BOMBARDIER
Toronto (de Havilland)
PROPRIETARY INFORMATION

PPS 6.01

PRODUCTION PROCESS STANDARD

Fabrication of Rigid Fluid Lines

Issue 26 - This standard supersedes PPS 6.01, Issue 25.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS related questions to PPS.Group@aero.bombardier.com or (416) 375-4365.
- This PPS is effective as of the distribution date.

Prepared By:	(Michael Wright)	November 26, 2013
	Production Process Standards (PPS)	
Approved By:	(L.K. John)	November 27, 2013
	Materials Technology	
	(Adam Gordon)	November 27, 2013
	Quality	

Table of Contents

Sections **Page**

Table of Contents

Tables **Page**

Figures

1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for fabrication of aluminum alloy, copper, corrosion resistant steel (CRES) and titanium rigid fluid lines.

1.2 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS must be followed to ensure compliance with all applicable specifications. In general, if this PPS conflicts with the engineering drawing, follow the engineering drawing. The requirements specified in this PPS are necessary to fulfil the engineering design and reliability objectives.

1.2.1 Refer to PPS 13.26 for the subcontractor provisions applicable to this PPS.

1.2.2 Procedure or requirements specified in a Bombardier BAPS, MPS, LES or P. Spec. **do not** supersede the procedure or requirements specified in this PPS.

2 Hazardous Materials

2.1 Before receipt at Bombardier Toronto (de Havilland), all materials must be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto (de Havilland) Environment, Health and Safety Department. Refer to the manufacturer's MSDS for specific safety data on any of the materials specified in this PPS. If the MSDS is not available, contact the Bombardier Toronto (de Havilland) Environment, Health and Safety Department.

3 References

3.1 PPS 1.06 - Tube Swaging.

3.2 PPS 6.03 - Installation of Aircraft Fluid Lines and Fittings.

3.3 PPS 6.04 - Identification of Fluid System Lines.

3.4 PPS 6.05 - Closure of Fluid Lines and Fluid System Components.

3.5 PPS 6.10 - Cleaning of Fluid System Components.

3.6 PPS 6.12 - Pressure Testing Hydraulic Components, Fuel and Bleed Air Lines.

3.7 PPS 6.13 - Installation of Permaswage Fittings.

3.8 PPS 6.14 - Installation of Wiggins Swaged Connectors.

3.9 PPS 6.20 - Installation of Rynglok fittings.

3.10 PPS 6.21 - Assembly and Installation of Quickfit Fittings.

3.11 PPS 6.23 - Installation of Cryoflare Sleeves/Nuts.

3.12 PPS 13.26 - General Subcontractor Provisions.

3.13 PPS 15.01 - Part Marking.

3.14 PPS 30.01 - Heat Treatment of Aluminum Alloys.

3.15 PPS 31.04 - Degreasing Processes.

3.16 PPS 31.17 - Manual Solvent Cleaning.

3.17 PPS 32.01 - Chemical Conversion Coating of Aluminum Alloys by Immersion.

3.18 PPS 34.08 - Application of Epoxy-Polyamide Primer (F19 and F45).

3.19 PPS 37.03 - Fusion Welding of Aluminum and Aluminum Alloys.

3.20 PPS 37.04 - Fusion Welding of Ferrous and Nickel Alloys.

3.21 PPS 37.07 - Brazing Processes.

3.22 PPS 37.13 - Induction Brazing.

3.23 PPS 37.16 - Orbital Fusion Welding.

4 Materials and Equipment

4.1 Materials

4.1.1 Tube drawing lubricants: oil-based (e.g., Pennwalt DP-1212 or Boelube 70106-04) or water soluble (e.g., Lubegard forming paste).

4.1.2 Cleaning solution (e.g., Produits Chimiques Provost PCP-1001).

4.1.3 Clean wiping cloths (e.g., DSC 378-2).

4.1.4 Polishing material (e.g., Scotch-Brite pads, Type A fine, maroon colour).

4.2 Equipment

4.2.1 Assorted hand or power tools suitable for cutting, bending, beading and flaring tubing used in aircraft systems.

4.2.2 Tube end flare preparation tools for single flare (e.g., TS.271.10.11) and for double flare (e.g., TS.278.02.00 end finishing machine fitted with a TS.278.20.12 tool bit).

4.2.3 Bead checking gauge, (e.g., SD8286).

4.2.4 Flare gauge (e.g., SD12294-1).

5 Procedure

5.1 General

5.1.1 Perform flaring and bending operations in the order which will best facilitate production for the bending equipment being used.

5.1.2 If chemical conversion coating (e.g., alodine) of aluminum alloy tubing is specified on the engineering drawing, apply the coating according to PPS 32.01 after all bending and welding operations. If necessary, it is acceptable to chemical conversion coat double walled tubes before bending. Touch-up chemical conversion coatings if damaged during subsequent operations.

5.1.3 It is acceptable to form tubes using either an oil-based or a water soluble tube drawing lubricant. However, ensure that all equipment to be used with water soluble tube drawing lubricant is clean and free of any and all oil-based contaminants.

5.1.4 Perform the following tests on new tools before use on production parts:

- For bend tooling, bend a test sample to a minimum angle of 90°. The test sample must not crack or wrinkle and must meet the requirements of this PPS.
- For flaring, beading, swaging or end forming tooling, prepare a test sample using the new tooling to ensure it can meet the requirements specified in this PPS and the engineering drawing.

5.2 Preparation of Tubing

5.2.1 Prepare tubing as follows:

Step 1. Using an abrasive saw or hacksaw (32 teeth per inch), cut the tubing to the length specified on the product sheet or assembly manual. The specified length includes allowances for end finishing, bending, flaring, beading, swaging, etc.

Step 2. Using the appropriate end facing equipment, square up the tube ends and deburr. Remove a minimum amount of material from titanium tube ends requiring deburring before orbital welding of end fittings. Ensure that tube ends are square to the axis of the tubing to within ±0.5°.

Step 3. If single or double flaring is to be performed, chamfer and radius the tube ends as shown in Figure 1 or Figure 2 using tube end flare preparation tools as specified in paragraph 4.2.2. CRES parts do not require passivation after chamfering.

Step 4. Remove any metal chips, dirt, etc. from the tube bore, by degreasing according to PPS 31.04 or, if required, clean as specified in PPS 6.10.

Step 5. If installing MS9483 brazed fittings, size the tube end by swaging according to PPS 1.06 to the dimensions specified on the engineering drawing.

Step 6. If the engineering drawing specifies chemical conversion coating of aluminum tubing, perform chemical conversion coating according to PPS 32.01 before flaring.

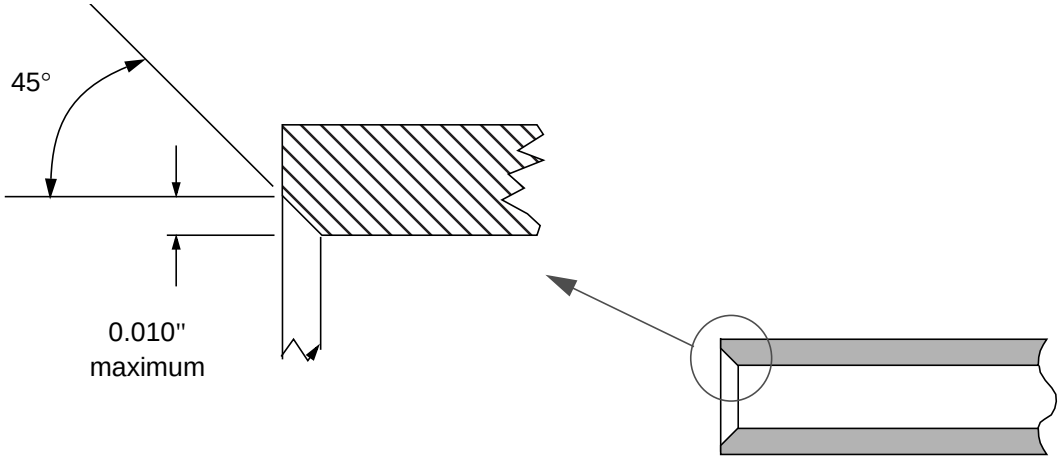


Figure 1 - Tube End Preparation for Single Flaring

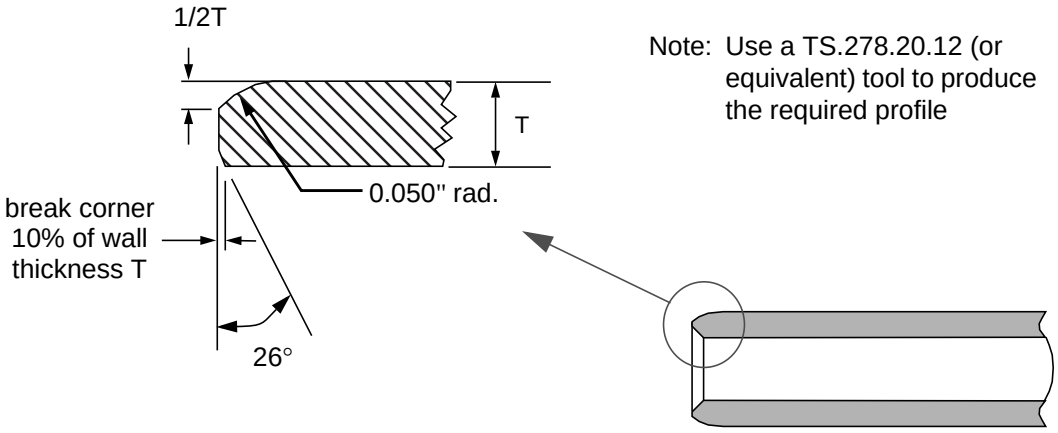


Figure 2 - Tube End Preparation for Double Flaring

5.3 Flaring

5.3.1 Flare aluminum alloy tubes in the “O” condition or T4 temper. Flare CRES and copper tubes in the annealed condition.

5.3.2 Single or double flare as specified by the engineering drawing. For DHC-6 and previous aircraft, 6061 aluminum alloy tubing with a diameter of 3/8'' or less may be double flared if the engineering drawing specifies a single flare.

5.3.3 Flare tubes as follows:

Step 1. Ensure that the flaring tool or punch is free from metal chips or swarf. When tubing material is changed, take particular care to ensure dissimilar metals will not be embedded into the flare.

Step 2. If necessary, apply a small amount of tube drawing lubricant to the tube end to lubricate the tool or punch.

Step 3. Assemble the required sleeves and nuts onto the tube.

Step 4. Flare the ends using a flaring machine or hand flaring tools.

Step 5. Remove tube drawing lubricant from tubes by either degreasing according to PPS 31.04 (for oil based lubricants) or by flushing through with clean water (for water soluble lubricants).

Step 6. Ensure that single flared tube ends meet the dimensional requirements of Table 1. and that double flared tube ends meet the dimensional requirements of Table 2. Use of a flare gauge (see Equipment section, paragraph 4.2.4), if available, is acceptable.

Table 1 - Dimensions of Single Flare (see Figure 3)

NOMINAL TUBE SIZE	RADIUS (R ±0.010")	FLARE DIAMETER (D)	FLARED WALL THICKNESS (T)
1/8" (0.125")	0.032"	0.190" - 0.200"	Wall thickness in the flare area shall be at least 80% of the original wall thickness
3/16" (0.1875")	0.032"	0.292" - 0.302"	
1/4" (0.250")	0.032"	0.349" - 0.359"	
5/16" (0.3125")	0.032"	0.411" - 0.421"	
3/8" (0.375")	0.046"	0.474" - 0.484"	
1/2" (0.500")	0.062"	0.646" - 0.656"	
5/8" (0.625")	0.062"	0.771" - 0.781"	
3/4" (0.750")	0.078"	0.927" - 0.937"	
1" (1.000")	0.093"	1.172" - 1.187"	
1-1/4" (1.250")	0.093"	1.485" - 1.500"	
1-1/2" (1.500")	0.109"	1.706" - 1.721"	

Table 2 - Dimensions of Double Flare (see Figure 3)

NOMINAL TUBE SIZE	RADIUS (R ±0.010")	FLARE DIAMETER (D)	NOMINAL TUBE WALL THICKNESS	INSIDE DIAMETER OF RETURN LIP (B)
3/16" (0.1875")	0.032"	0.292" -0.302"	0.028"	0.124" - 0.168"
			0.035"	0.110" - 0.158"
1/4" (0.250")	0.032"	0.349" - 0.359"	0.028" (Note 1)	0.187" - 0.230"
			0.035"	0.173" - 0.219"
5/16" (0.3125")	0.032"	0.411" - 0.421"	0.035"	0.235" - 0.281"
			0.049"	0.205" - 0.259"
3/8" (0.375")	0.046"	0.474" - 0.484"	0.028" (Note 1)	0.312" - 0.354"
			0.035"	0.298" - 0.344"
			0.049"	0.268" - 0.322"

Note 1 For 1/4" and 3/8" diameter 0.028" wall thickness aluminum tubes only, in place of the radius requirements specified in this table the radius is acceptable if the following conditions are met when the end fitting is assembled. Flares which do not meet the following conditions are considered oversize and are not acceptable.

- The fitting sleeve must contact the flared surface when pushed together by hand, without jamming at the radius.
- There must be free movement and rotation of the fitting nut.

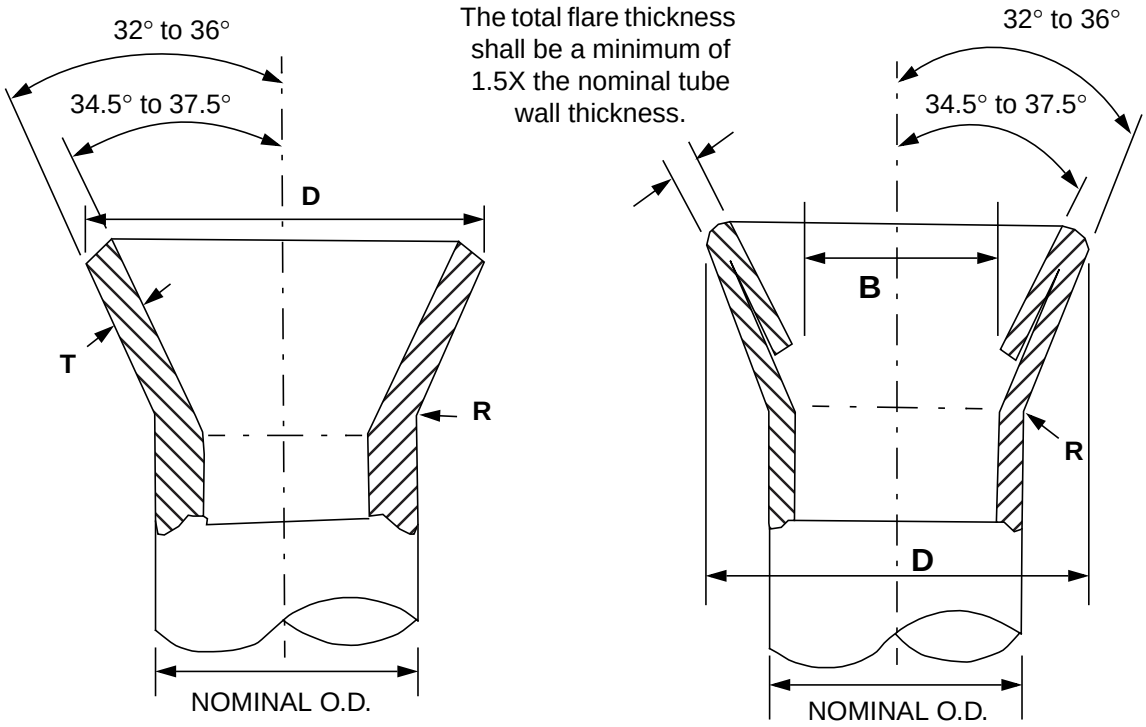


Figure 3 - Single and Double Flare Configuration (typ.)

5.4 Bending

5.4.1 If practical, flare tubing less than 1/2" in diameter before bending.

5.4.2 Using hand or power operated tube benders, bend tubing to meet the requirements of this PPS and the engineering drawing.

5.4.3 When bending 21-6-9 CRES tubing, the speed of the bending operation is critical. To prevent the possibility of cracking, the rate of bend must not exceed 4.5° per second (i.e. angular velocity of 180° in 40 seconds). If the bending operation is to be performed on a hand bending machine, bend parts slowly with an even amount of force.

5.4.4 Except as follows, bend MIL-T-7081 or WW-T-700/6 (6061) aluminum alloy tubing in either the T4 or T6 condition unless the engineering drawing specifies “O” as the final heat treat condition. If the engineering drawing specifies “O” as the final heat treat condition, bend tubes in the “O” condition.

- Bend aluminum tubing with an outside diameter greater than 3/8" or a wall thickness greater than 0.035" in the T4 condition.
- Bend aluminum tubing which forms part of the DHC-7 or DASH 8 hydraulic system in the T4 condition.

5.4.5 Before bending, clean bending tools using PCP-1001 or the solvent specified in PPS 31.17. After cleaning, check tooling to ensure surfaces are free from contamination. Take care to ensure that hydraulic fluid lines and hydraulic system components used with MIL-H-5606 hydraulic fluid do not come into contact with solvent blends containing isopropyl alcohol, also known as isopropanol and 2-propanol. Hydraulic fluid lines and hydraulic system components used with MIL-H-5606 hydraulic fluid which have been contaminated with solvent blends containing isopropyl alcohol must be cleaned according to PPS 6.10.

5.4.6 If bending CRES or titanium tubing, after cleaning generously lubricate running contacts between the tubing, tooling and dies with tube drawing lubricant. Take care to ensure that the lubricant does not become contaminated with metal chips or shop swarf.

5.4.7 During machine bending, firmly clamp tubes to prevent slippage. Support tubes internally with a mandrel and externally with a wiper block to prevent wrinkles and flats (particularly on thin gauge material).

5.4.8 Position mandrels a short distance beyond the bend point, as determined by trial bending with allowances made for the tube wall thickness, material and condition.

5.4.9 After bending:

- Check the finished tube profile against the engineering-approved master template, sample part or digitized information.
- Remove tube drawing lubricant from tubes by either degreasing according to PPS 31.04 (for oil based lubricants) or by flushing through with clean water (for water soluble lubricants).
- Check the tube for flatness according to Table 3. Use of a suitable Go/No-Go gauge, if available, is recommended.

5.4.10 Once a nominal tooling and machine setup condition is established, test bends must be carefully checked to determine if additional adjustments are needed to satisfy the requirements of section 6.

5.4.11 During production bending operations, bend quality must be monitored to determine if further adjustments are required to suit any production size or property variations. If further adjustments are required, refer to Table 9 for possible causes and methods for correcting the most commonly encountered bend quality problems.

Table 3 - Maximum Acceptable Flatness in Tubing Bends (Note 1)

NOMINAL TUBE SIZE	NON-HYDRAULIC		HYDRAULIC		
	Systems with working pressure under 1,000 psi	Systems with working pressure over 1,000 psi	CRES tubing	Aluminum alloy tubing	Titanium alloy tubing
1/4" (0.250")	0.025"	0.013"	0.013"	0.010"	0.008"
5/16" (0.3125")	0.031"	0.016"	0.016"	0.013"	0.009"
3/8" (0.375")	0.038"	0.019"	0.019"	0.015"	0.011"
1/2" (0.500")	0.050"	0.025"	0.025"	0.020"	0.015"
5/8" (0.625")	0.063"	0.032"	0.032"	0.025"	0.019"
3/4" (0.750")	0.075"	0.038"	0.038"	0.030"	0.023"
1" (1.000")	0.100"	0.050"	0.050"	0.040"	0.030"
1 1/4" (1.250")	0.130"	0.063"	0.063"	0.050"	0.038"
1 1/2" (1.500")	0.150"	0.075"	0.075"	0.060"	0.045"
1 3/4" (1.750")	0.175"	0.088"	0.088"	0.070"	0.053"
2" (2.000")	0.200"	0.100"	0.100"	0.080"	0.060"
3" (3.000")	0.300"	0.150"	0.150"	0.120"	0.090"
3 1/2" (3.500")	0.350"	0.175"	0.175"	0.140"	0.105"
4" (4.000")	0.400"	0.200"	0.200"	0.160"	0.120"
4 1/2" (4.500")	0.450"	0.225"	0.225"	0.180"	0.135"

Note 1 Flatness is defined as the difference between the maximum and minimum diameters of the tube as measured in the area of the bend exhibiting the greater degree of flattening.

5.5 Beading

5.5.1 Bead MIL-T-7081 or WW-T-700/6 aluminum alloy tubing in either the T4 or T6 condition.

5.5.2 Bead tubes as follows:

Step 1. Ensure that the beading tools are free from metal chips or swarf. When tubing material is changed, take particular care to ensure dissimilar metals will not be embedded into the bead.

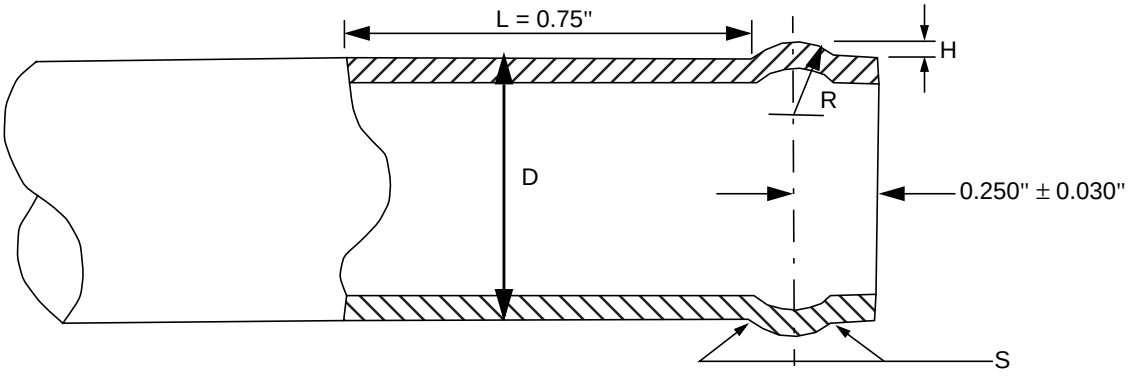
Step 2. If necessary, apply a small amount of tube drawing lubricant to the tube end to lubricate the tool.

Step 3. Bead the ends using hand or power operated tools.

Step 4. Remove tube drawing lubricant from tubes by either degreasing according to PPS 31.04 (for oil based lubricants) or by flushing through with clean water (for water soluble lubricants).

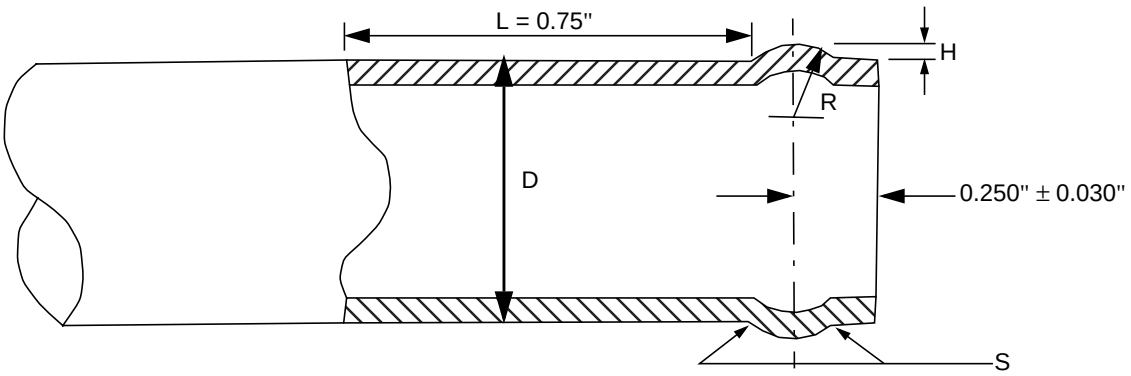
Step 5. Ensure that the formed beads meet the requirements of Table 4. Check the bead dimensions using a bead checking gauge (see Equipment section, paragraph 4.2.3), if available.

Table 4 - Dimensions of Beaded Tube End



NOMINAL TUBE SIZE	BEAD HEIGHT (H) + 0.010" - 0.003"	TOLERANCE ON DIAMETER (D) FOR LENGTH L	MAXIMUM R RADIUS	MAXIMUM S RADIUS
1/4" (0.250")	0.031"	+ 0.003" - 0.010"	0.125"	0.062"
5/16" (0.3125")	0.033"			
3/8" (0.375")	0.035"			
1/2" (0.500")	0.038"			
5/8" (0.625")				
3/4" (0.750")	0.038"	+ 0.004" - 0.010"		

Table 4 - Dimensions of Beaded Tube End



NOMINAL TUBE SIZE	BEAD HEIGHT (H) + 0.010" - 0.003"	TOLERANCE ON DIAMETER (D) FOR LENGTH L	MAXIMUM R RADIUS	MAXIMUM S RADIUS
1" (1.000")	0.062"	+ 0.005" - 0.010"	0.156"	0.093"
1 1/4" (1.250")				
1 1/2" (1.500")	0.072"			
1 3/4" (1.750")				
2" (2.000")	0.082"			
2 1/2" (2.500")	0.082"	+ 0.006" - 0.010"		
3" (3.000")				
3 1/4" (3.250")	0.088"			
3 1/2" (3.500")	0.088"	+ 0.008" - 0.010"		
3 3/4" (3.750")				
4" (4.000")				
4 1/4" (4.250")				
4 1/2" (4.500")				
4 3/4" (4.750")				
5" (5.000")				
5 1/4" (5.250")				
5 1/2" (5.500")	0.088"	± 0.010"		
5 3/4" (5.750")				
6" (6.000")				

5.6 Brazing of Fittings

5.6.1 Braze fittings to tubes using the process and method stated on the engineering drawing, according to PPS 37.07 or PPS 37.13, as applicable.

5.7 Welding of Tubes and Fittings

5.7.1 If welding of tubes and fittings is specified on the engineering drawing, weld tube sections and tube fittings according to PPS 37.03, PPS 37.04 or PPS 37.16, as applicable. Perform special welding processes for welding ferrules (e.g., Gamah, Wiggins, etc.) to tube ends as specified on the engineering drawing.

5.8 Post-Forming Procedure

5.8.1 Pressure Testing

5.8.1.1 Pressure test the rigid fluid lines listed in Table 5 according to the procedure specified therein. If the lines will be pressure tested during final assembly, fluid lines with one or more plain ends (i.e., no fitting, beading or flaring) do not require pressure testing after fabrication.

5.8.1.2 If tube assembly fittings are used to facilitate pressure testing, torque these fittings to the minimum torque values specified on the engineering drawing. If the engineering drawing does not specify a torque value, torque the tube assembly fittings to the minimum value specified in PPS 6.03.

Table 5 - Pressure Testing

FLUID SYSTEM	TEST PROCEDURE	POST TEST PROCEDURE
Hydraulic lines	According to PPS 6.12.	According to PPS 6.12.
Fuel lines		
High pressure oxygen lines	Pressure test with water at 3600 psi using a dead weight tester.	Clean according to PPS 6.10.
Low pressure oxygen lines	Pressure test with water at 400 psi using a dead weight tester, or pressure test with filtered nitrogen at 400 psi.	
Refrigerant lines (Freon)	Pressure test with water at 700 psi using a dead weight tester.	Blow dry thoroughly with clean compressed air or filtered nitrogen
Non-welded drain and vent lines	Not required unless specified on the engineering drawing.	N/A
Welded drain and vent lines	Pressure test with air or filtered nitrogen at 25 psi while submerged in water.	Blow dry thoroughly with clean compressed air or filtered nitrogen.
All others	Pressure test with air or nitrogen at 100 psi or as specified on the engineering drawing while submerged in water. Lines having fittings not suitable for testing at 100 psi may be tested at 25 psi.	

5.8.2 Age Hardening

5.8.2.1 If specified on the engineering drawing, age harden aluminum alloy tubing formed in the T4 condition to the T6 condition according to PPS 30.01 after welding or forming (i.e., bending, beading, flaring).

5.8.3 Cleaning and Capping

5.8.3.1 Immediately after fabrication and after any required heat treatment, clean all fluid lines according to PPS 6.10 and cap according to PPS 6.05.

5.8.3.2 Remove protective sealing caps or plugs only if checking or immediately before connecting the line to a circuit. Always take care to prevent any kind of contamination from entering the tubes.

5.8.4 Priming

5.8.4.1 If specified on the engineering drawing, prime fluid lines with F19 according to PPS 34.08 after all fabrication operations and post-forming heat treatment.

5.8.4.2 Mask tube ends to cover the sleeve, nut and cap (see Figure 4). If electrical bonding is specified on the engineering drawing, work order or assembly manual, continue masking for a distance of 1" beyond the free end of the sleeve. If Permaswage, Rynglok, or Wiggins swaged connectors are to be installed after priming, cap tube ends for a distance of 2" using round vinyl closures according to PPS 6.05 before masking.

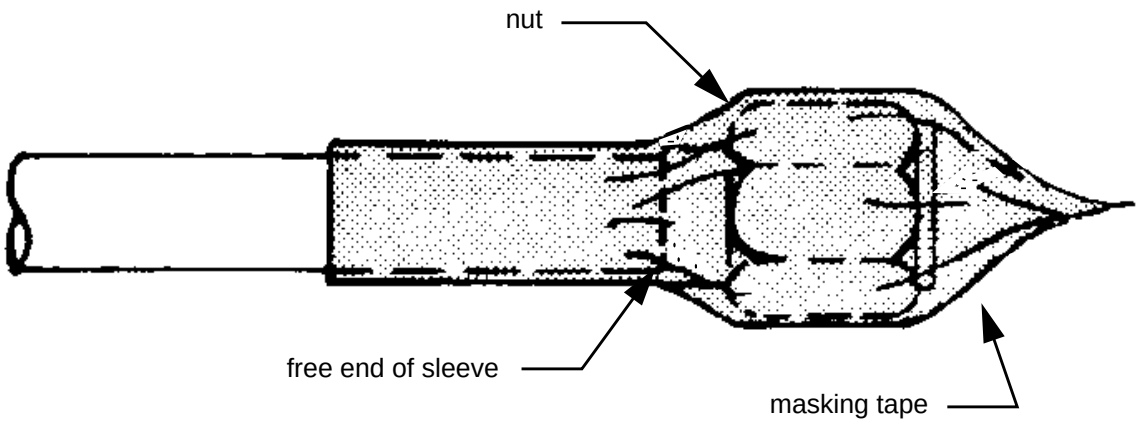


Figure 4 - Masking of Tube Assembly for Priming

5.8.4.3 If tube ends are not to be swaged or if electrical bonding is not specified, the presence of F19 primer on the back face of the nut is acceptable.

5.9 Handling and Storage

5.9.1 Do not handle fluid lines by their fittings. Ensure that protective caps are not loosened or removed.

5.9.2 Handle and store tubes in a manner that preserves their designed shape (i.e., prevents bending). Store similar shapes together.

5.9.3 Handle and protect fluid lines according to PPS 16.23.

5.9.4 Take care to prevent scratching, denting or nicking of the straight sections of the tubing.

5.10 Installation of Fittings

5.10.1 If use of any of the fittings listed in Table 6 is specified on the engineering drawing, install the fitting according to the PPS specified.

Table 6 - Installation of Fittings

FITTING TYPE	PPS REFERENCE
Cryoflare sleeves/nuts	PPS 6.23
Deutschlite	PPS 6.22
Permaswage	PPS 6.13
Rynglok	PPS 6.20

FITTING TYPE	PPS REFERENCE
Internal roller swage	PPS 6.19
Quickfit	PPS 6.21
Wiggins	PPS 6.14

5.11 Identification and Part Marking

5.11.1 Unless otherwise specified on the engineering drawing, identify function, direction of flow and high pressure warning of fluid system lines as specified in PPS 6.04.

5.11.2 Part mark fluid system lines according to PPS 15.01.

5.11.3 If a fluid system line has passed pressure testing according to section 5.8, ink stamp the words “PRESSURE TESTED” directly on the line or, if the lines are too small to be ink-stamped, on the tag bearing the part number.

6 Requirements

6.1 Visual Requirements

6.1.1 Fluid line assemblies having fittings with damaged threads are not acceptable.

6.1.2 Assemblies having cracks in either the tubing or fittings are not acceptable.

6.1.3 Flared portions of tubing shall be free from cracks, pits or tool marks and the seating area (inside the flare) shall be free from scratches or any other damage that may allow leakage of the line during service. Refer to Figure 5 for acceptance limits of marks on the exteriors of single and double flares. Refer to Figure 6 or Figure 7 for acceptance limits of marks on the interiors of single or double flares, as applicable.

6.1.4 The ends of tubes to which fittings are to be installed shall be free from nicks and longitudinal scratches.

6.1.5 Longitudinal scratches in the bores of lines used in systems having working pressures above 1,000 psi are not acceptable.

6.1.6 Scratches, nicks, dents, etc. on the sealing surface of the flare are not acceptable.

6.1.7 Scratches, nicks or dents on the exterior or interior of straight sections of the tube length which exceed 5% of the nominal tube wall thickness in depth are not acceptable. Scratches, nicks or dents which do not exceed 5% of the nominal tube wall thickness may be smoothly and completely blended out using Scotch-Brite pads. However, if this cannot be achieved, the defective tube is not acceptable.

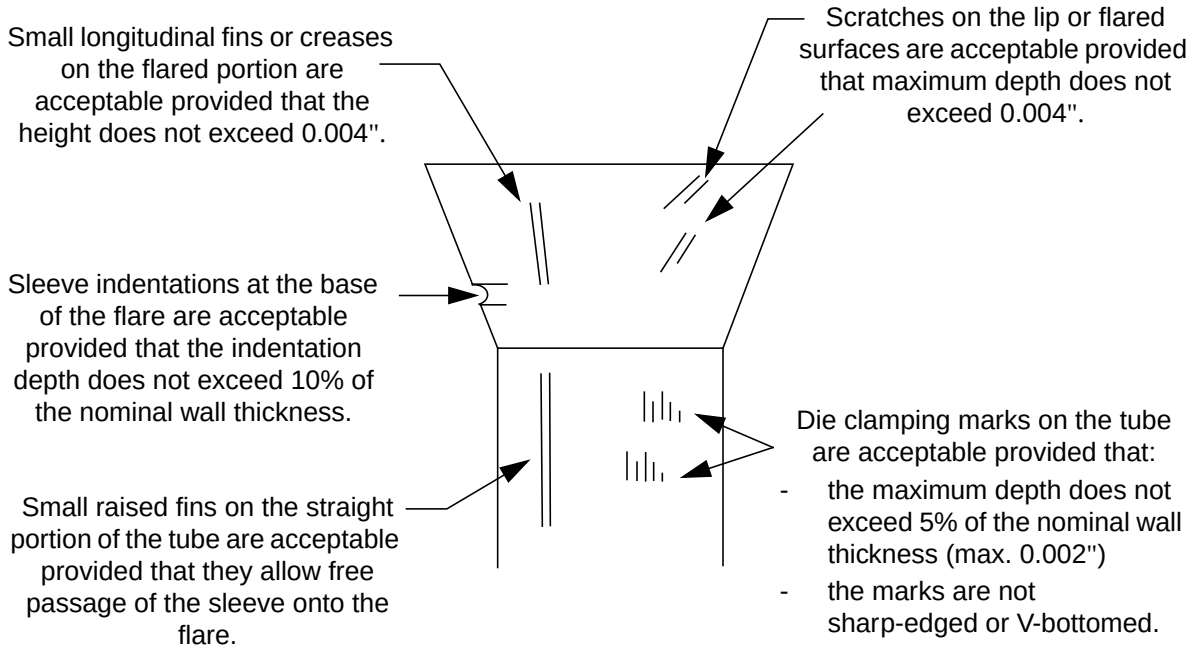


Figure 5 - Acceptance Limits for Exterior of Single or Double Flare

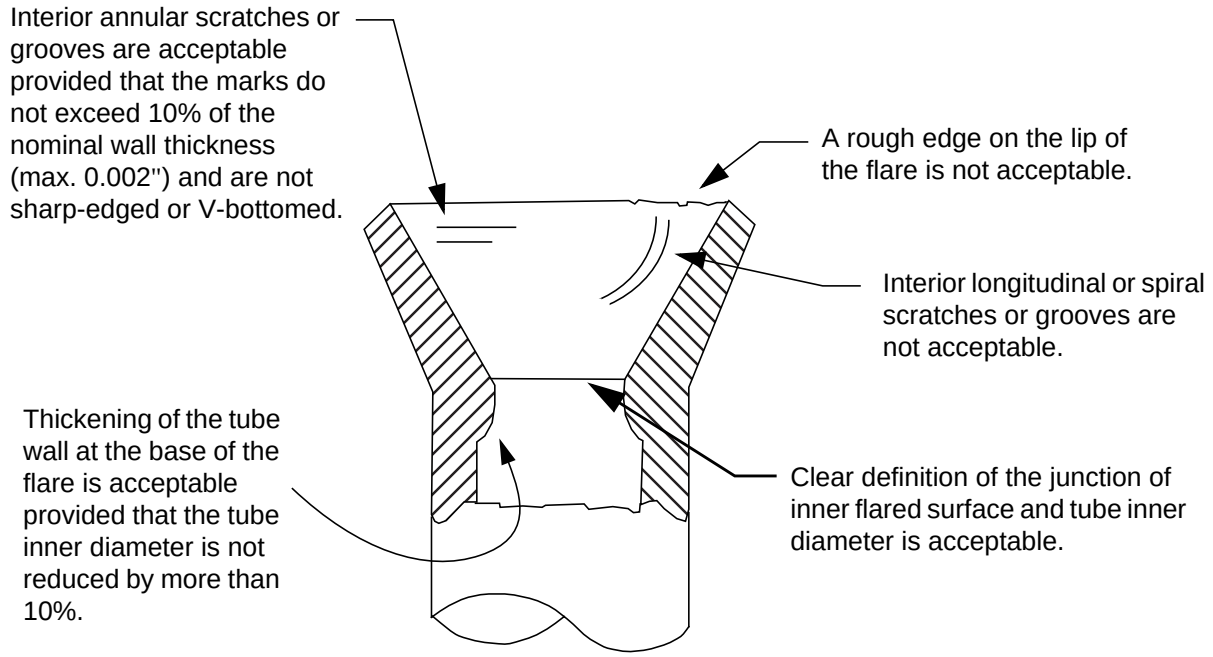


Figure 6 - Acceptance Limits for Interior of Single Flare

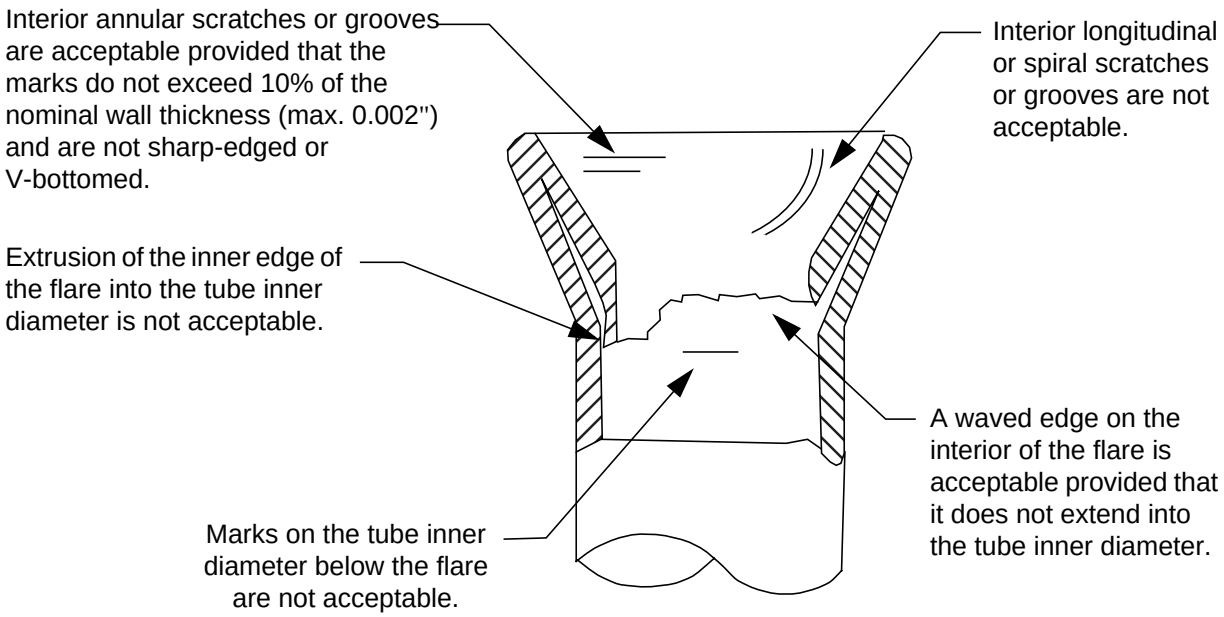


Figure 7 - Acceptance Limits for Interior of Double Flare

6.2 Dimensional Requirements

6.2.1 Unless otherwise specified by the engineering drawing, the bend radii shall not be less than three times the outside diameter of the tube. If it is not practical to produce a bend radii at least three times greater than the outside diameter of the applicable tube, approval must be obtained from Liaison Engineering.

6.2.2 Bent tube assemblies shall conform to the dimensional requirements of the engineering drawing, profile template or sample part.

6.2.3 Take particular care to ensure that the tube wall thickness is as specified on the engineering drawing. Failure could result if the tubing wall is too thin for the service pressure.

6.2.4 Single and double flares shall meet the dimensional requirements of Table 1 and Table 2, respectively.

6.2.5 The dimensions of beaded tube ends shall be according to the requirements of Table 4. An SD8286-1 bead checking gauge may be used to dimensionally check the bead height.

6.2.6 Slight flattening in bent sections of tubing is acceptable, provided that the degree of flatness does not exceed the limits specified in Table 3.

6.2.7 For hydraulic lines other than titanium, wrinkles and dents shall not exceed the limits specified in Table 7. For titanium hydraulic fluid lines (Ti-3Al-2.5V to AMS4945), there shall be no visible wrinkles or mandrel marks in bends on titanium.

6.2.8 The depth of nicks and scratches on hydraulic lines manufactured from titanium (Ti-3Al-2.5V to AMS 4945) shall not exceed 5% of the tubing wall thickness.

6.2.9 Tubes manufactured from 21-6-9 CRES and titanium shall not exceed the mandrel bump and neckdown limits as specified in Table 8.

Table 7 - Wrinkle and Dent Limits on Inner Radius of Tube Bends (Note 1)

NOMINAL TUBE SIZE	MAXIMUM WRINKLE HEIGHT
1/4" (0.250")	0.0025"
5/16" (0.3125")	0.0031"
3/8" (0.375")	0.0038"
1/2" (0.500")	0.0050"
5/8" (0.625")	0.0063"
3/4" (0.750")	0.0075"
7/8" (0.875")	0.0088"
1" (1.000")	0.0100"
1 3/4" (1.750")	0.0175"
2" (2.000")	0.0200"

Note 1 This table does not apply to hydraulic lines manufactured from titanium. For titanium hydraulic lines there shall be no visible wrinkles, mandrel marks or dents.

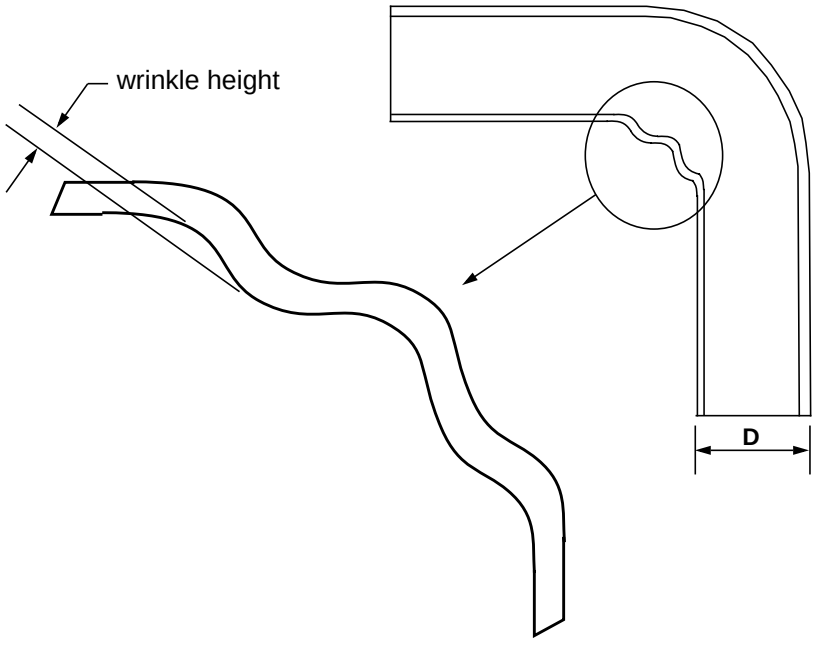
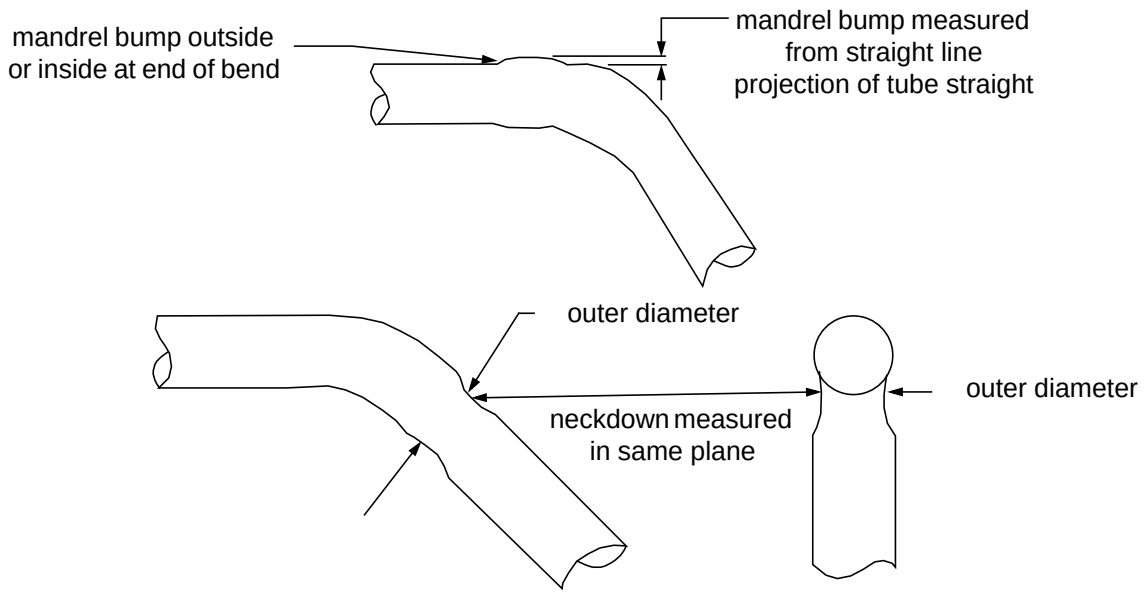


Table 8 - Mandrel Bump and Neckdown Limits

NOMINAL TUBE SIZE	TITANIUM TUBES	21-6-9 CRES TUBES	
	MAXIMUM CHANGE IN TUBE O.D. AT BEND	MAXIMUM ALLOWABLE MANDREL BUMP	MAXIMUM NECKDOWN
1/4" (0.250")	± 0.0075"	0.004"	5% (0.0125")
3/8" (0.375")	± 0.01125"	0.004"	5% (0.0188")
1/2" (0.500")	± 0.015"	0.008"	5% (0.0250")
5/8" (0.625")	± 0.01875"	0.008"	3% (0.0188")
3/4" (0.750")	± 0.0225"	0.010"	3% (0.0225")
1" (1.000")	± 0.03"	0.010"	3% (0.0300")



6.3 Pressure Testing

6.3.1 Lines which exhibit leakage during testing or deformation as a result of testing are not acceptable.

7 Safety Precautions

7.1 Observe general shop safety precautions when performing the procedure specified herein.

7.2 Observe standard safety practices for handling and use of compressed gas at all times.

7.3 Smoking is prohibited in areas where oxygen is used.

8 Personnel Requirements

8.1 Personnel responsible for fabrication of aluminum alloy, copper, CRES and titanium rigid fluid lines must have a good working knowledge of the procedure and requirements as specified herein and shall have exhibited their competency to their supervisor.

9 Special Points to Note

9.1 Be extremely careful when handling oxygen lines, at all stages of manufacture and testing, to prevent the tubes from contacting grease or oil of any kind.

10 Maintenance of Equipment

10.1 Keep bending, beading and flaring tools free from swarf, chips and pick-up. Replace worn or damaged tools immediately.

10.2 At Bombardier Toronto (de Havilland), observe the following equipment maintenance provisions:

- Any modification of tools requires the appropriate authorization.
- Ensure that pipe shop machines used to produce flared tube ends are maintained on a preventative maintenance program.

Table 9 - Bend Quality Troubleshooting Guide

PROBLEM	SYMPTOM	PROBABLE CAUSE	SOLUTION
Marks in the clamp die area	Scratches and marring of the clamp area	Dirt, scale, chips, burrs or other foreign matter in the clamping section of the bend die	Clean the clamp die and bend die grooves. Clean greasy or dirty tubing before loading on the bender.
	Pinch marks on the tube at both ends of the clamp die and/or along the top and bottom of the tube	Vertical misalignment of the clamp die with the bend die.	Align the clamp die groove with the bend die groove by vertical adjustment of the clamp die.
	Imprint of the entire clamp die on the tube	Excessive clamping pressure	Reduce the clamping pressure. If tube slips during bending, a longer clamp die is required.

Table 9 - Bend Quality Troubleshooting Guide

PROBLEM	SYMPTOM	PROBABLE CAUSE	SOLUTION
Marks in the pressure die area	Pinch marks on the top and/or bottom of tube throughout the length of bend	Vertical misalignment of the pressure die with the bend die	Align the pressure die groove with bend die groove by vertical adjustment of the pressure die. Ensure that the pressure die is aligned throughout its entire length.
	Circumferential impressions of soft tubing material	Initial impact of pressure die as it is closed at full hydraulic pressure	Incrementally back off the pressure die lead screw 1/8 to 1/4 of a turn until the marking problem is corrected.
	Longitudinal scratches and marring of the tube on the outside diameter of the bend	Dirt, scale, chips, burrs or other foreign matter in the pressure die groove	Clean the pressure die groove and the bend die groove. Clean the tubing before loading the bender.
		Unsatisfactory pressure die boost	Adjust the pressure die boost system.
Marks in the wiper die area	Scratches and marring of tube on outer radius of bend	Irregular or burred wiper die groove surface	Smooth the surface of the tube groove in the wiper die.
	Galling of the tube and pickup of material on wiper die	Material of the wiper die is incompatible with the tube material	Use a wiper die compatible material. Wiper dies of Ampco bronze are recommended for bending CRES. Use steel wipers dies for aluminum tubing.
Excessive ovality	Excessive flattening of the tube cross-section in the bend area	Inadequate support of tube by the mandrel due to improper positioning, worn mandrel or the wrong type	Advance the mandrel incrementally ahead of the tangent.
			Replace worn or undersized mandrel.
			Ensure that the mandrel is of the correct type.
		Bend die groove is worn or oversize	Replace the worn bend die.
		Tube is slipping through the clamp die during bending	Increase the clamping pressure. Use longer clamp die if necessary.

Table 9 - Bend Quality Troubleshooting Guide

PROBLEM	SYMPTOM	PROBABLE CAUSE	SOLUTION
Wrinkling	Tube wrinkles form along the inner radius of bend	Insufficient die pressure force	Incrementally increase the pressure die setting.
		The mandrel is not supporting the inside of the tube correctly due to mislocation of the mandrel body or a worn/undersized body	Advance mandrel towards the tangent in small increments.
		Tube is slipping in the clamp die during bending	Replace worn or undersized mandrels.
		Severe minimum radius or thin wall bending requirement	Install the wiper die.
		The wiper dies are not properly fitted to the bend die, misaligned or worn	Realign the wiper die. Replace the worn wiper die.
Excessive elongation	Extreme neckdown and/or chatter marks	Inadequate clearance between tube and mandrel	Replace the oversize mandrel.
		Mandrel position located too far forward of the bend tangent	Incrementally move the mandrel location aft.
		Incorrect bend radius input to the bender controller	Input the correct bend radius to match bend die radius.
	Tube ruptures or breaks during bending	Mandrel position is located too far forward of the bend tangent	Incrementally move the mandrel location aft.
		Inadequate mandrel lubrication causing excessive drag	Lubricate the mandrel.
		Severe minimum radius requirement	Reset the pressure die boost system.