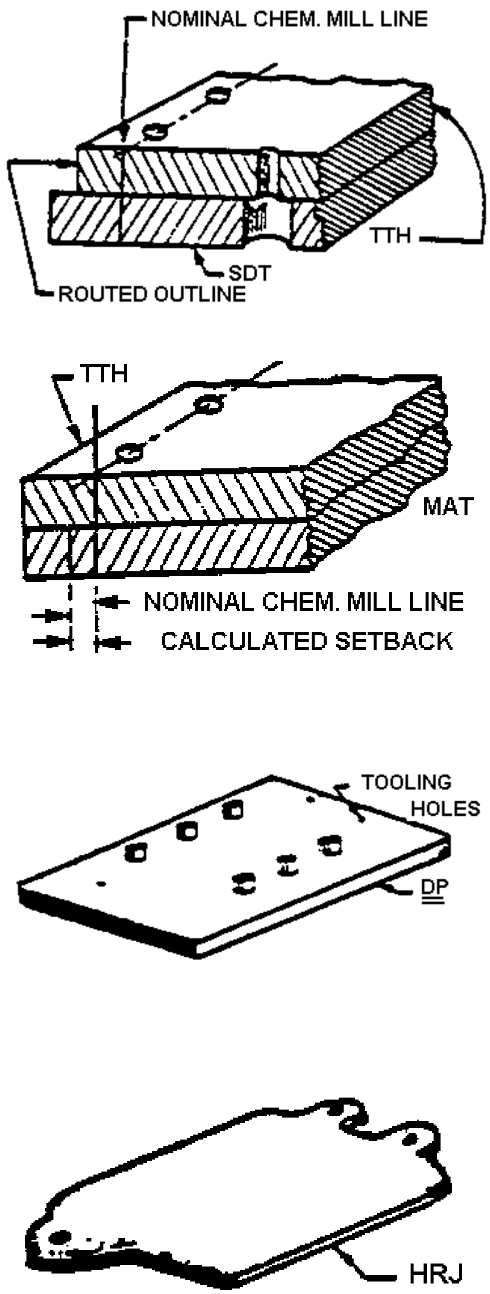
IJ Per the cover TTH plus $^{1}/_{64}$". Make of .125" aluminum alloy and chamfer the edge 45° to $^{1}/_{2}$ the chem-milled depth. Provide full size bushings for the interchangeable holes, and cutouts to permit C-clamping to the structure. Stamp "UP" and "FWD" for tool orientation. The gap between the IJ and the chem-milled opening must be kept constant on all sides by shimming.

5.2 (-2) Flat - Flange in Cover:



(-2) Flat - Flange in Cover; Step in Skin

5.2.1 *(-2) Cover Tooling:*



TTH Cut outline per loft. Provide full size interchangeable holes as called out on the tool order. Scribe the nominal chem-mill line and drill transfer holes along this line (SD20.113). Tooling holes are to be in ears.

SDT To provide excess material, hang holes, and tooling holes. Coordinate to the cover TTH for tooling holes and outline reference.

MAT For the chem-mill cut. It is not necessary to strip the alclad for depths of cut .040" or less, this chem-mill cut is not critical. Any chem-mill cuts of .040" or less also will not require a calculated setback (reference SD20.138).

ICT Not required. This is a non-critical chem-mill line.

DP Per the cover TTH. Provide bushings for the interchangeable hole pattern. Make the DP to drill the work-piece from the side opposite the chem-mill. The work-piece is located on the DP by using the tooling holes.

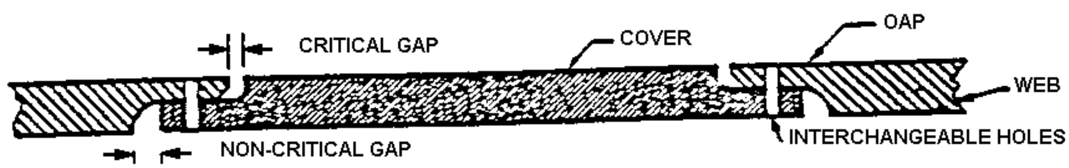
HRJ -- Per the cover TTH. Make the HRJ to route the work-piece with the chem-milled surface UP. Provide pickup pins (hard dowel) for the tooling holes. Remove the ears as part of the deburring operation (SD20.181).

(-2) Cover Tooling

5.2.2 *(-2) Skin Tooling:*

Same as 168-1 Skin Tooling.

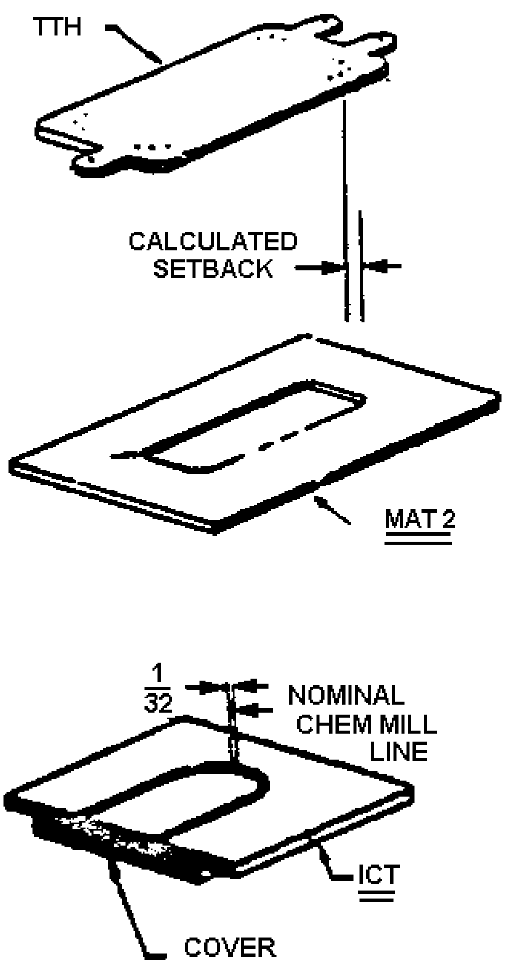
5.2.3 *(-2) Installation Tooling:*



(-2) Installation Tooling

Same as 168-1 Installation Tooling.

5.2.4 *(-2) Cover Tooling:*



(-2) Cover Tooling

TTH Per loft - same as (-2) cover.

SDT Per TTH - same as (-2) cover.

MAT For stripping the alclad. Coordinate to the chem-mill line cutout in the cover TTH and make cutout $^1/_{16}$" smaller on each edge (reference SD20.138).

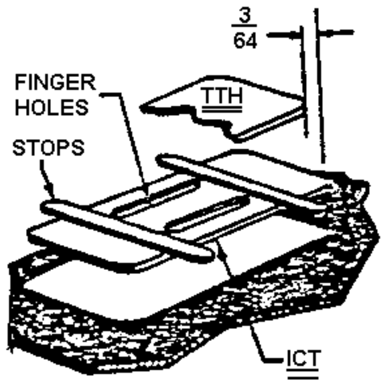
MAT2 For the chem-mill cut. <u>Shall have the calculated setback for all depths of cut.</u> Coordinate the outline to the cover TTH for clad or bare material (reference SD20.138).

DP Per the cover TTH - same as (-2) Skin.

HRJ Per the cover TTH - same as (-2) Skin.

ICT Female type to check the chem-mill cut. Make cutout $^1/_{32}$" larger on all sides than the chem-mill line on the cover TTH. Make of .063" aluminum alloy. Add inspection note: "Butt fit to $^1/_{16}$" gap allowed". Stamp "UP" and "FWD" for tool orientation.

5.3.1 *(-3) Skin Tooling:*



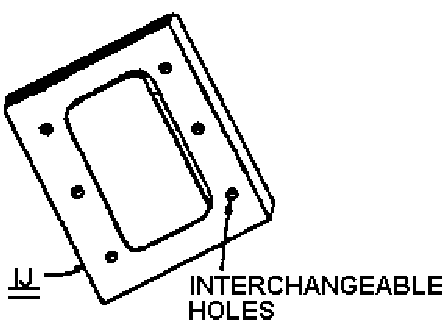
(-3) Skin Tooling

Same as (-1) Skin Tooling. The only deviation to be made is that the chem-mill cut is not critical and therefore, in most cases, does not require setback calculations or coordination to the cover TTH. A local ICT shall be made as follows to check the minimum size routed cutout:

ICT Make plug type per the cover TTH plus $^{1}/_{64}$". Make of .063" aluminum alloy. Provide finger holes for gripping the template. Add inspection note: "Butt fit to $^{1}/_{32}$" gap allowed". Stamp "UP" and "FWD" for tool orientation.

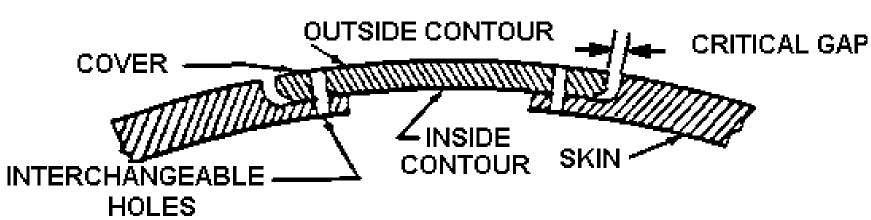
IJ Make female type to be used with visual alignment. The cutout shall be made per the cover TTH chem-mill line plus the critical gap dimension plus $^{1}/_{64}$" on all edges. Hole locations are per cover TTH. Stamp "UP" and "FWD" for tool orientation.

5.3.2 *(-3) Installation Tooling:*



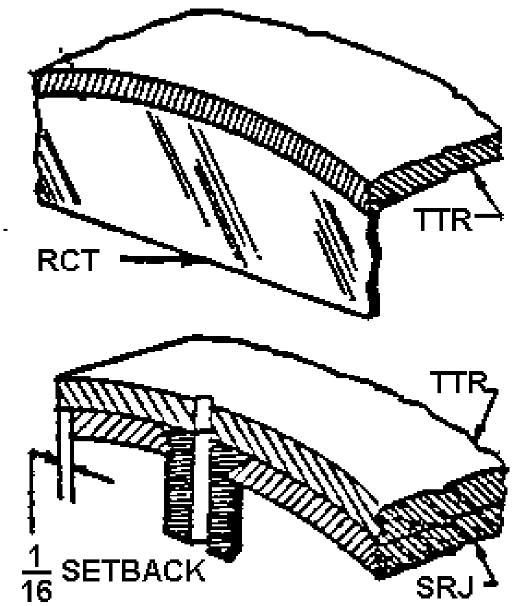
(-3) Installation Tooling

5.4 (-4) Formed - No Step in Cover; Step in Skin:



(-4) Formed - No Step in Cover; Step in Skin

5.4.1 *(-4) Cover Tooling:*



(-4) Cover Tooling (also reference SD167-2)

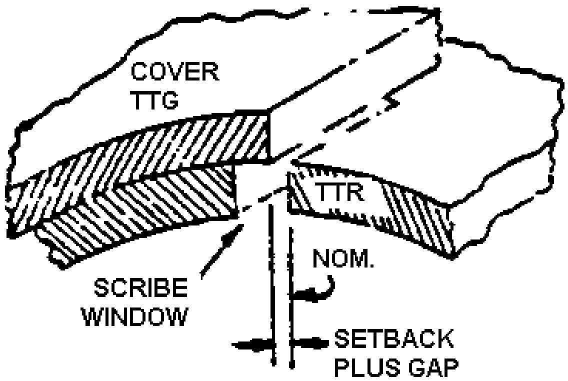
RCT For rolled covers. Cut to inside contour of cover. Inspect contour to the appropriate MCT.

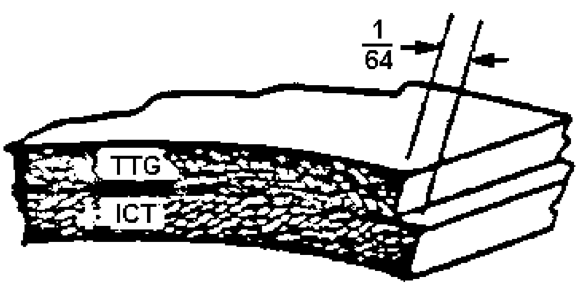
TTR Per WM - Roll .063" (or heavier) aluminum alloy to contour of cover RCT. Provide full size interchangeable holes as specified on the tool order.

TTG Per TTR trim. For use in mastering the Skin cutout. Make for application to outside contour.

SRJ Per TTR - make from .190" aluminum alloy and roll for application to outside contour of part. Provide full size bushings for the interchangeable holes. Provide a .063" backup plate for drilling parts of .032" or thinner.

5.4.2 *(-4) Skin Tooling:*





(-4) Skin Tooling

RCT Same as for (-4) cover when required for single curvature.

SD or DHD Tool design by the die group is required for forming operation on compound curvature. Inspect contour to the appropriate MUF or MCT.

TTR Per WM - Use a sample formed piece (not chem-milled). Provide full size holes as specified on the tool order in the interchangeable hole pattern. Cut the nominal routed outline. Coordinate chem-milled outline to cover TTG. Apply the required nominal gap and scribe the nominal chem-mill line. Cut out scribe windows along this line.

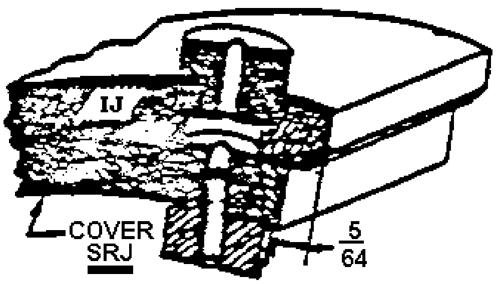
DST Make from overpress to provide excess material, tooling holes, and hang holes for chem-mill. Coordinate to the TTR for tooling holes and outline reference.

MAT Make from overpress. Same as (-1) Skin Tooling.

ICT Plug type to check the size of the chem-milled opening. Make from .063" aluminum alloy rolled to contour of cover RCT. Trim the plug to the cover TTG plus $^1/_{64}$" on all sides. Provide finger holes for gripping the template. Add inspection note: "Butt fit to $^1/_{16}$" gap allowed." Stamp "UP" and "FWD" for tool orientation.

SRJ & HF Per the TTR. Make the SRJ from an overpress or a fiberglass layup. Do not provide for drilling the interchangeable holes (reference SD20.136 , SD20.271).

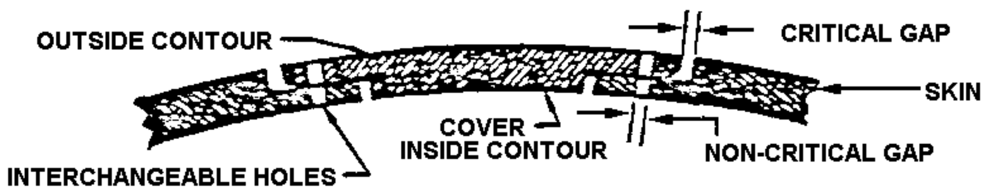
5.4.3 *(-4) Installation Tooling:*



-4) Installation Tooling

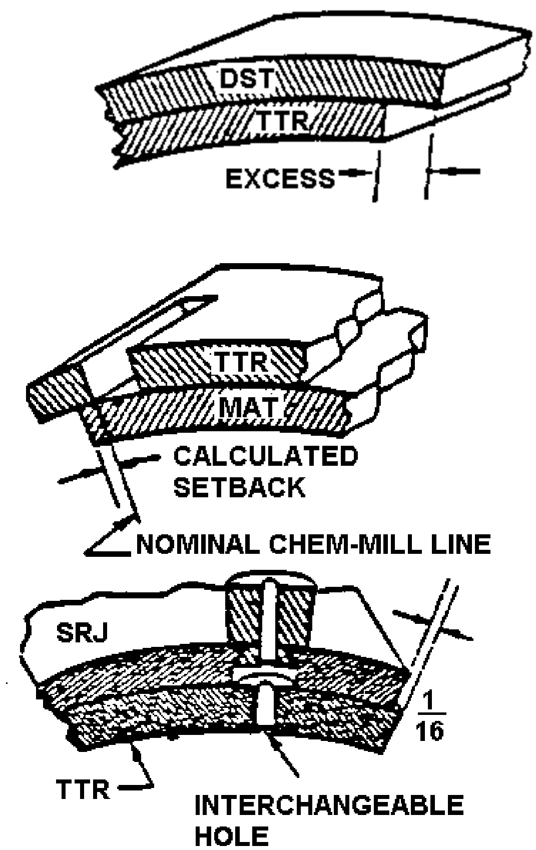
IJ Roll contour per cover RCT; use .125" aluminum alloy. Trim per the cover SRJ plus $^{5}/_{64}$" on all sides. Chamfer the bottom edge of the outline 45° for one-half the chem-mill depth. Provide full size bushings for the interchangeable holes. Provide cutouts to permit C-clamping to structure. Stamp "UP" and "FWD" for tool orientation.

5.5 (-5) Formed Flange in Cover; Step in Skin:



(-5) Formed - Flange in Cover; Step in Skin

5.5.1 *(-5) Cover Tooling:*



(-5) Cover Tooling

RCT Same as (-4) Cover Tooling.

DHR or PB Detail design by the die group is required for forming operation on compound curvature.

TTR Per WM - Roll aluminum alloy (cover thickness) to the cover RCT. Provide full size interchangeable holes as called out on the tool order. Cut scribe windows for the nominal chem-mill line. Use a sample FPC of the detail for compound curvature.

DST To provide excess material, hang holes, and tooling holes for chem-mill. Coordinate to the cover TTR for tooling holes and outline reference. Make for application to outside contour.

MAT For the chem-mill cut. It is not necessary to strip the alclad for depths of .040" or less, as this cut is not critical. Any chem-mill cuts of .040" or less will not require a calculated setback. Make for application to inside contour. Make per the chem-mill line on the cover TTR for clad or bare material (reference SD20.138).

ICT An ICT is not required. This is a non-critical chem-mill line.

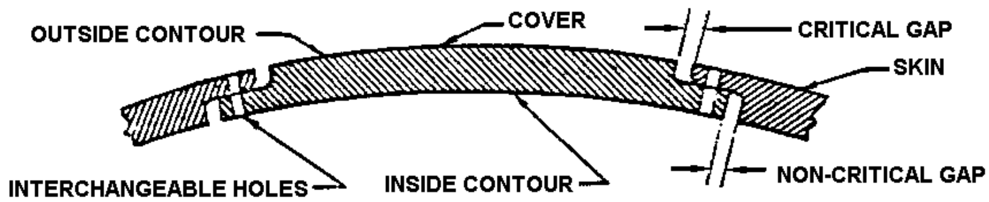
SRJ Per the TTR - Make from .190 aluminum alloy. Make for application to outside contour. Add bushings for interchangeable holes (reference SD20.136).

5.5.1 *(-5) Skin Tooling:*

Same as (-4) Skin Tooling.

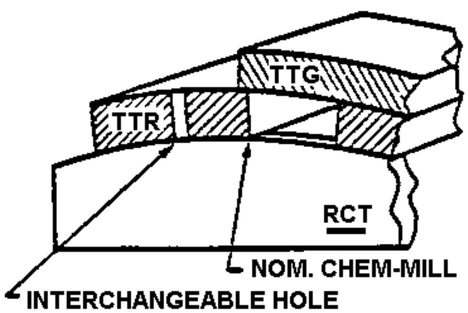
5.5.3 *(-5) Cover Tooling:*

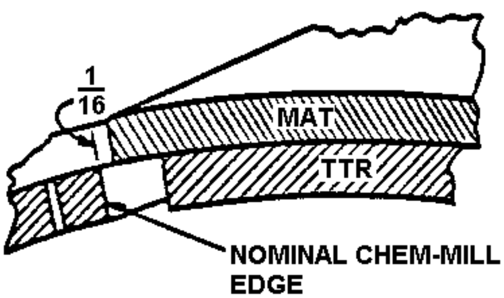
5.6 (-6) Formed - Step in Cover; Flange in Skin:



(-6) Formed - Step in Cover; Flange in Skin

5.6.1 *(-6) Cover Tooling:*





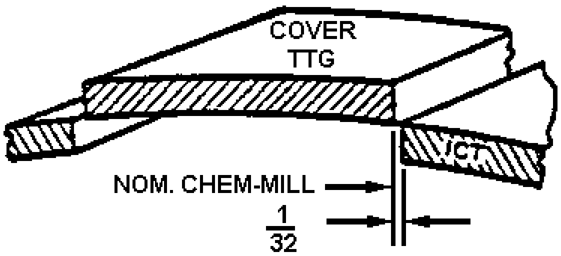
(-6) Cover Tooling

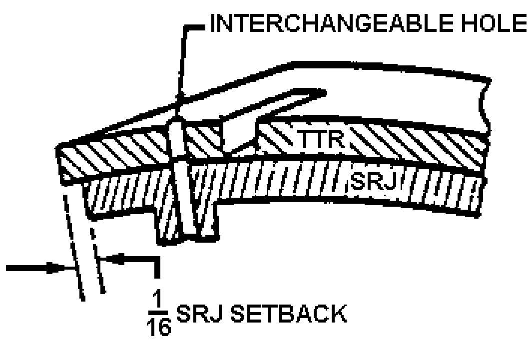
DHR or PB Detail design by the die group is required for forming operation on compound curvature.

TTR Per WM - Roll per cover RCT or use a sample FPC of the detail for compound curvature. Cut scribe windows on the nominal chem-mill line. Provide full size holes as specified on the tool order.

TTG Per chem-mill line in TTR - for use in mastering the skin cutout. Make for application to outside contour.

DST Per cover RCT -- For application to the outside contour. Make of .125" aluminum alloy. To provide excess material, tooling holes, and hang holes for chem-mill. Coordinate to the cover TTR for tooling holes and chem-mill reference. Use a fiberglass layup when required by compound curvature.





(-6) Cover Tooling (cont.)

MAT Per cover RCT - For application to the outside contour. Make of .064" aluminum alloy. Used for stripping the alclad. Make the scribe edge $^{1}/_{16}$" inside the nominal chem-mill line on the cover TTR (reference SD20.138). Use a fiberglass layup when required by compound curvature.

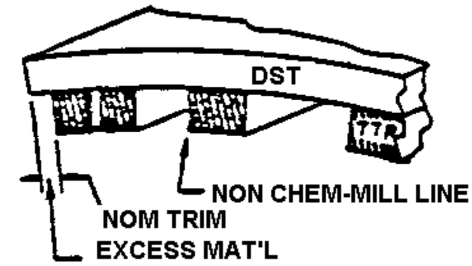
MAT2 Make as the MAT above. Used for the chem-mill cut. Shall have the calculated setback for all depths of cut. Coordinate the outline to the cover TTR for clad or bare material (reference SD20.138).

ICT Per cover RCT - Female type to check the chem-mill cut. Make of .063" aluminum alloy. Coordinate outline to TTG and adjust size $^{1}/_{32}$" larger than the nominal chem-mill line. Stamp "UP" and "FWD" for tool orientation. Provide finger holes for gripping the template. Use a fiberglass layup when required by compound curvature.

SRJ Same as (-4) cover Tooling. Use a fiberglass layup when required by compound curvature.

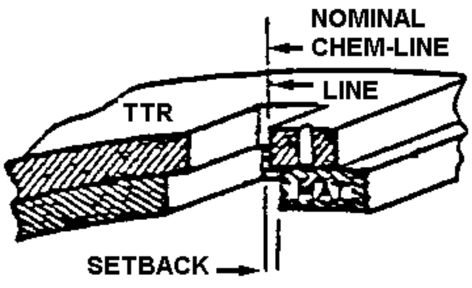
5.6.2 *(-6) Skin Tooling:*

RCT For rolled skins. Cut to inside contour of skin and inspect to the appropriate MCT.



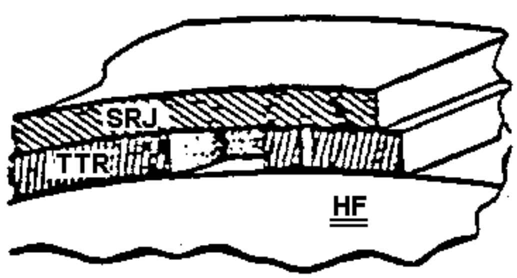
SD or DHD Tool design by the die group is required for forming operations on compound curvature. Inspect contour to the appropriate MUF or MCT.

TTR Per WM - Use a sample formed piece (not chem-milled). Provide full size interchangeable holes as specified on the tool order. Coordinate the chem-mill line to the cover SRJ; add $^{1}/_{16}$" plus the required nominal gap. Provide scribe windows for chem-mill outline. Insert tooling holes in ears.

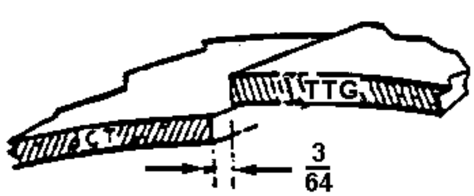


DST Roll or form from .125" aluminum alloy for application to the outside contour. To provide excess material, tooling holes, and hang holes for chem-mill. Coordinate to the skin TTR for tooling holes and outline reference.

MAT Roll or form from .063" aluminum alloy for application to the inside contour for the chem-mill cut. It is not necessary to strip the Alclad for depths of cut .040" or less - this chem-mill cut is not critical. Any chem-mill cuts of .040" or less will not require a calculated setback. Coordinate the outline of the skin TTR for clad or bare material (reference SD20.138).



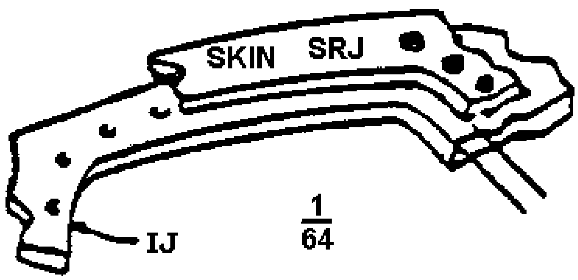
SRJ & HF Per the TTR. Make the SRJ from an overpress or a fiberglass layup for application to the outside contour of the skin. Do not provide for drilling the interchangeable holes (reference SD20.136, SD20.271).



ICT Per cover RCT - roll .063" aluminum alloy to contour. Make plug type to check for the minimum allowable routed cutout size. Provide finger holes for gripping the template. Trim to the cover TTG + $^{3}/_{64}$" on all sides.
Add inspection note: "Butt fit to $^{1}/_{32}$" gap allowed". Stamp "UP" and "FWD" for tool orientation.

(-6) Skin Tooling

5.6.3 *(-6) Installation Tooling:*



(-6) Installation Tooling

IJ Roll .125" aluminum alloy for single curvature. Use fiberglass layup for compound curvature. Apply to outside contour of skin. Cut a hole to the door opening in the skin SRJ plus $^1/_{64}$". Add full size bushings for interchangeable hole pattern. Stamp "UP" and "FWD" for tool orientation.

PLASTIC FACE STRETCH DIE (SD, SDH, SDM, SDS, HD)

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference section 3 for detailed information.

1.0 Definition:

- A stretch die is a form that is used to shape sheet metal into complex curves of large radii. The work-piece is stressed beyond its elastic limit by a stretch press, thereby assuring minimum spring back.

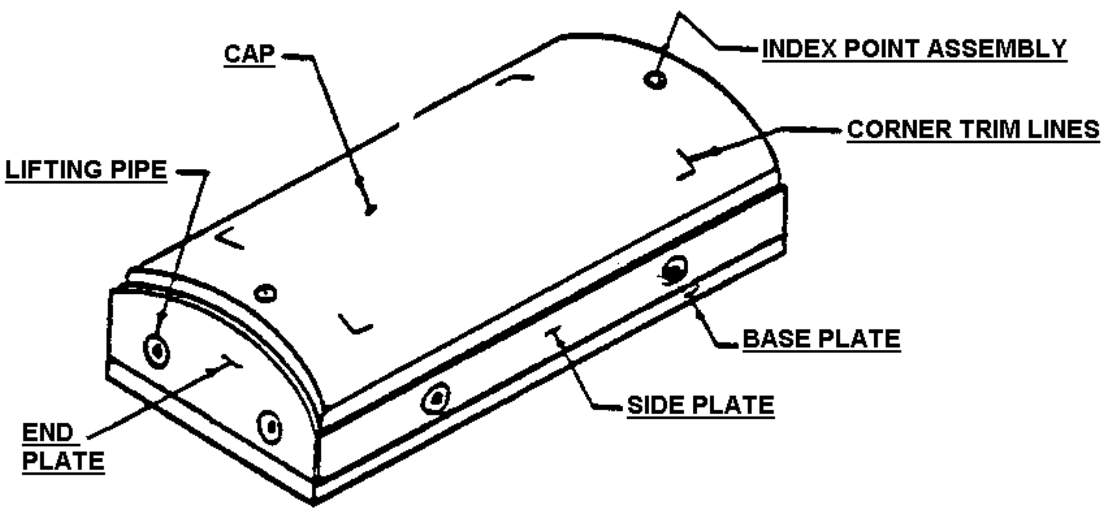


Figure 1

2.0 Construction:

2.1 Material:

- Cap:
  - Casting Resin (Phenolic)
  - Self Lubricating Coating

- Frame:
  - Base Plate - $^{1}/_{2}$" Hot Rolled Steel
  - Side Plates - $^{5}/_{8}$" Hot Rolled Steel
  - End Plates - $^{5}/_{8}$" Hot Rolled Steel
  - Lifting Pipes - 1 $^{1}/_{2}$" Diameter Black Steel Pipe
  - Support Pipes - Only when specified by an individual tool drawing
- Support Structure:
  - Core
  - Pouring Chimney - 4" diameter cardboard tube
- Protective Cover:
  - 3 layer epoxy - fiberglass laminate

2.2 Method:

- Plaster Cast:
  - Obtain plaster cast from MUF. Pick up index points and scribe trims (reference Information TTR and WM).
  - Setup cast and cut plywood templates for weld shop.
  - Wax cast to simulate part thickness only when specified on the individual drawing.
  - Spray wax with primer and seal with blue mold lacquer .

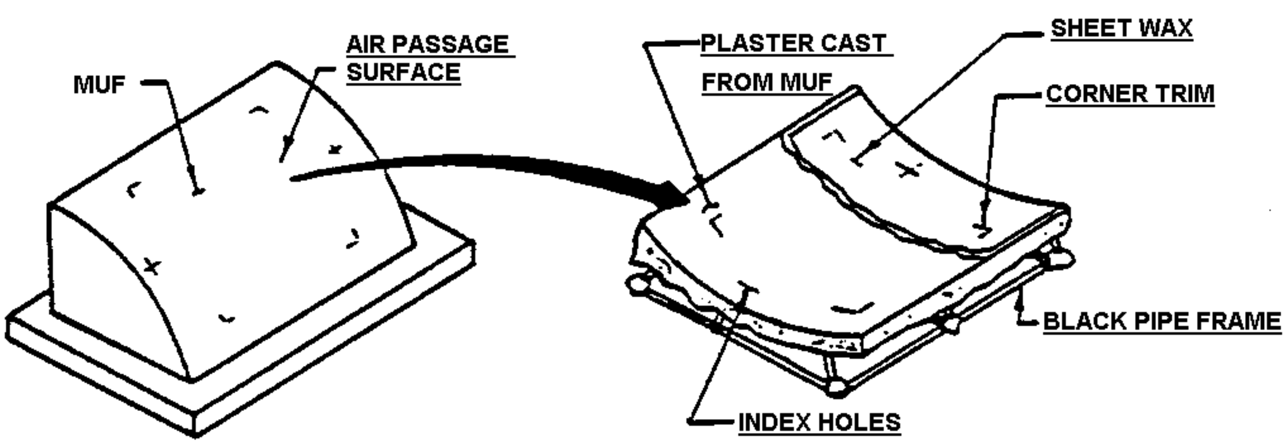


Figure 2

- Plywood Templates:
  - Cut ($^1/_4$") plywood templates - reference Figure 3.
  - Scribe pipe locations per individual tool drawing.
  - Scribe pouring hole to clear internal pipes.
  - Drill lifting pipe locations.
  - Obtain "X" - "Y" - "Z" locations from tool drawing/electronic model.
  - Identify individual templates for location.

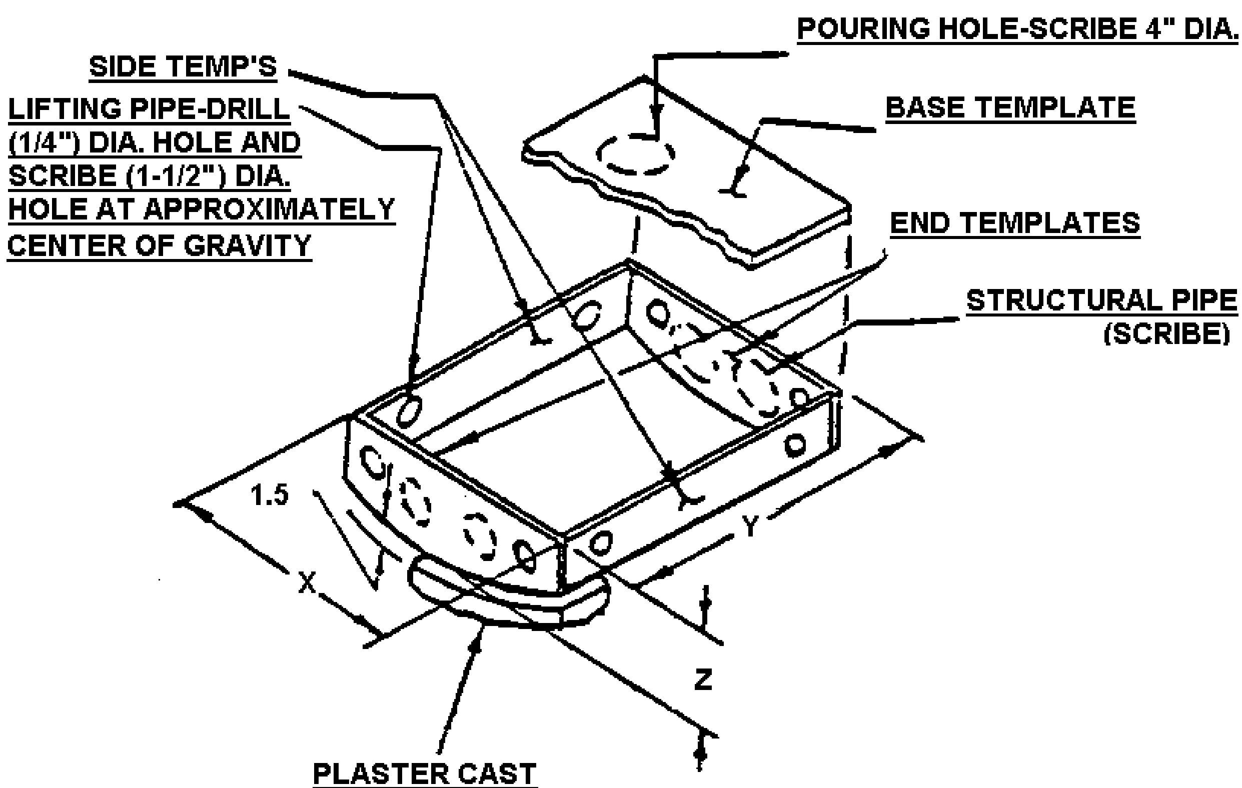


Figure 3

- Steel Frame:

- Cut steel frame details per plywood templates - machine base plate on one side, only if necessary.
- Weld steel frame - locate and weld structural pipe and lifting pipe per plywood templates.
- Break all corners and edges.

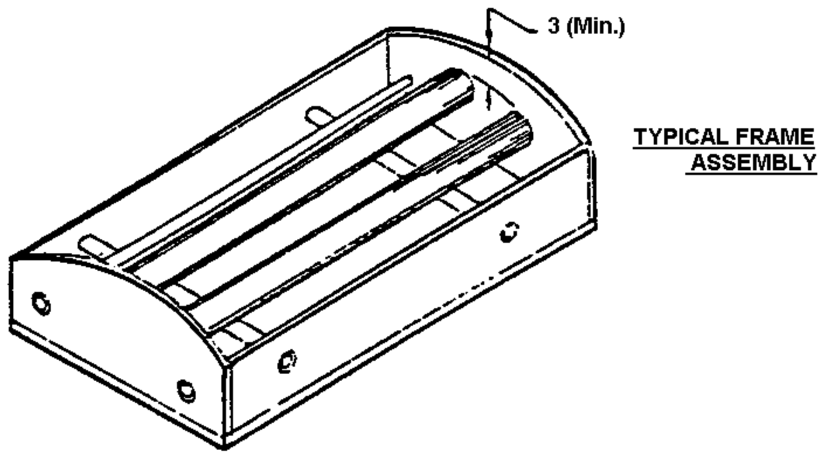


Figure 4

- Filler and Cap:
- Paint inside of steel frame with an approved adhesive per standard shop paractice.
- Secure pouring tube in frame.
- Fill frame with Epocore saturated in "Rezolin" (reference Figure 5).
- Bake in oven 200°F for eight hours.
- Set up "Epocore" filled frame on plaster cast - allow 1.5" clearance for cap - enclose with plywood and seal with superfine plaster.

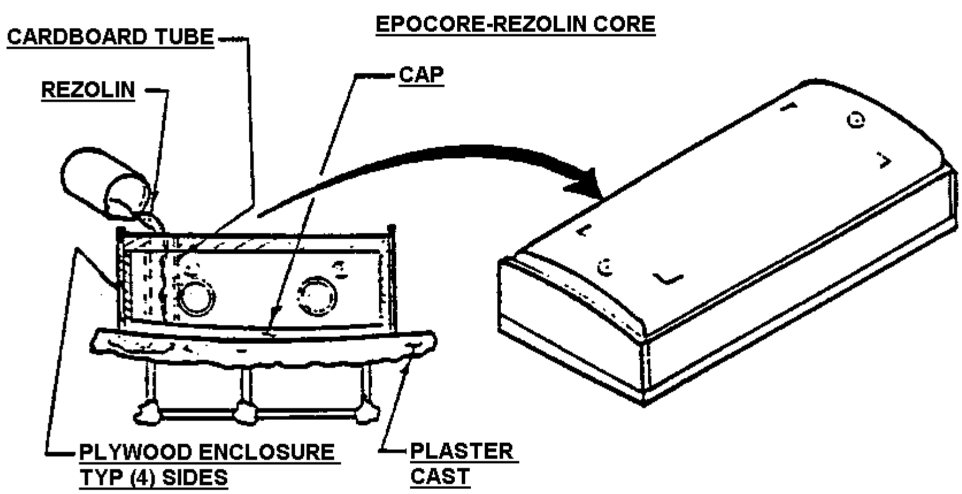


Figure 5

- Pour "Rezolin" cap to inside edges of steel frame (reference Figure 5).
- Air cure for twelve hours and then bake in oven at 200°F for eight hours and remove die from plaster cast.
- Remove any raised surface imperfections and curing glaze from cap surface with fine abrasive paper.

- Index Point Assembly:

  - Index point location is transferred to the cap from a pin in the plaster cast.

  - $^1/_4$" holes are drilled and counterbored to accommodate the index pin.

  - Bore $^7/_8$" diameter hole, with hole saw, to accommodate barrel (aluminum tube).

  - Insert barrel and pin. Point of index pin is placed flush + .000", - $^1/_{64}$" below the surface of the cap. Fill counterbore with Sonite LM-1.

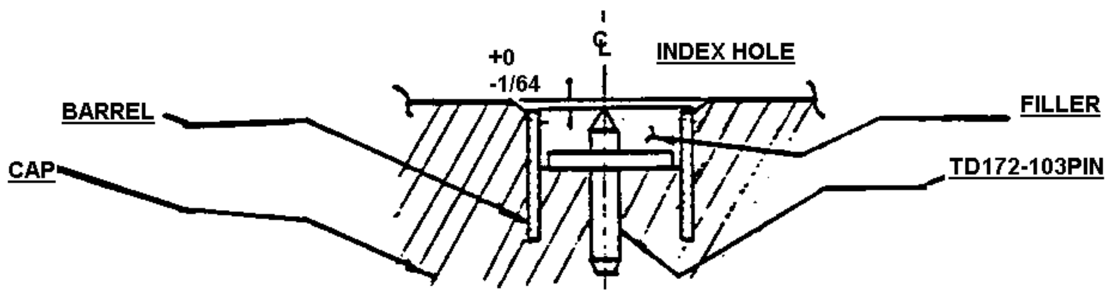


Figure 6

- Self Lubricating Die Surface:

  - Clean die surface thoroughly.

  - Mix four parts Teflon pigment with one part hardener component and stir vigorously.

  - For spraying application, reduce the mixture with two parts thinners. Pot life is six to eight hours.

  - Spray three cross-hatch coats of mixture over die surface allowing $^1/_2$ to 1 hour between coats.

- Protective Cover:

  - Drape one layer of Polyvinyl Chloride (PVC) over die surface. Make taut to remove any wrinkles.

  - Layup three layer epoxy-fiberglass laminate over PVC covered die surface - no index holes required.

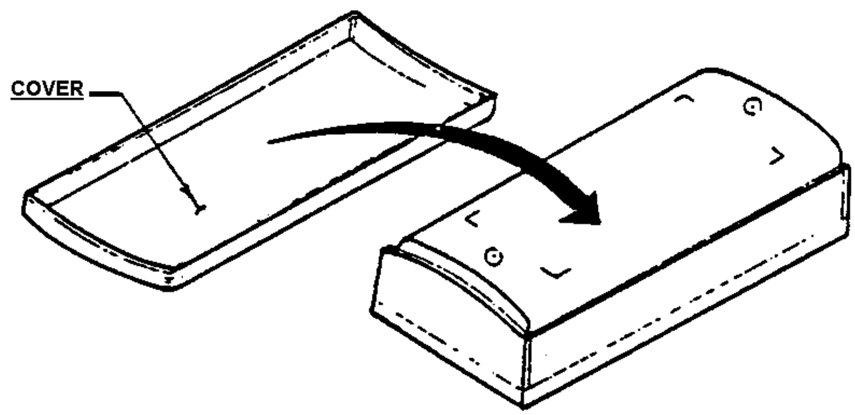


Figure 7

- Die Identification:

  - Scribe trim lines on all corners.

  - Paint frame with project tool color (reference SD1.400, Manufacturing Engineering Tool Design Manual, Tooling and Equipment Paint Information section.).

  - Identify tool per SD20.510 (Tool and Equipment Identification).

  - Weigh die. Stencil die weight on die.

  - Stencil part number on four sides if possible and on die cover.

  - Stencil "Fwd" and clad information on forward end of die - stencil "Fwd" on cover.

  - If die is used to form more than one part number, paint full trim lines and stencil appropriate part numbers on <u>cover only</u>.

3.0 **Reference Information:**

3.1 Tool Code Definition:

- SD - Stretch Die
- SDH - Stretch Die Hufford
- SDM - Stretch Die Maust
- SDS - Stretch Die Sheridan
- HD - Hufford Die

3.2 General Information:

Tool Code	Press.	Loc.	Type	Max. Ton	Mounting	Max. Sheet Size
SD	Sheridan	P1 # 3	Long'l	75	Horizontal	
SDH	Hufford # 44	P1 # 2	Stretch Wrap	200	Vertical	
(1) SDM	Maust & Sheridan	P1 # 3	Transverse	300	Horizontal	
SDS	Sheridan	P1 # 3	Stretch Wrap & Transverse	750	Horizontal	
HD	Hufford # A - 12 Pulldoze	P1 # 2	Stretch Wrap	60	Vertical	

(1) Dies designated "SDM" may be used on either the 300 ton Maust or the 300 ton Sheridan.

(2) For further information, consult a Manufacturing Engineering Forming Manual.

SHEAR and ROUTER Board (SRB)

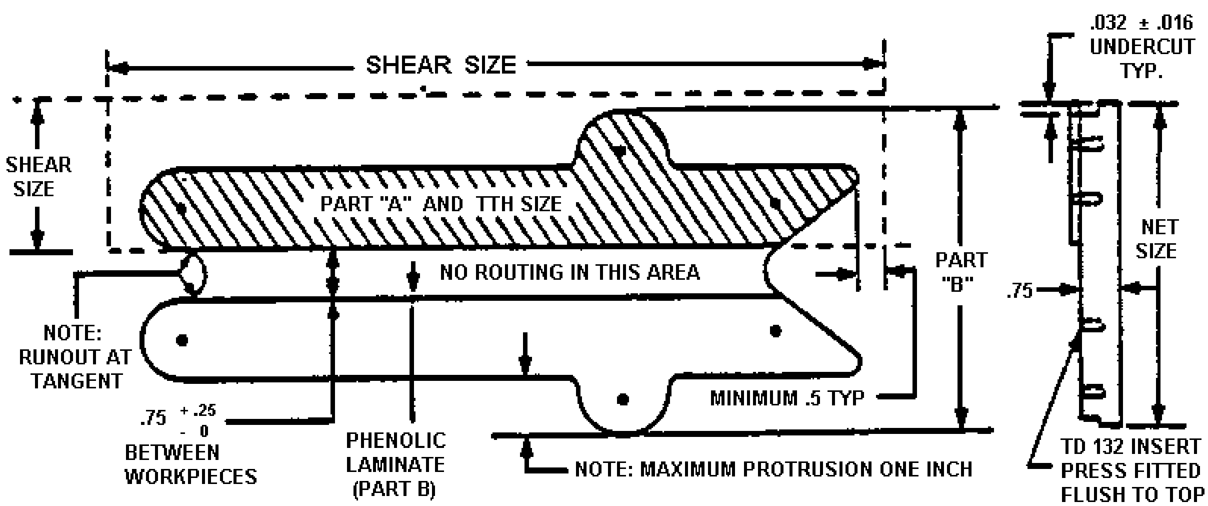
Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition:**

- A Shear and Router Board is a flat drilling and routing tool consisting of a drill template (Part "A") for use in stack drilling, and a router bard (Part "B") for use on a pin router. This tool reduces the length of the routed perimeter by protecting straight sheared sides and routing only contoured portions. Work-pieces shall have at least one straight side twelve inches or longer.

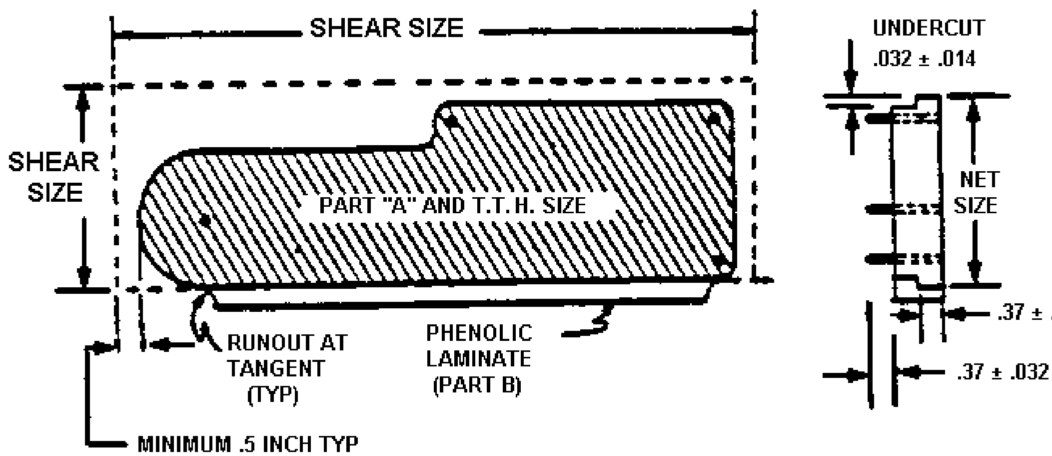
2.0 **Scope:**

- SD-180-1:
  - Under five inches wide, one straight side at least 12" long and a protrusion not exceeding one inch.
  - Part "A" - Duplicates only tooling and production holes in the TTH (SD20.113).
  - Part "B" - A two work-piece router board with the straight sides inboard.



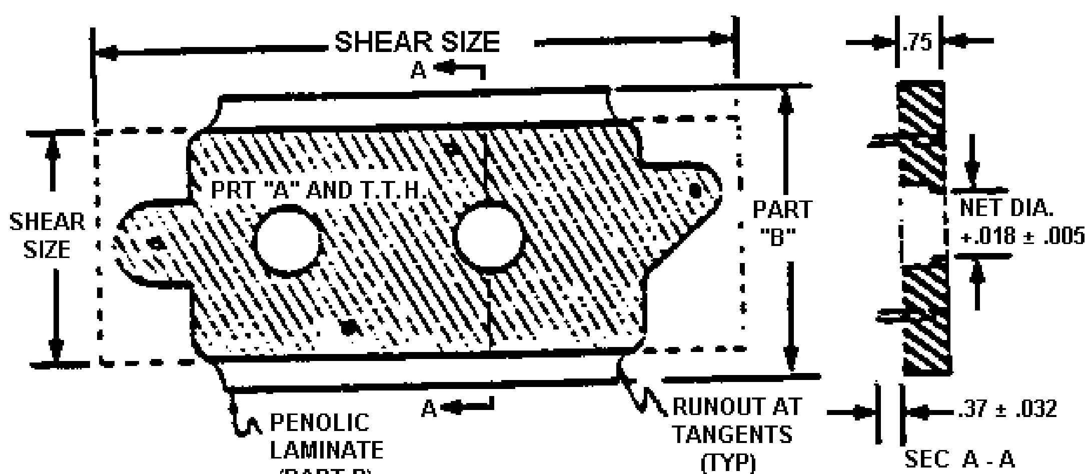
- SD-180-3:

  - Over 5" wide having only one straight side at least 12" long.
  - Part "A" - duplicates only tooling and production holes in the TTH (SD20.113).
  - Part "B" - A single or multiple work-piece router board.



- SD-180-7:

- Parallel straight sides requiring end and internal only. This may be made as a double when required for safety.
- Part "A" - Length: to match the TTH;
  width: twice that of the TTH plus $^3/_4$"; (+ $^1/_4$" - 0") space allowance between work-pieces.
- Part "B" - A single or double work-piece router board. Minimum width shall be 3".



3.0 Materials:

- .125" aluminum alloy (2024-T3)
- Phenolic Fiber Laminate
- Locating Pins
- Inserts
- 3.1 MM Drill

4.0 Construction:

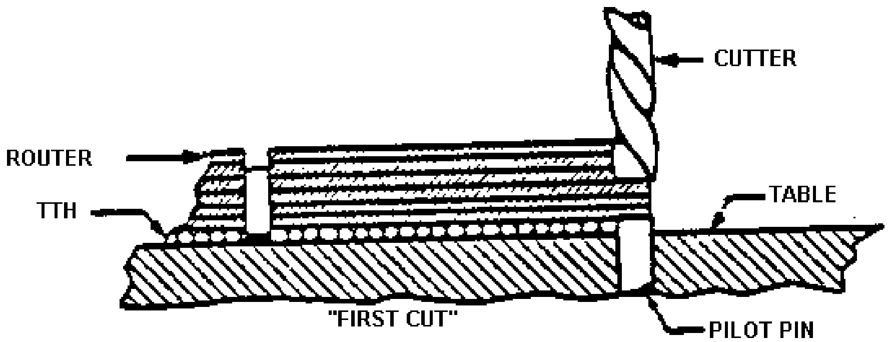
- Part "A" (Drill Template)
  - Align the straight edge of the TTH with a sheared edge of the .125" aluminum alloy. Transfer-punch all holes per the TTH.
  - Provide drill guide holes as follows:

Template Hole	Workpiece Hole
# 10 (.1935")	# 40 - # 30
.250"	# 21 - # 10
.312"	.250"

For holes between .250" and .500", the work-piece shall be pilot drilled # 30. "Steel Stamp" hole size at each hole or with tool code (if all holes are same size for SRB).

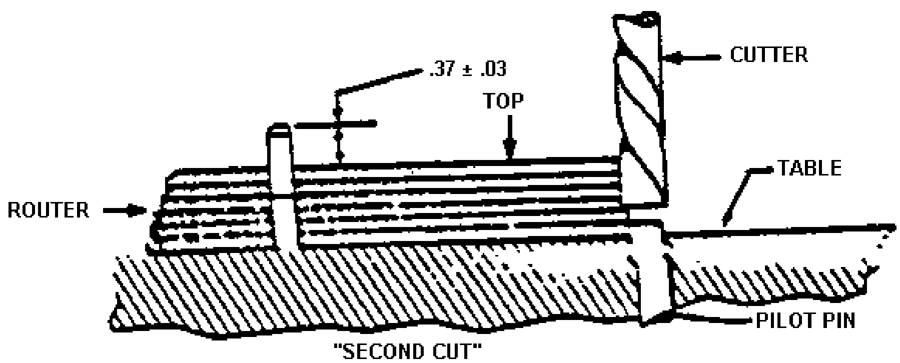
- Holes .500" or larger shall be routed full size.

- Part "B" (Router Board)
  - Use $^3/_4$" phenolic for SD-180-1, -3, and -7.
  - Use part "A" as a guide and drill 3.1 mm through the material for $^1/_8$" x $^3/_4$" locating pins in SD-180-1, -3, -7.
  - Locating pins shall be nine to twelve inches apart along the perimeter, for work-pieces over one inch wide. Pins shall be approximately six inches apart for those under one inch wide. Three pins shall be the minimum regardless of the tool size. When failsafe is not possible with existing hole pattern, add an unmastered failsafe pin outside the part outline.
  - Locating pins shall extend (TTH thickness) above the router board for making the "First Cut".
  - Scribe the TTH outline.
  - Rough cut the router board .120" ± .060" oversize, except on the straight side on which a minimum of .500" shall remain.
  - Place the TTH on the locating pins and turn the router board upside down. The TTH is used to guide the router pilot for .370" ± .060" deep "First Cut" of the outline and internal cutouts.



Note: Router run-out on sheared edges shall be made at tangent points. Refer to illustrations on page 2 and 3.

- Drive the locating pins back through the opposite surface so that they extend .370" ± .030".
- Reverse the board and use the "First Cut" as a guide to route the "Second Cut", removing the remaining excess material.



- Remove the locating pins and open holes with a # 4 drill. Press fit locating pins as required.

CUTTER and PILOT PIN SIZES			
	PILOT DIAMETER	**CUTTER DIAMETER**	**PILOT DIAMETER**
OUTLINE			
Standard	-----	-----	.250"
.250" Slots	-----	.250"	-----
INTERNAL CUTOUTS			
Standard	-----	-----	.250"
.250" Slots	-----	.250"	-----

- When proper pilots and cutters are used, the router board will have the following characteristics:

  Outline conforms to TTH except on straight edges.
  Hole diameters will be .018" oversize.
  TTH will overlap cutouts .009" on edges.

5.0 **Tolerances:**

- $\pm$ .010" with respect to TTH .

6.0 **Identification:**

- Part "A" (sheer and drill temp.) shall be stamped "Hold This Edge" with $^{1}/_{8}$" letters approximately .250" inch inside and along the straight side.
- Part "A" and part "B" shall be stamped SRB.
- Stamp identification as shown in SD20.510 of this manual.
- Scribe part outline on Part "A".
- Corresponding corners of Part "A" and "B" may be painted or otherwise identified to facilitate locating the drilled stock on the router board.

7.0 **Reference Documents:**

- Work-piece shear size callout.

  A minimum of .500" inch excess material shall be provided on all but straight sides.

<table>
<tr><th colspan="3">STANDARD CUT SIZE CHART
(Shear size shall be limited to the following:)</th></tr>
<tr><th colspan="2">WIDTHS</th><th>LENGTHS</th></tr>
<tr><td>1"</td><td rowspan="12">Note: Dimensions over 12" increase to 1" increments.</td><td rowspan="12">All lengths shall be rounded off to the next highest inch except for 20 $^{1}/_{2}$" and 28 $^{3}/_{4}$".

<u>EXAMPLE:</u>

The work-pieces measure:
5 $^{3}/_{4}$" x 19 $^{1}/_{4}$"
5 $^{3}/_{4}$" + $^{1}/_{2}$" = 6 $^{1}/_{4}$"
19 $^{1}/_{4}$" + 19 $^{1}/_{2}$" + $^{1}/_{2}$" = 20 $^{1}/_{4}$"

Shear size callout from chart should be 6 $^{7}/_{8}$" x 20 $^{1}/_{2}$".</td></tr>
<tr><td>2"</td></tr>
<tr><td>3"</td></tr>
<tr><td>4"</td></tr>
<tr><td>4 $^{51}/_{64}$"</td></tr>
<tr><td>5 $^{5}/_{16}$"</td></tr>
<tr><td>6"</td></tr>
<tr><td>6 $^{7}/_{8}$"</td></tr>
<tr><td>8"</td></tr>
<tr><td>9 $^{5}/_{8}$"</td></tr>
<tr><td>10"</td></tr>
<tr><td>12"</td></tr>
</table>

HAND ROUTER JIG (HRJ) - FLAT

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition and Scope:**

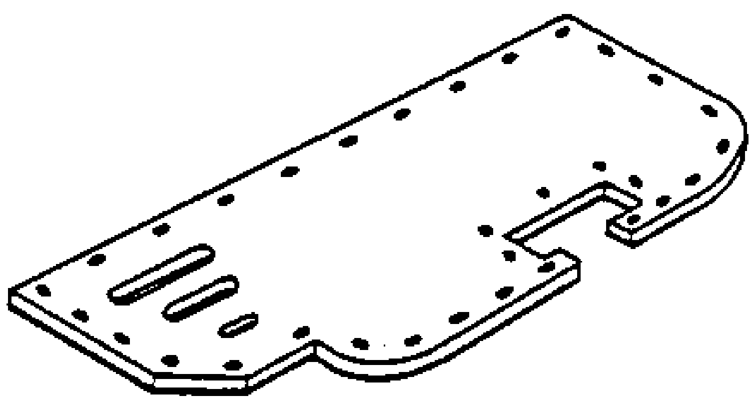
- A Hand Router Jig (Flat) is a flat template type tool used for routing and drilling aluminum alloy work-pieces that are too large or too thick for pin routing. The template is placed on the work-piece and both are nailed to the plywood table top. A hand guided radial arm router is used to trim the outline. Drilling is done with another unit of the same machine. Flat HRJ's are limited to the following work-piece categories.

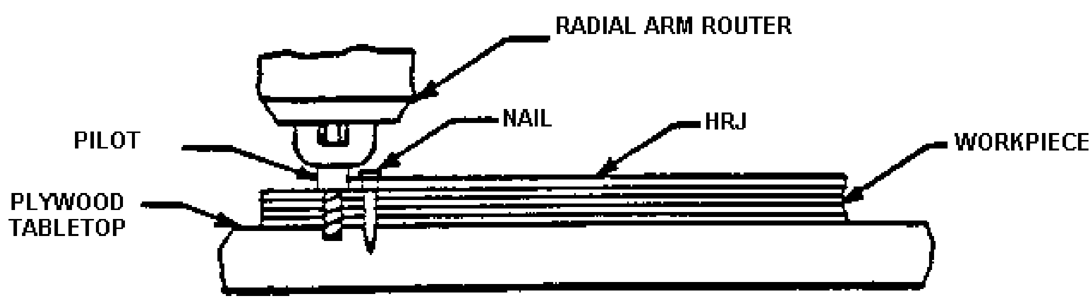
  .024" - .375" thick: 24" x 48" minimum

  .008" - .020" thick: 48" x 12" minimum

  .125" - .375" thick: 45" max. x 12" minimum

  Anything under these sizes, use a DRB.





2.0 **Material:**

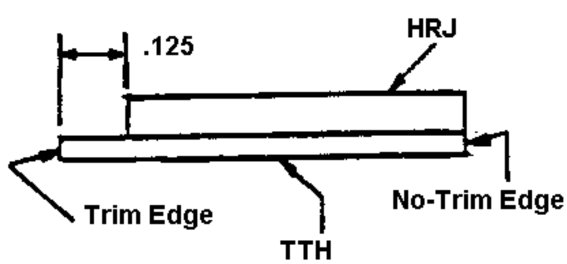
- Metal Template:
  - .250" thick, 2024-T3 aluminum alloy:
    (2014-T6 may be substituted if within specified flatness, reference para. 6.0).

3.0 **Construction:**

- Template:
  - .125" standard thickness may be replaced by .187" thick material if specifically required by the tool order instructions. The heavier thickness may be required to overcome storage and handling problems caused by irregular and unusual outlines.
  - .125" thick aluminum doubler $1^1/_2$" wide around periphery of tool to include all holes and cutouts in HRJ. This doubler will replace .125" plywood on all HRJ's. This will decrease wear on periphery and reduce set up time because the doubler will remain on the tool for both drill and router operations.

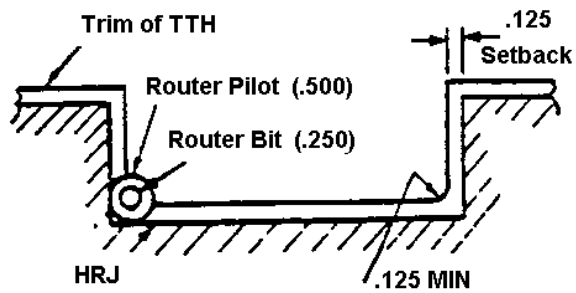
4.0 **Outlines:**

- Trim Edge:
  - The outline shall be obtained from TTH. Trim is normal to contour unless otherwise specified. Trim-edges (of the tool on perimeter, slots, holes, etc.) shall be set back .125".

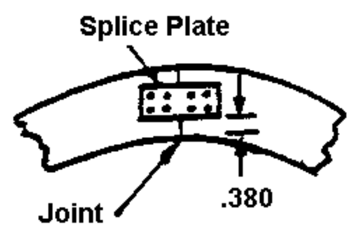


  - Tooling ears are added when they are included in the TTH outline.

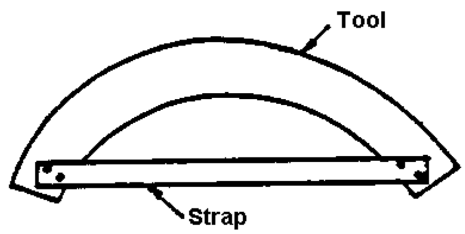
- Cutouts:
  - The minimum work-piece corner radius is .188" due to router cutter diameter. Inside corners of the HRJ may omit the radius if the work-piece radius is .188" or less.



- Holes:
  - Include all full size holes over $^5/_8$" inch in the work-piece.
- Slots:
  - Minimum slot width shall be $^5/_8$" inch in the work-piece.
- When splices are required on the tool, they shall have a clearance of .380" from the tool trim edge.



- Tools for chem-mill work-pieces shall have their outside outline established 1.50" $\pm$ .060" outside the final trim.
- Add a removable storage strap for horseshoe type tools.



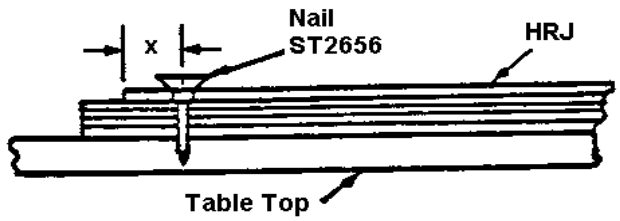
5.0 **Holes:**

- Hole Pattern:
  - The hole pattern location shall be obtained from the TTH.

- Tooling Holes:
  - A minimum of six tooling holes is required to hold the HRJ and work-piece to the router table during routing operations. These holes shall be spaced at approximately 12" on-center for large tools and approximately 6" on-center for small tools. The exact spacing is determined by the shape of the work-piece.

Note: Press kit bushings shall be added for tooling holes used for location of skins in fixtures, and for coordination of doublers to skins, unless tool order instructions specify otherwise.

  - Tooling holes located near an edge shall be no closer than the following distance from the center of the hole to the edge of the tool.



HRJ Hole Diameter	Minimum "X" Diameter
# 10 (.1935")	.470"
.250" & .312"	.530"

- Template holes for standard radial arm drill guides are required for work-piece hole sizes listed. Color code holes per SD20.510.

Drill Diameter	HRJ Hole Diameter
# 50 (.070")	# 10 (.1935")
# 40 (.098")	# 10 (.1935")
# 30 (.128")	# 10 (.1935")
# 21 (.159")	$^1/_4$" (.250")
# 10 (.1935")	$^1/_4$" (.250")
$^1/_4$" (.250")	$^5/_{16}$" (.312")

- "Steel Stamp" hole size at each hole or with tool code (if all holes are the same size). (For HRJ - Remove "Color Code" holes per SD20.510.)

  For wear resistance, a hardened plate ($^1/_8$" x $^9/_{16}$" x 1$^1/_8$"), containing a # 10 hole, shall be applied over each <u># 10 tooling hole</u> that is clear of the router pilot.

  Wear Plate:

  Material: CMS 4340 H/T Rc35-40

- Full size holes, interchangeable hole patterns and pilot holes for dimpling shall use template drill bushings (reference paragraph 2.2).

6.0 <u>Tolerance:</u>

- Setback edge (.125") shall have a tolerance of $\pm$ .005" in relation to the TTH. Hole diameters and their location shall have a tolerance of $\pm$ .002" with respect to the TTH.
- <u>Flatness:</u>
  - Surface variation of $\pm$ .010" per foot are permissible. This shall be measured from a base plane when the template lays flat of its own weight.
- Edges and holes shall have a surface finish of RMS32, approximately.

7.0 <u>Identification:</u>

- Refer to SD20.510: Tool and Equipment Identification for specific instructions.

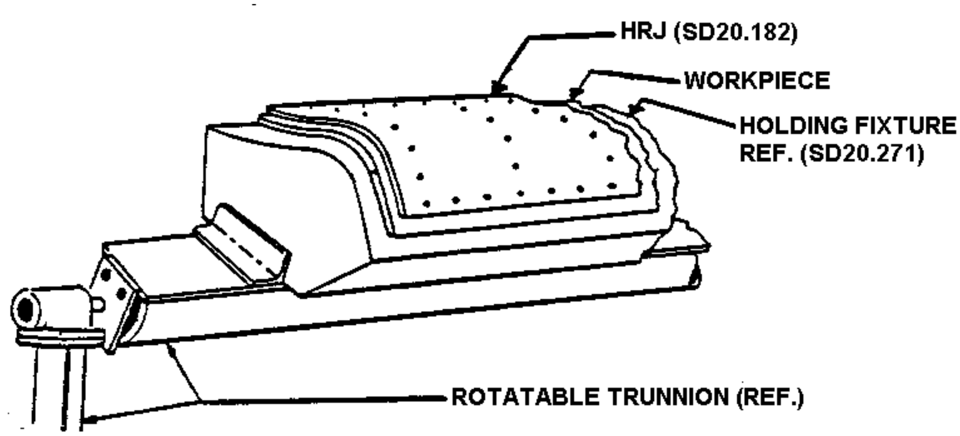
HAND ROUTER JIG (HRJ) - CONTOURED

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 **Definition and Scope:**

- A Hand Router Jig (contoured) is a template type tool used for routing and drilling aluminum work-pieces. The template is placed on the work-piece and both are secured to a holding fixture, HF (SD20.271). A hand guided radial arm routing machine is used to trim the outline. The drilling is done with a hand drill and standard drill guides. The tool size shall be limited by the following work-piece categories.

  - Larger than 60" x 36" and any size thickness up to .375".
  - Larger than 12" x 6" and .020" thick or less.
  - Over 12" long but less than 6" wide and over .125" thick.



Typical HRJ SD 182 for Contoured Parts

Figure 1

2.0 **Construction:**

- Materials:

  - A contoured fiberglass laminate coordinated to the MUF, TTR, or electronic model.
  - The laminate shall be from .250" thick.
  - The upper surface of the laminate shall be free of bumps and abrupt changes in elevation for a distance of .750" from the tool edge.
  - Aluminum alloy work-pieces may be used as an alternate material. The choice of this material is affected by work-piece thickness, availability, and the tool lead time. Thickness shall be in the range of .090" through .188".

- Outline:

  - *Trim Edges*:

    The outline shall be obtained from the TTR, WM, or electronic master.

    Trim-edges shall be set back .125" from the TTR or WM. Edges that are not to be routed shall be made net, painted black, and marked with the note "No Trim".

    Templates for work-pieces to be chem-milled shall have trim established 1.500" ± .060" outside the final trim. The excess material does not appear on the TTR.

- Cutouts and Slots:

  - Cutout edges shall be set back .125 from the TTR, WM, or electronic master.
  - The minimum work-piece slot is .500" which shall be guided by a .750" slot in the tool. The minimum work-piece inside corner radius is .125".
  - When a work-piece cutout cannot be made because of its configuration or restrictions, it shall be made exactly the same as the TTR or WM and clearly marked "Scribe Only".

- Hole Pattern:

- The hole pattern shall be obtained from the TTH, TTR, or electronic master.

- *Drill Guide Holes:*

Drill guide holes are preferred and shall be used whenever possible.

The HRJ shall be drilled to accommodate standard drill guides.

Drill Diameter	HRJ Hole Diameter
# 40 (.098")	# 10 (.1935")
# 30 (.128")	# 10 (.1935")
# 21 (.159")	.250"
# 10 (.1935")	.313"

When an area of the tool exceeds the .188" thickness, the drill holes in that area shall be counterbored .500" diameter to provide clearance for template fasteners (reference Figure 2).

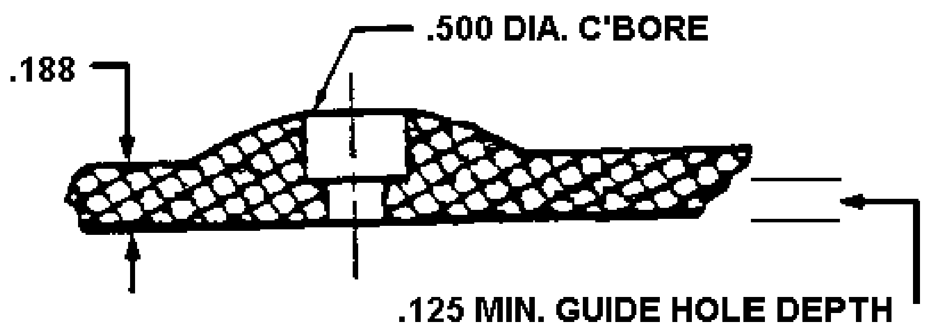


Figure 2

- *Potted Bushings:*

Knurled embedment bushings shall be used only for the following applications:

* For full size holes

* Interchangeable hole patterns

* Pilot hole for dimpling

* Tooling holes shall be used for the location of skins in fixtures and for the coordination of doublers to skins, unless tool order instructions specify otherwise.

* When bushings are used very close to a trim-edge, the bushing shall be restricted to $^1/_2$" maximum length to eliminate interference with the router guide (reference Figure 3).

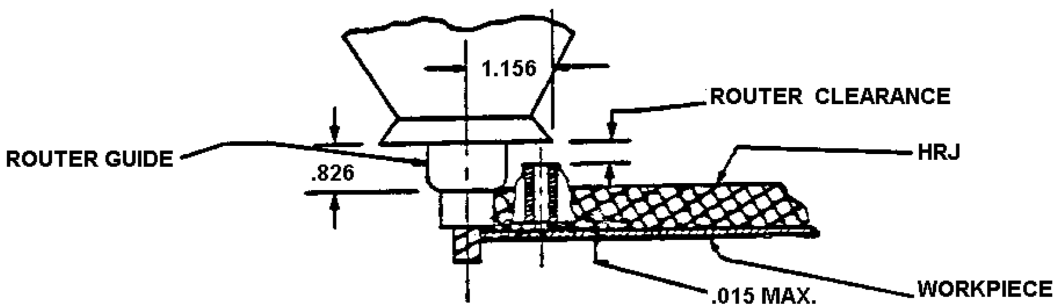


Figure 3

* In areas where no routing is required, the largest available OD and bushing lengths shall be used.

* Refer to SD20.166 for the method of potting Knurled Embedment Bushings.

- Tooling Holes and Ears:

  - Tooling ears may be added to accommodate tooling holes outside the work-piece outline. They are used for routing where it is impossible or impractical to use tooling holes in the work-piece. This shall be noted on the work order. The ears shall be cut off the work-piece when they are no longer required. Refer to SD20.276 for the appropriate shape.

- Chem-mill Provisions:

  - For pre-chem-mill work-piece, preliminary SRJ's/CSRJ's shall have tooling holes coordinated to the TTR, MAT, or electronic master.

  - Hang holes for suspending the chem-mill work-piece shall be added in the excess material around the perimeter. The distance from the hang hole edge to the final trim shall be approximately .750". These holes do not appear in the TTR/electronic master.

3.0 **Tolerance:**

- Setback edges (.125") shall have a tolerance of ± .005" in relation to the TTR. Hole diameters and their location shall have a tolerance of ± .002" with respect to the TTR.
- Edges and holes shall have a surface of RMS 32.

4.0 **Identification:**

- The tool identification area shall be located in a neutral (non-working) portion of the tool.
- For current tool identification information, refer to SD20.510 (Tool and Equipment Identification).

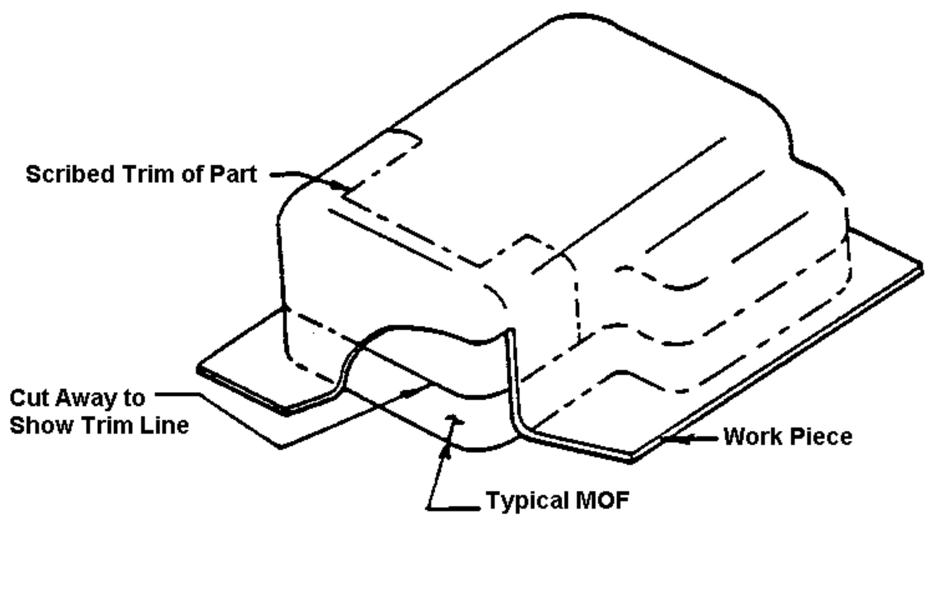
DETAIL TOOL 20

MOLDING FORM (MOF)

Note: In addition to the information contained in SD20.183, please adhere to the following criteria when requesting data for a MOF to thermoform plastic production parts.

- **Define the type of material the tool is to be fabricated from.**
- **Define if the mold will be a male or a female.**
- **Define, from the following dimensions, what the wall and the web thickness will be required to be after machining:**
  - **.625**
  - **.750**
  - **1.000**
- **Provide a raw material size for the production part, so the size of the base of the tool can be determined.**
- **Specify if a scallop cut will be required through the inner walls to create a vacuum chamber for the tool.**

Note: Alternate Manufacturing Method:
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.



1.0 Definition and Scope:

- A Molding Form is made to the shape of the required part, to which a thermoplastic or thermosetting is drawn by vacuum causing it to assume the outline of the form.
  - For thermoplastic parts, a heat softened ABS or polycarbonate work-piece is placed over the form and a vacuum is drawn causing the work-piece to assume the shape of the molding form.
  - For thermoplastic parts, the work-piece is placed on the form, covered and sealed with a flexible film, after which a vacuum is drawn in a process known as bag molding.
- There are six types of molding forms classed according to the material used in their construction:
  - SD183-1 - Phenolic Fiber Laminate (for thermoplastic)
  - SD183-3 - Mahogany
  - SD183-5 - High Temperature Epoxy (all purpose)
  - SD183-7 - High Temperature Epoxy (split mold for casting)
  - SD183-9 - Paraplast (for internal molds)
  - SD183-11 - Aluminum Alloy (for thermosetting and thermoplastic parts)

SIZE LIMITATIONS (Thermoplastics Only)			
Press #	**ABS Blank Sizes**	**Polycarbonate Blank Size**	**Tooling (MOF's) W L H**
# 1	17" x 23 $^3/_4$" (up to .156" thick)	17" x 23 $^3/_4$" (up to .156" thick)	14" x 20" x 1" 10" x 16" x 4"
# 2	24" x 28" (up to .156" thick)	24" x 28" (up to .156" thick)	20" x 24" x 1" 18" x 18" x 4" 10" x 10" x 12"
# 3	34" x 35" (.156" - .250" thick)	Does Not Apply	30" x 30" x 1" 26" x 26" x 4" 20" x 20" x 12"
# 4	38" x 62" (up to .250" thick)	38" x 62" (up to .250" thick)	36" x 60" x 1" 30" x 54" x 4" 24" x 48" x 12"

2.0 **Construction:**

- Materials:

  - The molding form material shall be determined by the work-piece to be formed (reference para. 1.0).
  - Phenolic Fiber Laminate "Richlite"
  - Mahogany
  - Epoxy
  - Aluminum Alloys (7075-T6 or 2024-T4)
  - Paraplast (castings)
  - Adhesive: Surface Coat

- Outline:

  - Forms shall be male whenever possible.
  - Hollow forms shall be made only when specifically ordered.
  - Walls of hollow forms shall be made to the thickness specified on the tool order.
  - Forms shall extend one inch beyond the trim line of thermoplastic parts and 1" to 1.500" beyond the trim for fiberglass parts unless otherwise specified.
  - Trim lines of the finished part shall be scribed on all surfaces, deep enough to make a legible impression on the work-piece.

- Lamination:

  - Phenolic fiber and mahogany forms shall be laminated, using adhesive specified in "Materials", so that the laminations are in a horizontal plane. Vertical lamination is acceptable only if a significant labor and material savings can be realized by its use.

- Shrinkage Correction:

  - No shrinkage correction is required for fiberglass parts.

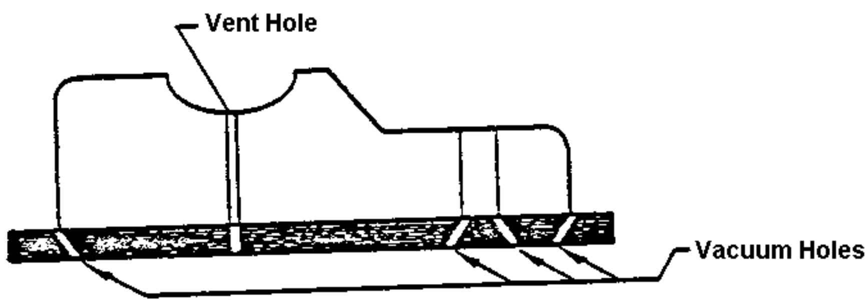
  - Add .007" per linear inch for male forms and .008" per linear inch for female forms used for the thermosetting plastics.

- Vacuum and Vent Holes:

  - Vacuum holes shall be # 50 (.070") diameter unless otherwise specified. (None required for thermosetting materials.)

  - Locate vacuum holes in all inside angles and corners. Spacing is determined by the outline of the part.

  - Vent holes shall be $^1/_{16}$" (.063") diameter and located in areas to relieve induced vacuum and facilitate separation of part and molding form.



- Draft Angle:

  - Specified by the engineering part drawing or the tool order.

- Fillet Radii:

  - Fillets greater than $^3/_{16}$" radius shall be made of the parent tool material.

  - Fillets of $^3/_{16}$" or smaller radius shall be formed with surface coat.

- Identification:

  - Apply standard tool identification per SD20.510: "Tool and Equipment Identification".

PROFILING TEMPLATE (PFT)

Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

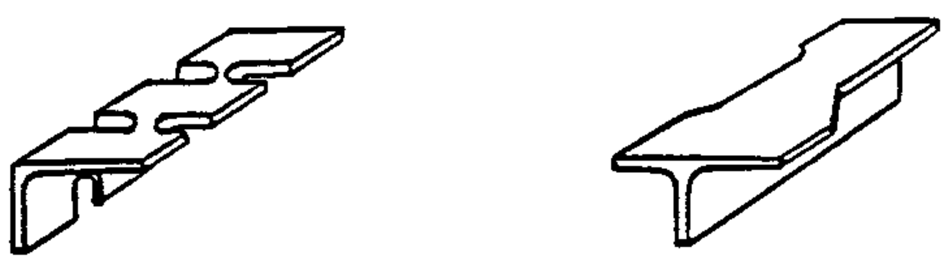
1.0 **Definition and Scope:**

- A Profiling Template is a tracing guide for trimming the outline of a work-piece on a profiling machine. This standard describes two types of profiling templates.

  - SD20.185-1:

    A metal extrusion template used as a tracing guide for trimming the outline of a work-piece on a profiling machine. A universal fixture, without the need for tooling holes or ears holds the work-piece and tool.

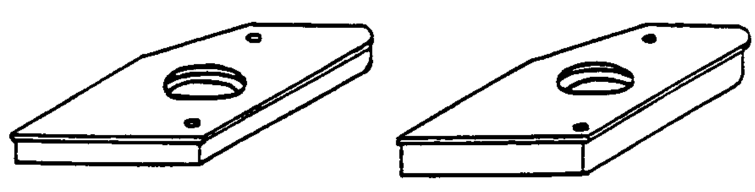
Tooling Parameters:	Maximum Length:	48"	
	Maximum Thickness:	.500"	
	Extrusion Shapes:	90°	Angles & Tees



  - SD20.185-3:

    A flat tracer template plus a work-piece holding unit that is located on the machine by coordinated dowel pin pick-ups to keep template and holding unit in alignment.

Tooling Parameters:	Maximum Length:	67"
	Maximum Width:	24"
	Maximum Work-piece Thickness:	.500"



2.0 **SD20.185-1:**

2.1 Construction (-1):

- A duplicate of the work-piece extrusion is used to eliminate the need to "build up" a cross section.

- *Materials:*

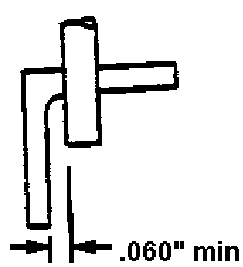
2.2 Outline (-1):

- The template shall be trimmed to the Engineering information.

- Multiple templates shall be made when specified by the tool order. The number of templates shall be determined by the manufacturing economics.

  - Multiple tools shall remain joined by a web that is also used to define cut-off line between individual parts. Minimum distance between individual parts shall be .370" with no minus tolerance. There is no positive tolerance, based on the shape of the parts.

- The tracing stylus and router bit cannot come closer than .060" to any vertical web.



- The minimum inside radius is .187".

2.3 Tag Holes (-1):

- Two # 50 (.070") holes shall be added to accept tag wires.

3.0 **SD20.185-3:**

3.1 Construction (-3):

- One part of the tool is the tracer template that is used to guide the tracing stylus. The second part of the tool is the holding fixture to which the work-piece is secured while on the machine.

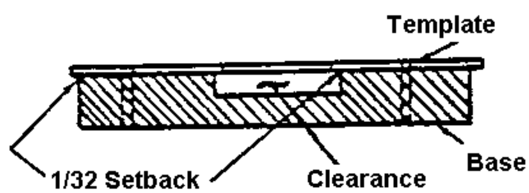
- Material:

Template: .125-2024-T3 Aluminum Alloy
Template Base: $^3/_4$" Phenolic Laminate

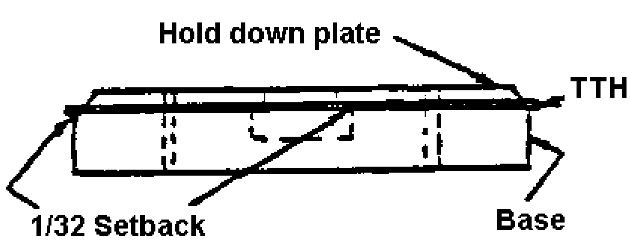
Hold-down Plate: .250-2024-T3 Aluminum Alloy
Hold-down Base: 1" Phenolic Laminate

3.2 Outline (-3):

- Tracing template shall be a duplicate of the TTH.
- Template base shall be set back $^1/_{32}$" from TTH outline. Provide $^3/_8$" deep clearance pockets for internal cutouts.



- Attach template to base with F/H screws.
- Install two .250" diameter pick-up holes coordinated to machine table hole pattern.
- Add coordinated hold-down holes, using approximately one for every 20 square inches, but never less than two on any tool.
- The holding fixture hold-down plate shall be .060" setback from the TTH. Add 45° x .220" chamfer all around. The plate edge thickness shall be .030" (+ .030" - .000").
- The base shall be set back $^1/_{32}$" from the TTH outline. Provide $^1/_2$" deep clearance pockets for internal cutouts.
- Install two .250" diameter pick-up holes coordinated to tracing template holes.



3.3 Tolerance (-3):

- *Outline:*

  ± .005" in comparison with Engineering information such as loft lines or EO (Engineering Order) dimensions.

- All other dimensions: ± .015"

3.4 Tag Holes (-3):

- Two # 50 (.070") holes shall be added to accept tag wires.

4.0 Identification:

- Refer to SD20.510, Tool and Equipment Identification Standard, for instructions.

BLANKING DIE, RUBBER (BDR)

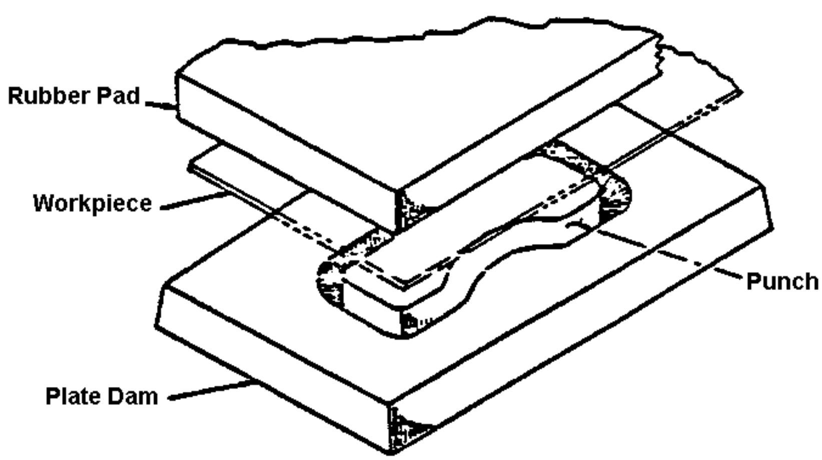
Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

1.0 Definition and Scope:

- A steel punch that uses a hard rubber pad as its die for blanking and piercing thin sheet metal work-piece. A dam surrounds the punch to intensify the shearing force applied in a high-pressure (20,000 psi) trapped rubber pad press.

2.0 Ordering Information:

- These dies produce flatter parts in thin sheet metal than matched dies and are recommended for economical low rate production within the listed limits. Shear size of the work-piece makes it necessary to plan multiple parts when the individual part is less than three inches on any side in order to minimize waste.
- For steel and titanium parts, a Punch Template (PT) is required to add die-location holes in the work-piece (not necessary for aluminum).
- Finished part size produced on BDR's is limited to 15" maximum diameter, 10" maximum square, and 5" x 18" maximum rectangle with the following material thickness:
  - Stainless Steel and Titanium up to .016" inclusive.
  - Aluminum alloys, all tempers up to .020" inclusive.



3.0 **Materials**

- Punch:

  .312" Tool Steel, AISI - 01, H/T to Rc 59-61.

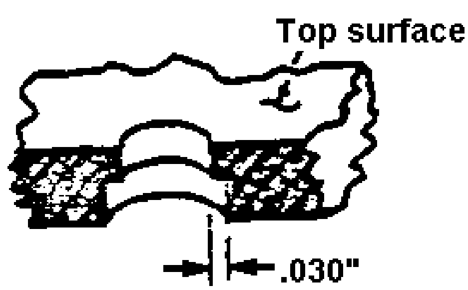
- Plate Dam:

  .375" Aluminum Alloy 2014-T6, 2024-T4, 7075-T6.

4.0 **Construction:**

- Outline (punch):

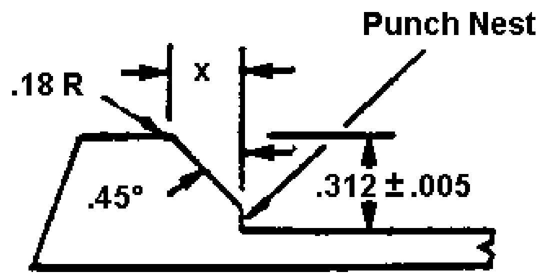
  - Trim-edges and hole locations are determined by the TTH.
  - Minimum hole diameters and slots are listed in Table I.
  - Hole relief of .030" is required on all holes and slots.



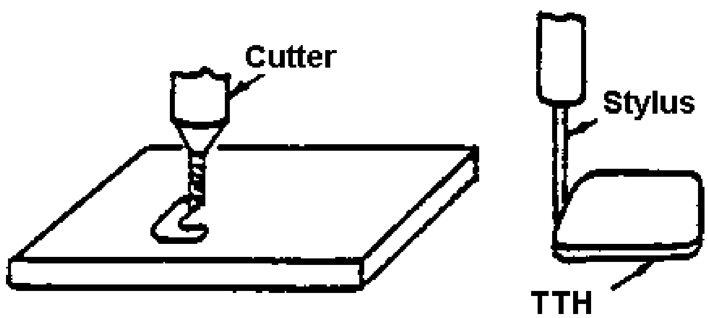
  - Top surface of the punch shall be finish ground after heat treatment.

- Outline (plate dam):

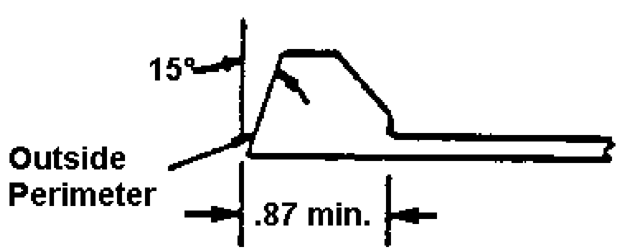
  - The nest for the punch perimeter is milled with a flat end mill to cut the nest and a chamfer to the "x" dimension and angle required in Table I.



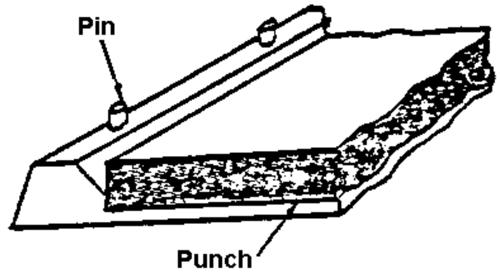
  - The cutter path is guided by the TTH on any duplicating type vertical-milling machine.



  - The outside perimeter of the dam is squared off to produce a rectangle with a .870" minimum distance from punch nest.



  - Steel and Titanium work-pieces require two .188" locating pins centered in the crown of the dam and coordinated to a PT.



- Incorporate two or more parting knives in the scrap area to split the work-piece scrap into pieces.

Materials	Thickness	Minimum Holes	Minimum Lots	"x" $\pm$ .020"
321 CRES	.015" .025" .032"	.312" .375" .625"	.312" .375" .625"	.312"
301 CRES $^{1}/_{4}$" H	.015" .025" .032"	.375" .563" .625"	.375" .563" .625"	.375"
301 CRES $^{1}/_{2}$" H	.015" .020"	.375" .563"	.375" .563"	.375"
302 CRES	.015" .020"	.312" .500"	.312" .500"	.312"
TITANIUM COMMERCIAL TITANIUM 8%	.012" .016" .025" .032"	.312" .375" .437" .500"	.312" .375" .437" .500"	.312" .375"
TITANIUM 6-6-2 (ANNEALED)	.015"	.375"	.375"	.375"
TITANIUM 6-4 (ANNEALED)	.017"	.375"	.375"	.375"
4130 CHROME-MOLY STEEL	.015" .025"	.375" .562"	.375" .562"	.375"

Table I

5.0 **Tolerance:**

- A die-tryout part shall be within $\pm$ .002" of the outline and hole location on the TTH.
- Punch edges and holes shall be RMS 63 approximately.

6.0 **Identification:**

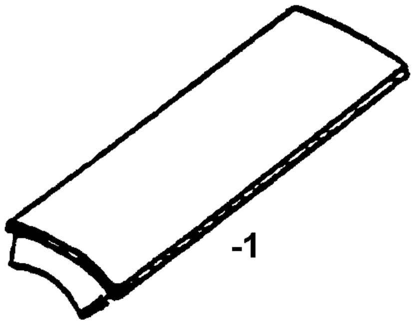
- Stamp all tool identification on bottom of tool, and per SD20.510, Tool and Equipment Identification.

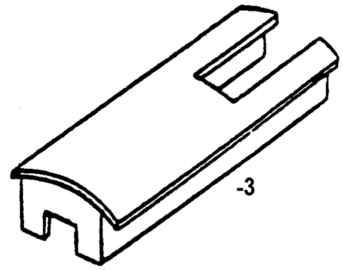
HOLDING FIXTURE (HF)

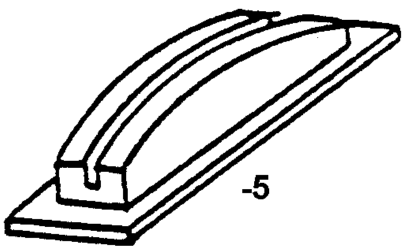
Note: **Alternate Manufacturing Method:**
This tool may be NC generated from computer model. Manufacturing Engineering, at their discretion, may designate usage of the master gageless tooling methodology for fabricating this tool. This alternate method encompasses the utilization of NC programming/electronic models. Reference Section III for detailed information.

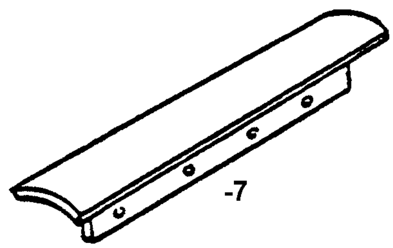
1.0 Definition and Scope:

- A fixture used to hold a work-piece or an assembly in proper alignment during production operations on the parts or assemblies.
- This standard describes four types of holding fixtures used with SRJ's and HRJ's for routing and drilling operations.
  - For "skins" over 12" x 18" that are contoured about a single axis.
  - For "skins" over 12" x 18" that have compound contours.
  - For contoured angles, tees, channels, hat sections, etc.
  - For "skins" up to 12" wide and from 12" to 216" long. Use with SRJ only.


-1


-3


-5


-7

2.0 **Materials:**

- Fiberglass/Epoxy Laminate
- Plywood, Grade A/C, Fir.
- Lumber: Fir or Spruce (Common Grade)
- Cellular Cellulose Acetate (CCA)
- Aluminum Alloys - Angles: .120" x 1.500" x 2", any T3 or T6 temper
  - Plate: .250" thick, any T3 or T6 temper
- Masonite
- Phenolic Laminate

3.0 **SD20.271-1:**

3.1 Construction:

- *Fiberglass/Epoxy Laminate Cover:*

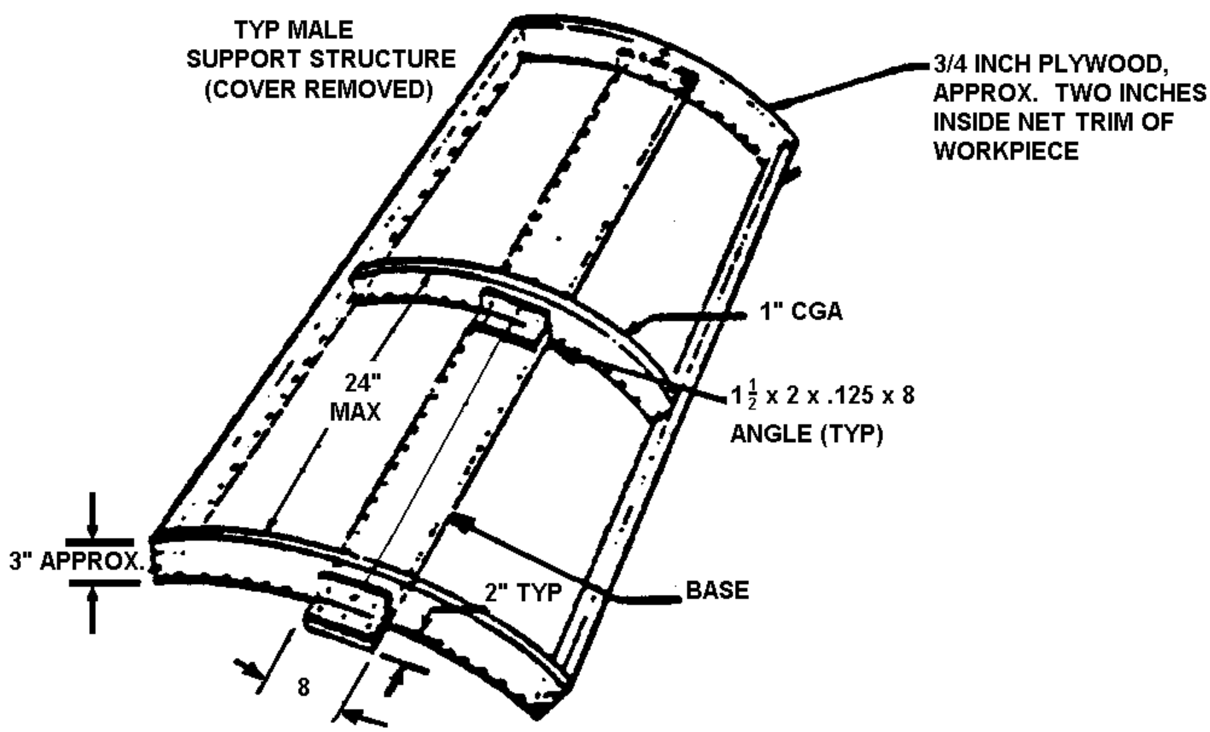
  - Fabricate to .180" thickness from a plaster cast of the desired surface and approximately 1" larger than the part trim.

  - Laminating techniques and materials established by the Special Tooling group shall control the fabrication of the laminate.

  - The outline of the cover shall be to the finished outline of SRJ or HRJ.

- *Support Structure:*

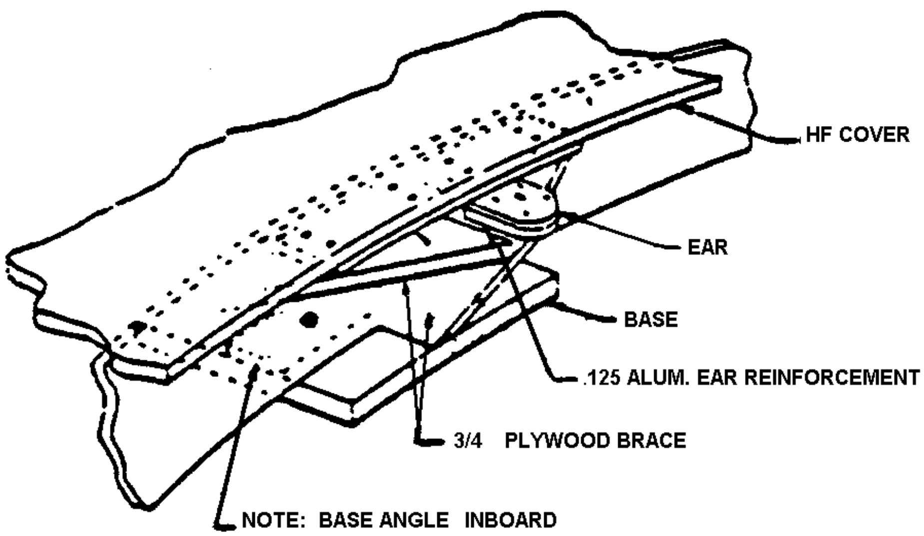
  - Frame shall be made of .750" thick plywood, approximately 3" deep and contoured to support the laminate at approximately 2" inside of the outside trim line.



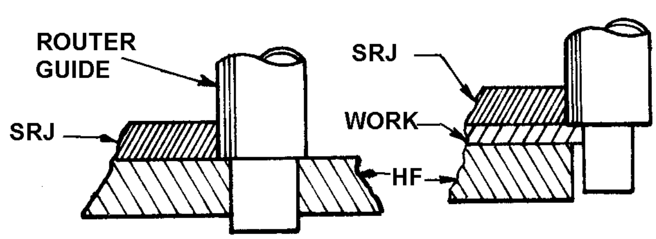
  - Intermediate supports shall be made of 1" thick CGA foam, evenly spaced and no more than 24" inches apart.

  - The base plate shall be .750" plywood, 8" wide and located in the center of the frames.

- *Assembly:*
  - The support structure shall be fastened together with nails and glue.
  - The base shall be fastened to the frame with screws and aluminum angles.
  - The laminate cover shall be fastened to the frame with fiberglass cloth and epoxy resin.
  - Support tooling ears with a plywood brace.



  - Locate the HRJ or SRJ on the laminate cover and transfer the index holes full size from the tool. Apply metal reinforcement under these holes.
  - If the tool index is transferred from the mock-up, only one index shall be provided and the other index shall be obtained from the TTR.
  - Provide a # 10 (.1935") clearance hole under each # 30 or # 40 production hole in the HRJ or SRJ.
  - Provide router clearance on all routing edges by trimming with router guide and a $^{5}/_{16}$" diameter carbide router bit using the SRJ or HRJ for the outline.



- Remove the laminate cover material under all internal cuts.

- Paint the underside portions of the tool with the standard tooling paint system as per SD1.400, Manufacturing Engineering Tool Design Manual, Tooling and Equipment Paint Information section.

4.0 **SD20.271-3:**

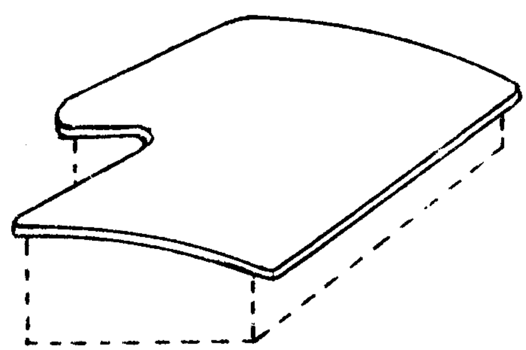
4.1 Construction:

- *Fiberglass/Epoxy Laminate Cover:*

  - Fabricate to .180" thickness from a plaster cast of the required surface, and approximately 1" larger than the part trim.

  - Laminating techniques and materials established by the Special Tooling group shall control the fabrication of the laminate.

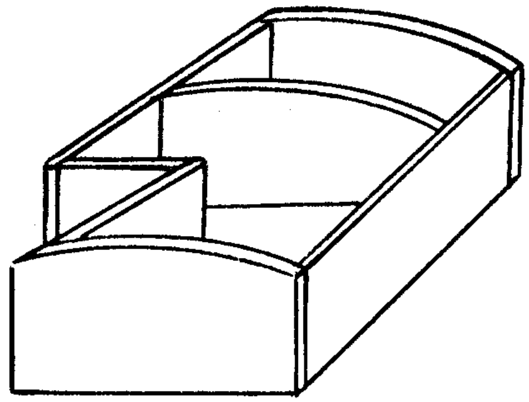
  - Outline of the cover shall be to the finished outline of the SRJ or HRJ.



- *Support Structure:*

  - The frame shall be constructed of .750" thick plywood contoured to match the laminate cover and extended to a common base line.

  - The frame shall follow the outline of the work-piece trim line and be approximately 1" to 2" inside the outline.



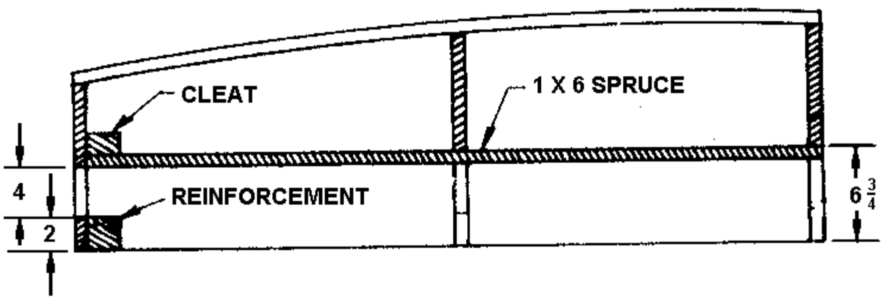
- Intermediate supports shall be constructed of .500" plywood to reduce overall weight and shall be evenly spaced and no more than 24" apart to provide adequate support to the laminate cover.

- *Assembly:*

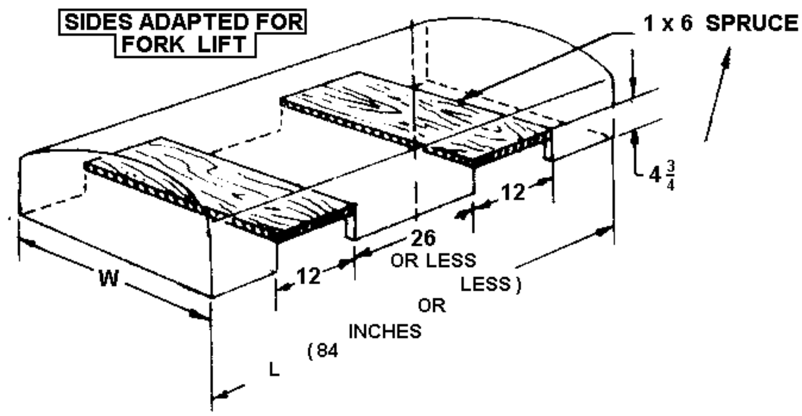
  - The support structure shall be fastened together with nails and glue.
  - The laminate cover shall be fastened to the support structure with fiberglass cloth and epoxy resin.
  - Apply the tool index holes to the laminate from the SRJ or HRJ and add metal reinforcement under these holes.
  - Provide a # 10 (.1935") clearance hole under each # 30 and # 40 production hole in the SRJ or HRJ.
  - Provide router clearance on all routing edges.
  - Remove the laminate cover under all internal cuts.
  - Provide fork lift openings in the ends of all HF's that weigh over 100 pounds or are over 36" x 36".

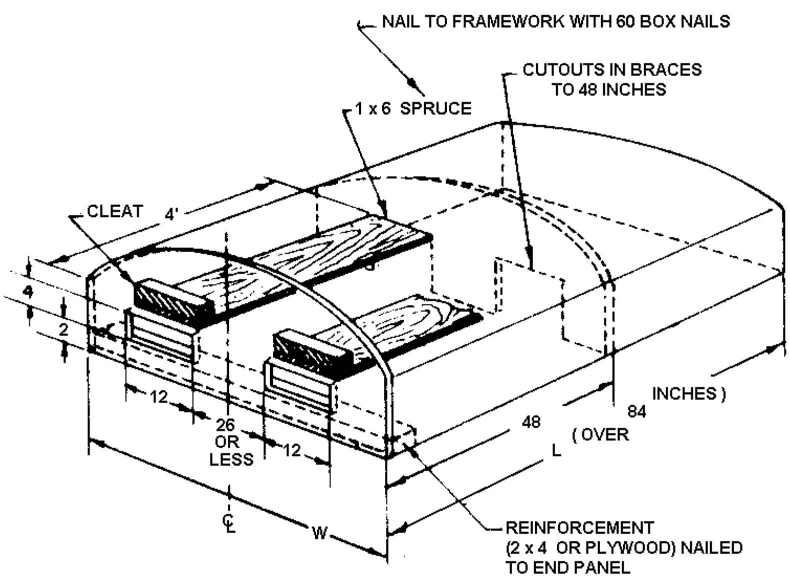
  Size of Openings:

TOOL	OPENING	QUANTITY
12" - 18" width	4" x 6"	(1)
19" - 24" width	4" x 12"	(1)
25" & over width	4" x 10"	(2)



- HF's up to 60" shall have the opening extend through the tool. Those tools over 60" shall be limited to approximately 48" from one side only.



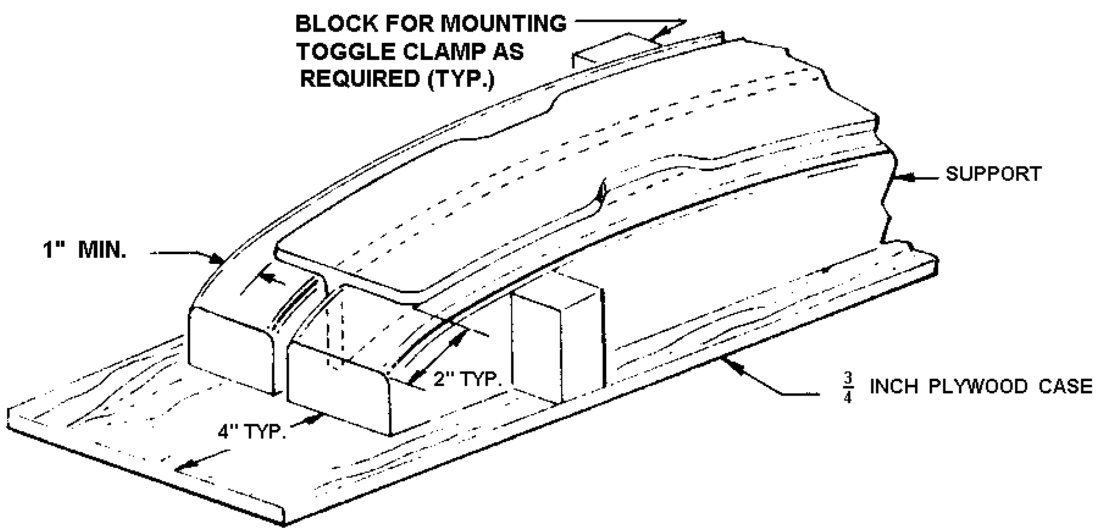


- Paint the exterior wood and fiberglass portions of the tool but not inside the support frame (reference SD1.400, Manufacturing Engineering Tool Design Manual, Tooling and Equipment Paint Information section.).

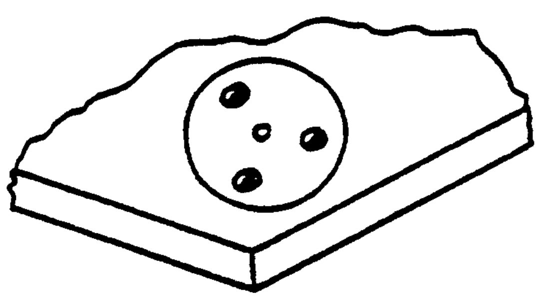
5.0 **Construction (SD20.271-5):**

5.1 Construction:

- *Support Structure:*
  - Fabricate the wood, masonite, or phenolic fiber laminate to the contour of the TTR.
  - Provide nesting and support, with .005" - .010" clearance for variations in contour.
  - Make the support 1" wider than the TTR on each side and 2" longer on each end.



- *Base Plate:*
  - Fabricate the .750" plywood, approximately 2" wider all around, than the support structure.
  - Blocks for mounting toggle clamps shall be added as required.
- *Assembly:*
  - Apply flush mounted steel plates for indexing and hold down holes.



- Use toggle clamps and end stops only if no hold-down holes are available.

- Provide router clearance on all routing edges.

- Coat the working surface of the support structure to prevent oil absorption and chip embedment.

- Paint the remainder of the tool with the standard tooling paint system as per SD1.400, Manufacturing Engineering Tool Design Manual, Tooling and Equipment Paint Information section.

6.0 **SD20.271-7:**

6.1 Construction:

- *Fiberglass/Epoxy Laminate:*

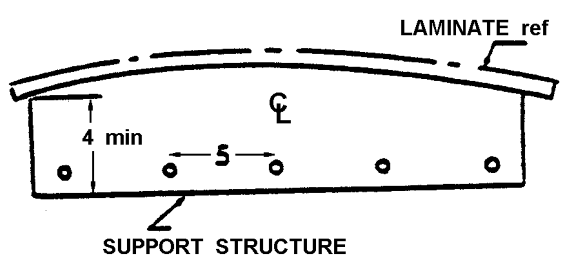
  - Fabricate to .250" thickness from a plaster cast of the desired surface, and approximately 1" larger than the part trim.

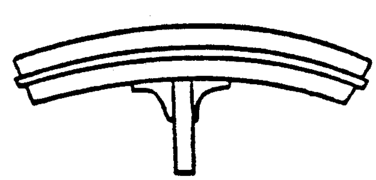
  - Laminating techniques and materials established by the Special Tooling group shall control the fabrication of the laminate.

  - Outline of the laminate shall be to the finished outline of SRJ.

- *Support Structure:*

  - Structure fabrication shall be .250" aluminum alloy plate, cut to match the contour of the laminate.





  - Drill .250" diameter holes every 5" ± .010" starting from center of plate.

- *Assembly:*

  - Join the laminate to the support structure with fiberglass cloth and epoxy resin.

  - Apply the tool index holes from the SRJ and add metal reinforcement under these holes.

  - Drill # 10 diameter clearance holes at every production hole location.

  - Provide router clearance on all routing edges as per "Assembly" section.

  - Paint the structure and the underneath portion of the laminate with the standard tooling paint system as per SD1.400, Manufacturing Engineering Tool Design Manual, Tooling and Equipment Paint Information section.

7.0 **Identification:**

- Apply tool identification per SD20.510, Tool and Equipment Identification.

- Apply the tool nameplate to the support structure.

- Stencil the tool number in 1" high characters on both ends of -1, -3, -5, and -7.

HOLE PLUGGING IN TEMPLATE TOOLS

Note: Holes in templates require moving from time to time. The method used for plugging the old hole should not deform the material which is being plugged. Any template which has been deformed by hole plugging shall not be acceptable and shall be remade. The following basic information is given to provide a uniform approach to hole plugging.

1.0 Master Templates (TTH, BPT, WM, etc.):

- Use an aluminum slug produced by Wiedemann Punch or other punch method when only a few holes need plugging. There must be a drive fit between plug and hole. This method is used only when there is no drilling to be done in the plug. Peen lightly with a ball-peen hammer on both sides of the plug and hole.
- When a new hole must be drilled through an aluminum plug. Ensure the plug does not rotate. A $^1/_8$" rivet in the circumference of the plug will act as a key, or the entire plug may be spot-welded. Staking is not acceptable.
- Use a thermosetting plastic when large numbers of holes are to be plugged in metal templates. Allow sufficient time for hardening before returning the tool to service. It is permissible to drill through this type of plug.
- On fiberglass tools, follow the recommendations above when plugging any holes.

2.0 Production Templates (CBT, TTP, SRJ, etc.)

- Use an aluminum slug produced by Wiedemann Punch or other punch method when only a few holes need plugging. There must be a drive fit between plug and hole. This method is used only when there is no drilling to be done in the plug. Peen lightly with a ball-peen hammer on both sides of the plug and hole.
- On metal templates, when a new hole must be drilled through an aluminum plug, ensure the plug does not rotate. A $^1/_8$" rivet in the circumference of the plug will act as a key, or the entire plug may be spot-welded. Staking is not acceptable.

  However, due to extra service given production tools, it is recommended that a new tool be made when possible. The responsible Manufacturing Engineer shall decide if current conditions (estimated time, length of contracts, etc.) warrant the making of a new tool.
- Use a thermosetting plastic when plugging any quantity of holes. New hole locations may be drilled through these plugs after they have hardened for at least 8 hours.

TOOLING EARS

1.0 **Definition and Scope:**

- Tooling ears are extra material that has been added to the part outline to provide a place for tooling holes that cannot be applied inside the part outline. Tooling holes in ears may be required for routing, forming or indexing, either separately or in combination.

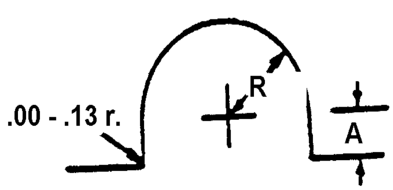
- Tooling ears shall be located on straight sides (2" minimum) to permit shear cutoff. They shall be applied on contoured edges only when no other choice is available.

  - SD20.276-1 To be removed after routing.
  - SD20.276-2 To be removed after forming or chem-mill.
  - SD20.276-3 To be removed after assembly.
  - SD20.276-4 To be removed after assembly.
  - SD20.276-5 Chem-Mill weight control only.

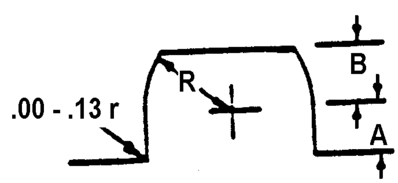
Note: **When size of "part" requires non-standard dimensions, it is important to maintain the general shape for proper identification.**

2.0 **Construction:**

- All dimensions shown are for the "part" and any required tool setback shall be calculated from these dimensions.

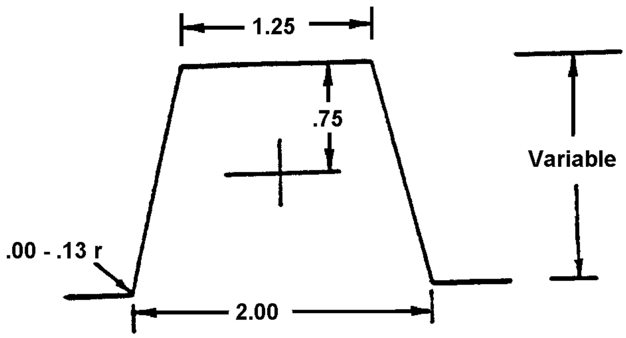


SD20.276 - 1

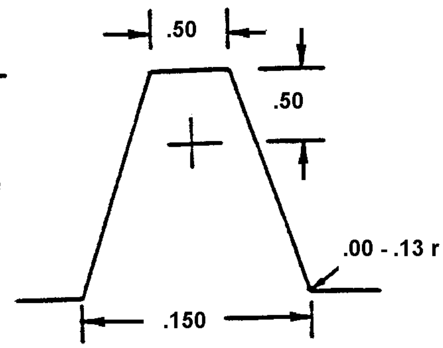


SD20.276 - 2

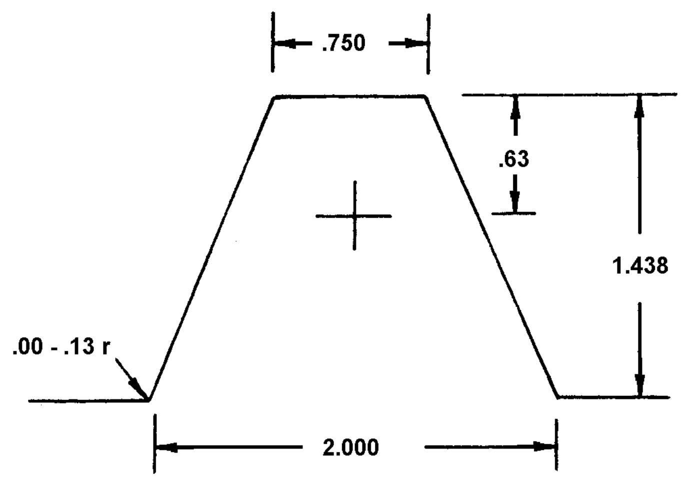
Dimensions	HRJ and Chem Mill	All Others
A	.750"	.250"
B	.630"	.310"
C	.630"	.500"



SD20.276 - 4
HRJ & FIBERGLASS TOOLS
WITH POTTED INDEX



SD20.276 - 3
ALL OTHERS



SD20.276 - 5

Weight (1 ear) - C x Mat'l. Thickness

C = .20 (All Aluminum)
C = .34 (All Titanium)
NC Router Part

3.0 **Tolerances:**

- Two place dimensions $\pm$ .030".
- Three place dimensions $\pm$ .005".

FORM BLOCK "DAM"

1.0 **Definition and Scope:**

- A Form Block "Dam" is a block that is added to the base plate of a form block. It is used to control the flow of the rubber press pad or bladder of a Verson press. A shrink flange (convex curve) in aluminum or steel may be formed without wrinkles by using a dam to restrict the movement of the work-piece as it forms. Permission to incorporate a dam on a form block must be obtained from Manufacturing Engineering.

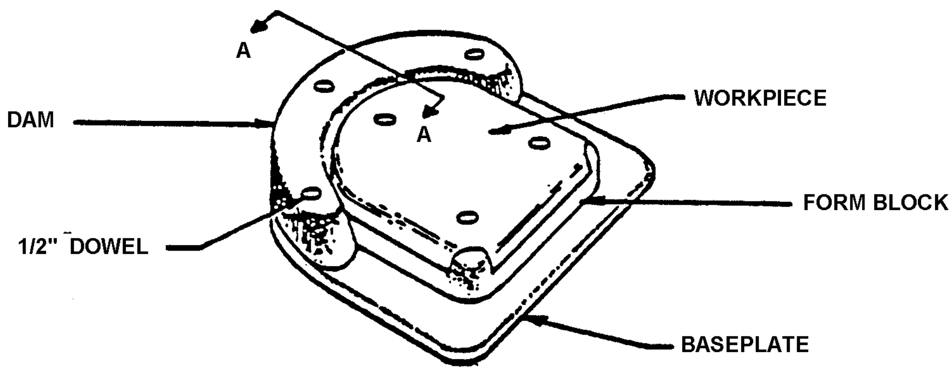


Figure 1

2.0 **Material:**

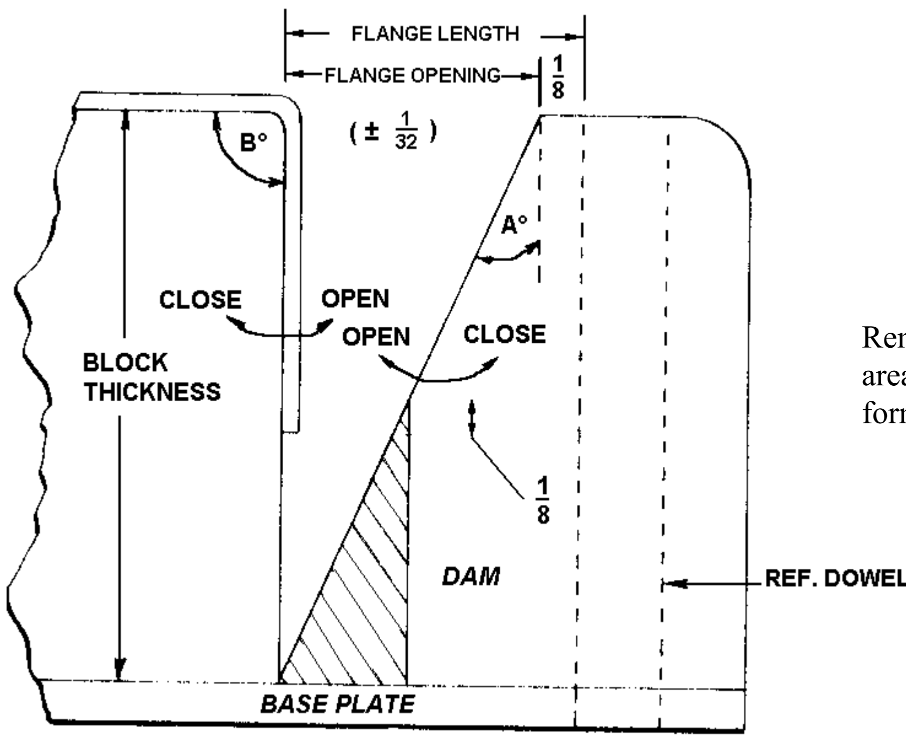
- A Dam shall be made of masonite, regardless of the form block material, unless otherwise specified.

3.0 **Fastening:**

- Machine screws ($^1/_4$" - 20") and $^1/_2$" diameters dowels shall be used to fasten the dam to the base plate of the form block.
- The dowels shall extend through the dam and be flush with the top. Use a minimum of three.

4.0 **Construction:**

- The curve of a dam is parallel to the block and is separated at the top by the flange opening (see Figure 2).
- A dam shall be installed only in the area where the work-piece wrinkles occur (see Figure 1).
- Both ends of a dam shall fair away from the form block (see Figure 1).
- Round non-working edges with $^3/_8$" $\pm$ $^1/_8$" radius.



Remove shaded area for better forming action.

Section A - A from Figure 1

Figure 2

- The chart on the following page suggests the dam angles for various flange lengths and block thicknesses. It is intended as a guide only. The finished dam must be shop developed.

Flange Opening	Block Thickness				
	1"	**1 1/4"**	**1 1/2"**	**1 3/4"**	**2"**
1/4"	14°	11 1/4°	9 1/2°	8 1/4°	7 1/4°
3/8"	20 1/2°	16 3/4°	14°	12°	10 1/2°
1/2"	26 1/2°	21 3/4°	18 1/2°	16°	14°
5/8"	32°	26 1/2	22 1/2°	19 1/2°	17 1/4°
3/4"	---	31°	26 1/2°	23 1/4°	20 1/2°
7/8"	---	35°	30°	26 1/4°	23 1/2°
1"	---	---	33 3/4°	29 3/4°	26 1/2°
1 1/16"	---	---	35°	31 1/4°	28°
1 1/8"	---	---	37°	32 3/4°	29 1/4°
1 3/16"	---	---	38 1/4°	34 1/4°	30 1/2°
1 1/4"	---	---	---	35 1/2°	32°
1 5/16"	---	---	---	37°	33 1/4°
1 3/8"	---	---	---	38 1/4°	34 1/4°
1 7/16"	---	---	---	39 1/4°	35 1/2°
1 1/2"	---	---	---	---	37°

The dam angle (A) opens and closes with the flange angle (B) (see Figure 2).

Example: Flange opening = 1"

Block thickness = 2"

Flange Angle	Block Angle
90°	26 1/2° (reference chart)
95° (open 5°)	21 1/2° (closed 5°)
85° (closed 5°)	31 1/2° (open 5°)

- A dam less than 90° is ineffective, therefore, the angle a flange may be open is limited to the degrees shown on the chart above.
- When closing the flange angle, care must be taken that the block thickness is not less than the flange length.

5.0 **Manufacturing Considerations:**

- A dam may be used on the Verson Press only when there is no alternative.
  - The maximum height of a dam to be used on the Verson Press shall not exceed four inches.
  - Non-working edges and corners of a dam block, when used on the Verson Press, shall be rounded with a minimum of a $^1/_2$" radius.
  - Approval of each dam block must be obtained from the press department foreman before it is used on the Verson Press.

FORM BLOCK INSERT

1.0 Definition and Scope:

- An insert is a removable tapered block that is added to the base of a form block. It is used to limit the forming of a "stretch flange" that is subject to tearing on an inside (concave) curve. When the insert is removed, the flange is finished by hand hammering. Permission to incorporate an insert on a form block must be obtained from Manufacturing Engineering.

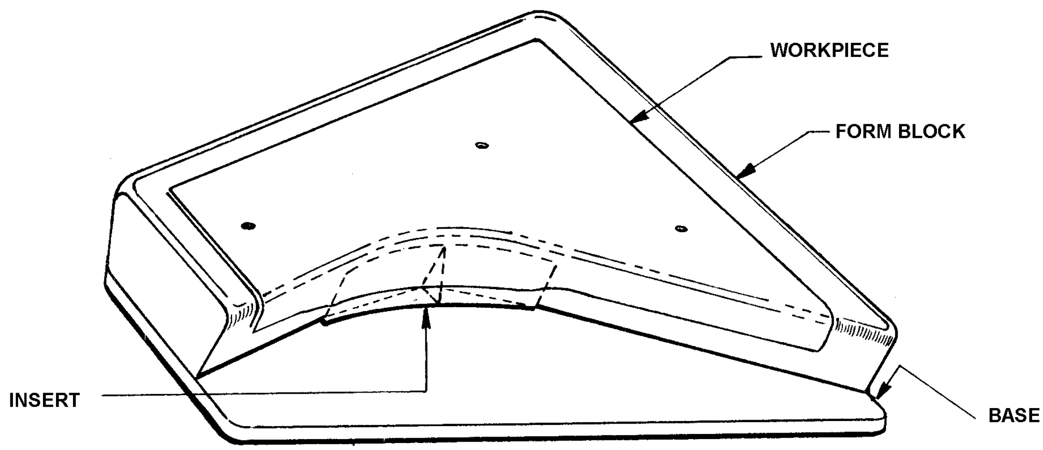


Figure 1

2.0 Material:

- Use "Masonite", 2024-T351 (T4) or 2014-T651 (T6) aluminum alloy.

3.0 Fastening:

- When a form block angle is 90° or open:
  - Use at least two dowels press fitted into the insert and slip fitted into the base of the form block.
- When a form block angle is closed:
  - Use at least two flat-head machine screws through the base of the form block, threaded into the insert.

4.0 **Construction:**

- The insert angle shall be less than the form block angle, and fair-back to the block just beyond the tear area (see Figure 1).
    - The exact angle of an insert must be shop developed.
- The insert shall butt the form block from the bend tangent of the radius to the base (see Figure 1).

TOOLING and EQUIPMENT IDENTIFICATION

1.0 Definition and Scope:

- This section establishes the procedure to be followed when applying identification information to Gulfstream Aerospace tools and equipment. The tool number, which is a composite of a drawing number and tool code, is the basis of tool identification. There are five types of tool numbers used at GAC and they shall be applied to the tool as they are shown on the tool work order. Asterisks are exceptions to this rule, as they are never applied to the tool, although they are shown on tool drawings, method records, and tool orders.

2.0 Tool Number:

- Project Tools:

Example: 1159B00000 ① -11-12 ② DT ③ 2 ④ # 3 ⑤ A/M ⑥

① Engineering drawing number.

② Dash number of Engineering detail or assembly

③ Tool code

④ One of a series of DT's required for -11-12 (numerical sequence).

⑤ A duplicate of the original tool.

⑥ A tool used to perform the same operation on other Engineering details or assemblies (not stamped on tools).

- Standard Tools:

Example: ST 1234 ① -101 ② MDP ③

① Standard tool drawing number.

② Tool assembly dash number

③ These tools also use the tool code and sequence numbering as stated in Project Tools (#4 and #5) above.

- Miscellaneous Tools:

Example: M12345 ① -1 ② MCA ③

① Miscellaneous tool drawing number

② Tool assembly dash number

③ These tools also use the tool code and sequence numbering as stated in Project Tools (#4 and #5).

3.0 **Revisions:**

- Revisions shall be stamped immediately after the tool number when it is stamped directly on the tool surface and in the revision space on tool nameplate.

Example: 1159B00000-11-12 DT 2 # 3 A (revision)

- The following is a list of the types of revisions (changes) and examples of how they are recorded:

  - Drawing Change: NC, A, B, etc.
  - Drawing Record Change: DR-A, DR-B, etc.
  - Tool Fabrication Sequence: FS-A, TFS-B, etc.
  - Engineering Order: EO-A1, EO-A2, etc.
  - Shop Work Order: SWO 10-02-02 (work order date).

4.0 **Method of Identification:**

- Impression Stamping on Tool Surfaces:

  - This method is used on flat surfaces of all non-designed tools and tool details, including designed tools that cannot support a nameplate.

  - Templates, form blocks, routers, etc.

    * Locate the identification area in a neutral zone of the tool when the location is not specified by an SD or tool drawing.

    * Apply property stamp.

    * Stamp the tool number and revisions as described. Use $^3/_{32}$" and $^1/_8$" letters and numbers on surfaces up to 12" x 24", and $^3/_{16}$" for all larger surfaces.

    * Long, narrow templates shall not be impression stamped (reference the "Engraving Section later in this chapter).

    * On template-type tools (i.e.: TH, PBT, etc.) the identification area shall be circumscribed with an orange stripe.

  - Tool Detail:

    * Stamp the full "P" number in a non-critical area using $^3/_{16}$" letters and numbers whenever possible. Use smaller characters only when required by limited space.

    * Use rounded character-style steel stamps for tool details that are to be heat-treated.

- Impression Stamping on Nameplate:

  - Nameplates are used on fiberglass tool surfaces of the designed tools where the application of a nameplate will not interfere with the function of the tool.

  - A nameplate shall be located in an area that does not interfere with the use of the tool.

  - On jigs and fixtures, the preferred location is along the perimeter at an eye-level position. When tool conditions require a nameplate to be mounted on a horizontal plane, the location shall avoid work areas.

  - The nameplate shall conform to the tool contour and be fastened to it with sheet metal screws or drive screws as required by the tool surface.

- Instruction for Entries:

  * Use $^{1}/_{8}$" letters and numbers for all information on the nameplate.

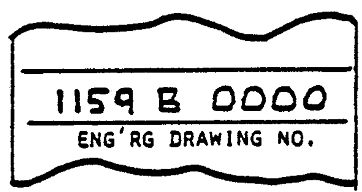
  * On line (A), apply property information.

Example: (A)

----

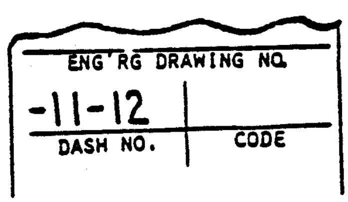
  * Engineering Drawing Number (B):
    Stamp applicable drawing number on this line. "P" number drawings are not added here.

Example: (B)



Dash Number (C):
Stamp detail or assembly numbers as shown on the work order.

Example: (C)



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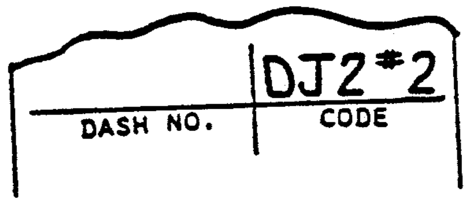
* Code (D):
Stamp the full tool code as shown on the work order.

Example: (D)



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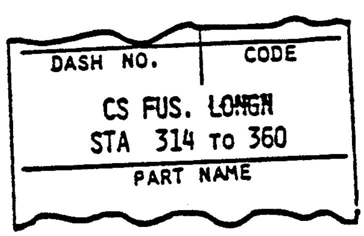
* Part Name (E):
Stamp as shown in the "List of Materials" on the drawing, or as shown in the "Title Block" when identifying an assembly. The space provided will accommodate a double row of stamping. However, it may be necessary to abbreviate.

The following is a list of accepted abbreviations for commonly used names:

Aileron	AIL	Forward	FWD
Antenna	ANT	Fuselage	FUS
Assembly	ASSY	Interior	INT
Bracket	BRKT	Longeron	LONGN
Bulkhead	BHD	Stabilizer	STAB
Center Section	CS	Station	STA
Exterior	EXT	Stringer	STGR

Example: (E)



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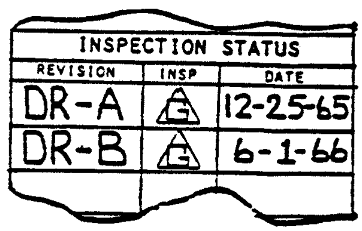
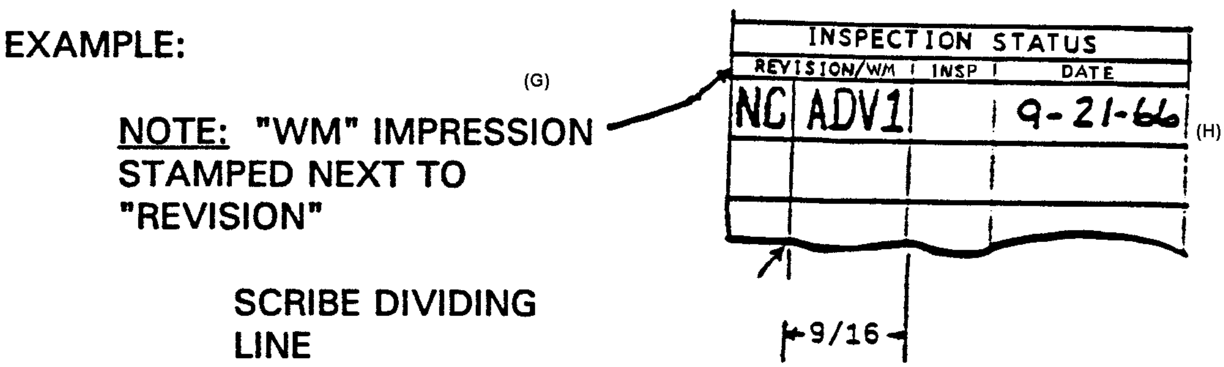
* Part Name (F):
Stamp all revisions.

Example: (F)



* For a White Master (WM) (G) change, divide the revision column as shown below so that the WM change may be coordinated to the Engineering Drawing Change.



* Date (H):
Stamp the date the tool is submitted for inspection. A "Shop Work Order" (SWO) shall be stamped with the date shown on the order.

- <u>Engraving:</u>

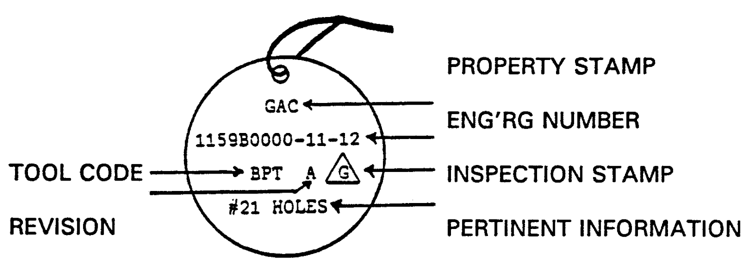
  - Legible and neat engraving is permitted on clean, bare metal tools when impression stamping may cause distortion (i.e.: long or narrow templates, formed tools, etc.).

  - The instructions for application are the same as for impression stamping (reference "Impression Stamping on Tool Surfaces" earlier in the chapter).

- Identification Tag (TD164):
  - TD164 shall be used only when the tool is too small for any other method of identification.
  - The tool shall be stamped with the minimum amount of identification:
    * "P" Number
    * Engineering Drawing Number
    * "ST" Number
    * "M" Number
    * etc.

    The tag shall contain all remaining information as shown in 2.0 and 3.0.
  - Letters and numbers smaller than $^1/_8$" may be used if necessary.
  - Wire the tag through a # 60 hole drilled in the tool.

Example of Tool Tag:



5.0 **Labels:**

- Interchangeable Labels (TD146):

  - All tools which directly produce an interchangeable part, edge, hole, pattern, or contour, and the tools which produce the mating configuration shall be prominently marked with "Interchangeable Part", "Interchangeable Area", or "Interchangeable Attach Points" labels.

Example:

  - For proper adhesion, the tool surface must be fairly smooth and free of scale and oil. Some fiberglass tools may require local sanding to remove the glass cloth fuzz.

  - "Interchangeable Part" labels shall be applied directly below or beside the tool identification if possible. "Interchangeable Area" labels shall be used only on tools which produce edges or holes mating with "Interchangeable Parts". These labels shall be applied in the area of the mating interchangeable edge for hole pattern.

6.0 Miscellaneous Identification:

- Drill Hole Color Code:

  - The following color code shall be painted on drilling tools, as required by the individual tool fabrication standard:

Drilled Hole Size	Color Dimples
# 50 (.0700 dia)	Brown
# 40 (.0980 dia)	Yellow
# 30 (.1285 dia)	Red / Yellow
# 26 (.1470 dia)	Orange
5/32 (.1562 dia)	Black
# 21 (.1590 dia)	Green
# 19 (.1660 dia)	Bright Red
# 18 (.1695 dia)	Purple
# 17 (.1730 dia)	Green / White
# 12 (.1890 dia)	Yellow / White
# 11 (.1910 dia)	Royal Dark Blue
# 10 (.1935 dia)	Light Blue
# 8 (.1990 dia)	White / Light Blue
# 2 (.2211 dia)	Yellow / Light Blue
15/64 (.2344 dia)	Blue / White
1/4 (.2500 dia)	White
(.2510 dia)	Blue / Light Blue
F (.2570 dia)	Green / Light Blue

  - Drill a 1/4 dia dimple at each hole location and for each color, logically inputted on the tool in an evenly spaced, consistent pattern (Aluminum and Steel tools only).

    Example: A # 21 hole will have one (1) Green dimple

    A # 17 hole will have one (1) Green dimple and one (1) White dimple

  - When all holes are the same size, stamp the hole size in the identification area. No color code is required.

  - When most holes in a part are the same size, note in the identification area:

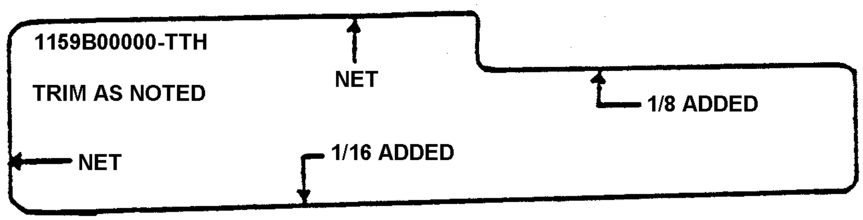
    "ALL HOLES # _________, EXCEPT AS SHOWN."

    Paint and stamp the hole size on the exceptions.

7.0 **Excess Material:**

- Excess material may be needed for final fitting of a part. It must be called out on the tool order when excess material is added. It shall be identified as shown below and the note "TRIM AS NOTED" shall be stamped below the identification area of Tooling Tools Only.

Example:



Section III

STANDARD DATA FOR ELECTRONICALLY GENERATED TOOLING

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

TOOL STEEL PANCAKE DIE (CBD, CBPD)

Note: The computer generated Tool Steel Pancake Die (CBD, CBPD) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The CBD and CBPD are dies in which the work-piece does not drop through the die, but is stripped from the die with cork.
- The primary criteria for manufacturing this tool, is defined in SD20.14 (Tool Steel Pancake Die BD, BPD). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CBD and CBPD will be documented in this procedure.

2.0 General:

- The pancake die can be eliminated if Engineering parts are NC routed. If die is required, then the profile of the die can be NC machined (3-axis) and the die can be completed using conventional methods.

3.0 Construction:

- NC data will be derived from CTTH.
- The outline, hold location, and hole diameter will be determined by the CTTH.
- CBP, CBPD is strictly for use in a conventional application. Specifying a CBP, CBPD indicates that the periphery will be derived electronically.

4.0 Inspection:

- Final parts are to be checked to the CTTH.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

ROUTER JIG (CROJ)

Note: The computer generated router jig (CROJ) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The router jig (CROJ) is a flat base router template type tool for holding and guiding a flat or formed work-piece during routing operations on pin routers.
- The primary criteria for manufacturing this tool, is defined in SD20.107 (Router Jig ROJ). Exceptions/ additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CROJ will be documented in this procedure.

2.0 General:

- Using a NC router could eliminate the router jig. If a fixture is necessary, then a computer generated holding fixture (CHF) will be required.

3.0 Construction:

- NC data will be derived from CTTH.
- CROJ is strictly for use on a conventional pin router. Specifying a CROJ indicates that the template will be machined from CTTH data.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

FORM BLOCK (Rubber Forming) (CPB, CPBH, CWPB, CHPB)

Note: The computer generated form block (rubber forming) (CPB, CPBH, CWPB, CHPB) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The form blocks in this standard are all male forms in the shape of the inside of the required work-piece (part) as determined by the CTTH.
- The primary criteria for manufacturing this tool is defined in SD20.110 (Form Block (rubber forming) PB, PBH, WPB, HPB). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CPB, CPBH, CWPB, and CHPB will be documented in this procedure.

2.0 General:

- NC data will be derived from CTTR.
- Index holes on block will coordinate with NC machine coordinates.
- Spring back data defined in Section SD20.5 will be utilized.
- If a setup template is needed, one will be generated from the CTTH and NC machined. It will be used as a manufacturing aid and will be discarded after use.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MASTER FLAT PATTERN TEMPLATE (CTTH)

Note: The computer generated master flat pattern template (CTTH) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- A master flat pattern is an electronic flat pattern tooling master made in the exact outline and hole pattern of an Engineering part.
- The primary criteria for manufacturing this tool are defined in SD20.113 (Master Flat Pattern Template TTH). Exceptions/additional requirements to accommodate implementing NC technology in manufacturing the CTTH will be documented in this procedure. This master template replaces the following physical tools and their applications:

- DU	- DST	- PT	- SDU
- DT	- SRT	- SCT	- STT
- CGT	- PNT	- PBT	- APT (3 types)
- URT	- PST	- CBT	- PFT (flat applications)

Note: Information to make these tools can be derived from the CTTH.

2.0 Equipment:

- The CTTH shall be built using CAD/CAM technology and will be derived from the developed MGM.

3.0 Construction:

- The CTTH will be constructed (plus OML, ML) electronically using the same criteria as the TTH (OML's, TLHS, and Bend Angles, etc.). The profile of the CTTH shall be contiguous and tangent. Where appropriate, if tooling tabs are used, they should be part of a contiguous geometry.

4.0 **Holes:**

- Holes larger than $^1/_2$" in diameter shall be displayed full size and routed out. Holes less than $^1/_2$" in diameter shall be displayed as a # 30 or as designated by ME Planning. # 40 holes shall be drilled at actual size.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

SETBACK ROUTER JIG (CSRJ)

Note: The computer generated setback router jig (CSRJ) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The CSRJ is a template tool used for hand routing and drilling of contoured aluminum alloy work-pieces.
- The primary criteria for manufacturing this tool are defined in SD20.136 (Setback Router Jig SRJ). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CSRJ will be documented in this procedure.

2.0 General:

- This tool may be eliminated with use of a 5-axis NC router, if available.

3.0 Construction:

- NC data will be derived from CTTR.
- CSRJ is strictly for use in a conventional application. Specifying a CSRJ indicates that the contour will be derived electronically.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

SAW FIXTURE (CSF)

Note: The computer generated saw fixture (CSF) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- A Saw Fixture is a device used to locate and support a straight saw-cut operation in a formed work-piece.
- The primary criteria for manufacturing this tool, is defined in SD20.137 (Saw Fixture SF). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CSF will be documented in this procedure.

2.0 General:

- This tool may be NC machined using information from CTTH or CTTR electronic master model.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MASKING TEMPLATE (CMAT, CMATP)

Note: The computer generated masking template (CMAT, CMATP) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- A Masking Template is a production template used for scribing the outline of a chem mill pocket to permit removal of the maskant in preparation for etching of the pocket.
- The primary criteria for manufacturing this tool is defined in SD20.138 (Masking Template MAT, MATP). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CMAT and CMATP will be documented in this procedure.

2.0 General:

- NC data will be derived from CTTH.
- Fabricate this tool per SD20.138, coordinating the outline to CTTH/CTTR.
- Use setback requirements specified in SD20.138.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MASTER GRAPHICS MODEL (MGM)

Note: The computer generated master graphics model (MGM) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The MGM is a 3D surfaced graphics model which contains geometric features needed for manufacture.
- This should be the controlling media for all derivative tools. A MGM should be developed by Engineering. Tooling would develop their needs from this MGM.

2.0 General:

- Electronic models can be used in conjunction with theodolite inspection to eliminate the need for white masters.

3.0 Construction:

- NC can generate and cut a machined surface using CATIA data when a solid 3D representation is necessary.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

DRILL and ROUTER BOARD (CDRB)

Note: The computer generated drill and router board (CDRB) is fabricated using CAD/CAM technology.

1.0 **Definition and Scope:**

- The CDRB is a flat base router template type tool for holding and guiding a flat or formed work-piece during routing operation on pin routers.
- The primary criteria for manufacturing this tool is defined in SD20.151, SD20.152, SD20.153 (Drill and Router Jig DRB). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CDRB will be documented in this procedure.

2.0 **General:**

- The Drill and Router Board can be eliminated if Engineering parts are NC routed. If a Drill and Router Board is required, then the profile of the Drill and Router can be NC machined and the CDRB can be completed using conventional methods.

3.0 **Construction:**

- NC data will be derived from CTTH.
- CDRB is strictly for use in a conventional application. Specifying a CDRB indicates that the contour will be derived electronically.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

RECORD TEMPLATE (CTTR)

Note: The computer generated record template (CTTR) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- A Record Template is an electronic, 3D, or solid model made to the exact outline and hole pattern of an Engineering part.
- The primary criteria for manufacturing this tool is defined in SD20.163 (Record Template CTTR). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CTTR will be documented in this procedure.
- This master template may replace all formed or contoured templates.

2.0 General:

- Utilize theodolite method coordinated to CTTR to check contour of part.

3.0 Construction:

- NC data will be derived from CATIA or CADAM point data.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

PLASTIC FACE STRETCH DIE (CSD, CSDH, CSDM, CSDS, CHD)

Note: The computer generated hand plastic face stretch die (CSD, CSDH, CSDM, CSDS, CHD) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The Plastic Face Stretch Die (CSD, CSDH, CSDM, CSDS, CHD) is a form used to shape sheet metal into complex curves of large radius.
- The primary criteria for manufacturing this tool is defined in SD20.179 (Plastic Face Stretch DS, SDH, SDM, SDS, and HD). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CSD, CSDH, CSDM, and CHD will be documented in this procedure.

2.0 General:

- An example of adapting NC technology would be to NC the stretch die surface (from kirksite billet or layup) or NC the MUF surface and lay-up this.

3.0 Construction:

- NC data will be derived from MGM, CTTR, and NC machined from a billet.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

SHEAR ROUTER BOARD (CSRB)

Note: The computer generated Shear Router Board (CSRB) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The Shear Router Board (CSRB) is a flat drilling and routing tool consisting of a drill template (Part "A") for use in stack drilling, and a router board (Part "B") for use on a pin router.
- The primary criteria for manufacturing this tool, is defined in SD20.180 (Shear Router Board SRB). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CSRB will be documented in this procedure.

2.0 General:

- This tool may be eliminated with the use of a NC router, if available.

3.0 Construction:

- NC data will be derived from CTTH.
- CSRB is strictly for use in a conventional application. Specifying a CSRB indicates that the periphery will be derived electronically.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

HAND ROUTER JIG, FLAT (CHRJ)

Note: The computer generated Hand Router Jig, flat (CHRJ), is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The Hand Router Jig is a flat template used for routing and drilling aluminum alloy work-pieces that are too large or too thick for pin routing.
- The primary criteria for manufacturing this tool, is defined in SD20.181 (Hand Router Jig, Flat HRJ). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CHRJ will be documented in this procedure.

2.0 General:

- This tool may be eliminated with the use of a 3-axis router, if available.

3.0 Construction:

- NC data will be derived from CTTH.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

HAND ROUTER JIG, CONTOURED (CHRJ)

Note: The computer generated Hand Router Jig Contoured (CHRJ) is fabricated using CAD/CAM technology.

1.0 **Definition and Scope:**

- The Hand Router Jig (contoured) (CHRJ) is a contoured template used for routing and drilling aluminum alloy work-pieces.
- The primary criteria for manufacturing this tool is defined in SD20.182 (Hand Router Jig Contoured CHRJ). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CHRJ will be documented in this procedure.
- This master template may replace all formed or contoured templates.

2.0 **General:**

- This tool may be eliminated with the use of a 5-axis NC router, if available.

3.0 **Construction:**

- NC data will be derived from CTTR.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

MOLDING FORM (CMOF)

Note: The computer generated Molding Form (CMOF) is fabricated using CAD/CAM technology.

Note: In addition to the information contained in SD20.283, please adhere to the following criteria when requesting data for a MOF.

- **Define the type of material the tool is to be made from.**
- **Define if the tool shall be male of female.**
- **Define bagging excess beyond the EOP and lay up excess line.**
- **Define the wall thickness after machining.**
- **Define if the tool will be pocketed out for cool down and heat up purposes.**
- **Define the thickness of the web in the pockets.**
- **Define what temperature the tool will be required to withstand. Tools for graphite parts will be required to withstand 350 degree cycles and regular pre-pregnated fiberglass will be required to withstand repeated cycles up to 250 degrees.**
- **Tool Design/NC Programming will determine the thermo coefficient to be factored into the tool.**
- **Scallops will only be added to the tool if specifically requested by the originator. The size and the depths of the scallops are to be determined by the NC Programmer.**
- **Tool Design/NC Programming will add provisions for lifting features on tools that weigh in excess of 20 pounds.**
- **Tool Design/NC Programming will add spoon drill features, per standard practice, in the excess area of the tool for coordination purposes.**
- **Tool Design/NC Programming will add an axis, to be scribed in outside the lay up area, defining the ply orientation per Engineering requirements.**

1.0 Definition and Scope:

- The Molding form (CMOF) is a 3D CAD/CAM model used to electronically define a MOF.
- The primary criteria for manufacturing this tool, is defined in SD20.183 (Molding Form MOF). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CMOF will be documented in this procedure.

2.0 General:

- NC data will be derived from CTTR and include appropriate shrinkage corrections.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

BLANKING DIE RUBBER (CBDR)

Note: The computer generated Blanking Die, Rubber (CBDR) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The Blanking Die Rubber (CBDR) is a steel punch that uses a hard rubber pad as its die for blanking and piercing thin sheet metal work-pieces.
- The primary criteria for manufacturing this tool, is defined in SD20.186 (Blanking Die Rubber BDR). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CBDR will be documented in this procedure.

2.0 General:

- This tool may be eliminated with the use of a 5-axis NC router, if available.

3.0 Construction:

- NC data will be derived from CTTH.
- CBDR is strictly for use in a conventional application. Specifying a CBDR indicates that the contour will be derived electronically.

Note:All acronyms referred to in this document are defined in "Tool & Equipment Code List" (SD1.665).

HOLDING FIXTURE (CHF)

Note: The computer generated Holding Fixture (CHF) is fabricated using CAD/CAM technology.

1.0 Definition and Scope:

- The CHF is a fixture used to hold a work-piece or an assembly in proper alignment during production operations on the parts or assemblies.
- The primary criteria for manufacturing this tool, is defined in SD20.271 (Holding Fixture HF). Exceptions/additional requirements to accommodate implementing CAD/CAM technology in manufacturing the CHF will be documented in this procedure.

2.0 General:

- A CHF may be used for NC routing of skin details traditionally cut with SRJ's, DRB's, or HRJ's.
- When a "CHF" is used for routing, cuts normal to the skin would be accomplished by utilizing a 5-axis NC router machine.

3.0 Construction:

- NC data will be derived from CTTR or MGM.

1.0 **Scope:**

- To define in general terminology, the "Tools" and "Equipment" codes currently in use at Gulfstream Aerospace Corporation (Savannah plant).

2.0 **Introduction:**

- Gulfstream Aerospace utilizes tool codes to abbreviate tool and equipment nomenclature. The code appears as part of the tool or equipment part number.

3.0 **Procedure:**

- To utilize the list of codes defined below, cross reference the Tool Code and Tool Description columns. A summary of the tools provided in this list will be provided prior to the exhibition of the detailed description of the tool codes and tool description.

Tool - Equipment Codes List

Note: When applicable as part of its description, (PROD) will designate a tool that is utilized primarily for part production whereas, (TOOLING) will designate a tool that is employed to manufacture another tool.

TOOL CODE	TOOL DESCRIPTION
ACF	**Age Creep Form:** (PROD) A tool that is typically utilized in the forming of machined skins, in a flat condition, to the defined engineering contour configuration. Tool configuration includes an over form spring back surface and vacuum features to pull skin to tool contour surface. Skin is subsequently processed in an Autoclave environment to achieve the engineering defined surface configuration and skin metallic required qualities.
ADJ	**Assembly Drill Jig:** (PROD) A tool that holds parts or sub-assemblies in correct relationship for a drilling operation, and provides bushings or other guides for the cutting tools.
AF	**Assembly Fixture**: (PROD) A device that holds parts or sub-assemblies in correct alignment for drilling and assembly.
AHF	**Autoriveter Holding Fixture**: (PROD) A multiple piece contour board type fixture, generally fabricated from Richlite, Phenolic, or Aluminum, that will be used in conjunction with the Autoriveter and will provide the Engineering contoured surface of skin assemblies. Fixture to provide index features for orientation to the Autoriveter. Tool will provide strapping assemblies ensure positive contact with the contour board features.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

APT — **Air Punch Template**:

ARB — **Arbor:** (PROD) A cylindrical shaft used to hold cutters, hobs, molding forms, or work-pieces during machining, or filament winding operations.

BB — **Bending Block:** (PROD) A form block, about which parts are formed by hand or hand tools.

BD — **Blanking Die:** (PROD) A male and female die similar to a blank and pierce die but without hole punches.

BDR — **Blanking Die (rubber):** (PROD) A steel punch and rubber die combination using the shearing force of rubber trapped around the punch perimeter. This tool is used in a high pressure rubber press to produce work-pieces with or without holes.

BKB — **Bucking Bar:** (PROD) A shaped bar used to upset the shank (bucked) end of a rivet during the riveting operation.

BMF — **Boring Mill Fixture:** (PROD) A tool assembly consisting of a machine set-up (holding fixture, tracing can or model, cutter and other accessories) used on the tracer boring mill for machining two or three dimensional contours of a part.

BOF — **Bonding Fixture:** (PROD) A tool to hold detail parts and/or assemblies of honeycomb sandwich construction during the adhesive curing (bonding) cycle.

BPD — **Blank and Pierce Die:** (PROD) A male and female die to stamp out blank pieces from sheet metal and pierce holes in the blanks.

BPT — **Blank and Pierce Template:** (PROD) A tool used to make blank and pierce dies. It is the same as TTH except BPT reflects full size holes (TTH shows pilot holes for end size hole).

BRF — **Broaching Fixture:** (PROD) A tool that holds a part in proper position on the table for broaching operations.

BSK — **Basket:**

BSP — **Special Adaptor:** (PROD) An adapter or special bushing used in machining operations.

BT — **Brake Template:** (PROD) A guide of sheet or plate metal usually with pins for picking up a part and locating it in a leaf or press brake for forming. It may also have marking holes on the bend line.

BXD — **Blank, Pierce, and Form Die:** (PROD) A male and female die to blank and pierce as well as form sheet metal.

BXT — **Blank, Pierce, and Form Die Template:** (TOOLING) This template gives the flat pattern, location of holes to be pierced and location of mold line for forming.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

BZF **Brazing Fixture:** (PROD) A fixture to locate and hold parts to be joined by any of the various brazing processes such as induction brazing, furnace brazing, dip brazing, etc.

CB **Core Box:**

CBT **Pneumatic Router Box Template:** (PROD) A flat type of production routing and drilling template having mounted provisions coordinated with pneumatic router box, ST1772.

CC **Contour Cam:** (PROD & TOOLING) Tracing Guides for controlling machining operations on tracer-cutter machines. They may be profile plates, templates, cams, models, or master parts.

CCA **Cellular, Cellulose, Acetate:**

CDR **Combination Die (Rubber):**

CF **Checking Fixture:** (TOOLING) A tool that is used to check the accuracy of another tool; usually a set of templates mounted on a base, or a plastic lay-up to define the shape of a part. It is used to check compound contours of a production-forming tool by checking a few sample parts.

COF **Combination Fixture:** (PROD) A tool to hold parts in proper relationship to each other for more than one type of operation, such as drilling and milling, boring and milling, etc. (Not to be used for single operation tools.)

CP **Plug:** (PROD) A mandrel or spindle used to support the work during machining or fabricating operations.

CR **Contour Roller:** (PROD) These are used on roll-bending machines for curving extruded and rolled sections. They may also be used to alter the surface or cross-section of the material.

CRD **Corner Radius Die:** (PROD) A die to trim a radius on outside corners of sheet metal.

CRF **Chamfer Routing Fixture:** (PROD) A fixture to guide a sheet or plate metal part whose edges are to be beveled on a router milling machine.

CRS **Cold Rolled Steel:**

CSB **Controlled Stroke Form Block:**

CT **Contour Template:** (PROD & TOOLING) A flat template made to a mold line for the purpose of mastering the contour of another tool or a work-piece.

CTTR **Computer Generated Record Template:** Fabricated using CAD/CAM technology: A Record Template is an electronic, 3D, or solid model made to the exact outline and hole pattern of an Engineering part.

DA **Die Accessory:** (PROD) Any necessary items used in conjunction with dies.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

DD **Draw Die:** (PROD) A die used to form deep shapes in sheet metal by pressure clamping the metal over a female cavity and forcing a punch into the cavity; thus forming the metal to the shape of the punch.

DDR **Draw Die Rubber:** (PROD) A male and female block with a draw ring for draw forming in a rubber press. The size of the finished part shall not exceed 2" x 10" x 16". Refer to DD for larger parts.

DDT **Draw Die Template:** (TOOLING) A template giving the profile to inside of sling of the male portion of draw die.

DHD **Drop Hammer Die:** (PROD) A matched male and female die used to form parts with intricate contours by impact on a drop hammer.

DHR **Drop Hammer Die (rubber):** (PROD) A male forming block, used in a drop hammer in conjunction with a rubber pad female, to form sheet metal parts by impact.

DID **Diameter Die:** (PROD) A die for punching round holes in parts.

DJ **Drill Jig:** (PROD) A tool that locates and clamps work in position for drilling through bushed holes in the jigs.

DKD **Dinkling Die:** (PROD) A hollow punch, with a sharp beveled cutting edge, used to punch shapes from cardboard, rubber, fabric, etc. It employs wood or other suitable material as an anvil.

DMD **Dimpling Die:** (PROD) A male and female die used to form a conical depression around a hole in sheet metal.

DOL **Dolly:** (PROD) A wheeled fixture used for transporting a work-piece.

DP **Drill Plate:** (PROD) A flat tool, $^1/_4$" or more in thickness, containing bushings for drilling purposes exclusively. It is located in relation to the work-piece.

DRB **Drill and Route Board:** (PROD) A flat routing and drilling tool for sheet metal work-piece.

DRJ **Drill and Ream Jig:** (PROD) This tool is defined the same as a drill jig, except it has slip renewable bushings that enable holes to be reamed as well as drilled in the same work holder.

DRP **Drill and Ream Plate:** (PROD) This tool is defined the same as a drill plate, except it has slip renewable bushings for reaming.

DST **Drill and Scribe Template (formed):** (PROD) A template type tool containing both trim lines for scribing and provisions for drilling. It may contain bushings or drill guide holes or both.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

DSU **Drill and Scribe Template (flat):** (PROD) A template type tool containing both trim lines for scribing and provisions for drilling. It may contain bushings or drill guide holes or both.

DT **Drill Template (formed):** (PROD) A template type tool less than $^1/_4$" thick and containing provisions for drilling only. It may contain bushings or drill guide holes or both.

DU **Drill Template (flat):** (PROD) A template type tool less than $^1/_4$" thick and containing provisions for drilling only. It may contain bushings or drill guide holes or both.

ED **Expandable Die:** (PROD) A split or sectional female die. The material to be formed is bulged or stretched outward to the given shape by a hydraulic, mechanical, or explosive force from within the work-piece.

EHB **Electrical Wiring Harness Board:** (PROD) A full size wiring layout board on which harness assemblies are fabricated. It contains wire holding and guiding devices, harness outline lay-out, markings for connector locations, and special assembly instructions where required.

EMT **Engraving Template:**

ERD **End Radius Die:** (PROD) A die used to trim radii on the ends of sheet metal strips.

ERF **Automatic Riveting Fixture:** (PROD) A fixture used on an automatic drilling and riveting or punching and riveting machine for assembly of ribs, bulkheads, and other relatively shallow assemblies with many rivets of the same size.

EXT **Expendable Tool:** (PROD) A tool that cannot be accounted for because of its expendable nature. Examples include: service kit tools, throw-away tools, and tools used up in the tool's function (but excludes all tools valued at more than $250).

FAD **Flattening Die:** (PROD) A flat surfaced anvil and punch to flatten ends of such items as tubing, extrusions, rolled sections, and round stock.

FCM **Hot Form Matched HTD Ceramic Die:**

FCV **Hot Formed Vacuum HTD:**

FD **Form Die:** (PROD) A die, which may contain cams, levers, springs, wiping plates, or other special devices used for particular forming operations.

FDT **Form Die Template:** (TOOLING) A flat template made to the inside mold line of a part for producing the male punch of the form die.

FFU **Hot Form Flat Die (US IND):**

FFW **Hot Form Flat Die (WW):**

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

FLD — **Flanging Die:** (PROD) A die that forms flanges on lightening holes.

FMH — **Hot Form Match HTD Metallic Die:**

FMP — **Hot Form Matched Die:**

FP — **Flat Pattern:** (TOOLING) A developed flat pattern on mylar material of a composite part, that includes any pertinent information, such as material excess and edge of plies. This is to be used as a master for manufacturing ply cutting templates (TTP).

FPD — **Formed and Pinch-Off Die:** (PROD) A die to form a part and then trim it at the bottom of the stroke by pinching the material between mating knife edges of the male and female portions of the die.

FPU — **Hot Formed Press Pad Die (US IND):**

FPW — **Hot Formed Press Pad Die (WW):**

FT — **Form Tool:** (PROD) All cutting tools employing a shaped cutting edge which imparts a desired form to a work-piece. Applied only to fixed position single point tools.

FTD — **Form & Trim Die:** (PROD) A die to form and trim parts to a given contour. (This includes plastic parts.)

FWF — **Flashwelding Fixture:** (PROD) This tool includes all attachments required for flash-welding of a particular assembly.

FWM — **Flexible White Master:**

GCT — **Grind Check Template;** (PROD) A steel flat pattern template used to check nibbled parts in edge grinding operations.

GF — **Grinding Fixture:** (PROD) A tool that holds parts in proper position during grinding operations.

GMC — **Miscellaneous Cutter:** (PROD) All cutting tools containing rotating cutting edges. Examples of this type tool include special drills, counterbores, spot-facers, milling contours, boring bars, etc.

GMX — **Miscellaneous Gage:** (PROD) All gages that are not elsewhere classified.

GPT — **Gang Punch Template:** (PROD) A duplicate extruded section or formed piece used to locate punches, edge stops, and end stops for punching holes in parts with a gang punch.

HB — **Hammer Block:** (PROD) This tool is a block made of steel, kirksite aluminum alloy, or masonite, with no allowance for springback. A part is finished on it by hand hammering after being formed by another tool. The block may be full length or at a specific section of the part for joggles, sharp bends, etc.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

HBT **Hammer Block Template (TOOLING):**

HCT **Honeycomb Core Contour Template:**

HD **Hufford Die:** (PROD) A male form used for curving extrusions, rolled sections, etc. on the A10 and A12 Hufford stretch wrap forming machines.

HDT **Hufford Die Template:** (TOOLING) This template gives the contour of the HD to a specified face of the part. The face to which it is made must be stamped on the template together with all angles and trim lines.

HE **Handling Equipment:** (PROD & TOOLING) All materials handling equipment that cannot be otherwise classified. See DOL, HOE, PSR, and SCD codes.

HF **Holding Fixture:** (PROD) A fixture to hold parts and/or assemblies in proper alignment during production operations on the parts or assemblies.

HFD **Hydroform Die:** (PROD) A hydroform die consists of a punch and draw ring only. Hydroforming is a simplified method of producing deep drawn shapes from sheet materials. This method differs from conventional deep drawing in that a special press is employed having a hydraulic actuated flexible diaphragm in place of the conventional "Hard" female.

HFT **Hydroform Die Template:** (TOOLING) A tooling template used in making a hydroform die.

HLD **Holder of Tools:** (PROD) Any tool designed to hold cutting tools or attachments while operating a milling machine or lathe.

HOE **Hoisting Equipment:** (PROD) Equipment such as slings and rigs. Used in hoisting work-pieces, assemblies, etc.

HPB **High Pressure Block:** (PROD) A form block used as a male die half, with a rubber pad acting as the mating half, for forming a work-piece under a pressure of 20,000 psi.

HRJ **Hand Router Jig:** (PROD) A router jig for trimming and drilling large flat pattern parts, intended for use with either a radial arm router or large hand router.

HST **Honeycomb Core Saw Template:**

HTA **Heat Treat Accessory:** (PROD) An accessory required in the heat treating of metals.

HTF **Hydrotel Fixture:** (PROD) A holding fixture, used in conjunction with a cam or template, to hold the part to be milled on the Hydrotel Machine. Each assembly must be plainly marked to assure the proper use of all the tool components.

ICF **Inspection Checking Fixture:** (PROD) A fixture mainly used by production inspection to check parts, assemblies, aileron-throw, etc. However, it may also be used in other departments, such as for checking work operations at any point of development. The ICF is made to conform to the checking fixture (CF) when frequent inspection is required. When need for ICF for compound curvature formed parts is in question, consult tooling department.

ICT **Inspection Checking Template:** (PROD) A template mainly used to check parts or assemblies, etc. in various stages of fabrication.

IF **Installation Fixture:** (PROD) A fixture used to install a part on an assembly by locating it from some previously established points on the assembly.

IHF **IPAC Holding Fixture:** A multiple piece contour board or variable shaped board type fixture, generally fabricated from Richlite that will be used in conjunction with the IPAC CNC Riveting Machine, that will provide engineering defined definition of assemblies. Tool will also be utilized in an IPAC work cell to install non-IPAC structural components required to manufacture a completed assembly or sub-assembly.

IJ **Installation Jig:** (PROD) A jig designed for installing a part to an assembly by locating it from some previously established points on the assembly. It may contain bushings for drilling the part on installation.

ILA **IPAC Locating Accessory:** Tooling Details and/or Assemblies used in conjunction with and oriented by the IPAC Sub-Frame to positively locate and fasten the Engineering structure in the IPAC Numerical Control Automated Fastening Machine.

JD **Joggle Die:** (PROD) A die used to form offsets in rolled or extruded sections. The dies may be electrically heated for forming tougher materials.

JDI **Joggle Die Insert:**

JDT **Joggle Die Contour Template:** (TOOLING) A template giving the contour of the JD without the joggle. A set of two is required: the male template gives the contour of the female die half and the female template the male die half.

JI **Jaw Insert:** (PROD) Insert for the jaws of the stretch presses (Hufford, Sheridan, etc.), also any special vise jaws, chuck jaws, etc.

JLT **Joggle Location Template:** (PROD) A sample part which locates joggles by means of an adjustable end stop or pick-up hole or joggle die, also shows length, depth, and number of joggles.

JST **Joggle Set-Up Template:**

LF **Lathe Fixture:** (PROD) Special collets, chucks, face plates, and fixtures used to hold parts during lathe operations may be included in this code. Any lathe or lathe fixture accessories not elsewhere classified may be given this code.

LT **Locating Template:** (PROD) A flat or formed template used for orientation of holes and parts. It may be used for assembly operations that do not require the rigidity of an assembly fixture (AF).

LTD **Laser Target Display:**

LTE **Lab Test Equipment:** Test equipment to be used for testing materials, tools, and equipment other than that directly associated with tooling and production parts.

MA **Milling Accessory:** (TOOLING or PROD) This category includes special accessories used on milling machines or on milling fixtures.

MAT **Masking Template:** (PROD) A template used to mask portions of a part while applying liquids such as adhesives, paints, etc. It may also be used to outline the etch area of a work-piece which is to be chemically milled. In this case, it serves as a guide for a cutting device in removing the mask and from an outlined area.

MATP **Masking Template (Primer):** A masking template primer is used to distinguish the various types of templates required for use in the priming of components that specifically require designated areas to be free of primer for the purpose of electrical bonding and lightning protection.

MCA **Machine Accessory:** (PROD) Items used as a part of, and in conjunction with, any machine.

MCT **Master Contour Template:** (TOOLING) A template cut from a lined drawing, it is required by Engineering department for lofting bulkheads, wing ribs, stringers, etc.

MDP **Master Drill Plate:** (TOOLING) A prime tool to define a pattern of holes in a single plane and relate them to reference points, lines, or contours, to ensure interchangeability of hole patterns between two mating parts or assemblies. It may be used to fabricate and check aircraft production and inspection tools, and to serve, in some cases, as a control master.

MF **Milling Fixture:** (PROD) A fixture used to hold a part on a milling machine.

MFB **Male and Female Block:** (PROD) Mating blocks, usually made of masonite, used either in a rubber press or an arbor press to form parts.

MFT **Male and Female Block Template:** (TOOLING) A male made to inside mold lines and generally the profile of the part. This tool masters an MFB.

MIN **Minimum:**

MOD **Model:** (TOOLING) A full scale tool made to the shape of a contoured part. The part may have component details; (e.g.: a segmented duct). The tool is usually made of solid wood or cast plaster to the overall size of the part (i.e.: no allowance for material thickness).

MOF	**Molding Form:** (PROD) A form used to produce plastic and laminated parts. Usually bag-molding techniques are employed to make the part material assume the desired shape or given form.
MOP	**Manufacturing Operation Procedure:**
MP	**Master Part:** (TOOLING) A duplicate of a finished part used as reference or for making other tools. It must be painted red for identification.
MPC	**Permanent and Semi-Permanent Mold:** (PROD) A form into which molten metal or plastic is poured or injected to make a part. It is usually made of one of the softer metals (permanent) or metal with sand core (semi-permanent).
MPD	**Miscellaneous Press Die:** (PROD) A general code applied to punch press dies for operations, or combinations of operations, not covered under specific die codes.
MPT	**Miscellaneous Press Die Template:** (TOOLING) A flat template showing the mold lines, hole locations, etc., required to manufacture an MPD.
MTD	**Drivematic Masking Template:**
MTX	**Numerical Control Program:** (TOOLING) Program to control 2-axis NC routers.
MUF	**Mockup Fixture:** (TOOLING) This fixture consists of a series of templates cut from loftings, mounted on a base, and usually filled with plaster to describe a contoured section of the airplane.
NCE	**Numerical Control Media (Engineering):** (TOOLING) Punched paper or mylar tape, magnetic tape, or tape cartridge for the control of any Engineering drafting machine used in creating aircraft lines, drawings, etc.
NCL	**Numerical Control Media (Lathe):** (PROD) A punched paper or mylar tape, magnetic tape, or tape cartridge for the control of a lathe machine for operations such as turning, threading, boring, etc.
NCM	**Numerical Control Media (Machining):** (PROD) Punched paper or mylar tape, magnetic tape, or tape cartridge for control of 3-axis, 4-axis, or 5-axis continuous path machine for operations such as milling, routing, profiling, or machining center type operations.
NCP	**Numerical Control Media (Point-to-Point):** (PROD) Punched paper or mylar tape, magnetic tape, or tape cartridge for control of 2-axis positioning machines for operations such as drilling, punching, or boring.
NCT	**Numerical Control Media (Tool):** (TOOLING) Punched paper or mylar tape, magnetic tape, or tape cartridge for continuous path or point-to-point control of machines for tooling purposes.
OAF	**Optical Alignment Fixture:** (PROD) A support structure for optical equipment such as a telescope and target. It is used when components of a tool or product are to be aligned optically prior to assembly.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

OTA — **Optical Tooling Accessory:** (TOOLING) Details or components used in conjunction with other optical tooling items already classified.

PB — **Press Block:** (PROD) A form block used as a male die half for forming parts at low pressure in a rubber press where the rubber pad becomes the female.

PBC — **Precision Build Cart:** (PROD) A modular tool that provides the ability to assemble an engineering configuration that can be utilized in one or more multiple manufacturing stations. The tool will provide the capability to transport an assembly and can be positively indexed, relative to next assembly requirements, in subsequent phase stations.

PBD — **Press Brake Die:** (PROD) This tool is used on a press brake for bending long, thin sections to shape.

PBH — **Combination Press and Hammer Block:** (PROD) A form block used when parts are to be formed at low pressure in a rubber press and finished by hand hammering.

PBT — **Press Block Template:** (TOOLING) A template made to inside mold lines of a part with tooling holes and all bend information included. It is used for making PB, PBH, WPB, WWB, or DHR.

PCD — **Pierce and Cut-Off Die:** (PROD) A die to pierce holes and cut a part to a given length.

PCT — **Part Check Template:** (PROD) A template required where tools for making parts do not conform to a definite known shape (i.e.: where springback is included on tools).

PD — **Pierce Die:** (PROD) A punch and die combination used to make one or several, round or odd-shaped holes in flat or formed pieces.

PDT — **Pierce Die Template:** (TOOLING) A flat pattern template showing location of punches in a pierce die.

PDW — **Pierce Die (Wales):** (PROD) This is the same as a piercing die (PD), but for use only on Wales Strippit fabricator.

PE — **Plating Equipment:** (PROD or TOOLING) Any equipment which is used for plating or metal coating operations (i.e.: electroplating, hot dipping, molten metal coatings, or sprayed metal coatings).

PEA — **Portable Equipment Attachment:** (PROD) GAC designed semi-contained attachment used with portable equipment. It requires a power assist to function.

PF — **Profiling Fixture:** (PROD) A fixture used to hold a part and its tracing cam on a profiling machine.

PHN — **Photo Negative:**

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

PHP **Photo Positive:**

PHT **Portable Hand Tool:** (PROD) A GAC designed self-contained hand held tool, capable of functioning without power but, may require an accessory.

PIP **Pierce and Trim Die:**

PLF **Proof Loading Fixture:** (PROD) A fixture used to stress parts to Engineering specification, as part of the inspection procedure.

PMT **Portable Mill Fixture:** (PROD) This is a portable device consisting of a powered milling head that traverses a set of ways for milling surfaces which cannot be done by a fixed milling machine (e.g.: fuselage butt joints on wing assemblies).

PNT **Punch and Nibble Template:** (PROD) This tool consists of two templates, a steel punch template made to the cut size of the part material, and a steel plate nibble template for cutting the outline of the part on the nibbling machine.

POA **Portable Accessory:** (PROD) A GAC designed unit that performs no unique function but is required as part of hand tools, power tool, or attachment.

POT **Pierce and Cut-Off Die Template:** (TOOLING) A flat pattern template giving the location of all holes and trimming edges for mastering a PCD.

PP **Pressure Pad:** (PROD) Tool used to “de-intensify” areas where resin flow or content may be affected.

PPE **Portable Power Equipment:** (PROD) A GAC designed power equipment used in manufacturing processes such as trimming, drilling, track machining, and fastening.

PRC **Protective Cover:** (PROD) Covers, containers, and other devices used to protect a work-piece during shipment, storage, or assembly operations.

PRF **Portable Router Fixture:** (PROD) Steel tracked guide used with a portable router for trimming sheet metal (i.e.: double-curved skins).

PRT **Press Brake Die Template:** (TOOLING) A template giving the profile of the rail die with springback allowance included for mastering a PBD.

PSR **Parts and Equipment Storage Rack:** (PROD) Any stationary or mobile rack used in holding or storing a work-piece or assembly.

PST **Punch and Scribe Template (Prod):** (PROD) A template, usually made of steel, conforming to the shape of the part for scribing trim lines and with holes for transfer-punching part material. Used primarily for steel parts when PNT or blanking dies are unsuitable.

PSU **Punch and Scribe Template (Flat):**

PT **Punch Template:** (PROD) A template used to locate holes in a part by transfer-punching through holes in the template onto the part.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

PTD — **Pierce and Trim Die:** (PROD) A die used for piercing holes and trimming flat, formed or extruded parts.

PTN — **Pattern:** (TOOLING) A tool, usually made of plaster or hardwood, simulating the contours of a part with allowances for draft angle, shrinkage, etc. It is used to form the cavity in sand for casting operations.

RCT — **Roll Contour Template:** (PROD) A tool made to check curved parts formed on contour rollers. It is usually made as curved male template.

RD — **Roll Die:** (PROD) Progressively contoured rollers used on a roll forming machine for forming sections from strip stock.

RF — **Riveting Fixture:** (PROD) This supports assemblies for convenience in riveting operations.

RJ — **Reaming Jig:** (PROD) This tool holds part and guides reamer for accurate reaming operations.

ROB — **Router Board:** (PROD) This tool is used to hold the part and guide the cutter on pin or radial arm routers. It is heavy construction for formed parts or parts with extreme contours. For "Shown" and "Opposite" parts, which differ only in hole pattern, an ROJ shall be used to cut the flat pattern, with separate drill templates for drilling each hole pattern.

ROJ — **Router Jig:** (PROD) A flat pin-router type tool for routing the outline of a "formed" work-piece having horizontal edges to be cut. It is made of phenolic laminate with the same construction as a DRB without the drill template.

RVS — **Rivet Set:** (PROD) A tool used as a hammer against the manufactured head of a rivet during the riveting operations.

SAF — **Safety Equipment:** (PROD) Equipment or tools used for safety on aircraft, machines, or employees (e.g.: safety locks on wings, landing gear guards, wheel chocks, chip guards on machines, personal protective equipment, etc.).

SB — **Strongback:** (PROD) A tool that is used to present skins to an assembled engineering internal framework configuration in a major assembly fixture. Strongback utilizes both vacuum and precision contour board features to maintain engineering defined skin OML relative to the assembly internal framework. Contour board features must be geometrically located relative to the major assembly fixture tool reference system to ensure precision installation of skin relative to internal structure.

SC — **Spinning Chuck:** (PROD) A contoured block that is made to rotate on a spinning machine or lathe. The part is produced by forcing a sheet metal blank, to assume the shape of the block as it revolves. The chuck may be collapsible to permit removal of the spun part.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

SCA **Spinning Chuck Accessory:** (PROD or TOOLING) Any device such as a follower, template, clamping ring, spindle, adapter, etc. which is used to facilitate the manufacture or use of a spinning chuck.

SCD **Scaffold:** (PROD) Self-contoured work stands, scaffolds, and structures used in supporting employees above floor level in conjunction with assembly operation or tooling.

SCF **Scribe Fixture:** (PROD) This fixture is rigidly constructed and is not designed to lay over a part. Rather, the part or assembly is nested or aligned in the tool and then trim lines are scribed.

SCH **Stretch Die (Hufford):** (PROD) A male die against which sheet metal is formed by stretch wrapping on an A44 Hufford stretch press.

SCL **Special Clamp:** (PROD) Any non-standard clamp required in tooling or part fabrication.

SCT **Scribe and Trim Template:** (PROD) A template used to locate trim lines on flat parts.

SD **Stretch Die:** (PROD) A male die against which sheet metal is formed by stretch wrapping on a 90T Sheridan stretch press.

SDM **Stretch Die (Maust):** (PROD) A male die against which sheet metal is formed by stretch wrapping on the 300T Sheridan or Maust stretch press.

SDR **Schematic Drawing:** A schematic representation of facilities such as electrical wiring or piping, where the purpose of the drawing is to show the proper arrangement or rearrangement of existing equipment.

SDS **Stretch Die (Sheridan):** (PROD) A male die against which sheet metal is formed by stretch wrapping on a 90T Sheridan stretch press.

SDT **Shear and Drill Template:** (PROD) A shear template, as above, but with guide holes for drilling the sheared part.

SF **Saw Fixture:** (PROD) A fixture for holding parts to be trimmed by circular saws.

SHR **Shipping Rig:**

SKF **Skin Mill Fixture:** (PROD) A tool assembly consisting of a machine set-up on a skin mill for tracing or plain milling purposes.

SMF **Spar Mill Fixture:** (PROD) This tool holds parts and/or guide cutters on spar milling machines.

SP **Sample Part (BAe):** Master set-up gage BAe tubing.

SPT **Strippit Punch Template:** (PROD) A flat template used to set the punches on the Wales Strippit fabricator.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

SRB **Shear and Router Board:** (PROD) A flat routing and drilling tool for work-pieces having at least one straight edge. This tool saves re-cutting of the sheared edge during the routing of the other edges.

SRJ **Setback Router Jig:** (PROD) A router jig for trimming and drilling formed or extruded parts. It is intended for use with the Quackenbush or other small hand routers and tableless pin routers.

SRT **Shear Template:** (PROD) A template, usually rectangular, used to set stops on shearing machines.

ST **Saw Template:**

STE **Silk Screen Stencil:** (PROD) A pattern or design produced on a silk cloth stretched over a frame, then used as a stencil or mask to apply paints and reproduce the desired design.

STT **Scribe and Trim Template:** (PROD) A template used to locate trim lines on flat parts.

SUG **Set-Up Gage:** (PROD) A part simulator used as an aid by the machine operator in setting up a machine for production.

SWA **Spotweld Accessory:** (PROD) Any accessory that is required in spot-welding operations.

SWD **Swaging Die:** (PROD) A die used in presses for reducing the diameter of tube ends and terminals. It is also used in swaging machines for securing cables to terminals.

SWF **Spotweld Fixture:** (PROD) A fixture for holding parts to be assembled by spot-welding.

SWT **Spotweld Template:** (PROD) A template, usually made from a formed piece of fiberglass, with holes for marking parts for locations of spotwelds.

TBA **Tube Bending Accessory:** (PROD) Items required in conjunction with tube bending machines for bending specific sizes of tubes.

TBD **Tube Bending Die:** (PROD) This is a form about which tubing is bent on mechanical tube bending machines.

TD **Trim Die:** (PROD) A type of blanking die to cut irregular edge such as scallops, on a portion of a flat part. It may be used to trim formed work-pieces.

TEF **Testing Fixture:**

TEK **Tool and Equipment Kit:**

TEQ **Testing Equipment:** (TOOLING) Items required for various tests made on tools or parts.

TFS **Fiberglass Tools:**

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

TFT **Tube Forming Tool:** (PROD)

TP **Test Plug:** (PROD) A stop or expandable device designed to seal tubes of tanks for pneumatic or hydraulic testing operations.

TSBL **Theoretical Skin Butt Line:**

TTA **Arvey Die Master:** (TOOLING) The master template of an arvey die (an arvey die is a steel rule-type die for blanking our metal parts and is a process of the Arvey company).

TTB **Jig Master:** (TOOLING) A master tool that simulates a part of an assembly. Fabricated of stable construction and used as a master in building duplicate tools.

TTC **Jig Template:** (TOOLING) A template used for making a jig or some specific portion of a jig. The edges must be clearly and fully labeled for proper orientation.

TTD **Control Master:** (TOOLING) The prime or master tool used for making and/or checking jig masters.

TTE **Master Tool Template:** (TOOLING) A template made to show the outside mold line of a bulkhead, rib, or other assembly and containing all holes for attaching parts. It is used to master all the tools for the details.

TTF **Facility Gage:** (TOOLING) This gage is an optical tooling accessory employed to locate some detail or component on a jig or fixture with reference to one or more lines of sight.

TTG **General Tooling Tool:** (TOOLING) This category is to be used only for an otherwise unclassified tooling tool.

TTH **Master Flat Pattern Template:** (TOOLING) A flat pattern template used as the master of production tools such as dies, routers, etc.

TTP **Flat Pattern Production Template:** (TOOLING & PROD) The TTP is a flat template showing the developed flat pattern of a part. The TTP also shows the hole pattern and cutouts.

TTR **Record Template:** (TOOLING) A tool, other than a flat pattern tool, which records the functional operation that a tool performs. It need not resemble the work-piece and need not be complete in respect to operations prior or subsequent to the operation the TTR is recording. Each production (parent) tool so represented must be called out on the TTR and be kept up-to-date on all changes.

TTS **Master Flat Pattern Template:**

TTT **Thompson Tracing Tool:**

TTW **Wiping Template:** (TOOLING) A profile template used in wiping plaster or plastic to a specific cross-section while it is in a workable state.

UPT **Upholstery Template:** (PROD) A metal template used to make holes and seams in upholstery material. (Use # 40 holes to define seams, pleats, etc., and # 30 holes to locate hole fasteners.)

URT **Universal Router Template:** (PROD) A flat pattern template used in conjunction with the universal router jig for routing quantities of parts not warranting a drill and router board.

VACF **Vacuum Fixture:** (PROD) A fixture used to hold contoured or formed detail parts in proper alignment using a vacuum or suction force. This facilitates the use of NC programs to cut the part periphery, cutouts, drill fastener holes and other types of holes per the engineering drawing for use in next higher assemblies.

VHF **Vacuum Holding Fixture:** (PROD) A fixture used to hold contoured or formed detail parts in proper alignment using a vacuum or suction force. This facilitates the use of NC programs to cut the part periphery, cutouts, drill fastener holes and other types of holes per the engineering drawing for use in next higher assemblies. For use on 60P parts for the G650 aircraft.

WA **Welding Accessory:** (PROD) Any accessory required in welding operations.

WD **Washer Die:** (PROD) A blank and pierce die used for stamping washers from sheet metal.

WF **Welding Fixture:** (PROD) This tool holds parts in correct alignment for welding operations.

WM **White Master:** A three dimensional representation of a skin or skin assembly to which all other assemblies are made. Although it is ordered for any skin, it is not considered as a tool. It serves as a three-dimensional drawing, thus eliminating curved surface representation on a flat plane (vellum or lofts).

WPB **Verson Press Block:** (PROD) Similar to press block (PB) but having additional construction features, making it suitable for use in Verson-Wheelon Presses.

WPD **Wiping Die:** (PROD) A die to form a part into shape by mechanically forcing the material about a male form.

WWB **Williams White Block:** (PROD) A form block made to the same standards as a PB, but of such a height or configuration as to require the use of the Williams White 1400 psi Rubber Press.

YOK **Squeezer Yoke:** (PROD) Special jaws of either "C" or alligator type for use on pneumatic squeezers for setting hard-to-reach rivets.

Note: An asterisk (*) preceding any of the tool codes designates that the tool is used as a shop aid.

APPENDIX

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APPENDIX 1

Bend Allowance Chart for 1° Bend

R \ T	.020 .022	.023 .025	.031 .032	.038 .040	.050 .051	.063 .064	.081	.091 .094	.125 .129
1/32	.00072	.00073	.00079	.00086	.00094	.00104	.00117	.00125	.00154
1/16	.00126	.00128	.00135	.00140	.00149	.00159	.00172	.00180	.00209
3/32	.00180	.00183	.00188	.00195	.00203	.00213	.00226	.00234	.00263
1/8	.00235	.00237	.00243	.00249	.00258	.00268	.00281	.00289	.00317
5/32	.00290	.00292	.00297	.00304	.00312	.00322	.00335	.00343	.00372
3/16	.00344	.00346	.00352	.00358	.00367	.00377	.00390	.00398	.00426
7/32	.00398	.00401	.00406	.00412	.00421	.00431	.00444	.00452	.00481
1/4	.00454	.00455	.00461	.00467	.00476	.00486	.00500	.00507	.00535
9/32	.00507	.00510	.00515	.00521	.00530	.00540	.00553	.00561	.00590
5/16	.00562	.00564	.00570	.00576	.00584	.00595	.00608	.00616	.00644
11/32	.00616	.00619	.00624	.00630	.00639	.00649	.00662	.00670	.00699
3/8	.00671	.00673	.00679	.00685	.00693	.00704	.00717	.00725	.00753
13/32	.00725	.00728	.00733	.00739	.00748	.00758	.00771	.00779	.00808
7/16	.00780	.00782	.00787	.00794	.00802	.00812	.00826	.00834	.00862
15/32	.00834	.00836	.00842	.00848	.00857	.00867	.00880	.00888	.00917
1/2	.00889	.00891	.00886	.00903	.00911	.00921	.00935	.00943	.00971
17/32	.00943	.00945	.00951	.00957	.00968	.00976	.00989	.00997	.01025
9/16	.00998	.01000	.01005	.01012	.01020	.01030	.01044	.01051	.01080
19/32	.01051	.01054	.01058	.01065	.01073	.01083	.01098	.01106	.01133
5/8	.01107	.01109	.01114	.01121	.01129	.01139	.01152	.01160	.01189
21/32	.01161	.01163	.01170	.01175	.01183	.01193	.01207	.01214	.01245
11/16	.01216	.01218	.01223	.01230	.01238	.01248	.01261	.01269	.01298
23/32	.01269	.01272	.01276	.01283	.01291	.01301	.01316	.01322	.01351
3/4	.01324	.01327	.01332	.01338	.01347	.01357	.01370	.01378	.01407
25/32	.01378	.01381	.01386	.01392	.01401	.01411	.01425	.01432	.01461
13/16	.01433	.01436	.01441	.01447	.01456	.01466	.01479	.01487	.01516
27/32	.01487	.01490	.01494	.01501	.01509	.01519	.01534	.01540	.01569
7/8	.01542	.01545	.01550	.01556	.01565	.01575	.01588	.01596	.01623
29/32	.01595	.01599	.01604	.01611	.01619	.01629	.01643	.01650	.01677
15/16	.01650	.01654	.01659	.01665	.01674	.01684	.01697	.01705	.01732
31/32	.01704	.01708	.01713	.01720	.01728	.01738	.01752	.01759	.01786
1	.01759	.01763	.01768	.01774	.01783	.01793	.01806	.01814	.01841

Note: To find bend allowance:

- **Find the factor above for the particular bend radius (R) and thickness (T).**
- **Multiply this factor by the number of degrees of bend.**

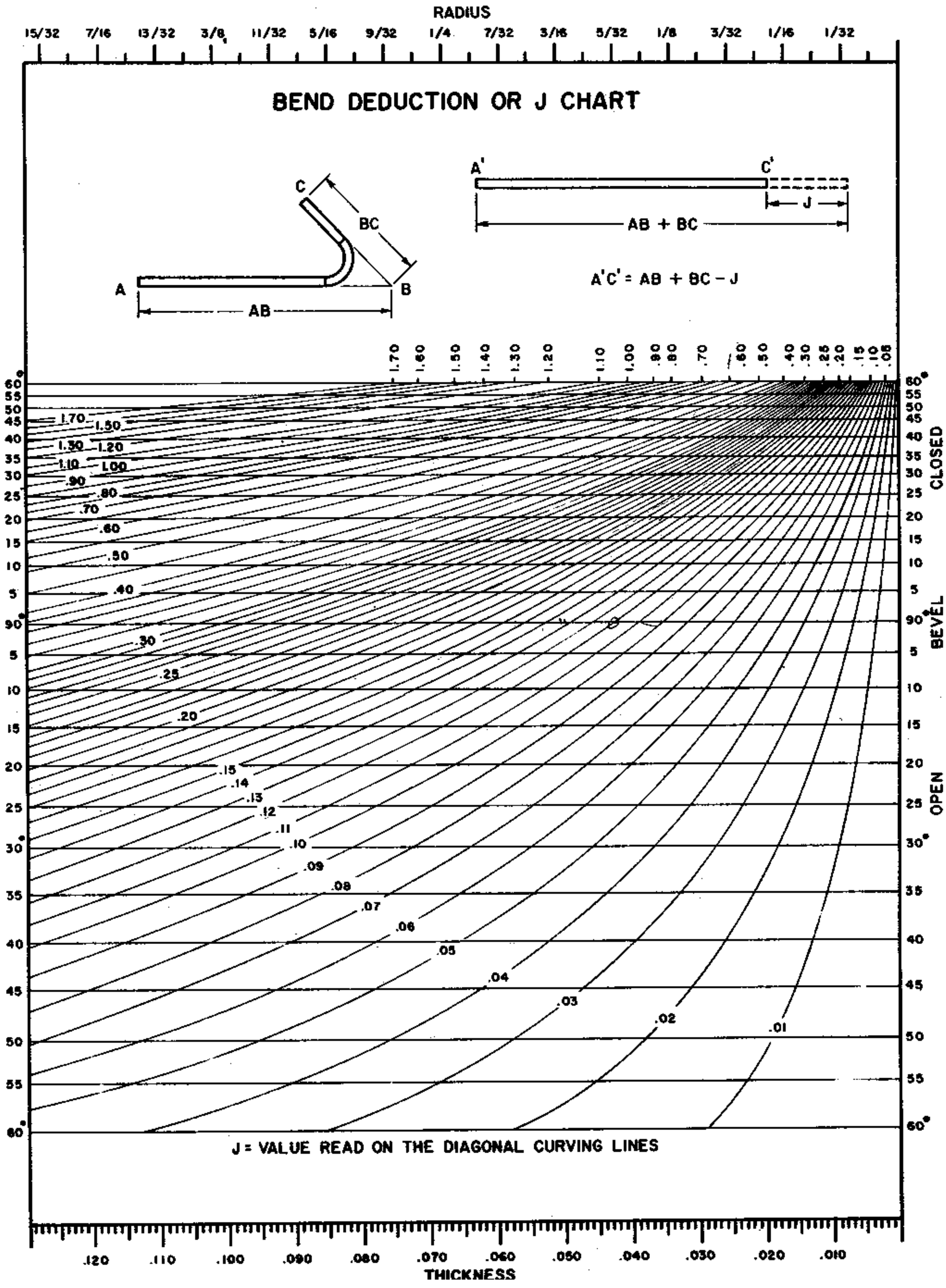
APPENDIX 2

Bend Allowance for 90° Bend Only

R \ T	.016	.018	.020	.025	.032	.036	.040	.050	.063	.071	.080	.090	.095	.100	.125	.160	.190
1/32	.060	.062	.063	.067	.071	.074	.077										
1/16	.109	.110	.112	.116	.120	.123	.126	.134	.143	.148							
3/32	.158	.160	.161	.164	.170	.172	.175	.183	.192	.197	.204						
1/8	.207	.209	.211	.214	.219	.222	.224	.232	.241	.247	.253	.260	.264	.267	.284		
5/32	.256	.258	.259	.262	.267	.270	.273	.281	.290	.295	.302	.308	.312	.316	.332	.357	
3/16	.305	.307	.308	.312	.314	.319	.322	.330	.339	.344	.351	.358	.361	.364	.382	.406	.428
7/32	.354	.356	.357	.361	.366	.368	.371	.379	.388	.393	.400	.407	.410	.413	.431	.455	.476
1/4	.403	.405	.406	.410	.415	.418	.420	.428	.437	.442	.449	.456	.459	.462	.480	.505	.526
9/32	.452	.454	.455	.459	.464	.466	.469	.477	.486	.491	.498	.505	.508	.511	.529	.554	.574
5/16	.501	.503	.504	.508	.513	.516	.518	.526	.535	.540	.547	.554	.557	.560	.578	.599	.624
11/32	.550	.552	.553	.557	.562	.565	.567	.575	.584	.589	.596	.603	.606	.609	.627	.652	.673
3/8	.599	.601	.602	.606	.610	.614	.616	.624	.633	.638	.645	.652	.655	.658	.676	.701	.722
13/32	.648	.650	.651	.655	.660	.662	.665	.673	.682	.687	.694	.701	.704	.707	.725	.750	.771
7/16	.697	.699	.700	.704	.709	.712	.714	.722	.731	.736	.743	.750	.753	.756	.774	.799	.820
15/32	.747	.748	.749	.753	.758	.761	.763	.771	.780	.785	.792	.799	.802	.805	.823	.848	.869
1/2	.796	.797	.798	.802	.807	.810	.812	.820	.829	.834	.841	.848	.851	.856	.872	.897	.918
9/16	.894	.895	.896	.900	.905	.908	.910	.918	.927	.932	.939	.946	.949	.953	.970	.995	1.016
5/8	.991	.993	.994	.998	1.003	1.006	1.009	1.016	1.025	1.030	1.037	1.044	1.047	1.051	1.068	1.093	1.114
11/16	1.090	1.091	1.092	1.096	1.101	1.104	1.107	1.114	1.123	1.128	1.135	1.142	1.145	1.149	1.166	1.191	1.219
3/4	1.188	1.189	1.191	1.194	1.199	1.202	1.205	1.212	1.221	1.226	1.233	1.240	1.243	1.247	1.264	1.289	1.310

Note: T = Material Thickness
R = Bend Radius

APPENDIX 3



RADIUS
15/32
7/16
13/32
3/8
11/32
5/16
9/32
1/4
7/32
3/16
5/32
1/8
3/32
1/16
1/32
BEND DEDUCTION OR J CHART
A
B
C
AB
BC
A'
C'
J
AB + BC
A'C' = AB + BC − J
CLOSED
BEVEL
OPEN
J = VALUE READ ON THE DIAGONAL CURVING LINES
.120
.110
.100
.090
.080
.070
.060
.050
.040
.030
.020
.010
THICKNESS

APPENDIX 4

Bend Deduction for 90° Bend Only

R \ T	.016	.018	.020	.025	.032	.036	.040	.050	.063	.071	.080	.090	.095	.100	.125	.160	.190
1/32	.034	.036	.039	.046	.055	.060	.065										
1/16	.048	.051	.053	.059	.068	.074	.079	.093	.110	.120							
3/32	.061	.063	.066	.073	.082	.087	.092	.107	.124	.134	.146	.159					
1/8	.075	.077	.080	.086	.095	.100	.106	.120	.137	.147	.159	.172	.176	.183	.216		
5/32	.088	.090	.093	.100	109	.114	.119	.134	.150	.161	.173	.186	.190	.196	.230	.275	
3/16	.102	.104	.107	.113	.122	.128	.133	.147	.164	.174	.186	.199	.204	.211	.243	.289	.327
7/32	.115	.117	.120	.127	.136	.141	.146	.161	.177	.188	.199	.212	.217	.224	.257	.302	.342
1/4	.129	.131	.134	.140	.149	.154	.160	.174	.191	.201	.213	.226	.231	.238	.270	.315	.354
9/32	.142	.144	.147	.154	.163	.168	.173	.187	.204	.215	.226	.239	.244	.251	.284	.328	.368
5/16	.156	.158	.161	.167	.176	.181	.187	.201	.218	.228	.240	.253	.258	.265	.297	.346	.381
11/32	.169	.171	.174	.181	.190	.194	.200	.214	.231	.242	.253	.266	.271	.278	.311	.355	.394
3/8	.183	.185	.188	.194	.203	.208	.214	.228	.245	.255	.267	.280	.285	.292	.324	.369	.408
13/32	.196	.198	.201	.208	.216	.222	.227	.241	.258	.269	.280	.293	.298	.305	.337	.382	.421
7/16	.209	.212	.215	.221	.230	.235	.241	.255	.272	.281	.294	.307	.312	.319	.351	.396	.435
15/32	.223	.225	.228	.235	.244	.248	.254	.268	.285	.296	.307	.320	.325	.332	.364	.409	.448
1/2	.236	.239	.242	.248	.257	.262	.268	.282	.299	.309	.321	.334	.339	.344	.378	.423	.462
9/16	.263	.266	.269	.275	.284	.289	.295	.309	.326	.336	.348	.361	.366	.372	.405	.450	.489
5/8	.290	.293	.296	.302	.311	.316	.321	.336	.353	.363	.375	.388	.383	.399	.432	.477	.516
11/16	.317	.320	.322	.329	.338	.343	.348	.363	.380	.390	.402	.415	.420	.426	.459	.504	.536
3/4	.344	.347	.349	.356	.365	.370	.375	.390	.407	.417	.429	.442	.447	.453	.486	.531	.570

Note: T = Material Thickness
R = Bend Radius

APPENDIX 5

Form Block Joggle Dimensions

Note: 1. This chart is for rolled sections only. See Chart 6 for extruded shapes, and 7 for sheet stock.

2. α is 25°.

FOR ROLLED SECTION PARTS ONLY

Engineering Depth of Joggle					**.016**	**.020**	**.025**	**.032**	**.040**	**.050**	**.063**	**.071**	**.080**	**.090**	**.100**	**.125**	**.187**	**.250**
Die Dimensions (Springback Added)	**A Joggle Dies Only**				.031	.035	.040	.047	.055	.066	.079	.087	.096	.106	.117	.145	.207	.270
	F				.066	.075	.086	.101	.118	.142	.169	.186	.206	.227	.251	.311	.444	.579
Material Thickness	**G**	**H**	**R**	**R + T**	**"E" DIMENSION (Includes .005" allowance for lengthwise springback)**													
.016	.015	.003	.063	.079	.102	.111	.122	.137	.154	.178	.205	.222	.242	.263	.287	.337	.470	.605
.020	.018	.004	.063	.083	.103	.112	.123	.138	.155	.179	.206	.223	.243	.264	.288	.388	.471	.606
.025	.020	.005	.063	.088	.106	.115	.126	.141	.158	.182	.209	.226	.246	.267	.291	.341	.474	.609
.032	.021	.007	.063	.095	.106	.115	.126	.141	.158	.182	.209	.226	.246	.267	.291	.341	.474	.609
.040	.030	.009	.094	.134	.122	.131	.142	.157	.174	.198	.225	.242	.262	.283	.307	.357	.490	.625
.050	.039	.011	.125	.176	.138	.147	.158	.173	.190	.214	.241	.258	.278	.299	.323	.373	.506	.641
.063	.049	.014	.156	.220	.155	.164	.175	.190	.207	.231	.258	.275	.295	.316	.340	.390	.523	.658
.071	.057	.016	.187	.259	.169	.178	.189	.204	.221	.245	.272	.289	.309	.330	.354	.404	.537	.672
.080	.067	.018	.219	.300	.187	.196	.207	.222	.239	.263	.290	.307	.327	.348	.372	.422	.555	.690
.090	.076	.020	.250	.341	.203	.212	.223	.238	.255	.279	.306	.323	.343	.364	.388	.438	.571	.706
.100	.092	.023	.312	.414	.232	.241	.252	.267	.284	.308	.335	.352	.372	.393	.417	.467	.600	.735
.125	.111	.028	.375	.500	.265	.274	.285	.300	.317	.341	.368	.385	.405	.426	.450	.500	.633	.768
.187	.166	.041	.562	.749	.362	.371	.382	.397	.414	.438	.465	.482	.502	.523	.547	.597	.730	.865
.250	.222	.055	.750	1.00	.460	.469	.480	.495	.512	.536	.563	.580	.600	.621	.645	.695	.828	.963

APPENDIX 6

Form Block Joggle Dimensions

Note: 1. This chart is for rolled sections only.
2. α is 20°.

FOR EXTRUDED SECTIONS ONLY

Engineering Depth of Joggle		.016	.020	.025	.032	.040	.051	.063	.071	.080	.090	.100	.125	.187	.250	G	H	R	R & T
Die Dimensions (Springback Added)	A	.031	.035	.040	.047	.055	.066	.079	.087	.096	.106	.117	.145	.207	.270				
	F	.085	.096	.110	.129	.151	.181	.217	.239	.264	.291	.321	.398	.568	.742				
Material Thickness		"E" DIMENSION - .005” added for lengthwise springback																	
.016"		.115	.126	.140	.159	.181	.211	.247	.269	.294	.321	.351	.416	.586	.759	.014	.003	.063	.079
.020"		.116	.127	.141	.160	.182	.212	.248	.270	.295	.322	.352	.417	.587	.760	.015	.004	.063	.083
.025"		.117	.128	.142	.161	.183	.213	.249	.271	.296	.323	.353	.418	.588	.761	.016	.005	.063	.088
.032"		.118	.129	.143	.162	.184	.214	.250	.272	.297	.324	.354	.419	.589	.762	.017	.006	.063	.095
.040"		.131	.142	.156	.175	.197	.227	.263	.285	.310	.337	.367	.432	.602	.775	.024	.007	.094	.134
.051"		.143	.154	.168	.187	.209	.239	.275	.297	.322	.349	.379	.444	.614	.787	.031	.009	.125	.176
.063"		.157	.168	.182	.201	.223	.253	.289	.311	.336	.363	.393	.458	.628	.801	.039	.011	.156	.220
.071"		.169	.180	.194	.213	.235	.265	.301	.323	.348	.375	.405	.470	.640	.813	.046	.013	.187	.259
.080"		.182	.193	.207	.226	.248	.278	.314	.336	.361	.388	.418	.483	.653	.826	.053	.014	.219	.300
.090"		.194	.205	.219	.238	.260	.290	.326	.348	.373	.400	.430	.495	.665	.838	.060	.016	.250	.341
.100"		.218	.229	.243	.262	.284	.314	.350	.372	.397	.424	.454	.519	.689	.862	.073	.018	.312	.414
.125"		.244	.255	.269	.288	.310	.340	.376	.398	.423	.450	.480	.545	.715	.888	.088	.022	.375	.500
.187"		.321	.332	.346	.365	.387	.417	.453	.475	.500	.527	.557	.622	.792	.965	.132	.033	.562	.749
.250"		.398	.409	.423	.442	.464	.494	.530	.552	.577	.604	.634	.699	.869	1.042	.176	.044	.750	1.000

APPENDIX 7

Form Block Joggle Dimensions **FOR SHEET METAL FORMED PARTS ONLY**

Note: 1. Press block depth "A" has .005" added for lengthwise springback.
2. Joggle relief as shown is required on all form blocks.

Engineering Depth of Joggle				.008	.012	.016	.020	.024	.028	.032	.036	.040	.045	.050	.056	.063	.071	.080	.090	.100	.125
	A			.013	.017	.021	.025	.029	.033	.037	.041	.045	.050	.055	.061	.068	.076	.085	.095	.105	.130
	F			.028	.037	.045	.053	.062	.071	.079	.088	.096	.107	.118	.131	.146	.163	.182	.204	.225	.278
T	**G**	**H**	**R**	**"E" DIMENSION - .(no allowance for lengthwise springback)**																	
.008	.008	.001	.031	.043	.052	.060	.068	.077	.086	.094	.103	.111	.122	.133	.146	.161	.178	.197	.219	.240	.293
.012	.009	.002	.031	.044	.053	.061	.069	.078	.087	.095	.104	.112	.123	.134	.147	.162	.179	.198	.220	.241	.294
.016	.017	.003	.063	.059	.068	.076	.084	.093	.102	.110	.119	.127	.138	.149	.162	.177	.194	.213	.235	.256	.309
.020	.018	.004	.063	.060	.069	.077	.085	.094	.103	.111	.120	.128	.139	.150	.163	.178	.195	.214	.236	.257	.310
.024	.019	.005	.063	.061	.070	.078	.086	.095	.104	.112	.121	.129	.140	.151	.164	.179	.196	.215	.237	.258	.311
.028	.020	.006	.063	.062	.071	.079	.087	.096	.105	.113	.122	.130	.141	.152	.165	.180	.197	.216	.238	.259	.312
.032	.021	.007	.063	.063	.072	.080	.088	.097	.106	.114	.123	.131	.142	.153	.166	.181	.198	.217	.239	.260	.313
.036	.029	.008	.094	.078	.087	.095	.103	.112	.121	.129	.138	.146	.157	.168	.181	.196	.213	.232	.254	.275	.328
.040	.030	.009	.094	.079	.088	.096	.104	.113	.122	.130	.139	.147	.158	.169	.182	.197	.214	.233	.255	.276	.329
.045	.034	.010	.109	.086	.095	.103	.111	.120	.129	.137	.146	.154	.165	.176	.189	.204	.221	.240	.262	.283	.336
.050	.039	.011	.125	.095	.104	.112	.120	.129	.138	.146	.155	.163	.174	.185	.198	.213	.230	.249	.271	.292	.345
.056	.044	.012	.141	.103	.112	.120	.128	.137	.146	.154	.163	.171	.182	.193	.206	.221	.238	.257	.279	.300	.353
.063	.049	.014	.156	.112	.121	.129	.137	.146	.155	.163	.172	.180	.191	.202	.215	.230	.247	.266	.288	.309	.362
.071	.057	.016	.187	.126	.135	.143	.151	.160	.169	.177	.186	.194	.205	.216	.229	.244	.261	.280	.302	.323	.376
.080	.067	.018	.219	.144	.153	.161	.169	.178	.187	.195	.204	.212	.223	.234	.247	.262	.279	.298	.320	.341	.394
.090	.076	.020	.250	.160	.169	.177	.185	.194	.203	.211	.220	.228	.239	.250	.263	.278	.295	.314	.336	.357	.410
.100	.092	.023	.312	.189	.198	.206	.211	.223	.232	.240	.249	.257	.268	.279	.292	.307	.324	.343	.365	.386	.439
.125	.111	.028	.375	.222	.231	.239	.247	.256	.265	.273	.282	.290	.301	.312	.325	.340	.357	.376	.398	.419	.472
.160	.119	.036	.375	.230	.239	.247	.255	.264	.273	.281	.290	.298	.309	.320	.333	.348	.365	.384	.406	.427	.480
.190	.167	.042	.562	.320	.329	.337	.345	.354	.363	.371	.380	.388	.399	.410	.423	.438	.455	.474	.496	.517	.570
.250	.222	.055	.750	.415	.426	.434	.442	.451	.460	.468	.477	.485	.496	.507	.520	.535	.552	.572	.593	.614	.667

APPENDIX 7 (cont.)

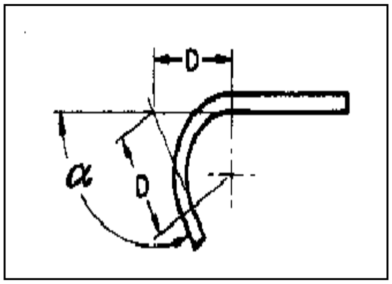
Form Block Joggle Dimensions **FOR SHEET METAL FORMED PARTS ONLY**

Note: 1. Press block depth "A" has .005" added for lengthwise springback.
2. Joggle relief as shown is required on all form blocks.

Engineering Depth of Joggle				.160	.190	.220	.250	.280	.305	.335	.375
	A			.165	.195	.225	.255	.285	.310	.340	.380
	F			.354	.418	.483	.547	.611	.665	.729	.815
T	G	H	R	"E" DIMENSION - .(no allowance for lengthwise springback)							
.008	.008	.001	.031	.369	.433	.498	.562	.626	.680	.744	.830
.012	.009	.002	.031	.370	.434	.499	.563	.627	.681	.745	.831
.016	.017	.003	.063	.385	.449	.510	.574	.638	.692	.756	.842
.020	.018	.004	.063	.386	.450	.515	.579	.643	.692	.761	.847
.024	.019	.005	.063	.387	.451	.516	.580	.644	.698	.762	.848
.028	.020	.006	.063	.388	.452	.517	.581	.645	.699	.763	.849
.032	.021	.007	.063	.389	.453	.518	.582	.646	.700	.763	.850
.036	.029	.008	.094	.404	.468	.533	.597	.661	.715	.779	.865
.040	.030	.009	.094	.405	.469	.534	.598	.662	.716	.780	.866
.045	.034	.010	.109	.412	.476	.541	.605	.669	.723	.787	.873
.050	.039	.011	.125	.421	.485	.550	.614	.678	.732	.796	.882
.056	.044	.012	.141	.429	.493	.559	.623	.687	.741	.805	.891
.063	.049	.014	.156	.438	.502	.567	.631	.695	.749	.813	.899
.071	.057	.016	.187	.452	.516	.581	.645	.709	.763	.827	.913
.080	.067	.018	.219	.470	.534	.599	.663	.727	.781	.845	.931
.090	.076	.020	.250	.486	.550	.615	.679	.743	.797	.861	.947
.100	.092	.023	.312	.515	.579	.644	.708	.772	.826	.890	.976
.125	.111	.028	.375	.548	.612	.677	.741	.805	.859	.923	1.009
.160	.119	.036	.375	.556	.620	.685	.749	.813	.867	.931	1.017
.190	.167	.042	.562	.646	.710	.775	.839	.903	.957	1.021	1.107
.250	.222	.055	.750	.743	.807	.872	.936	1.000	1.054	1.118	1.204

APPENDIX 8

Radius Correction



To determine the distance from the inside mold line to the bend tangent, multiply the bend radius by the factor "K" found in the following chart.

RC=(K) (Bend Radius)

Example: Bend Radius = $^{3}/_{16}$",
= 20° closed (=
Radius Correction = (1.4281") (.1875") = .268"

∝	K	∝	K	∝	K	∝	K	∝	K
1°	.00873	37°	.33459	73°	.73996	109°	1.4019	145°	3.1716
2°	.01745	38°	.34433	74°	.75335	110°	1.4281	146°	3.2708
3°	.02618	39°	.35412	75°	.76733	111°	1.4550	147°	3.3759
4°	.03492	40°	.36397	76°	.78129	112°	1.4826	148°	3.4874
5°	.04366	41°	.37388	77°	.79544	113°	1.5108	149°	3.6059
6°	.05241	42°	.38386	78°	.80978	114°	1.5399	150°	3.7320
7°	.06116	43°	.39391	79°	.82434	115°	1.5697	151°	3.8667
8°	.06993	44°	.40403	80°	.83910	116°	1.6003	152°	4.0108
9°	.07870	45°	.41421	81°	.85408	117"	1.6318	153°	4.1653
10°	.08749	46°	.42447	82°	.86929	118°	1.6643	154°	4.3315
11°	.09629	47°	.43481	83°	.88473	119°	1.6977	155°	4.5107
12°	.10510	48°	.44523	84°	.90040	120°	1.7320	156°	4.7046
13°	.11393	49°	.45573	85°	.91633	121°	1.7675	157°	4.9151
14°	.12278	50°	.46631	86°	.93251	122°	1.8040	158°	5.1445
15°	.13165	51°	.47697	87°	.94896	123°	1.8418	159°	5.3955
16°	.14054	52°	.48773	88°	.96570	124°	1.8807	160°	5.6713
17°	.14945	53°	.49858	89°	.98270	125°	1.9210	161°	5.9758
18°	.15838	54°	.50953	90°	1.00000	126°	1.9626	162°	6.3138
19°	.16734	55°	.52057	91°	1.0176	127°	2.0057	163°	6.6912
20°	.17633	56°	.53171	92°	1.0355	128°	2.0503	164°	7.1154
21°	.18534	57°	.54296	93°	1.0538	129°	2.0965	165°	7.5958
22°	.19438	58°	.55431	94°	1.0724	130°	2.1445	166°	8.1443
23°	.20345	59°	.56577	95°	1.0913	131°	2.1943	167°	8.7769
24°	.21256	60°	.57735	96°	1.1106	132°	2.2460	168°	9.5144
25°	.22169	61°	.58904	97°	1.1303	133°	2.2998	169°	10.3854
26°	.23087	62°	.60086	98°	1.1504	134°	2.3558	170°	11.4301
27°	.24008	63°	.61280	99°	1.1708	135°	2.4142	171°	12.7062
28°	.24933	64°	.62487	100°	1.1918	136°	2.4751	172°	14.3007
29°	.25862	65°	.63707	101°	1.2131	137°	2.5386	173°	16.3498
30°	.26795	66°	.64941	102°	1.2349	138°	2.6051	174°	19.0811
31°	.27732	67°	.66188	103°	1.2572	139°	2.6746	175°	22.9037
32°	.28674	68°	.67451	104°	1.2799	140°	2.7475	176°	28.6363
33°	.29621	69°	.68728	105°	1.3032	141°	2.8239	177°	38.1885
34°	.30573	70°	.70021	106°	1.3270	142°	2.9042	178°	57.2900
35°	.31530	71°	.71329	107°	1.3514	143°	2.9887	179°	114.5886
36°	.32492	72°	.72654	108°	1.3764	144°	3.0777	180°	infinite

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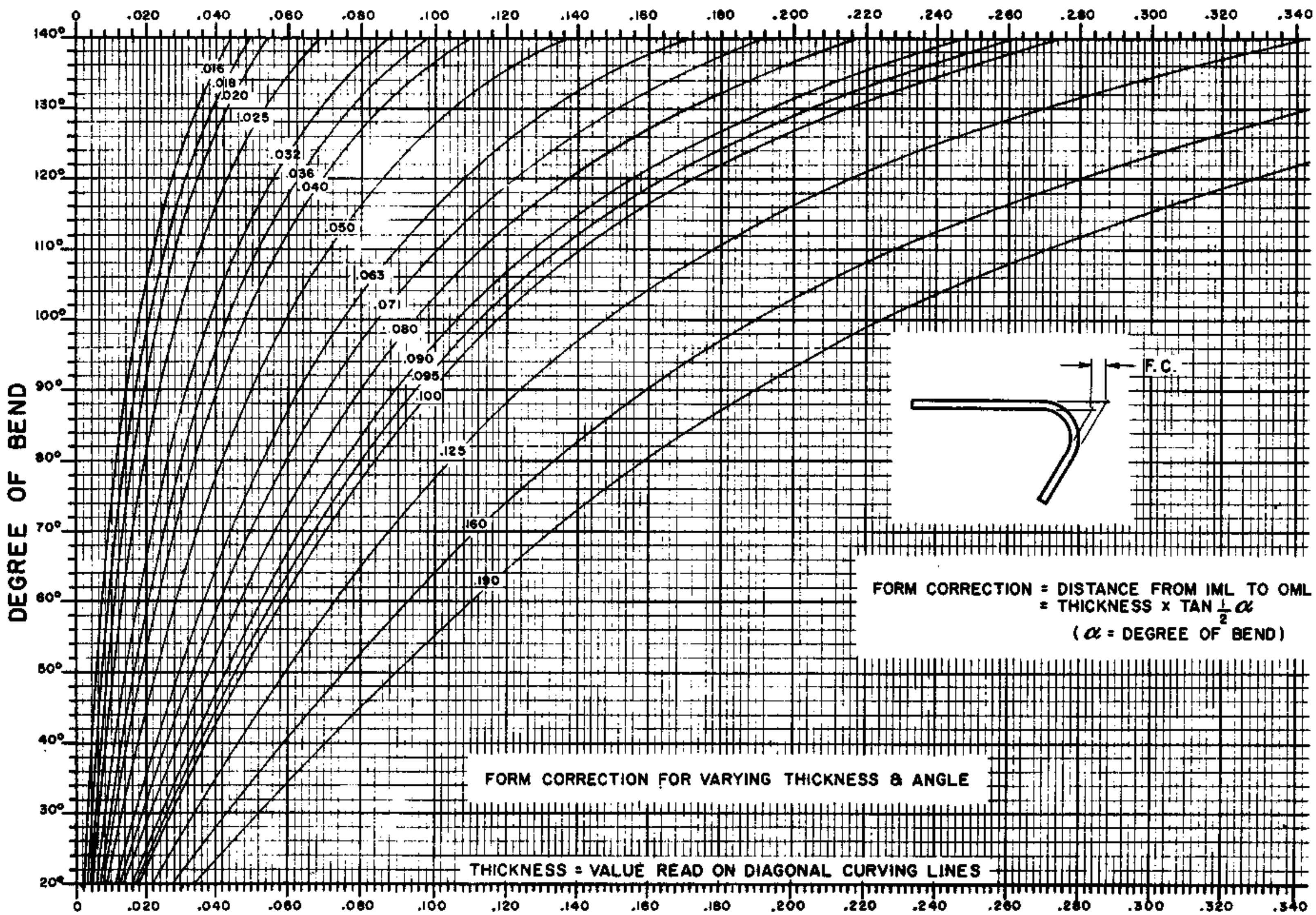
DETAIL TOOL 20



Form Correction Distance

APPENDIX 10-1

Springback

2,000; 10,000; 20,000 psi Forming Pressure

The following charts (10-1 through 10-14) give typical values of springback, in degrees, for the three forming pressures (when applicable) in use at GAC. The values are given for straight line 90° bends and depend on materials, temper, bend radius, thickness, and forming pressure. Each chart lists average figures because of material variations and slight corrections may be required on springback over 8°. Under most conditions the values are accurate within $\pm$ 1/2°.

Use the correction chart on the last page of this appendix when springback for angles other than 90° is required.

19-9 DL, AMS 5526, Condition A, Stainless Steel - 10,000 psi

Sheet Thick.	Bend Radius (inches)													
	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.018"	4 1/2	5 1/4	7	8 1/2	10									
.020"	4 1/4	5	6 1/2	8	9 1/2	11								
.025"	4	4 3/4	6	7 1/4	8 1/2	9 3/4	10 3/4							
.028"		4 1/4	5 1/4	6 1/2	7 3/4	8 1/2	9 3/4	10 3/4						
.032"		3 3/4	4 3/4	5 3/4	6 3/4	7 1/2	8 1/2	9 1/4	10 1/4	11				
.036"		3 1/2	4 1/2	5 1/4	6 1/4	7	8	8 3/4	9 1/2	10 1/4	11			
.040"			4 1/4	5	5 3/4	6 1/2	7 1/4	8	8 3/4	9 1/2	10	10 3/4		
.045"			4	4 3/4	5 1/2	6	6 3/4	7 1/4	8	8 1/2	9 1/4	9 3/4	10 3/4	
.050"			3 3/4	4 1/2	5	5 1/2	6 1/4	6 3/4	7 1/4	7 3/4	8 1/4	8 3/4	9 3/4	
.056"				4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7 1/4	7 3/4	8 1/4	9	9 3/4
.063"				4	4 1/2	5	5 1/2	6	6 1/4	6 3/4	7 1/4	7 3/4	8 1/2	9 1/4
.070"				3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6	6 1/2	6 3/4	7 1/4	8	8 3/4
.080"					4	4 1/2	5	5 1/4	5 3/4	6 1/4	6 1/2	6 3/4	7 1/2	8 1/4
.090"					3 3/4	4 1/4	4 1/2	5	5 1/4	5 3/4	6 1/4	6 1/2	7	7 3/4
.095"						4	4 1/2	4 3/4	5 1/4	5 1/2	6	6 1/4	6 3/4	7 1/2

19-9 DL, AMS 5526, Cond. A, Stainless Steel - 20,000 psi

Sheet Thick.	Bend Radius (inches)													
	$^{3}/_{64}$	$^{1}/_{16}$	$^{3}/_{32}$	$^{1}/_{8}$	$^{5}/_{32}$	$^{3}/_{16}$	$^{7}/_{32}$	$^{1}/_{4}$	$^{9}/_{32}$	$^{5}/_{16}$	$^{11}/_{32}$	$^{3}/_{8}$	$^{7}/_{16}$	$^{1}/_{2}$
.018"	$4^{1}/_{2}$	4	$5^{3}/_{4}$	$7^{1}/_{4}$	$8^{3}/_{4}$	$10^{1}/_{2}$								
.020"	$4^{1}/_{4}$	$3^{3}/_{4}$	$5^{1}/_{4}$	$6^{3}/_{4}$	$8^{1}/_{4}$	$9^{3}/_{4}$								
.025"	4	$3^{1}/_{2}$	$4^{3}/_{4}$	6	$7^{1}/_{4}$	$8^{1}/_{2}$	$9^{1}/_{2}$	$10^{3}/_{4}$						
.028"		3	4	$5^{1}/_{4}$	$6^{1}/_{2}$	$7^{1}/_{4}$	$8^{1}/_{2}$	$9^{1}/_{2}$	$10^{1}/_{2}$					
.032"		$2^{1}/_{2}$	$3^{1}/_{2}$	$4^{1}/_{2}$	$5^{1}/_{2}$	$6^{1}/_{4}$	$7^{1}/_{4}$	8	9	$9^{3}/_{4}$	$10^{3}/_{4}$			
.036"		$2^{1}/_{4}$	$3^{1}/_{4}$	4	5	$5^{3}/_{4}$	$6^{3}/_{4}$	$7^{1}/_{2}$	$8^{1}/_{4}$	9	$9^{3}/_{4}$	$10^{1}/_{2}$		
.040"			3	$3^{3}/_{4}$	$4^{1}/_{2}$	$5^{1}/_{4}$	6	$6^{3}/_{4}$	$7^{1}/_{2}$	$8^{1}/_{4}$	$8^{3}/_{4}$	$9^{1}/_{2}$		
.045"			$2^{3}/_{4}$	$3^{1}/_{2}$	$4^{1}/_{4}$	$4^{3}/_{4}$	$5^{1}/_{2}$	6	$6^{3}/_{4}$	$7^{1}/_{2}$	8	$8^{1}/_{2}$	$9^{1}/_{2}$	
.050"			$2^{1}/_{2}$	$3^{1}/_{4}$	$3^{3}/_{4}$	$4^{1}/_{4}$	5	$5^{1}/_{2}$	6	$6^{3}/_{4}$	7	$7^{1}/_{2}$	$8^{1}/_{2}$	
.056"				3	$3^{1}/_{2}$	4	$4^{1}/_{2}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7	$7^{3}/_{4}$	$8^{1}/_{2}$
.063"				$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{3}/_{4}$	$4^{1}/_{4}$	$4^{3}/_{4}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	$7^{1}/_{4}$	8
.070"				$2^{1}/_{2}$	3	$3^{1}/_{2}$	4	$4^{1}/_{2}$	$4^{3}/_{4}$	$5^{1}/_{4}$	$5^{1}/_{2}$	6	$6^{3}/_{4}$	$7^{1}/_{2}$
.080"					$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{3}/_{4}$	4	$4^{1}/_{2}$	5	$5^{1}/_{4}$	$5^{1}/_{2}$	$6^{1}/_{4}$	7
.090"					$2^{1}/_{2}$	3	$3^{1}/_{4}$	$3^{3}/_{4}$	4	$4^{1}/_{2}$	5	$5^{1}/_{4}$	$5^{3}/_{4}$	$6^{1}/_{2}$
.095"						$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{1}/_{2}$	4	$4^{1}/_{4}$	$4^{3}/_{4}$	5	$5^{1}/_{2}$	$6^{1}/_{4}$

APPENDIX 10-2

17-7 PH, Cond. A, Stainless Steel - 10,000 psi

Sheet Thick.	Bend Radius (inches)														
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.010"	2 1/2	3 1/2	4 1/2	6 1/4	8 1/4	10									
.012"	2 1/2	3 1/4	4 1/4	6	7 3/4	9 1/2	11								
.013"	2 1/4	3 1/4	4	5 3/4	7 1/2	9	10 1/2								
.015"	2 1/4	3	3 3/4	5 1/2	7	8 1/2	10								
.016"	2 1/4	3	3 3/4	5 1/4	6 3/4	8 1/4	9 1/2	11							
.018"		2 1/2	3 1/4	4 3/4	6	7 1/4	8 3/4	10	11						
.020"			3	4 1/4	5 1/2	6 3/4	7 3/4	9	10	11					
.025"			2 1/2	3 1/2	4 1/2	5 1/2	6 1/2	7 1/4	9	9	9 1/2	10 1/4			
.028"			2 1/4	3 1/4	4 1/4	5 1/4	6	6 3/4	7 1/2	8 1/4	9	9 3/4	10 1/4		
.032"			2 1/4	3 1/4	4	4 3/4	5 1/2	6 1/4	7	7 3/4	8 1/4	9	9 1/2		
.036"			2 1/4	3	3 3/4	4 1/2	5 1/4	5 3/4	6 1/2	7 1/4	7 3/4	8 1/4	8 3/4		
.040"			2	2 3/4	3 1/2	4	4 3/4	5 1/4	6	6 1/2	7 1/4	7 3/4	8 1/4		
.045"				2 1/2	3 1/4	3 3/4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	8 1/4	
.050"				2 1/2	3	3 1/2	4 1/4	4 3/4	5 1/4	5 3/4	6	6 1/2	7	7 1/2	8 1/4
.056"				2 1/4	2 3/4	3 1/4	4 1/4	4 1/4	4 3/4	5	5 1/2	5 3/4	6 1/4	6 3/4	7 1/4
.063"					2 1/2	3	3 1/2	3 3/4	4 1/4	4 1/2	4 3/4	5 1/4	5 1/2	6	6 1/2
.070"					2 1/4	2 3/4	3 1/4	3 1/2	4	4 1/4	4 1/2	4 3/4	5	5 1/2	6
.080"						2 1/2	3	3 1/4	3 1/2	4	4 1/4	4 1/2	4 3/4	5 1/4	5 1/2
.090"							2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/2	4 3/4	5

17-7 PH, Cond. A, Stainless Steel - 20,000 psi

Sheet Thick.	Bend Radius (inches)														
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.010"	1 3/4	2 3/4	3 3/4	5 1/2	7 1/2	9 1/4									
.012"	1 3/4	2 1/2	3 1/2	5 1/4	7	8 3/4	10 1/4								
.013"	1 1/2	2 1/2	3 1/4	5	6 3/4	8 1/4	9 3/4								
.015"	1 1/2	2 1/4	3	4 3/4	6 1/4	7 3/4	9 1/4	10 1/2							
.016"	1 1/2	2 1/4	3	4 1/2	5 1/4	7 1/2	8 3/4	10 1/4							
.018"		1 3/4	2 1/2	4	4 3/4	6 1/2	8	9 1/4	10 1/4						
.020"			2 1/4	3 1/2	3 3/4	6	7	8 1/4	9 1/4	10 1/4					
.025"			1 3/4	2 3/4	3 1/2	4 3/4	5 3/4	6 1/2	7 1/4	8 1/4	8 3/4	9 1/2	10 1/4		
.028"			1 1/2	2 1/2	3 1/4	4 1/2	5 1/4	6	6 3/4	7 1/2	8 1/4	9	9 1/2		
.032"			1 1/2	2 1/2	3	4	4 3/4	5 1/2	6 1/4	7	7 1/2	8 1/4	8 3/4		
.036"			1 1/2	2 1/4	2 3/4	3 3/4	4 1/2	5	5 3/4	6 1/2	7	7 1/2	8		
.040"			1 1/4	2	2 1/4	3 1/4	4	4 1/2	5 1/4	5 3/4	6 1/2	7	7 1/2		
.045"				1 3/4	2 1/4	3	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7 1/2	
.050"				1 3/4	2	2 3/4	3 1/2	4	4 1/2	5	5 1/4	5 3/4	6 1/4	6 3/4	7 1/2
.056"				1 1/2	1 3/4	2 1/2	3	3 1/2	4	4 1/4	4 3/4	5	5 1/2	6	6 1/2
.063"					1 1/2	2 1/4	2 3/4	3	3 1/2	3 3/4	4	4 1/2	4 3/4	5 1/4	5 3/4
.070"						2	2 1/2	2 3/4	3 1/4	3 1/2	3 3/4	4	4 1/2	4 3/4	5 1/4
.080"						1 3/4	2 1/4	2 1/2	2 3/4	3 1/4	3 1/2	3 3/4	4	4 1/2	4 3/4
.090"							2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	4	4 1/4

APPENDIX 10-3

301 $\frac{1}{4}$ H Stainless Steel - 10,000 psi

Sheet Thick.	Bend Radius (inches)														
	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
.015"	6	$8\frac{1}{4}$	$10\frac{1}{4}$	$14\frac{1}{2}$	$18\frac{1}{2}$	$22\frac{1}{2}$	$26\frac{1}{2}$	$30\frac{1}{2}$	$34\frac{3}{4}$						
.018"	$5\frac{3}{4}$	$7\frac{1}{2}$	$9\frac{1}{4}$	13	$16\frac{1}{2}$	20	$23\frac{3}{4}$	$27\frac{1}{2}$	$30\frac{3}{4}$						
.020"		7	$8\frac{1}{2}$	$11\frac{1}{2}$	$14\frac{3}{4}$	$17\frac{3}{4}$	21	24	27	30					
.025"			$7\frac{1}{2}$	$10\frac{1}{4}$	13	$15\frac{1}{2}$	$18\frac{1}{4}$	$20\frac{3}{4}$	$23\frac{1}{4}$	$25\frac{3}{4}$	$28\frac{1}{4}$				
.028"			$7\frac{1}{4}$	$9\frac{3}{4}$	12	$14\frac{1}{2}$	$16\frac{3}{4}$	$19\frac{1}{4}$	$21\frac{1}{2}$	$23\frac{3}{4}$	26	28			
.032"			7	$9\frac{1}{4}$	$11\frac{1}{4}$	$13\frac{1}{2}$	$15\frac{1}{2}$	$17\frac{1}{2}$	$19\frac{1}{2}$	$21\frac{3}{4}$	$23\frac{1}{2}$	$25\frac{1}{2}$			
.036"			$6\frac{1}{2}$	$8\frac{1}{4}$	$10\frac{1}{4}$	12	$13\frac{3}{4}$	$15\frac{1}{2}$	$17\frac{1}{2}$	19	$20\frac{3}{4}$	$22\frac{1}{4}$	24		
.040"				$7\frac{3}{4}$	$9\frac{1}{2}$	11	$12\frac{3}{4}$	$14\frac{1}{4}$	$15\frac{3}{4}$	$17\frac{1}{4}$	$18\frac{3}{4}$	20	$21\frac{1}{2}$		
.045"				$7\frac{1}{4}$	$8\frac{3}{4}$	10	$11\frac{1}{2}$	13	$14\frac{1}{4}$	$15\frac{1}{2}$	$16\frac{3}{4}$	18	19		
.050"				7	8	$9\frac{1}{4}$	$10\frac{1}{2}$	$11\frac{3}{4}$	$12\frac{3}{4}$	$13\frac{3}{4}$	$14\frac{3}{4}$	$15\frac{3}{4}$	$16\frac{3}{4}$	$18\frac{1}{2}$	
.056"					$7\frac{3}{4}$	$8\frac{3}{4}$	10	11	12	$12\frac{3}{4}$	$13\frac{3}{4}$	$14\frac{1}{2}$	$15\frac{1}{2}$	17	$18\frac{1}{2}$
.063"					$7\frac{1}{2}$	$8\frac{1}{2}$	$9\frac{1}{4}$	$10\frac{1}{4}$	11	12	$12\frac{3}{4}$	$13\frac{1}{2}$	$14\frac{1}{4}$	$15\frac{1}{2}$	$16\frac{3}{4}$

DETAIL TOOL 20

301 $^1/_4$ Hard Stainless Steel - 20,000 psi

Sheet Thick.	Bend Radius (inches)														
	$^1/_{32}$	$^3/_{64}$	$^1/_{16}$	$^3/_{32}$	$^1/_8$	$^5/_{32}$	$^3/_{16}$	$^7/_{32}$	$^1/_4$	$^9/_{32}$	$^5/_{16}$	$^{11}/_{32}$	$^3/_8$	$^7/_{16}$	$^1/_2$
.015"	4	$6^1/_4$	$8^1/_4$	$12^1/_2$	$16^1/_2$	$20^1/_2$	$24^1/_2$	$28^1/_2$	$32^3/_4$						
.016"															
.018"	$3^3/_4$	$5^1/_2$	$7^1/_4$	11	$14^1/_2$	18	$21^3/_4$	$25^1/_2$	$28^3/_4$						
.020"		5	$6^1/_2$	$9^1/_2$	$12^3/_4$	$15^3/_4$	19	22	25	28					
.025"			$5^1/_2$	$8^1/_4$	11	$13^1/_2$	$16^1/_4$	$18^3/_4$	$21^1/_4$	$23^3/_4$	$26^1/_4$				
.028"			$5^1/_4$	$7^3/_4$	10	$12^1/_2$	$14^3/_4$	$17^1/_4$	$19^1/_2$	$21^3/_4$	24	26			
.032"			5	$7^1/_4$	$9^1/_4$	$11^1/_2$	$13^1/_2$	$15^1/_2$	$17^1/_2$	$19^3/_4$	$21^1/_2$	$23^1/_2$			
.036"			$4^1/_2$	$6^1/_4$	$8^1/_4$	10	$11^3/_4$	$13^1/_2$	$15^1/_2$	17	$18^3/_4$	$20^1/_4$	22		
.040"				$5^3/_4$	$7^1/_2$	9	$10^3/_4$	$12^1/_4$	$13^3/_4$	$15^1/_4$	$16^3/_4$	18	$19^1/_2$		
.045"				$5^1/_4$	$6^3/_4$	8	$9^1/_2$	11	$12^1/_4$	$13^1/_2$	$14^3/_4$	16	17		
.050"				5	6	$7^1/_4$	$8^1/_2$	$9^3/_4$	$10^3/_4$	$11^3/_4$	$12^3/_4$	$13^3/_4$	$14^3/_4$	$16^1/_2$	
.056"					$5^3/_4$	$6^3/_4$	8	9	10	$10^3/_4$	$11^3/_4$	$12^1/_2$	$13^1/_2$	15	$16^1/_2$
.063"					$5^1/_2$	$6^1/_2$	$7^1/_4$	$8^1/_4$	9	10	$10^3/_4$	$11^1/_2$	$12^1/_4$	$13^1/_2$	$14^3/_4$

DETAIL TOOL 20

301 $^1/_2$ Hard Stainless Steel - 10,000 psi

Sheet Thick.	Bend Radius (inches)														
	$^1/_{32}$	$^3/_{64}$	$^1/_{16}$	$^3/_{32}$	$^1/_8$	$^5/_{32}$	$^3/_{16}$	$^7/_{32}$	$^1/_4$	$^9/_{32}$	$^5/_{16}$	$^{11}/_{32}$	$^3/_8$	$^7/_{16}$	$^1/_2$
.015"	8	$10^1/_4$	$12^1/_4$	$16^1/_2$	$20^1/_2$	$24^1/_2$	$28^1/_2$	$32^1/_2$	$34^3/_4$						
.016"															
.018"	$7^3/_4$	$9^1/_2$	$11^1/_4$	15	$18^1/_2$	22	$25^3/_4$	$29^1/_2$	$32^3/_4$						
.020"		9	$10^1/_2$	$13^1/_2$	$16^3/_4$	$19^3/_4$	23	26	29	32					
.025"			$9^1/_2$	$12^1/_4$	15	$17^1/_2$	$20^1/_4$	$22^3/_4$	$25^1/_4$	$27^3/_4$	$30^1/_4$				
.028"			$9^1/_4$	$10^3/_4$	14	$16^1/_2$	$18^3/_4$	$21^1/_4$	$23^1/_2$	$25^3/_4$	28	30			
.032"			9	$11^1/_4$	$13^1/_4$	$15^1/_2$	$17^1/_2$	$19^1/_2$	$21^1/_2$	$23^3/_4$	$25^1/_2$	$27^1/_2$			
.036"			$8^1/_2$	$10^1/_4$	$12^1/_4$	14	$15^3/_4$	$17^1/_2$	$19^1/_2$	21	$22^3/_4$	$24^1/_4$	26		
.040"				$9^3/_4$	$11^1/_2$	13	$14^3/_4$	$16^1/_4$	$17^3/_4$	$19^1/_4$	$20^3/_4$	22	$23^1/_2$		
.045"				$9^1/_4$	$10^3/_4$	12	$13^1/_2$	15	$16^1/_4$	$17^1/_2$	$18^3/_4$	20	21		
.050"				9	10	$11^1/_4$	$12^1/_2$	$13^3/_4$	$14^3/_4$	$15^3/_4$	$16^3/_4$	$17^3/_4$	$18^3/_4$	$20^1/_2$	
.056"					$9^3/_4$	$10^3/_4$	12	13	14	$14^3/_4$	$15^3/_4$	$16^1/_2$	$17^1/_2$	19	$20^1/_2$
.063"					$9^1/_2$	$10^1/_2$	$11^1/_4$	$12^1/_4$	13	14	$14^3/_4$	$15^1/_2$	$16^1/_4$	$17^1/_2$	$18^3/_4$

DETAIL TOOL 20

301 Full Hard Stainless Steel - 20,000 psi

Sheet Thick.	Bend Radius (inches)														
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.015"	6	8 1/4	10 1/4	14 1/2	18 1/2	22 1/2	26 1/2	30 1/2	34 3/4						
.016"															
.018"	5 3/4	7 1/2	9 1/4	13	16 1/2	20	23 3/4	27 1/2	30 3/4						
.020"		7	8 1/2	11 1/2	14 3/4	17 3/4	21	24	27	30					
.025"			7 1/2	10 1/4	13	15 1/2	18 1/4	20 3/4	23 1/4	25 3/4	28 1/4				
.028"			7 1/4	9 3/4	12	14 1/2	16 3/4	19 1/4	21 1/2	23 3/4	26	28			
.032"			7	9 1/4	11 1/4	13 1/2	15 1/2	17 1/2	19 1/2	21 3/4	23 1/2	25 1/2			
.036"			6 1/2	8 1/4	10 1/4	12	13 3/4	15 1/2	17 1/2	19	20 3/4	22 1/4	24		
.040"				7 3/4	9 1/2	11	12 3/4	14 1/4	15 3/4	17 1/4	18 3/4	20	21 1/2		
.045"				7 1/4	8 3/4	10	11 1/2	13	14 1/4	15 1/2	16 3/4	18	19		
.050"				7	8	9 1/4	10 1/2	11 3/4	12 3/4	13 3/4	14 3/4	15 3/4	16 3/4	18 1/2	
.056"					7 3/4	8 3/4	10	11	12	12 3/4	13 3/4	14 1/2	15 1/2	17	18 1/2
.063"					7 1/2	8 1/2	9 1/4	10 1/4	11	12	12 3/4	13 1/2	14 1/4	15 1/2	16 3/4

APPENDIX 10-4

301 Full Hard Stainless Steel - 10,000 psi

Sheet Thick	Bend Radius (inches)										
	$^{1}/_{16}$	$^{3}/_{32}$	$^{1}/_{8}$	$^{5}/_{32}$	$^{3}/_{16}$	$^{7}/_{32}$	$^{1}/_{4}$	$^{9}/_{32}$	$^{5}/_{16}$	$^{11}/_{32}$	$^{3}/_{8}$
.005"											
.010"	20	28	37	$47^{1}/_{2}$	60	74	90				
.012"											
.013"											
.015"											
.016"											
.018"											
.020"											
.025"		$17^{1}/_{2}$	$21^{1}/_{2}$	$25^{3}/_{4}$	$30^{1}/_{4}$	35	$40^{1}/_{2}$	$46^{1}/_{2}$	$52^{1}/_{2}$	59	66
.028"											
.032"											
.036"											
.040"											

301 Full Hard Stainless Steel - 20,000 psi

Sheet Thick	Bend Radius (inches)										
	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.005"											
.010"	$16\frac{1}{2}$	23	$30\frac{1}{2}$	39	48	$58\frac{1}{2}$	70				
.012"											
.013"											
.015"											
.016"											
.018"											
.020"											
.025"		14	$17\frac{1}{2}$	21	$24\frac{1}{2}$	29	34	39	45	$50\frac{1}{2}$	57
.028"											
.032"											
.036"											
.040"											

321 Stainless Steel - Annealed - 10,000 psi

Sheet Thick.	Bend Radius (inches)														
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.010"	2 3/4	3	3 1/4	4	4 3/4	5 1/2	6	6 3/4	7 1/2	8	8 1/2				
.012"	2 1/2	2 3/4	3	3 3/4	4 1/2	5	5 3/4	6 1/2	7	7 3/4	8 1/4				
.013"	2 1/2	2 3/4	3	3 3/4	4 1/2	5	5 3/4	6 1/4	6 3/4	7 1/2	8	8 1/2	9		
.015"	2 1/4	2 1/2	3	3 1/2	4 1/4	4 3/4	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2		
.016"	2 1/4	2 1/2	3	3 1/2	4 1/4	4 3/4	5 1/2	6	6 1/2	7	7 1/2	8	8 1/2		
.018"	2	2 1/2	2 3/4	3 1/2	4	4 1/2	5 1/4	5 3/4	6 1/4	6 3/4	7 1/4	7 3/4	8 1/4		
.020"	2	2 1/4	2 3/4	3 1/4	3 3/4	4 1/2	4	5 1/2	6	6 1/2	7	7 1/2	8		
.025"	2	2 1/4	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2		
.028"	1 3/4	2	2 1/4	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 1/2	7		
.032"		2	2 1/4	2 1/2	3 1/4	3 3/4	4	4 1/2	5	5 1/2	5 3/4	6 1/4	6 1/2		
.036"		1 3/4	2	2 1/4	3	3 1/4	3 3/4	4 1/4	4 1/2	5	5 1/2	5 3/4	6		
.040"			2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	5	5 1/4	5 3/4		
.045"			1 3/4	2	2 1/2	2 3/4	3 1/4	3 3/4	4	4 1/2	5	5	5 1/4		
.050"			1 3/4	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	4 3/4	5		
.056"				1 3/4	2 1/4	2 3/4	3	3 1/4	3 3/4	4	4 1/4	4 1/2	4 3/4		
.063"				1 3/4	2	2 1/2	2 3/4	3	3 1/2	3 3/4	4	4 1/4	4 1/2	5	
.070"					2	2 1/4	2 3/4	3	3 1/4	3 1/4	3 3/4	4	4 1/4	4 3/4	5 1/4
.080"					1 3/4	2 1/4	2 1/2	2 3/4	3	3 1/4	3 3/4	4	4	4 1/2	4 3/4
.090"					1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 1/2	3 1/2	3 3/4	4 1/4	4 1/2
.095"					1 1/2	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4
.100"					1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
.120"						1 1/2	1 1/2	2	2	2 1/4	2 1/2	2 1/2	2 3/4	3	3 1/4
.125"						1 1/4	1 1/2	1 3/4	2	2	2 1/4	2 1/2	2 1/2	2 3/4	3

APPENDIX 10-5

321 Stainless Steel - Annealed - 20,000 psi

Sheet Thick.	Bend Radius (inches)														
	$^{1}/_{32}$	$^{3}/_{64}$	$^{1}/_{16}$	$^{3}/_{32}$	$^{1}/_{8}$	$^{5}/_{32}$	$^{3}/_{16}$	$^{7}/_{32}$	$^{1}/_{4}$	$^{9}/_{32}$	$^{5}/_{16}$	$^{11}/_{32}$	$^{3}/_{8}$	$^{7}/_{16}$	$^{1}/_{2}$
.010"	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$	$3^{1}/_{2}$	$4^{1}/_{4}$	5	$5^{1}/_{2}$	$6^{1}/_{4}$	7	$7^{1}/_{2}$	8				
.012"	2	$2^{1}/_{4}$	$2^{1}/_{2}$	$3^{1}/_{4}$	4	$4^{1}/_{2}$	$5^{1}/_{4}$	6	$6^{1}/_{2}$	$7^{1}/_{4}$	$7^{3}/_{4}$				
.013"	2	$2^{1}/_{4}$	$2^{1}/_{2}$	$3^{1}/_{4}$	4	$4^{1}/_{2}$	$5^{1}/_{4}$	$5^{3}/_{4}$	$6^{1}/_{4}$	7	$7^{1}/_{2}$	8	$8^{1}/_{2}$		
.015"	$1^{3}/_{4}$	2	$2^{1}/_{2}$	3	$3^{3}/_{4}$	$4^{1}/_{4}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7	$7^{1}/_{2}$	8		
.016"	$1^{3}/_{4}$	2	$2^{1}/_{2}$	3	$3^{3}/_{4}$	$4^{1}/_{4}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7	$7^{1}/_{2}$	8		
.018"	$1^{1}/_{2}$	2	$2^{1}/_{4}$	3	$3^{1}/_{2}$	4	$4^{3}/_{4}$	$5^{1}/_{4}$	$5^{3}/_{4}$	$6^{1}/_{4}$	$6^{3}/_{4}$	$7^{1}/_{4}$	$7^{3}/_{4}$		
.020"	$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{3}/_{4}$	$3^{1}/_{4}$	4	$4^{1}/_{2}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7	$7^{1}/_{2}$		
.025"	$1^{1}/_{2}$	$1^{3}/_{4}$	2	$2^{1}/_{2}$	3	$3^{1}/_{2}$	4	$4^{1}/_{2}$	5	$5^{1}/_{2}$	6	$6^{1}/_{2}$	7		
.028"	$1^{1}/_{4}$	$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{3}/_{4}$	$4^{1}/_{4}$	$4^{3}/_{4}$	$5^{1}/_{4}$	$5^{3}/_{4}$	6	$6^{1}/_{2}$		
.032"		$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{1}/_{2}$	4	$4^{1}/_{2}$	5	$5^{1}/_{4}$	$5^{3}/_{4}$	6		
.036"		$1^{1}/_{4}$	$1^{1}/_{2}$	2	$2^{1}/_{2}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{3}/_{4}$	4	$4^{1}/_{2}$	5	$5^{1}/_{4}$	$5^{1}/_{2}$		
.040"			$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{1}/_{2}$	3	$3^{1}/_{4}$	$3^{3}/_{4}$	4	$4^{1}/_{2}$	$4^{3}/_{4}$	$5^{1}/_{4}$		
.045"			$1^{1}/_{4}$	$1^{1}/_{2}$	2	$2^{1}/_{4}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{1}/_{2}$	4	$4^{1}/_{2}$	$4^{1}/_{2}$	$4^{3}/_{4}$		
.050"			$1^{1}/_{4}$	$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{1}/_{2}$	3	$3^{1}/_{4}$	$3^{3}/_{4}$	4	$4^{1}/_{4}$	$4^{1}/_{2}$		
.056"				$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{1}/_{2}$	$3^{3}/_{4}$	4	$4^{1}/_{4}$		
.063"				$1^{1}/_{4}$	$1^{1}/_{2}$	2	$2^{1}/_{4}$	$2^{1}/_{2}$	3	$3^{1}/_{4}$	$3^{1}/_{2}$	$3^{3}/_{4}$	4	$4^{1}/_{2}$	
.070"				$1^{1}/_{4}$	$1^{1}/_{2}$	$1^{3}/_{4}$	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{1}/_{2}$	$3^{3}/_{4}$	$4^{1}/_{4}$	$4^{3}/_{4}$
.080"				1	$1^{1}/_{4}$	$1^{3}/_{4}$	2	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$	$3^{1}/_{4}$	$3^{1}/_{2}$	$3^{1}/_{2}$	4	$4^{1}/_{4}$
.090"				$^{3}/_{4}$	$1^{1}/_{4}$	$1^{1}/_{2}$	$1^{3}/_{4}$	2	$2^{1}/_{2}$	$2^{3}/_{4}$	3	3	$3^{1}/_{4}$	$3^{3}/_{4}$	4
.095"					1	$1^{1}/_{2}$	$1^{3}/_{4}$	2	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$	3	$3^{1}/_{4}$	$3^{1}/_{2}$	$3^{3}/_{4}$
.100"					1	$1^{1}/_{4}$	$1^{1}/_{2}$	$1^{3}/_{4}$	2	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$	3	$3^{1}/_{4}$	$3^{1}/_{2}$
.120"						1	1	$1^{1}/_{2}$	$1^{1}/_{2}$	$1^{3}/_{4}$	2	2	$2^{1}/_{4}$	$2^{1}/_{2}$	$2^{3}/_{4}$
.125"						$^{3}/_{4}$	1	$1^{1}/_{4}$	$1^{1}/_{2}$	$1^{1}/_{2}$	$1^{3}/_{4}$	2	2	$2^{1}/_{4}$	$2^{1}/_{2}$

4130 CM Stainless - Annealed - 10,000 psi

CM= Chromium-Molybdenum

Sheet Thick.	Bend Radius (inches)													
	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.036"	2	2 1/4	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7 1/4		
.040"	2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7		
.045"		2	2 1/2	3	3 1/2	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7 3/4	
.050"		2	2 1/4	2 3/4	3 1/4	3 3/4	4	4 1/2	5	5 1/2	6	6 1/2	7 1/2	8 1/2
.056"			2 1/4	2 1/2	3	3 1/2	4	4 1/4	4 3/4	5 1/4	5 3/4	6	7	8
.063"				2 1/2	2 3/4	3 1/4	3 3/4	4	4 1/2	5	5 1/4	5 3/4	6 3/4	7 1/2
.070"				2 1/4	2 3/4	3	3 1/4	3 3/4	4 1/4	4 1/2	5	5 1/4	6 1/4	7
.080"					2 1/2	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	5	5 3/4	6 1/2
.090"					2 1/4	2 1/2	3	3 1/4	3 1/2	4	4 1/4	4 3/4	5 1/4	6
.095"						2 1/2	3	3 1/4	3 1/2	4	4 1/4	4 1/2	5 1/4	6
.100"						2 1/2	2 3/4	3 1/4	3 1/2	3 3/4	4	4 1/2	5	5 3/4
.120"							2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4 1/2	5
.125"							2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4 1/4	4 3/4

4130 CM Stainless Steel - Annealed - 20,000 psi

CM= Chromium-Molybdenum

Sheet Thick.	Bend Radius (inches)													
	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.036"	1	1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4		
.040"	1	1	1 1/2	2	2 1/2	3	3 1/2	4	4 1/2	5	5 1/2	6		
.045"		1	1 1/2	2	2 1/2	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 3/4	
.050"		1	1 1/4	1 3/4	2 1/4	2 3/4	3	3 1/2	4	4 1/2	5	5 1/2	6 1/2	7 1/2
.056"			1 1/4	1 1/2	2	2 1/2	3	3 1/4	3 3/4	4 1/4	4 3/4	5	6	7
.063"				1 1/2	1 3/4	2 1/4	2 3/4	3	3 1/2	4	4 1/4	4 3/4	5 3/4	6 1/2
.070"				1 1/4	1 3/4	2	2 1/4	2 3/4	3 1/4	3 1/2	4	4 1/4	5 1/4	6
.080"					1 1/2	1 3/4	2	2 1/2	2 3/4	3 1/4	3 1/2	4	4 3/4	5 1/2
.090"					1 1/4	1 1/2	2	2 1/4	2 1/2	3	3 1/4	3 3/4	4 1/4	5
.095"						1 1/2	2	2 1/4	2 1/2	3	3 1/4	3 1/2	4 1/4	5
.100"						1 1/2	1 3/4	2 1/4	2 1/2	2 3/4	3	3 1/2	4	4 3/4
.120"							1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/2	4
.125"							1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/4	3 3/4

APPENDIX 10-6

2014-W Aluminum - Unstable - 2,000 psi

Sheet Thick.	Bend Radius (inches)													
	$\frac{1}{64}$	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.016"	3	$3\frac{1}{2}$	4	$4\frac{1}{4}$	$5\frac{1}{4}$	6	7	$7\frac{3}{4}$	$8\frac{1}{2}$	9	$9\frac{3}{4}$	$10\frac{1}{2}$	11	
.020"	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	5	$5\frac{3}{4}$	$6\frac{1}{2}$	$7\frac{1}{4}$	8	$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$	
.025"	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{3}{4}$	$5\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{2}$	$8\frac{1}{4}$	$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{4}$
.032"	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{2}$	7	$7\frac{3}{4}$	$8\frac{1}{4}$	$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$
.036"		$2\frac{3}{4}$	3	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{2}$	6	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{3}{4}$	$8\frac{1}{4}$	$8\frac{3}{4}$	9
.040"		$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	4	$4\frac{1}{2}$	5	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{3}{4}$	8	$8\frac{1}{2}$
.045"			$2\frac{3}{4}$	3	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{1}{2}$	8
.050"				$2\frac{3}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{1}{2}$
.056"				$2\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	6	$6\frac{1}{4}$	$6\frac{3}{4}$	7
.063"				$2\frac{1}{2}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{1}{2}$
.071"				$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	$5\frac{3}{4}$	6
.080"					$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$
.090"					$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5
.100"					2	$2\frac{1}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$
.125"						$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$

3,000, 4,000, & 5,000 psi same as 2,000 psi

2014-W Aluminum - Unstable - 10,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	2 3/4	3 1/4	3 3/4	4	5	5 3/4	6 3/4	7 1/2	8 1/4	8 3/4	9 1/2	10 1/4	10 3/4	
.020"	2 1/2	3	3 1/2	4	4 3/4	5 1/2	6 1/4	7	7 3/4	8 1/2	9	9 1/2	10 1/4	10 3/4
.025"	2 1/4	2 3/4	3 1/4	3 3/4	4 1/2	5 1/4	6	6 1/2	7 1/4	8	8 1/2	9	9 1/2	10
.032"	2 1/4	2 1/2	3	3 1/2	4 1/4	5	5 1/2	6 1/4	6 3/4	7 1/2	8	8 1/2	9	9 1/2
.036"		2 1/2	2 3/4	3 1/4	4	4 1/2	5 1/4	5 3/4	6 1/2	7	7 1/2	8	8 1/2	8 3/4
.040"		2 1/4	2 1/2	3	3 3/4	4 1/4	4 3/4	5 1/2	6	6 1/2	7	7 1/2	7 3/4	8 1/4
.045"			2 1/2	2 3/4	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/4	7 3/4
.050"				2 1/2	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6	6 1/2	7	7 1/4
.056"				2 1/4	3	3 1/2	4	4 1/2	5	5 1/4	5 3/4	6	6 1/2	6 3/4
.063"				2 1/4	2 3/4	3 1/4	3 1/2	4	4 1/2	5	5 1/4	5 1/2	6	6 1/4
.071"				2	2 1/2	3	3 1/2	3 3/4	4	4 1/2	4 3/4	5 1/4	5 1/2	5 3/4
.080"					2 1/4	2 3/4	3	3 1/2	3 3/4	4	4 1/2	4 3/4	5	5 1/4
.090"					2	2 1/4	2 3/4	3	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4
.100"					1 3/4	2	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4
.125"						1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3	3 1/4

DETAIL TOOL 20

2014-W Aluminum - Unstable - 20,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	2 1/2	3	3 1/2	3 3/4	4 3/4	5 1/2	6 1/2	7 1/4	8	8 1/2	9 1/4	10	10 1/2	11 1/4
.020"	2 1/4	2 3/4	3 1/4	3 3/4	4 1/2	5 1/4	6	6 3/4	7 1/2	8 1/4	8 3/4	9 1/4	10	10 1/2
.025"	2	2 1/2	3	3 1/2	4 1/4	5	5 3/4	6 1/4	7	7 3/4	8 1/4	8 3/4	9 1/4	9 3/4
.032"	2	2 1/4	2 3/4	3 1/4	4	4 3/4	5 1/4	6	6 1/2	7 1/4	7 3/4	8 1/4	8 3/4	9 1/4
.036"		2 1/4	2 1/2	3	3 3/4	4 1/4	5	5 1/2	6 1/4	6 3/4	7 1/4	7 3/4	8 1/4	8 1/2
.040"		2	2 1/4	2 3/4	3 1/4	4	4 1/2	5 1/4	5 3/4	6 1/4	6 3/4	7 1/4	7 1/2	8
.045"			2 1/4	2 1/2	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7	7 1/2
.050"				2 1/4	3	3 1/2	4	4 1/2	5	5 1/2	5 3/4	6 1/4	6 3/4	7
.056"				2	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5	5 1/2	5 3/4	6 1/4	6 1/2
.063"				2	2 1/2	3	3 1/4	3 3/4	4 1/4	4 3/4	5	5 1/4	5 3/4	6
.071"				1 3/4	2 1/4	2 3/4	3 1/4	3 1/2	3 3/4	4 1/4	4 1/2	5	5 1/4	5 1/2
.080"					2	2 1/2	2 3/4	3 1/4	3 1/2	3 3/4	4 1/4	4 1/2	4 3/4	5
.090"					1 3/4	2	2 1/2	2 3/4	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2
.100"					1 1/2	1 3/4	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4
.125"						1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	2 3/4	3

APPENDIX 10-7

2014-O Aluminum - 2,000 psi

Sheet Thick.	Bend Radius (inches)													
	$^1/_{64}$	$^1/_{32}$	$^3/_{64}$	$^1/_{16}$	$^3/_{32}$	$^1/_8$	$^5/_{32}$	$^3/_{16}$	$^7/_{32}$	$^1/_4$	$^9/_{32}$	$^5/_{16}$	$^{11}/_{32}$	$^3/_8$
.016"	$2^1/_4$	$2^1/_2$	$2^1/_2$	$2^3/_4$	$3^1/_4$	$3^1/_2$	4	$4^1/_2$	5	$5^1/_4$	$5^3/_4$	$6^1/_4$	$6^3/_4$	$7^1/_4$
.020"	2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^3/_4$	$5^1/_4$	$5^3/_4$	6	$6^1/_2$	7
.025"		$2^1/_4$	$2^1/_4$	$2^1/_2$	3	$3^1/_4$	$3^3/_4$	4	$4^1/_2$	5	$5^1/_2$	$5^3/_4$	$6^1/_4$	$6^3/_4$
.032"		2	$2^1/_4$	$2^1/_2$	$2^3/_4$	$3^1/_4$	$3^1/_2$	4	$4^1/_4$	$4^3/_4$	$5^1/_4$	$5^3/_4$	6	$6^1/_2$
.036"		2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^3/_4$	5	$5^1/_2$	$5^3/_4$	$6^1/_4$
.040"		2	$2^1/_4$	$2^1/_4$	$2^1/_2$	3	$3^1/_4$	$3^3/_4$	4	$4^1/_2$	$4^3/_4$	$5^1/_4$	$5^1/_2$	6
.045"			2	$2^1/_4$	$2^1/_2$	$2^3/_4$	$3^1/_4$	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^1/_2$	5	$5^1/_4$	$5^3/_4$
.050"			2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^3/_4$	4	$4^1/_2$	$4^3/_4$	$5^1/_4$	$5^1/_2$
.056"				2	$2^1/_4$	$2^1/_2$	3	$3^1/_4$	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^1/_2$	5	$5^1/_4$
.063"				2	$2^1/_4$	$2^1/_2$	$2^3/_4$	$2^3/_4$	$3^1/_4$	$3^3/_4$	4	$4^1/_4$	$4^3/_4$	5
.071"				$1^3/_4$	2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^1/_2$
.080"					$1^3/_4$	2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^1/_2$	$3^3/_4$	4
.090"					$1^3/_4$	$1^3/_4$	2	$2^1/_4$	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^1/_2$
.100"					$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^3/_4$	2	$2^1/_4$	$2^1/_2$	$2^1/_2$	$2^3/_4$	3
.125"						$1^1/_4$	$1^1/_4$	$1^3/_4$	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^3/_4$	2

3,000, 4,000, & 5,000 psi same as 2,000 psi

2014-O Aluminum - Unstable - 10,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	2	2 1/4	2 1/4	2 1/2	3	3 1/4	3 3/4	4 1/4	4 3/4	5	5 1/2	6	6 1/2	7
.020"	1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/2	5	5 1/2	5 3/4	6 1/4	6 3/4
.025"		2	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 3/4	5 1/4	5 1/2	6	6 1/2
.032"		1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 3/4	4	4 1/2	5	5 1/2	5 3/4	6 1/4
.036"		1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/2	4 3/4	5 1/4	5 1/2	6
.040"		1 3/4	2	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	5	5 1/4	5 3/4
.045"			1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 1/2	4	4 1/4	4 3/4	5	5 1/2
.050"			1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	5	5 1/4
.056"				1 3/4	2	2 1/4	2 3/4	3	3 1/4	3 1/2	4	4 1/4	4 3/4	5
.063"				1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/2	3 3/4	4	4 1/2	4 3/4
.071"				1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	4	4 1/4
.080"					1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4
.090"					1 1/4	1 1/2	1 3/4	2	2	2 1/4	2 1/2	2 3/4	3	3 1/4
.100"					1 1/4	1 1/4	1 1/2	1 1/2	1 3/4	2	2 1/4	2 1/4	2 1/2	2 3/4
.125"						1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 3/4

2014-O Aluminum - 20,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	1 3/4	2	2	2 1/4	2 3/4	3	3 1/2	4	4 1/2	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4
.020"	1 1/2	1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 1/2	6	6 1/2
.025"	1 1/2	1 3/4	1 3/4	2	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/2	5	5 1/4	5 3/4	6 1/4
.032"	1 1/2	1 1/2	1 3/4	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 3/4	5 1/4	5 1/2	6
.036"		1 1/2	1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 3/4	4 1/4	4 1/2	5	5 1/4	5 3/4
.040"		1 1/2	1 3/4	1 3/4	2	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/4	4 3/4	5	5 1/2
.045"			1 1/2	1 3/4	2	2 1/4	2 3/4	3	3 1/4	3 3/4	4	4 1/2	4 3/4	5 1/4
.050"			1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/4	4 3/4	5
.056"				1 1/2	1 3/4	2	2 1/2	2 3/4	3	3 1/4	3 3/4	4	4 1/2	4 3/4
.063"				1 1/2	1 3/4	2	2 1/4	2 1/4	2 3/4	3 1/4	3 1/2	3 3/4	4 1/4	4 1/2
.071"				1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 3/4	4
.080"					1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2
.090"					1 1/4	1 1/4	1 1/2	1 3/4	1 3/4	2	2 1/4	2 1/2	2 3/4	3
.100"					1	1	1 1/4	1 1/4	1 1/2	1 3/4	2	2	2 1/4	2 1/2
.125"						3/4	3/4	3/4	1	1	1	1 1/4	1 1/4	1 1/2

APPENDIX 10-8

2014-T3 Aluminum - 2,000 psi

Sheet Thick.	Bend Radius (inches)														
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.016"	5	5 3/4	6 3/4	8 1/2	10 1/4	12	14	15 1/2	17 1/4						
.020"		5 1/4	6 1/4	7 3/4	9 1/2	11	12 3/4	14 1/4	16	17 1/2					
.025"			5 3/4	7	8 1/2	10 1/4	11 1/2	13 1/4	15	16 1/2	18				
.032"			5	6 1/2	8	9 1/2	10 3/4	12 1/2	14	15 1/4	17	18 1/4			
.036"				6 1/4	7 3/4	9 1/4	10 1/2	12	13 1/2	15	16 1/4	17 1/2	18 1/2		
.040"				6	7 1/4	8 3/4	10 1/4	11 3/4	13	14 1/4	15 1/2	17	18	19 1/2	
.045"					7	8 1/2	9 3/4	11	12 1/2	13 1/2	14 1/2	15 1/2	16 1/2	18 1/4	
.050"					6 1/2	8 1/4	9	10 1/4	11 1/2	12 1/2	13 1/2	14 1/4	15 1/4	16 1/2	17 1/2
.056"						7 1/4	8 1/2	9 3/4	10 3/4	11 3/4	12 3/4	13 1/2	14 1/4	15 1/2	16 1/2
.063"						6 3/4	8	9	10 1/4	11 1/2	12	12 3/4	13 1/2	14 1/2	15 3/4
.071"							7 1/4	8 1/2	9 3/4	10 1/2	11 1/2	12	12 3/4	13 1/4	14 1/2
.080"								8	9	9 3/4	10 3/4	11 1/2	12	13	14
.090"									8 1/2	9 1/4	10 1/4	10 3/4	11 1/2	12 1/4	13 1/4
.100"											9 3/4	10 1/4	10 3/4	11 3/4	12 3/4
.125"												8 1/2	9	9 3/4	10 3/4

2014-T3 Aluminum - 10,000 psi

Sheet Thick.	Bend Radius (inches)														
	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
.016"	4	$4\frac{3}{4}$	$5\frac{3}{4}$	$7\frac{1}{2}$	$9\frac{1}{4}$	11	13	$14\frac{1}{2}$	$16\frac{1}{4}$						
.020"		$4\frac{1}{4}$	$5\frac{1}{4}$	$6\frac{3}{4}$	$8\frac{1}{2}$	10	$11\frac{3}{4}$	$13\frac{1}{4}$	15	$16\frac{1}{2}$					
.025"			$4\frac{3}{4}$	6	$7\frac{1}{2}$	$9\frac{1}{4}$	$10\frac{1}{2}$	$12\frac{1}{4}$	14	$15\frac{1}{2}$	17				
.032"			4	$5\frac{1}{2}$	7	$8\frac{1}{2}$	$9\frac{3}{4}$	$11\frac{1}{2}$	13	$14\frac{1}{4}$	16	$17\frac{1}{4}$			
.036"				$5\frac{1}{4}$	$6\frac{3}{4}$	$8\frac{1}{4}$	$9\frac{1}{2}$	11	$12\frac{1}{2}$	14	$15\frac{1}{4}$	$16\frac{1}{2}$	$17\frac{1}{2}$		
.040"				5	$6\frac{1}{4}$	$7\frac{3}{4}$	$9\frac{1}{4}$	$10\frac{3}{4}$	12	$13\frac{1}{4}$	$14\frac{1}{2}$	16	17	$18\frac{1}{2}$	
.045"					6	$7\frac{1}{2}$	$8\frac{3}{4}$	10	$11\frac{1}{2}$	$12\frac{1}{2}$	$13\frac{1}{2}$	$14\frac{1}{2}$	$15\frac{1}{2}$	$17\frac{1}{4}$	
.050"					$5\frac{1}{2}$	$7\frac{1}{4}$	8	$9\frac{1}{4}$	$10\frac{1}{2}$	$11\frac{1}{2}$	$12\frac{1}{2}$	$13\frac{1}{4}$	$14\frac{1}{4}$	$15\frac{1}{2}$	$16\frac{1}{2}$
.056"						$6\frac{1}{4}$	$7\frac{1}{2}$	$8\frac{3}{4}$	$9\frac{3}{4}$	$10\frac{3}{4}$	$11\frac{3}{4}$	$12\frac{1}{2}$	$13\frac{1}{4}$	$14\frac{1}{2}$	$15\frac{1}{2}$
.063"						$5\frac{3}{4}$	7	8	$9\frac{1}{4}$	$10\frac{1}{2}$	11	$11\frac{3}{4}$	$12\frac{1}{2}$	$13\frac{1}{2}$	$14\frac{3}{4}$
.071"							$6\frac{1}{4}$	$7\frac{1}{2}$	$8\frac{3}{4}$	$9\frac{1}{2}$	$10\frac{1}{2}$	11	$11\frac{3}{4}$	$12\frac{1}{4}$	$13\frac{1}{2}$
.080"								7	8	$8\frac{3}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$	11	12	13
.090"									$7\frac{1}{2}$	$8\frac{1}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$	$11\frac{1}{4}$	$12\frac{1}{4}$
.100"											$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{3}{4}$	$11\frac{3}{4}$
.125"												$7\frac{1}{2}$	8	$8\frac{3}{4}$	$9\frac{3}{4}$

2014-T3 Aluminum - 20,000 psi

Sheet Thick.	Bend Radius (inches)														
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8	7/16	1/2
.016"	3	3 3/4	4 3/4	6 1/2	8 1/4	10	12	13 1/2	15 1/4						
.020"		3 1/4	4 1/4	5 3/4	7 1/2	9	10 3/4	12 1/4	14	15 1/2					
.025"			3 3/4	5	6 1/2	8 1/4	9 1/2	11 1/4	13	14 1/2	16				
.032"			3	4 1/2	6	7 1/2	8 3/4	10 1/2	12	13 1/4	15	16 1/4			
.036"				4 1/4	5 3/4	7 1/4	8 1/2	10	11 1/2	13	14 1/4	15 1/2	16 1/2		
.040"				4	5 1/4	6 3/4	8 1/4	9 3/4	11	12 1/4	13 1/2	15	16	17 1/2	
.045"					5	6 1/2	7 3/4	9	10 1/2	11 1/2	12 1/2	13 1/2	14 1/2	16 1/4	
.050"					4 1/2	6 1/4	7	8 1/4	9 1/2	10 1/2	11 1/2	12 1/4	13 1/4	14 1/2	15 1/2
.056"						5 1/4	6 1/2	7 3/4	8 3/4	9 3/4	10 3/4	11 1/2	12 1/4	13 1/2	14 1/2
.063"						4 3/4	6	7	8 1/4	9 1/2	10	10 3/4	11 1/2	12 1/2	13 3/4
.071"							5 1/4	6 1/2	7 3/4	8 1/2	9 1/2	10	10 3/4	11 1/4	12 1/2
.080"								6	7	7 3/4	8 3/4	9 1/2	10	11	12
.090"									6 1/2	7 1/4	8 1/4	8 3/4	9 1/2	10 1/4	11 1/4
.100"											7 3/4	8 1/4	8 3/4	9 3/4	10 3/4
.125"												6 1/2	7	7 3/4	8 3/4

APPENDIX 10-9

2024-W Aluminum - Unstable - 2,000 psi

Sheet Thick.	Bend Radius (inches)												
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	3 3/4	4 1/4	4 1/2	5 1/2	6 1/4	7 1/4	8	8 3/4	9 1/4	10	10 3/4		
.020"	3 1/2	4	4 1/2	5 1/4	6	6 3/4	7 1/2	8 1/4	9	9 1/2	10		
.025"	3 1/4	3 3/4	4 1/4	5	5 3/4	6 1/2	7	7 3/4	8 1/2	9	9 1/2	10	
.032"	3	3 1/2	4	4 3/4	5 1/2	6	6 3/4	7 1/4	8	8 1/2	9	9 1/2	10
.036"	3	3 1/4	3 3/4	4 1/2	5	5 3/4	6 1/4	7	7 1/2	8	8 1/2	9	9 1/4
.040"		3	3 1/2	4 1/4	4 3/4	5 1/4	6	6 1/2	7	7 1/2	8	8 1/4	8 3/4
.045"			3 1/4	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/2	7 3/4	8 1/4
.050"			3	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 1/2	7	7 1/2	7 3/4
.056"			2 3/4	3 1/2	4	4 1/2	5	5 1/2	5 3/4	6 1/4	6 1/2	7	7 1/4
.063"				3 1/4	3 3/4	4	4 1/2	5	5 1/2	5 3/4	6	6 1/2	6 3/4
.071"				3	3 1/2	4	4 1/4	4 1/2	5	5 1/4	5 3/4	6	6 1/4
.080"				2 3/4	3 1/4	3 1/2	4	4 1/4	4 1/2	5	5 1/4	5 1/2	5 3/4
.090"					2 3/4	3 1/4	3 1/2	4	4 1/4	4 1/2	4 3/4	5	5 1/4
.100"					2 1/2	3	3 1/4	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4
.125"						2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 1/2	3 3/4

3,000, 4,000, & 5,000 psi same as 2,000 psi

2024-W Aluminum - Unstable - 10,000 psi

Sheet Thick.	Bend Radius (inches)												
	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.016"	$3\frac{1}{2}$	4	$4\frac{1}{4}$	$5\frac{1}{4}$	6	7	$7\frac{3}{4}$	$8\frac{1}{2}$	9	$9\frac{3}{4}$	$10\frac{1}{2}$		
.020"	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	5	$5\frac{3}{4}$	$6\frac{1}{2}$	$7\frac{1}{4}$	8	$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$	
.025"	3	$3\frac{1}{2}$	4	$4\frac{3}{4}$	$5\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{2}$	$8\frac{1}{4}$	$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{4}$
.032"	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{2}$	7	$7\frac{3}{4}$	$8\frac{1}{4}$	$8\frac{3}{4}$	$9\frac{1}{4}$	$9\frac{3}{4}$
.036"	$2\frac{3}{4}$	3	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{2}$	6	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{3}{4}$	$8\frac{1}{4}$	$8\frac{3}{4}$	9
.040"		$2\frac{3}{4}$	$3\frac{1}{4}$	4	$4\frac{1}{2}$	5	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{3}{4}$	8	$8\frac{1}{2}$
.045"			3	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{1}{2}$	8
.050"			$2\frac{3}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{1}{2}$
.056"			$2\frac{1}{2}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	6	$6\frac{1}{2}$	$6\frac{3}{4}$	7
.063"				3	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{1}{2}$
.071"				$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	$5\frac{3}{4}$	6
.080"				$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$
.090"					$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5
.100"					$2\frac{1}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$
.125"						2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$

2024-W Aluminum - Unstable - 20,000 psi

Sheet Thick.	Bend Radius (inches)												
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	3 1/4	3 3/4	4 1/4	5	5 3/4	6 3/2	7 1/2	8 1/4	8 3/4	9 1/2	10 1/4	10 3/4	11 1/2
.020"	3	3 1/2	4	4 3/4	5 1/2	6 3/4	7	7 3/4	8 1/2	9	9 1/2	10 1/4	10 3/4
.025"	2 3/4	3 1/4	3 3/4	4 1/2	5 1/4	6	6 1/2	7 1/4	8	8 1/2	9	9 1/2	10
.032"	2 1/2	3	3 1/2	4 1/4	5	5 1/2	6 1/4	6 3/4	7 1/2	8	8 1/2	9	9 1/2
.036"		2 3/4	3 1/4	4	4 1/2	5 1/4	5 3/4	6 1/2	7	7 1/2	8	8 1/4	8 3/4
.040"		2 1/2	3	3 3/4	4 1/4	4 3/4	5 1/2	6	6 1/2	7	7 1/2	7 3/4	8 1/4
.045"			2 3/4	3 1/2	4	4 1/2	5	5 1/2	6	6 1/2	7	7 1/4	7 3/4
.050"				3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6	6 1/2	7	7 1/4
.056"				3	3 1/2	4	4 1/2	5	5 1/4	5 3/4	6	6 1/2	6 3/4
.063"				2 3/4	3 1/4	3 3/4	4	4 1/2	5	5 1/4	5 1/2	6	6 1/4
.071"				2 1/2	3	3 1/2	3 3/4	4	4 1/2	4 3/4	5 1/4	5 1/2	5 3/4
.080"					2 3/4	3	3 1/2	3 3/4	4	4 1/2	4 3/4	5	5 1/4
.090"					2 1/4	2 3/4	3	3 1/2	3 3/4	4	4 1/4	4 1/2	4 3/4
.100"					2	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4	4	4 1/4
.125"						1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2

APPENDIX 10-10

2024-O Aluminum - 2,000 psi

Sheet Thick.	Bend Radius (inches)													
	$^1/_{64}$	$^1/_{32}$	$^3/_{64}$	$^1/_{16}$	$^3/_{32}$	$^1/_8$	$^5/_{32}$	$^3/_{16}$	$^7/_{32}$	$^1/_4$	$^9/_{32}$	$^5/_{16}$	$^{11}/_{32}$	$^3/_8$
.016"	$2^1/_4$	$2^1/_2$	$2^1/_2$	$2^3/_4$	$3^1/_4$	$3^1/_2$	4	$4^1/_2$	5	$5^1/_4$	$5^3/_4$	$6^1/_4$	$6^3/_4$	$7^1/_4$
.020"	2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^3/_4$	$5^1/_4$	$5^3/_4$	6	$6^1/_2$	7
.025"		$2^1/_4$	$2^1/_4$	$2^1/_2$	3	$3^1/_4$	$3^3/_4$	4	$4^1/_2$	5	$5^1/_2$	$5^3/_4$	$6^1/_4$	$6^3/_4$
.032"		2	$2^1/_4$	$2^1/_2$	$2^3/_4$	$3^1/_4$	$3^1/_2$	4	$4^1/_4$	$4^3/_4$	$5^1/_4$	$5^3/_4$	6	$6^1/_2$
.036"		2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^3/_4$	5	$5^1/_2$	$5^3/_4$	$6^1/_4$
.040"		2	$2^1/_4$	$2^1/_4$	$2^1/_2$	3	$3^1/_4$	$3^3/_4$	4	$4^1/_2$	$4^3/_4$	$5^1/_4$	$5^1/_2$	6
.045"			2	$2^1/_4$	$2^1/_2$	$2^3/_4$	$3^1/_4$	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^1/_2$	5	$5^1/_4$	$5^3/_4$
.050"			2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^3/_4$	4	$4^1/_2$	$4^3/_4$	$5^1/_4$	$5^1/_2$
.056"				2	$2^1/_4$	$2^1/_2$	3	$3^1/_4$	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^1/_2$	5	$5^1/_4$
.063"				2	$2^1/_4$	$2^1/_2$	$2^3/_4$	$2^3/_4$	$3^1/_4$	$3^3/_4$	4	$4^1/_4$	$4^3/_4$	5
.071"				$1^3/_4$	2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^1/_2$	$3^3/_4$	$4^1/_4$	$4^1/_2$
.080"					$1^3/_4$	2	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^1/_2$	$3^3/_4$	4
.090"					$1^3/_4$	$1^3/_4$	2	$2^1/_4$	$2^1/_4$	$2^1/_2$	$2^3/_4$	3	$3^1/_4$	$3^1/_2$
.100"					$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^3/_4$	2	$2^1/_4$	$2^1/_2$	$2^1/_2$	$2^3/_4$	3
.125"						$1^1/_4$	$1^1/_4$	$1^1/_4$	$1^1/_2$	$1^1/_2$	$1^1/_2$	$1^3/_4$	$1^3/_4$	2

3,000, 4,000, & 5,000 psi same as 2,000 psi

DETAIL TOOL 20

2024-O Aluminum - 10,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	2	2 1/4	2 1/4	2 1/2	3	3 1/4	3 3/4	4 1/4	4 3/4	5	5 1/2	6	6 1/2	7
.020"	1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/2	5	5 1/2	5 3/4	6 1/4	6 3/4
.025"		2	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 3/4	5 1/4	5 1/2	6	6 1/2
.032"		1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 3/4	4	4 1/2	5	5 1/2	5 3/4	6 1/4
.036"		1 3/4	2	2 1/4	2 1/2	2 3/4	3 1/4	3 1/2	4	4 1/2	4 3/4	5 1/4	5 1/2	6
.040"		1 3/4	2	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	5	5 1/4	5 3/4
.045"			1 3/4	2	2 1/4	2 1/2	3	3 1/4	3 1/2	4	4 1/4	4 3/4	5	5 1/2
.050"			1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/2	3 3/4	4 1/4	4 1/2	5	5 1/4
.056"				1 3/4	2	2 1/4	2 3/4	3	3 1/4	3 1/2	4	4 1/4	4 3/4	5
.063"				1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/2	3 3/4	4	4 1/2	4 3/4
.071"				1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	4	4 1/4
.080"					1 1/2	1 3/4	2	2 1/4	2 1/2	2 3/4	3	3 1/4	3 1/2	3 3/4
.090"					1 1/2	1 1/2	1 3/4	2	2	2 1/4	2 1/2	2 3/4	3	3 1/4
.100"					1 1/4	1 1/4	1 1/2	1 1/2	1 3/4	2	2 1/4	2 1/4	2 1/2	2 3/4
.125"						1	1	1	1 1/4	1 1/4	1 1/4	1 1/2	1 1/2	1 3/4

DETAIL TOOL 20

2024-W Aluminum - Unstable - 20,000 psi

Sheet Thick.	Bend Radius (inches)													
	$\frac{1}{64}$	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.016"	$1\frac{3}{4}$	2	2	$2\frac{1}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$
.020"	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	6	$6\frac{1}{2}$
.025"	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$
.032"	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$	6
.036"		$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{1}{2}$	5	$5\frac{1}{4}$	$5\frac{3}{4}$
.040"		$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$
.045"			$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$	$5\frac{1}{4}$
.050"			$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5
.056"				$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$
.063"				$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{1}{2}$
.071"				$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4
.080"					$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$
.090"					$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3
.100"					1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	2	$2\frac{1}{4}$	$2\frac{1}{2}$
.125"						$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$	1	1	1	$1\frac{1}{4}$	$1\frac{1}{4}$	$1\frac{1}{2}$

APPENDIX 10-11

2024-T3 Aluminum - 2,000 psi

Sheet Thick.	Bend Radius (inches)													
	$^3/_{64}$	$^1/_{16}$	$^3/_{32}$	$^1/_8$	$^5/_{32}$	$^3/_{16}$	$^7/_{32}$	$^1/_4$	$^9/_{32}$	$^5/_{16}$	$^{11}/_{32}$	$^3/_8$	$^7/_{16}$	$^1/_2$
.016"	$7^1/_2$	9	$11^3/_4$	$14^1/_2$	$17^1/_2$	$19^1/_2$	24	$27^3/_4$						
.020"		$7^1/_2$	$10^1/_4$	$12^1/_2$	$15^1/_4$	$17^1/_2$	$20^1/_2$	$23^1/_2$						
.025"			$8^3/_4$	$10^3/_4$	13	$15^1/_4$	$17^1/_2$	20	$22^1/_4$					
.032"			8	$9^1/_2$	$11^1/_2$	$13^1/_2$	$15^1/_4$	$17^1/_4$	19	$20^1/_2$				
.036"				9	$10^3/_4$	$12^1/_4$	$14^1/_4$	$15^3/_4$	$17^1/_4$	19	$20^1/_2$			
.040"				$8^1/_2$	10	$11^1/_2$	13	$14^1/_2$	$15^3/_4$	$17^1/_4$	$18^1/_2$	20	$22^1/_4$	
.045"					9	$10^1/_2$	12	$13^1/_4$	$14^1/_2$	$15^3/_4$	$17^1/_4$	$18^1/_4$	$20^3/_4$	
.050"					$8^1/_2$	$9^3/_4$	11	$12^1/_4$	$13^1/_2$	$14^1/_2$	$15^3/_4$	17	$19^1/_4$	$21^1/_2$
.056"						9	$10^1/_4$	$11^1/_4$	$12^3/_4$	$13^1/_2$	$14^3/_4$	$15^3/_4$	$17^3/_4$	20
.063"							$9^1/_4$	$10^1/_2$	$10^1/_2$	$12^3/_4$	$13^1/_2$	$14^1/_2$	$16^1/_2$	$18^1/_2$
.071"							$8^3/_4$	$9^3/_4$	$10^1/_4$	$11^3/_4$	$12^3/_4$	$13^1/_2$	$15^1/_2$	$17^1/_4$
.080"								$9^1/_4$	$10^1/_4$	11	$11^3/_4$	$12^3/_4$	$14^1/_4$	$15^3/_4$
.090"									$9^1/_2$	$10^1/_2$	11	$11^3/_4$	$13^1/_4$	$14^1/_2$
.100"										$9^3/_4$	$10^1/_2$	11	12	$13^1/_4$
.125"											9	$9^3/_4$	$10^3/_4$	$11^3/_4$

2024-T3 Aluminum - 10,000 psi

Sheet Thick.	Bend Radius (inches)													
	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
.016"	$6\frac{1}{2}$	8	$10\frac{3}{4}$	$13\frac{1}{2}$	$16\frac{1}{2}$	$19\frac{3}{4}$	23	$26\frac{3}{4}$						
.020"		$6\frac{1}{2}$	$9\frac{1}{4}$	$11\frac{1}{2}$	$14\frac{1}{4}$	$16\frac{1}{2}$	$19\frac{1}{2}$	$22\frac{1}{2}$						
.025"			$7\frac{3}{4}$	$9\frac{3}{4}$	12	$14\frac{1}{4}$	$16\frac{1}{2}$	19	$21\frac{1}{4}$					
.032"			7	$8\frac{1}{2}$	$10\frac{3}{4}$	$12\frac{1}{2}$	$14\frac{1}{4}$	$16\frac{1}{4}$	18	$19\frac{1}{2}$				
.036"				8	$9\frac{3}{4}$	$11\frac{1}{4}$	$13\frac{1}{4}$	$14\frac{3}{4}$	$16\frac{1}{4}$	18	$19\frac{1}{2}$			
.040"				$7\frac{1}{2}$	9	$10\frac{1}{2}$	12	$13\frac{1}{2}$	$14\frac{3}{4}$	$16\frac{1}{4}$	$17\frac{1}{2}$	19	$21\frac{1}{4}$	
.045"					8	$9\frac{1}{2}$	11	$12\frac{1}{4}$	$13\frac{1}{2}$	$14\frac{3}{4}$	$16\frac{1}{4}$	$17\frac{1}{4}$	$19\frac{3}{4}$	22
.050"					$7\frac{1}{2}$	$8\frac{3}{4}$	10	$11\frac{1}{4}$	$12\frac{1}{2}$	$13\frac{1}{2}$	$14\frac{3}{4}$	16	$18\frac{1}{4}$	$20\frac{1}{2}$
.056"						8	$9\frac{1}{4}$	$10\frac{1}{4}$	$11\frac{3}{4}$	$12\frac{1}{2}$	$13\frac{3}{4}$	$14\frac{3}{4}$	$16\frac{3}{4}$	19
.063"							$8\frac{1}{4}$	$9\frac{1}{2}$	$10\frac{1}{2}$	$11\frac{3}{4}$	$12\frac{1}{2}$	$13\frac{1}{2}$	$15\frac{1}{2}$	$17\frac{1}{2}$
.071"							$7\frac{3}{4}$	$8\frac{3}{4}$	$9\frac{3}{4}$	$10\frac{3}{4}$	$11\frac{3}{4}$	$12\frac{1}{2}$	$14\frac{1}{2}$	$16\frac{1}{4}$
.080"								$8\frac{1}{4}$	$9\frac{1}{4}$	10	$10\frac{3}{4}$	$11\frac{3}{4}$	$13\frac{1}{4}$	$14\frac{3}{4}$
.090"									$8\frac{1}{2}$	$9\frac{1}{2}$	10	$10\frac{3}{4}$	$12\frac{1}{4}$	$13\frac{1}{2}$
.100"										$8\frac{3}{4}$	$9\frac{1}{2}$	10	11	$12\frac{1}{4}$
.125"											8	$8\frac{3}{4}$	$9\frac{3}{4}$	$10\frac{3}{4}$

2024-T3 Aluminum - 20,000 psi

Sheet Thick.	Bend Radius (inches)													
	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$
.016"	$5\frac{1}{2}$	7	$9\frac{3}{4}$	$12\frac{1}{2}$	$15\frac{1}{2}$	$18\frac{3}{4}$	22	$25\frac{3}{4}$						
.020"		$5\frac{1}{2}$	$8\frac{1}{4}$	$10\frac{1}{2}$	$13\frac{1}{4}$	$15\frac{1}{2}$	$18\frac{1}{2}$	$21\frac{1}{2}$						
.025"			$6\frac{3}{4}$	$8\frac{3}{4}$	11	$13\frac{1}{4}$	$15\frac{1}{2}$	18	$20\frac{1}{4}$					
.032"			6	$7\frac{1}{2}$	$9\frac{1}{2}$	$11\frac{1}{2}$	$13\frac{1}{4}$	$15\frac{1}{4}$	17	$18\frac{1}{2}$				
.036"				7	$8\frac{3}{4}$	$10\frac{1}{4}$	$12\frac{1}{4}$	$13\frac{3}{4}$	$15\frac{1}{4}$	17	$18\frac{1}{2}$			
.040"				$6\frac{1}{2}$	8	$9\frac{1}{2}$	11	$12\frac{1}{2}$	$13\frac{3}{4}$	$15\frac{1}{4}$	$16\frac{1}{2}$	18	$20\frac{1}{4}$	
.045"					7	$8\frac{1}{2}$	10	$11\frac{1}{4}$	$12\frac{1}{2}$	$13\frac{3}{4}$	$15\frac{1}{4}$	$16\frac{1}{4}$	$18\frac{3}{4}$	21
.050"					$6\frac{1}{2}$	$7\frac{3}{4}$	9	$10\frac{1}{4}$	$11\frac{1}{2}$	$12\frac{1}{2}$	$13\frac{3}{4}$	15	$17\frac{1}{4}$	$19\frac{1}{2}$
.056"						7	$8\frac{1}{4}$	$9\frac{1}{4}$	$10\frac{3}{4}$	$11\frac{1}{2}$	$12\frac{3}{4}$	$13\frac{3}{4}$	$15\frac{3}{4}$	18
.063"							$7\frac{1}{4}$	$8\frac{1}{2}$	$9\frac{1}{2}$	$10\frac{3}{4}$	$11\frac{1}{2}$	$12\frac{1}{2}$	$14\frac{1}{2}$	$16\frac{1}{2}$
.071"							$6\frac{3}{4}$	$7\frac{3}{4}$	$8\frac{3}{4}$	$9\frac{3}{4}$	$10\frac{3}{4}$	$11\frac{1}{2}$	$13\frac{1}{2}$	$15\frac{1}{4}$
.080"								$7\frac{1}{4}$	$8\frac{1}{4}$	9	$9\frac{3}{4}$	$10\frac{3}{4}$	$12\frac{1}{4}$	$13\frac{3}{4}$
.090"									$7\frac{1}{2}$	$8\frac{1}{2}$	9	$9\frac{3}{4}$	$11\frac{1}{4}$	$12\frac{1}{2}$
.100"										$7\frac{3}{4}$	$8\frac{1}{2}$	9	10	$11\frac{1}{4}$
.125"											7	$7\frac{3}{4}$	$8\frac{3}{4}$	$9\frac{3}{4}$

APPENDIX 10-12

7075-W Aluminum - Unstable - 2,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	4	4 1/2	5	5 1/2	6 1/4	7	8	8 3/4	9 1/2	10				
.020"		4 1/4	4 3/4	5 1/4	6	6 3/4	7 1/2	8 1/4	9	9 3/4	10 1/4			
.025"			4 1/2	5	5 3/4	6 1/2	7 1/4	7 3/4	8 1/2	9 1/4	9 3/4	10 1/4		
.032"			4 1/4	4 3/4	5 1/2	6 1/4	6 3/4	7 1/2	8	8 3/4	9 1/4	9 3/4	10 1/4	
.036"				4 1/2	5 1/4	5 3/4	6 1/2	7	7 3/4	8 1/4	8 3/4	9 1/4	9 3/4	
.040"				4 1/4	5	5 1/2	6	6 3/4	7 1/4	7 3/4	8 1/4	8 3/4	9	
.045"					4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7 1/4	7 3/4	8 1/4	8 1/2	
.050"					4 1/2	5	5 1/2	6	6 1/2	7	7 1/4	7 3/4	8 1/4	8 1/2
.056"						4 3/4	5 1/4	5 3/4	6 1/4	6 1/2	7	7 1/4	7 3/4	8
.063"						4 1/2	4 3/4	5 1/4	5 3/4	6 1/4	6 1/2	6 3/4	7 1/4	7 1/2
.071"							4 1/2	5	5 1/4	5 3/4	6	6 1/2	6 3/4	7
.080"								4 3/4	5	5 1/4	5 3/4	6	6 1/4	6 1/2
.090"								4 1/4	4 3/4	5	5 1/4	5 1/2	5 3/4	6
.100"									4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2
.125"										3 3/4	4	4 1/4	4 1/4	4 1/2

DETAIL TOOL 20

7075-W Aluminum - Unstable - 10,000 psi

Sheet Thick.	Bend Radius (inches)													
	$\frac{1}{64}$	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.016"	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	5	6	$6\frac{3}{4}$	$7\frac{3}{4}$	$8\frac{1}{2}$	$9\frac{1}{4}$	$9\frac{3}{4}$	$10\frac{1}{2}$			
.020"		4	$4\frac{1}{2}$	5	$5\frac{3}{4}$	$6\frac{1}{2}$	$7\frac{1}{4}$	$7\frac{3}{4}$	$8\frac{3}{4}$	$9\frac{1}{2}$	10	$10\frac{1}{2}$		
.025"			$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{2}$	$6\frac{1}{4}$	7	$7\frac{1}{2}$	$8\frac{1}{4}$	9	$9\frac{1}{2}$	10		
.032"			4	$4\frac{1}{2}$	$5\frac{1}{4}$	6	$6\frac{1}{2}$	$7\frac{1}{4}$	$7\frac{3}{4}$	$8\frac{1}{2}$	9	$9\frac{1}{2}$	10	
.036"				$4\frac{1}{4}$	5	$5\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{2}$	8	$8\frac{1}{2}$	9	$9\frac{1}{2}$	
.040"				4	$4\frac{3}{4}$	$5\frac{1}{4}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{2}$	$8\frac{3}{4}$	$9\frac{1}{4}$
.045"					$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	8	$8\frac{1}{4}$	$8\frac{3}{4}$
.050"					$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$	7	$7\frac{1}{2}$	8	$8\frac{1}{4}$
.056"						$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{4}$	$6\frac{3}{4}$	7	$7\frac{1}{2}$	$7\frac{3}{4}$
.063"						$4\frac{1}{4}$	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{4}$	$6\frac{1}{2}$	7	$7\frac{1}{4}$
.071"							$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{1}{2}$	$6\frac{3}{4}$
.080"								$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{2}$	$5\frac{3}{4}$	6	$6\frac{1}{4}$
.090"								4	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$	$5\frac{1}{2}$	$5\frac{3}{4}$
.100"									4	$4\frac{1}{4}$	$4\frac{1}{2}$	$4\frac{3}{4}$	5	$5\frac{1}{4}$
.125"										$3\frac{1}{2}$	$3\frac{3}{4}$	4	4	$4\frac{1}{4}$

7075-W Aluminum - Unstable - 20,000 psi

Sheet Thick.	Bend Radius (inches)													
	1/64	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	3 1/2	4	4 1/2	5	5 3/4	6 1/2	7 1/2	8 1/4	9	9 1/2				
.020"		3 3/4	4 1/4	4 3/4	5 1/2	6 1/4	7	7 3/4	8 1/2	9 1/4	9 3/4			
.025"			4	4 1/2	5 1/4	6	6 3/4	7 1/4	8	8 3/4	9 1/4	9 3/4		
.032"			3 3/4	4 1/4	5	5 3/4	6 1/4	7	7 1/2	8 1/4	8 3/4	9 1/4	9 3/4	
.036"				4	4 3/4	5 1/4	6	6 1/2	7 1/4	7 3/4	8 1/4	8 3/4	9 1/4	
.040"				3 3/4	4 1/4	5	5 1/2	6 1/4	6 3/4	7 1/4	7 3/4	8 1/4	8 1/2	
.045"					4 1/4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	7 1/4	7 3/4	8	8 1/2
.050"					4	4 1/2	5	5 1/2	6	6 1/2	6 3/4	7 1/4	7 3/4	8
.056"						4 1/4	4 3/4	5 1/4	5 3/4	6	6 1/2	6 3/4	7 1/4	7 1/2
.063"						4	4 1/4	4 3/4	5 1/4	5 3/4	6	6 1/4	6 3/4	7
.071"							4	4 1/2	4 3/4	5 1/4	5 1/2	6	6 1/4	6 1/2
.080"								4 1/4	4 1/2	4 3/4	5 1/4	5 1/2	5 3/4	6
.090"								3 3/4	4 1/4	4 1/2	4 3/4	5	5 1/4	5 1/2
.100"									3 3/4	4	4 1/4	4 1/2	4 3/4	5
.125"										3 1/4	3 1/2	3 3/4	3 3/4	4

APPENDIX 10-13

7075-O Aluminum - 2,000 psi

Sheet Thick.	Bend Radius (inches)												
	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.016"	2	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{3}{4}$	$4\frac{1}{2}$	$5\frac{1}{2}$	$6\frac{1}{4}$	7	$7\frac{1}{2}$	$8\frac{1}{4}$	9		
.020"	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{2}$	$4\frac{1}{4}$	5	$5\frac{3}{4}$	$6\frac{1}{2}$	$7\frac{1}{4}$	$7\frac{3}{4}$	$8\frac{1}{4}$		
.025"	$1\frac{1}{2}$	2	$2\frac{1}{2}$	$3\frac{1}{4}$	4	$4\frac{3}{4}$	$5\frac{1}{4}$	6	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{3}{4}$		
.032"		$1\frac{3}{4}$	$2\frac{1}{4}$	3	$3\frac{3}{4}$	$4\frac{1}{4}$	5	$5\frac{1}{2}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	$7\frac{3}{4}$	
.036"		$1\frac{1}{2}$	2	$2\frac{3}{4}$	$3\frac{1}{4}$	4	$4\frac{1}{2}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{3}{4}$	$7\frac{1}{4}$	
.040"			$1\frac{3}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	$6\frac{1}{4}$	$6\frac{1}{2}$	
.045"			$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	6	
.050"			$1\frac{1}{4}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{3}{4}$	
.056"				$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$	$5\frac{1}{4}$	$5\frac{1}{2}$
.063"				$1\frac{1}{2}$	2	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$	$4\frac{3}{4}$	5
.071"					$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	4	$4\frac{1}{4}$	$4\frac{1}{2}$
.080"					$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$	4
.090"						$1\frac{1}{2}$	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$
.100"							$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3
.125"							$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	$1\frac{3}{4}$	2

7075-O Aluminum - 10,000 psi

Sheet Thick.	Bend Radius (inches)												
	$\frac{1}{32}$	$\frac{3}{64}$	$\frac{1}{16}$	$\frac{3}{32}$	$\frac{1}{8}$	$\frac{5}{32}$	$\frac{3}{16}$	$\frac{7}{32}$	$\frac{1}{4}$	$\frac{9}{32}$	$\frac{5}{16}$	$\frac{11}{32}$	$\frac{3}{8}$
.016"	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{1}{2}$	$3\frac{1}{2}$	$4\frac{1}{4}$	$5\frac{1}{4}$	6	$6\frac{3}{4}$	$7\frac{1}{4}$	8	$8\frac{3}{4}$		
.020"	$1\frac{1}{2}$	2	$2\frac{1}{2}$	$3\frac{1}{4}$	4	$4\frac{1}{4}$	$5\frac{1}{2}$	$6\frac{1}{4}$	7	$7\frac{1}{2}$	8		
.025"	$1\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{4}$	3	$3\frac{3}{4}$	$4\frac{1}{2}$	5	$5\frac{3}{4}$	$6\frac{1}{2}$	7	$7\frac{1}{2}$		
.032"		$1\frac{1}{2}$	2	$2\frac{3}{4}$	$3\frac{1}{2}$	4	$4\frac{3}{4}$	$5\frac{1}{4}$	6	$6\frac{1}{2}$	7	$7\frac{1}{2}$	
.036"		$1\frac{1}{4}$	$1\frac{3}{4}$	$2\frac{1}{2}$	3	$3\frac{3}{4}$	$4\frac{1}{4}$	5	$5\frac{1}{2}$	6	$6\frac{1}{2}$	7	
.040"			$1\frac{1}{2}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	6	$6\frac{1}{4}$	
.045"			$1\frac{1}{4}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5	$5\frac{1}{2}$	$5\frac{3}{4}$	
.050"			1	$1\frac{3}{4}$	$2\frac{1}{4}$	$2\frac{3}{4}$	$3\frac{1}{4}$	$3\frac{3}{4}$	$4\frac{1}{4}$	$4\frac{1}{2}$	5	$5\frac{1}{2}$	
.056"				$1\frac{1}{2}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	5	$5\frac{1}{4}$
.063"				$1\frac{1}{4}$	$1\frac{3}{4}$	2	$2\frac{1}{2}$	3	$3\frac{1}{2}$	$3\frac{3}{4}$	4	$4\frac{1}{2}$	$4\frac{3}{4}$
.071"					$1\frac{1}{2}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{3}{4}$	4	$4\frac{1}{4}$
.080"					$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{4}$	$3\frac{1}{2}$	$3\frac{3}{4}$
.090"						$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$	3	$3\frac{1}{4}$
.100"							$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{3}{4}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	$2\frac{3}{4}$
.125"							$\frac{1}{2}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{3}{4}$

7075-O Aluminum - 20,000 psi

Sheet Thick.	Bend Radius (inches)												
	1/32	3/64	1/16	3/32	1/8	5/32	3/16	7/32	1/4	9/32	5/16	11/32	3/8
.016"	1 1/2	2	2 1/2	3 1/4	4	5	5 3/4	6 1/2	7	7 3/4	8 1/2		
.020"	1 1/4	1 3/4	2 1/4	3 1/4	3 3/4	4 1/2	5 1/4	6	6 3/4	7 1/4	7 3/4		
.025"	1	1 1/2	2	2 3/4	3 1/2	4 1/4	4 3/4	5 1/2	6 1/4	6 3/4	7 1/4		
.032"		1 1/4	1 3/4	2 1/2	3 1/4	3 3/4	4 1/2	5	5 3/4	6 1/4	6 3/4	7 1/4	
.036"		1	1 1/2	2 1/4	2 3/4	3 1/2	4	4 3/4	5 1/4	5 3/4	6 1/4	6 3/4	
.040"			1 1/4	2	2 1/2	3	3 3/4	4 1/4	4 3/4	5 1/4	5 3/4	6	
.045"			1	1 3/4	2 1/4	2 3/4	3 1/4	3 3/4	4 1/4	4 3/4	5 1/4	5 1/2	
.050"			3/4	1 1/2	2	2 1/2	3	3 1/2	4	4 1/4	4 3/4	5 1/4	
.056"				1 1/4	1 3/4	2 1/4	2 3/4	3 1/4	3 1/2	4	4 1/4	4 3/4	5
.063"				1	1 1/2	1 3/4	2 1/4	2 3/4	3 1/4	3 1/2	3 3/4	4 1/4	4 1/2
.071"					1 1/4	1 1/2	2	2 1/4	2 3/4	3	3 1/2	3 3/4	4
.080"					1	1 1/4	1 3/4	2	2 1/4	2 3/4	3	3 1/4	3 1/2
.090"						1	1 1/4	1 3/4	2	2 1/4	2 1/2	2 3/4	3
.100"							1	1 1/4	1 1/2	1 3/4	2	2 1/4	2 1/2
.125"							1/4	1/2	3/4	1	1 1/4	1 1/2	1 3/4

APPENDIX 10-14

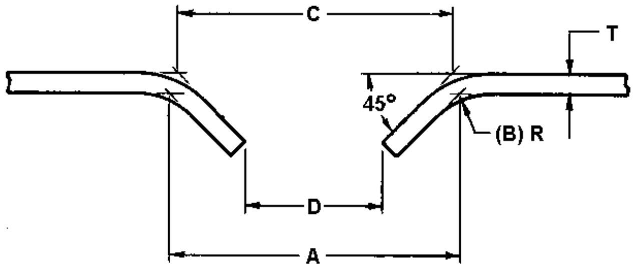
Springback Correction Factors for Angles other than 90° (0° to 135°)

Open Angles				Closed Angles	
Degree of Bend	Factor	Degree of Bend	Factor	Degree of Bend	Factor
0°	.00	90°	1.00	90°	1.00
1°	.01	89°	.99	91°	1.01
2°	.02	88°	.98	92°	1.02
3°	.03	87°	.97	93°	1.03
4°	.04	86°	.96	94°	1.04
5°	.06	85°	.94	95°	1.06
6°	.07	84°	.93	96°	1.07
7°	.08	83°	.92	97°	1.08
8°	.09	82°	.91	98°	1.09
9°	.10	81°	.90	99°	1.10
10°	.11	80°	.89	100°	1.11
11°	.12	79°	.88	101°	1.12
12°	.13	78°	.87	102°	1.13
13°	.14	77°	.86	103°	1.14
14°	.16	76°	.84	104°	1.16
15°	.17	75°	.83	105°	1.17
16°	.18	74°	.82	106°	1.18
17°	.19	73°	.81	107°	1.19
18°	.20	72°	.80	108°	1.20
19°	.21	71°	.79	109°	1.21
20°	.22	70°	.78	110°	1.22
21°	.23	69°	.77	111°	1.23
22°	.24	68°	.76	112°	1.24
23°	.26	67°	.74	113°	1.26
24°	.27	66°	.73	114°	1.27
25°	.28	65°	.72	115°	1.28
26°	.29	64°	.71	116°	1.29
27°	.30	63°	.70	117°	1.30
28°	.31	62°	.69	118°	1.31
29°	.32	61°	.68	119°	1.32
30°	.33	60°	.67	120°	1.33
31°	.34	59°	.66	121°	1.34
32°	.36	58°	.64	122°	1.36
33°	.37	57°	.63	123°	1.37
34°	.38	56°	.62	124°	1.38
35°	.39	55°	.61	125°	1.39
36°	.40	54°	.60	126°	1.40
37°	.41	53°	.59	127°	1.41
38°	.42	52°	.58	128°	1.42
39°	.43	51°	.57	129°	1.43
40°	.44	50°	.56	130°	1.44
41°	.46	49°	.54	131°	1.46
42°	.47	48°	.53	132°	1.47
43°	.48	47°	.52	133°	1.48
44°	.49	46°	.51	134°	1.49
45°	.50	45°	.50	135°	1.50

EXAMPLE: 7075-O aluminum, .040 thick, $^{3}/_{16}$ bend radius, 10° closed angle. Springback for 90° (from chart) = $4^{1}/_{4}$°.
Factor for 10° (from chart) = 1.11. 1.11 x $4^{1}/_{4}$° = $4^{3}/_{4}$°.

APPENDIX 11

Form Block Diameters for Lightening Holes



D = Diameter of Routed Hole
C = Outside Mold Line diameter
A = Form Block Diameter

			Form Block Diameters						
			Material Thickness						
			.020	**.032**	**.040**	**.051**	**.064**	**.081**	**.091**
			Bend Radius *						
GAH11F	**D**	**C**	$^1/_{16}$	$^3/_{32}$	$^1/_8$	$^3/_{16}$	$^7/_{32}$	$^9/_{32}$	$^{11}/_{32}$
-6	0.750	$1^1/_8$	1.141	1.151	1.158	1.167	1.178	1.192	1.200
-7	0.875	$1^1/_4$	1.266	1.276	1.283	1.292	1.303	1.317	1.325
-10	1.000	$1^3/_8$	1.391	1.401	1.408	1.417	1.428	1.442	1.450
-11	1.125	$1^1/_2$	1.516	1.526	1.533	1.542	1.553	1.570	1.578
-12	1.250	$1^5/_8$	1.641	1.651	1.658	1.667	1.678	1.692	1.700
-13	1.375	$1^3/_4$	1.766	1.776	1.783	1.792	1.803	1.817	1.825
-14	1.500	$1^7/_8$	1.891	1.901	1.908	1.917	1.928	1.942	1.950
-15	1.625	2	2.016	2.026	2.033	2.042	2.053	2.067	2.075
-16	1.750	$2^1/_8$	2.141	2.151	2.158	2.167	2.178	2.192	2.200
-17	1.875	$2^1/_4$	2.266	2.276	2.283	2.292	2.303	2.317	2.325
-20	2.000	$2^3/_8$	2.391	2.401	2.408	2.417	2.428	2.442	2.450
-22	2.250	$2^3/_4$	2.766	2.776	2.783	2.792	2.803	2.817	2.825
-24	2.500	3	3.016	3.026	3.033	3.042	3.053	3.067	3.075
-26	2.750	$3^1/_4$	3.266	3.276	3.283	3.292	3.303	3.317	3.325
-30	3.000	$3^1/_2$	3.516	3.526	3.533	3.542	3.553	3.567	3.575
-32	3.250	$3^3/_4$	3.766	3.776	3.783	3.792	3.803	3.817	3.825
-34	3.500	4	4.016	4.026	4.033	4.042	4.053	4.067	4.075
-36	3.750	$4^1/_4$	4.266	4.276	4.283	4.292	4.303	4.317	4.325
-40	4.000	$4^1/_2$	4.516	4.526	4.533	4.542	4.553	4.567	4.575
-44	4.500	5	5.016	5.026	5.033	5.042	5.053	5.067	5.075
-50	5.000	$5^1/_2$	5.516	5.526	5.533	5.542	5.553	5.567	5.575
-60	6.000	$6^1/_2$	6.516	6.526	6.533	6.542	6.553	6.567	6.575

* Radius for all aluminum alloy tempers except 7075-T6

Material Thickness	.020	.032	.040	.051	.064	.081	.091
Radius for 7075-T6	$^3/_{32}$	$^5/_{32}$	$^3/_{16}$	$^1/_4$	$^5/_{16}$	$^3/_8$	$^1/_2$

APPENDIX 13

Minimum Bend Radii for Aluminum Alloy Sheet
Straight or Slightly Curved Bends from 0° to 110°

ALLOY / GAGE	3003-0 5052-0 6061-0	2014-0 2024-0 2219-0 6061-T4	7075-0 7178-0	2014-W 2024-W 2219-W	7075-W 7178-W	2014-T3 6061-T6	2024-T3 2219-T31	2014-T6 2024-T81 2219-T81	7075-T6 7178-T6	ALLOY / GAGE
.016	.031	.031	.047	.047	.047	.062	.062	.078	.094	.016
.020	.031	.031	.047	.047	.047	.062	.062	.078	.11	.020
.024	.031	.031	.047	.047	.062	.062	.078	.11	.12	.024
.028	.031	.047	.062	.062	.078	.062	.094	.11	.14	.028
.032	.031	.047	.062	.078	.078	.078	.11	.14	.16	.032
.036	.047	.047	.078	.078	.094	.078	.12	.16	.19	.036
.040	.047	.062	.078	.094	.11	.094	.14	.17	.22	.040
.045	.047	.062	.094	.11	.11	.11	.16	.19	.25	.045
.050	.047	.078	.11	.11	.12	.12	.17	.22	.28	.050
.056	.062	.078	.12	.14	.14	.14	.19	.25	.31	.056
.063	.062	.094	.14	.16	.16	.16	.22	.28	.34	.063
.071	.078	.11	.16	.17	.19	.19	.25	.33	.41	.071
.080	.078	.12	.17	.19	.22	.20	.28	.38	.44	.080
.090	.094	.14	.20	.22	.23	.25	.34	.44	.53	.090
.100	.11	.16	.22	.25	.25	.28	.38	.50	.59	.100
.125	.12	.19	.28	.31	.34	.38	.50	.62	.75	.125
.160	.16	.25	.38	.41	.44	.53	.66	.83	1.00	.160
.190	.19	.28	.47	.50	.56	.66	.84	1.03	1.25	.190

Tolerance shall be as per standard drawing format.
± .010 for 3 place decimals and ± .03 for 2 place decimals.

APPENDIX 14

Table of Minimum Bend Radii for Steel Sheet

For Bends of 90° ± 10°

STAINLESS STEEL		
Gage	**Annealed**	**1/2 Hard ***
.018	$^{1}/_{32}$	$^{1}/_{16}$
.025	$^{1}/_{32}$	$^{1}/_{16}$
.032	$^{1}/_{16}$	$^{3}/_{32}$
.036	$^{1}/_{16}$	$^{3}/_{32}$
.050	$^{1}/_{16}$	$^{1}/_{8}$
.063	$^{3}/_{32}$	$^{1}/_{8}$
.080	$^{3}/_{32}$	
.095	$^{1}/_{8}$	
.125	$^{3}/_{16}$	

CHROME MOLY & CARBON STEEL	
Gage	**Annealed**
.020	$^{1}/_{32}$
.036	$^{1}/_{16}$
.050	$^{1}/_{16}$
.063	$^{1}/_{16}$
.080	$^{3}/_{32}$
.095	$^{3}/_{32}$
.125	$^{1}/_{8}$
.160	$^{3}/_{16}$
.190	$^{3}/_{16}$

* For bends up to 90° only.

Table of Minimum Bend Radii for Titanium Alloys

Ti Alloy	Tolerances (Parts)		Bend Radius		
	Bend Angle	**Mold Line**	**Thick**	**Hot**	**Cold**
4 Al - 3 Mo - 1V (ST)	± 0°- 30'	± .010 Critical Parts Only	All	N/A	$4\ ^{1}/_{2}$ T
5 Al - 2.5 Sn (Annealed)			Up to .070 .071 - .125	$1\ ^{1}/_{2}$ T 2 T	$4\ ^{1}/_{2}$ T 5 T
6 Al - 4V (Annealed)			Up to .070 .071 - .125	$1\ ^{1}/_{2}$ T 2 T	5 T 6 T
6 Al - 6V - 2 Sn (Annealed)		± .015 All Others	Up to .070 .071 - .125	$1\ ^{1}/_{2}$ T 2 T	5 T $5\ ^{1}/_{2}$ T
8 Mn (Annealed)			Up to .070 .071 - .125	$1\ ^{1}/_{2}$ T 2 T	$3\ ^{1}/_{2}$ T 4 T
Comm. Pure (Annealed)			Up to .070 .071 - .125	$1\ ^{1}/_{2}$ T 2 T	3 T $3\ ^{1}/_{2}$ T

APPENDIX 15-1

Corrected Joggle Depth in PBT's when Joggles are in Open or Closed Flanges

Flange Angle (Deg. Open or Closed)	Joggle Depth Shown on Loft												
	.010	.015	.020	.025	.030	.035	.040	.045	.050	.055	.060	.065	.070
10	.010	.015	.020	.025	.030	.036	.041	.046	.051	.056	.061	.066	.071
15	.010	.016	.021	.026	.031	.036	.041	.047	.052	.057	.062	.067	.072
20	.011	.016	.021	.027	.032	.037	.042	.048	.053	.058	.064	.069	.074
25	.011	.016	.022	.028	.033	.039	.044	.050	.055	.061	.066	.072	.077
30	.012	.017	.023	.029	.035	.040	.046	.052	.058	.064	.069	.075	.081
32	.012	.018	.024	.029	.035	.041	.047	.053	.059	.065	.071	.077	.082
35	.012	.018	.024	.030	.037	.043	.049	.055	.061	.067	.073	.079	.085
38	.013	.019	.025	.032	.038	.044	.051	.057	.063	.070	.076	.082	.089
40	.013	.019	.026	.033	.039	.046	.052	.059	.065	.072	.078	.085	.091
42	.013	.020	.027	.034	.040	.047	.054	.060	.067	.074	.081	.087	.094
45	.014	.021	.028	.035	.042	.049	.056	.064	.071	.078	.085	.092	.099
48	.015	.022	.030	.037	.045	.052	.060	.067	.075	.082	.090	.097	.104
50	.016	.023	.031	.039	.047	.054	.062	.070	.078	.086	.093	.101	.109
52	.016	.024	.032	.041	.049	.057	.065	.073	.081	.089	.097	.106	.114
54	.017	.026	.034	.042	.051	.060	.068	.076	.085	.094	.102	.110	.119
56	.018	.027	.036	.045	.054	.062	.072	.080	.089	.098	.107	.116	.125
58	.019	.028	.038	.047	.057	.066	.075	.085	.094	.104	.113	.123	.132
60	.020	.030	.040	.050	.060	.070	.080	.090	.100	.110	.120	.130	.140
61	.021	.031	.041	.052	.062	.072	.082	.093	.103	.113	.124	.134	.144
62	.021	.032	.042	.053	.064	.074	.085	.096	.106	.117	.128	.138	.149
63	.022	.033	.044	.055	.066	.077	.088	.099	.110	.121	.132	.143	.154
64	.023	.034	.046	.057	.068	.080	.091	.103	.114	.125	.137	.148	.160
65	.024	.035	.047	.059	.071	.083	.095	.106	.118	.130	.142	.154	.166
66	.025	.037	.049	.061	.074	.086	.098	.111	.123	.135	.147	.160	.172
67	.026	.038	.051	.064	.077	.090	.102	.115	.128	.141	.154	.166	.179
68	.027	.040	.053	.067	.080	.093	.107	.120	.133	.147	.160	.173	.187
69	.028	.042	.056	.070	.084	.098	.112	.126	.140	.153	.167	.181	.195
70	.029	.044	.058	.073	.088	.102	.117	.132	.146	.161	.175	.190	.205

Note: 1. For proper use of this Appendix, see SD20.126.

2. When correcting PBT's, use this table first. Then use Appendix 7.

APPENDIX 15-2

Corrected Joggle Depth in PBT's when Joggles are in Open or Closed Flanges

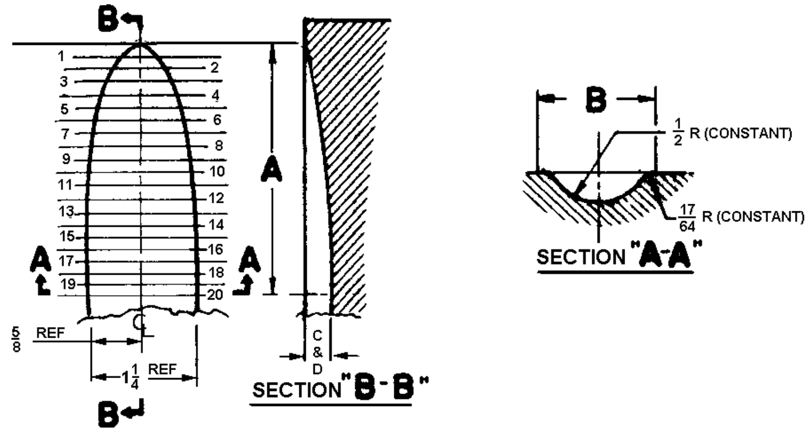
Flange Angle (Deg. Open or Closed)	Joggle Depth Shown on Loft											
	.076	.080	.085	.090	.095	.100	.105	.110	.115	.120	.125	.130
10	.076	.081	.086	.091	.096	.102	.107	.112	.117	.122	.127	.132
15	.078	.083	.088	.093	.098	.104	.109	.114	.119	.124	.129	.134
20	.080	.085	.090	.096	.101	.106	.112	.117	.122	.128	.133	.138
25	.083	.088	.094	.099	.105	.110	.116	.121	.127	.132	.138	.143
30	.087	.092	.098	.104	.110	.116	.121	.127	.133	.139	.144	.150
32	.088	.094	.100	.106	.112	.118	.124	.130	.136	.141	.147	.153
35	.092	.098	.104	.110	.116	.122	.128	.134	.140	.146	.153	.159
38	.095	.102	.108	.114	.120	.127	.133	.140	.146	.152	.159	.165
40	.098	.104	.111	.117	.124	.130	.137	.144	.150	.157	.163	.170
42	.101	.108	.114	.121	.128	.134	.141	.148	.155	.161	.168	.175
45	.106	.113	.120	.127	.134	.141	.148	.156	.163	.170	.177	.184
48	.112	.120	.127	.134	.142	.149	.157	.164	.172	.179	.187	.194
50	.117	.124	.132	.140	.148	.156	.163	.171	.179	.187	.194	.202
52	.122	.130	.138	.146	.154	.162	.170	.179	.187	.195	.203	.211
54	.128	.136	.144	.153	.162	.170	.179	.187	.196	.204	.213	.221
56	.134	.143	.152	.161	.170	.179	.188	.197	.206	.214	.224	.232
58	.142	.151	.160	.170	.179	.189	.198	.208	.217	.226	.236	.245
60	.150	.160	.170	.180	.190	.200	.210	.220	.230	.240	.250	.260
61	.155	.165	.175	.186	.196	.206	.216	.227	.237	.247	.258	.268
62	.160	.170	.181	.192	.202	.213	.224	.234	.245	.255	.266	.277
63	.165	.176	.187	.198	.209	.220	.231	.242	.253	.264	.275	.286
64	.171	.182	.194	.205	.217	.228	.240	.251	.262	.274	.285	.296
65	.177	.189	.201	.213	.225	.237	.248	.260	.272	.284	.296	.308
66	.184	.197	.209	.221	.234	.246	.258	.270	.283	.294	.307	.320
67	.192	.205	.218	.230	.243	.256	.269	.281	.294	.307	.320	.333
68	.200	.214	.227	.240	.254	.267	.280	.294	.307	.320	.334	.347
69	.209	.223	.237	.251	.265	.279	.293	.307	.321	.335	.349	.363
70	.219	.234	.248	.263	.278	.292	.307	.322	.336	.351	.366	.380

Note: 1. For proper use of this Appendix, see SD20.126.

2. When correcting PBT's, use this table first. Then use Appendix 7.

APPENDIX 16-1

Form Block Dimensions for Rubber Press Forming (10,000 psi) of GB 13A, B, C, E Beads



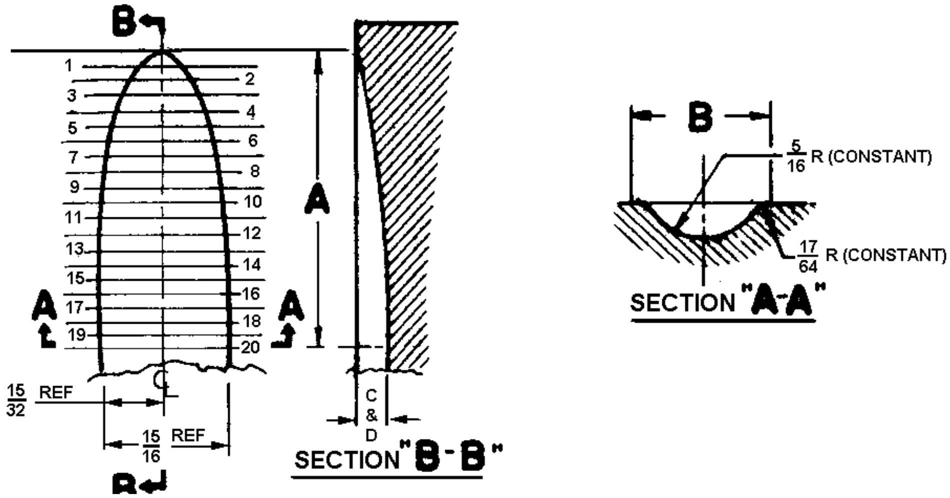
			MATERIAL	
			.050" UP	.016" - .045"
STATION	**A**	**B**	**C**	**D**
0	0	0	0	0
1	.150"	.490"	.035"	.014"
2	.300"	.665"	.077"	.056"
3	.450"	.783"	.107"	.086"
4	.600"	.866"	.135"	.114"
5	.750"	.938"	.160"	.139"
6	.900"	.991"	.182"	.161"
7	1.050"	1.041"	.202"	.181"
8	1.200"	1.079"	.222"	.201"
9	1.350"	1.111"	.242"	.221"
10	1.500"	1.140"	.260"	.239"
11	1.650"	1.165"	.272"	.251"
12	1.800"	1.184"	.282"	.261"
13	1.950"	1.200"	.291"	.270"
14	2.100"	1.213"	.299"	.278"
15	2.250"	1.224"	.306"	.285"
16	2.400"	1.233"	.312"	.291"
17	2.550"	1.240"	.318"	.297"
18	2.700"	1.246"	.323"	.302"
19	2.850"	1.249"	.328"	.307"
20	3.000"	1.250"	.328"	.307"

Note: 1. Tolerance: "A & B" & fractional dimensions $\pm$ .015". "C & D" dimensions + .010" -.000"

2. All dimensions are to the Point of Tangency of Radii.

3. Springback of .015" is included in depths "C & D".

APPENDIX 16-2



			MATERIAL	
			.050" UP	.016" - .045"
STATION	**A**	**B**	**C**	**D**
0	0	0	0	0
1	.075"	.338"	.025"	.004"
2	.150"	.480"	.048"	.027"
3	.225"	.580"	.075"	.054"
4	.300"	.648"	.098"	.077"
5	.375"	.700"	.118"	.097"
6	.450"	.743"	.135"	.114"
7	.525"	.778"	.150"	.129"
8	.600"	.803"	.163"	.142"
9	.675"	.830"	.175"	.154"
10	.750"	.850"	.186"	.165"
11	.825"	.868"	.196"	.175"
12	.900"	.885"	.205"	.184"
13	.975"	.900"	.212"	.191"
14	1.050"	.908"	.217"	.196"
15	1.125"	.915"	.222"	.201"
16	1.200"	.920"	.225"	.204"
17	1.275"	.925"	.228"	.207"
18	1.350"	.930"	.230"	.209"
19	1.425"	.935"	.232"	.211"
20	1.500"	.938"	.234"	.213"

Note: 1. Tolerance: "A & B" & fractional dimensions ± .015"
"C & D" dimensions + .010" -.000"
2. All dimensions are to the Point of Tangency of Radii.
3. Springback of .015" is included in depths "C & D".