BOMBARDIER
Toronto (de Havilland)
PROPRIETARY INFORMATION

PPS 1.08

PRODUCTION PROCESS STANDARD

Magnetic Pulse Forming of End Fittings

Issue 19
- This standard supersedes PPS 1.08, Issue 18.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- Direct PPS 1.08 related questions to michael.wright@aero.bombardier.com.
- This PPS is effective as of the distribution date.

Prepared By:	(Michael Wright)	September 5, 2014
	Production Process Standards (PPS)	
Approved By:	(L.K. John)	September 8, 2014
	Materials Technology	
	(Adam Gordon)	September 11, 2014
	Quality	

Signed original on file. Validation of paper prints is the responsibility of the user.

Table of Contents

Sections **Page**

Tables

Figures

Table of Contents

Flow Charts **Page**

1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for the attachment of end fittings by means of magnetic pulse forming (magneforming).

1.1.1 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.

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

1.1.3 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 DHMS M2.21 - Tubing, Aluminum Alloy, Drawn Seamless, Special Surface Quality.

3.2 PPS 1.09 - Drilling and Reaming.

3.3 PPS 12.04 - Installation of Interference Fit Bushings using Liquid Nitrogen.

3.4 PPS 13.26 - General Subcontractor Provisions.

3.5 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.6 PPS 14.01 - Torquing - Method and Identification.

3.7 PPS 16.01 - Application of Hard and Soft Film (F13) Corrosion Preventive Compound.

3.8 PPS 16.23 - Handling and Protecting Critical Aircraft Parts.

3.9 PPS 20.01 - Magnetic Particle Inspection.

3.10 PPS 20.03 - Fluorescent Penetrant Inspection.

3.11 PPS 24.02 - Ion Vapour Deposited Aluminum Coating (M2).

3.12 PPS 27.05 - Manual Edge Finishing Equipment.

3.13 PPS 27.09 - Repair of Surface Defects in Aluminum Alloy Tubing.

3.14 PPS 31.02 - Cleaning Processes for Aluminum and Aluminum Alloys.

3.15 PPS 31.04 - Degreasing Processes.

3.16 PPS 31.17 - Solvent Usage.

3.17 PPS 32.03 - Chromic Acid Anodizing (A1).

3.18 PPS 33.01 - Cadmium Plating (E1).

3.19 PPS 34.08 - Application of Epoxy-Polyamide Primer (F19 & F45).

3.20 Magneform schedule (e.g., DH Form #4283).

4 Materials, Equipment and Facilities

4.1 Materials

4.1.1 Tubing, end fittings and sleeves as specified on the engineering drawing.

4.1.2 Pressure sensitive vinyl tape, 1" wide minimum (e.g., DSC91-1-3A).

4.1.3 Masking tape, 1" wide minimum.

4.2 Equipment

4.2.1 Magneform machines (e.g., General Dynamics Model 16A, CE #7918 or Maxwell Model 16, CE #3288).

4.2.2 Locating tools, insulators and field shapers (e.g., TS.291.01.00).

4.2.3 Magneform test piece slitting saw (e.g., TS.291.30.10 MK1).

4.2.4 Torque test rig (e.g., 72760122-001-141).

4.3 Facilities

4.3.1 This PPS has been categorized as a “Controlled Special Process” according to PPS 13.39 and as such only facilities specifically approved according to PPS 13.39 are authorized to perform magnetic pulse forming of end fittings according to this PPS.

4.3.2 Bombardier subcontractors must direct requests for approval to Bombardier Aerospace Supplier Quality Management. Bombardier Aerospace facilities must direct requests for approval to the appropriate internal Quality Manager.

4.3.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report must detail the materials and equipment to be used, the process sequence to be followed and the laboratory facilities used to show compliance with the requirements of this PPS. Any deviation from the procedure or requirements of this PPS must be detailed in the facility report. Based upon the facility report, Bombardier Toronto (de Havilland) Materials Technology may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification must be prepared to demonstrate their capability. Once approved, no changes to subcontractor facilities may be made without prior written approval from Bombardier Aerospace Supplier Quality Management.

4.3.3.1 Unless otherwise specified by Bombardier Aerospace Supplier Quality Management, for approval of subcontractor facilities to perform magnetic pulse forming of end fittings according to this PPS completion of a test program and submission of suitable test samples representative of production parts is required. Test samples must meet the requirements specified in section 6.

5 Procedure

5.1 General

5.1.1 Unless otherwise specified on the engineering drawing, carry out manufacturing operations such as swaging, plating or anodizing, before magneforming.

5.1.2 Handle magneformed tube assemblies designated by the engineering drawings as “SPECIAL QUALITY PARTS” according to PPS 16.23.

5.1.3 Refer to Flow Chart 1 for the procedure for processing steel alloy tubes. Refer to Flow Chart 2 for the procedure for processing aluminum alloy tubes.

5.2 Preparation of Parts

5.2.1 Prepare parts for magneforming as follows:

Step 1. Cut the tube to length, taking into account the linear expansion of the tube which occurs during magneforming as recorded in the Remarks area of the magneform schedule.

Step 2. If specified, magneform swage the tube ends according to section 5.3. After swaging, remove swaging wrinkles within the tube by reaming to the diameter specified by the magneform schedule according to PPS 1.09.

Step 3. Face the tube to length, square to the longitudinal axis of the tube.

Step 4. Chamfer the inside edge of tubes having a wall thickness of 0.049" or greater as shown in Figure 1 according to PPS 27.05.

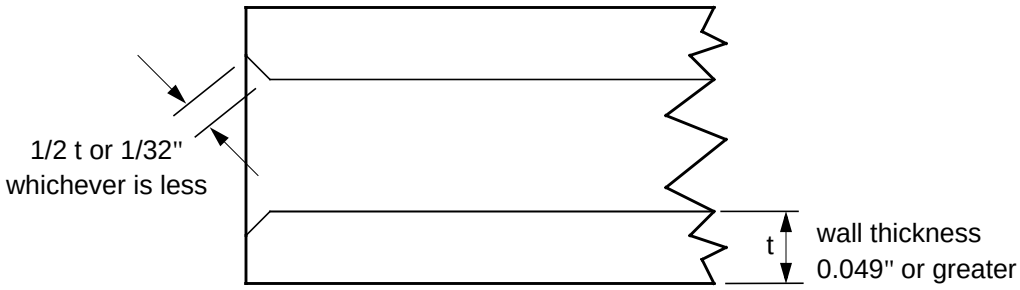


Figure 1 - Detail of Chamfer on Tube End

Step 5. Remove grease, oil or foreign matter from tubes. For steel tubes, clean according to PPS 31.03. For aluminum tubes, clean according to PPS 31.02.

Step 6. Fluorescent penetrant or magnetic particle inspect according to section 6.6.

Step 7. For aluminum tubes, chromic acid anodize according to PPS 32.03. For steel tubes, cadmium plate according to PPS 33.01 or Ivadize according to PPS 24.02.

5.3 Magneform Procedure

5.3.1 Except as noted below, set up the magneform machine according to the magneform schedule.

- For magneforming CSP 373 sleeves, use the tools and machine settings specified in Table 1. Locate CSP 373 sleeves flush with the end of the tube.
- When preparing test specimens, set up the magneform machine as specified by the process sheet.

5.3.2 When forming 2 grooves, form the groove adjacent to the end fitting first and then rotate the tube approximately 180° before forming the second groove.

5.3.3 When forming 3 grooves, form the centre groove first, the groove adjacent to the end fitting second, and the groove furthest from the end fitting third. Except when forming end fittings to torque tube assemblies, rotate the tube approximately 120° after forming each groove. When forming end fittings to torque tube assemblies, rotate the tube approximately 180° to form the second groove and 90° to form the third while ensuring that the field shaper split is located midway between the torque grooves and holes.

5.3.4 When using a copper driver in the magneforming operation, wrap a piece of vinyl tape (see Materials section, paragraph 4.1.2) around the tube before forming, to prevent arcing from the driver to the tube.

Table 1 - Tools and Machine Settings for Magneforming CSP 373 Sleeves

CSP 373 SLEEVE (Note 1)		TUBE WALL THICKNESS	MAGNEFORM TOOLS (Note 5)		MACHINE ENERGY/OPERATING LEVEL (Notes 2, 3 & 4)	
DASH NUMBER	OUTSIDE DIAMETER		END LOCATOR TS.291.10.12	SOLID FIELD SHAPER TS.291.11.11	NEW MAXWELL MODEL 16A	OLD MAXWELL MODEL 16
1	1.625"	0.028", 0.035", 0.049", 0.065" or 0.083"	MK 4	MK 1625	30%	39%
2	1.375"		MK 4	MK 1375		
3	1.000"	0.035" or 0.049"	MK 3	MK 1000	32%	42%
4	0.750"	0.035", 0.049" or 0.058"	MK 3	MK 750	34%	45%
5	0.875"	0.028"	MK 5	MK 875	32%	42%
		0.035" or 0.049"	MK 3	MK 875		
		0.058", 0.065" or 0.095"	MK 4	MK 875		
6	1.125"	0.035", 0.049" or 0.065"	MK 3	MK 1125	30%	39%
7	1.250"	0.035" or 0.049"	MK 3	MK 1250		
8	0.625"	0.028" or 0.035"	MK 5	MK 625	34%	45%
9	1.250"	0.065", 0.083" or 0.095"	MK 4	MK 1250	30%	39%
10	1.000"	0.065"	MK 4	MK 1000	32%	42%
11	0.875"	0.058", 0.065" or 0.095"	MK 4	MK 875		
12	0.625"	0.035" or 0.049"	MK 3	MK 625	35%	46%
13	1.500"	0.065"	MK 4	MK 1500	30%	39%
14	0.500"	0.035"	MK 3	MK 500	37%	48%

Note 1. Except on swaged tube assemblies, use sleeves with a wall thickness of 0.058". On swaged tube assemblies use sleeves with a wall thickness of 0.049" and having a part number with a 'T' suffix in the dash number (e.g. CSP 373-3T).
Note 2. For sleeves with the suffix "T" reduce the energy/operating level 10%.
Note 3. When using a split field shaper increase the energy/operating level 10%.
Note 4. When using magneforming equipment other than the Maxwell Model 16 or 16A, use a machine energy/operating level appropriate for the equipment used.
Note 5. It is acceptable to use alternative equivalent magneform tools to those specified herein provided that the magneformed assembly meets all the requirements specified herein.

5.3.5 If an interference fit condition exists between the fitting and the tube it is acceptable to freeze fit using liquid nitrogen according to PPS 12.04 provided that both the fitting and tubing are within the dimensions specified on the engineering drawing.

5.4 Installation of Sleeves

5.4.1 If use of CSP 358 sleeves is specified, locate the sleeves flush with the end of the tube and bond in place using the sealant specified on the engineering drawing. For certification test specimens only, it is acceptable to tape CSP 358 sleeves in place using masking tape in place of bonding.

5.4.2 If use of CSP 373 sleeves is specified, magneform them in place according to section 5.3.

6 Requirements

6.1 Visual Examination Requirements

6.1.1 Visually check raw aluminum tubes before preparation for magneforming, to ensure that the raw materials meet the requirements of DHMS M2.21. Refer tubing with defects exceeding the limits specified in DHMS M2.21 to Bombardier Toronto (de Havilland) Material Review Board (MRB) or Bombardier Toronto (de Havilland) delegated MRB for authorization to repair according to PPS 27.09 and re-check.

6.1.2 Installed CSP 358 sleeves must be flush with the end of the tube and be completely filled with the sealant specified on the engineering drawing.

6.1.3 Installed CSP 373 sleeves must be flush with the end of the tube and show evidence of visible deformation of the sleeve into the 2 outer grooves of the tube assembly.

6.1.4 After proof loading, if any, examine each assembly for the following defects. Examine assemblies requiring proof loading using a 5X magnifying glass. Examine assemblies that do not require proof loading visually without magnification.

- Assemblies showing evidence of cracks are not acceptable.
- Tubes and end fittings with arcing marks are not acceptable.
- Parts showing any evidence of rotation, separation or linear play of the end fitting within the tube, or any other signs of looseness when checked manually are not acceptable.

6.2 Dimensional Requirements

6.2.1 Dimensionally check each assembly after the forming of end fittings against the engineering drawing.

6.3 Proof Loading

6.3.1 Proof load production **push rod** assemblies requiring proof loading in **tension** to the proof load value specified on the engineering drawing. Push rod assemblies showing evidence of slipping of the end fitting during proof loading are not acceptable.

6.3.2 Proof load production **torque tube** assemblies requiring proof loading in **torsion** to the proof load value specified on the engineering drawing. Apply torque loading in one direction only. Tubes showing evidence of rotation of the end fitting during proof loading are not acceptable.

6.4 Torque Resistance Testing

6.4.1 For all aluminum magneformed tubes with a wall thickness of 0.028", carry out a torque resistance test as follows:

Step 1. Secure one end of the end fitting assembly in a holding fixture and apply a small longitudinal stripe across the end fitting and tube connection using a suitable marker.

Step 2. Using a suitable torque wrench, apply a load of 25 inch pounds (according to PPS 14.01) to the free end of the assembly.

Step 3. Check the stripe applied to the tube and the end fitting to ensure that neither fitting experienced rotation. Re-magneform the end fittings that show evidence of rotation (misalignment of stripe across tube-fitting connection), according to section 5.3 and re-test according to this section. Assemblies failing to meet torque requirements a second time are not acceptable. Report any failure to Liaison Engineering.

6.5 Sleeve Requirements

6.5.1 After final assembly, check push rod assemblies with sleeves as follows.

- CSP 358 sleeves must be flush with the end of the tube and be completely filled with the sealant specified on the engineering drawing.
- CSP 373 sleeves must be flush with the end of the tube and show evidence of visible deformation of the sleeve into the 2 outer grooves of the tube assembly.
- Assemblies showing any evidence of looseness or rotation, when checked manually are not acceptable.

6.6 Non-Destructive Testing

6.6.1 Before magneforming, fluorescent penetrant inspect prepared aluminum tubes over their entire length according to PPS 20.03. Refer tubing with defects exceeding the limits specified in DHMS M2.21 or with **any** defects within 3" of the tube ends to Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB for authorization to repair according to PPS 27.09 and re-inspect.

6.6.2 Before magneforming, magnetic particle inspect prepared steel tubes according to PPS 20.01, for a distance of 2" from each end.

6.6.3 Fluorescent penetrant inspect proof load tested aluminum tubes according to PPS 20.03 for a distance of 2" from each end. Take extreme care to prevent ingress and entrapment of solutions inside the assembly. Apply penetrant by brush rather than dipping the part in solution.

6.7 Magneform Schedules

6.7.1 Except as noted below, a certified magneform schedule must be prepared for each combination of tube and end fitting in production. It is acceptable to use the same magneforming schedule for more than one part number if the tube data, end fitting configuration and field shaper type for the parts are the same.

- For parts where the engineering drawing does not specify PROOF LOAD REQUIRED, magneforming schedules may be prepared on the basis of similarity with other parts and need not be certified.
- A certified magneforming schedule is not required for magneforming CSP 373 sleeves.

6.7.2 Certify magneform schedules by making up, forming and testing test specimens according to the flow chart specified in the following table:

TUBE ASSEMBLY	FLOW CHART FOR MAKE-UP, FORMING AND TESTING
Aluminum tube assembly **without** sleeves	Flow Chart 3
Steel tube assemblies **without** sleeves	Flow Chart 4
Aluminum or Steel tube assemblies **with** sleeves	Flow Chart 5

6.8 Verification of Magneform Machine Capability

6.8.1 Every month, verify each magneform machine capability as follows:

Step 1. Prepare 2 test specimens according to a magneform schedule chosen at random by Quality Assurance. Do not use sleeved assemblies for machine verification test specimens.

Step 2. Submit the test specimens for failure testing according to section 6.9.

Step 3. If one or both of the test specimens fail, determine and correct the cause for the failure and test another 2 test specimens.

6.9 Failure Testing

6.9.1 Make up test specimens as follows:

- Use tubing of the same diameter, wall thickness, material type, temper, tube end configuration and finish as the represented part. Use a 6" length of tube for parts having non-swaged ends, a 16" length for parts having swaged ends (see Figure 2). If the engineering drawing allows both an E1 (cadmium plated) or an M2 (Ivadized) finish, for steel tubes with a wall thickness of over 0.028" it is sufficient to prepare one set of two cadmium plated test specimens; for steel tubes with a wall thickness of 0.028" or less, prepare one set of two cadmium plated test specimens and one set of two Ivadized test specimens and test both sets.
- If possible, use production end fittings for test specimens. If production end fittings are not available, prepare end fittings of the same material, size, configuration and finish as the represented part, except that the free end configuration shall match that specified in Table 2 to facilitate Laboratory testing.
- For test specimen sleeves, use the same part number as used on the represented production part.
- Prepare test specimen components for magneforming according to section 5.2.
- Magneform test specimen tubes to end fittings according to section 5.3.
- For **push rod** test specimens only, after magneforming tubes to end fittings make a 0.020" wide slit in one end of each of the test specimens using a slitting saw to simulate a crack before securing the appropriate sleeve in place according to section 5.4. For tubes up to 1.0" in diameter make a 1 1/2" long slit. For tubes over 1.0" in diameter make the slit one and a half times the tube diameter.

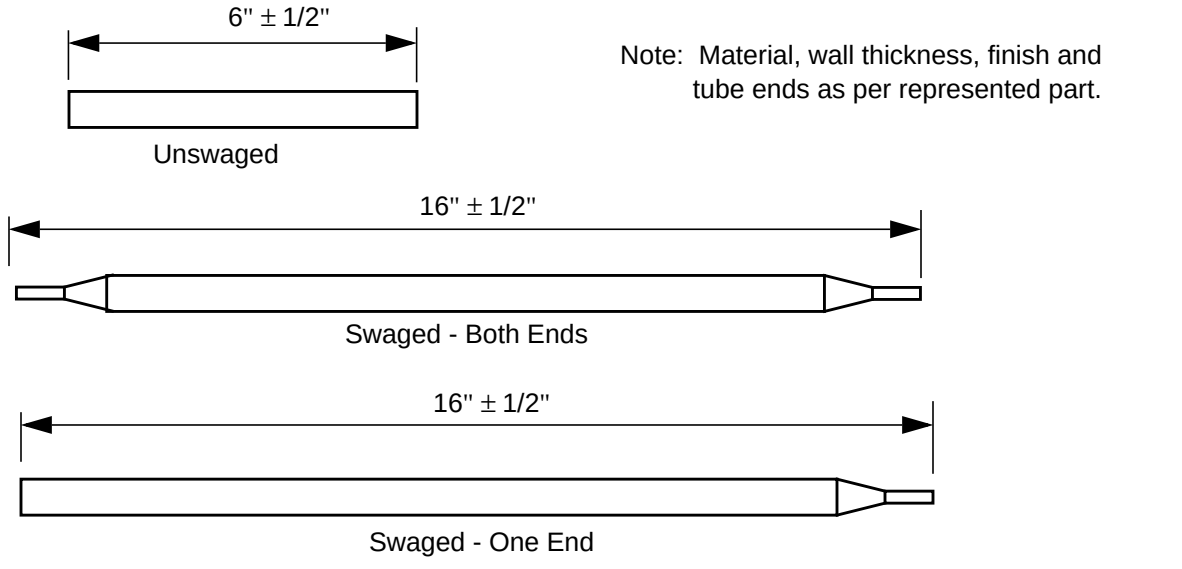
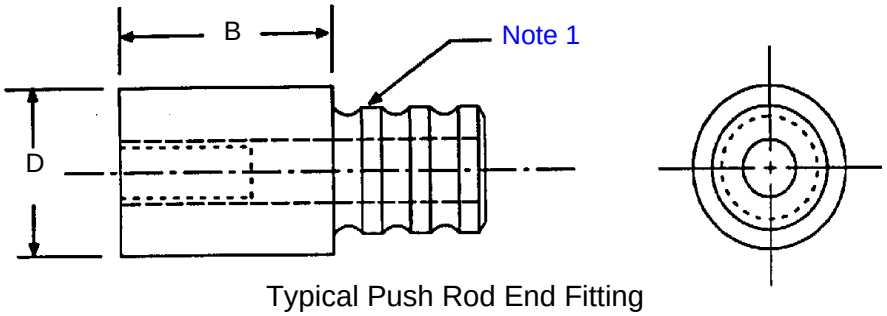


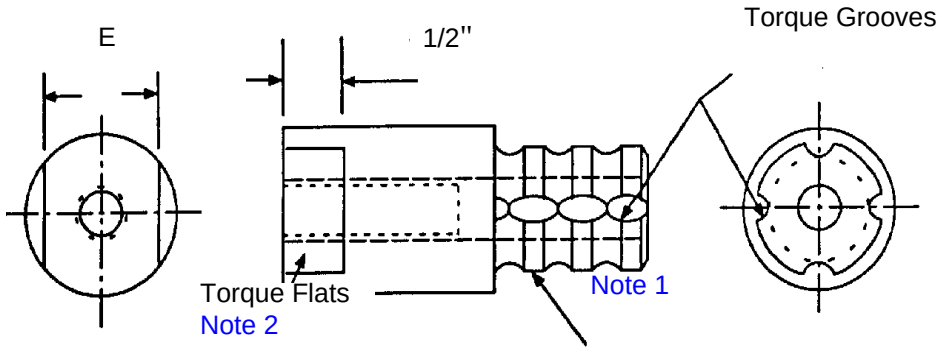
Figure 2 - Test Specimen Tube Details

Table 2 - Test Specimen End Fittings

TUBE DIAMETER	THREAD	"B" LENGTH	"E" WIDTH	"D" DIAMETER
0.250" - 0.4375"	Drill 1" for 1/4-28 Thread (Tap 0.7" deep)	1.25"	0.437"	0.50"
0.500" - 0.6875"	Drill 1" for 5/16-24 Thread (Tap 0.8" deep)	1.25"	0.437"	Same as the tube diameter
0.750" - 1.000"	Drill 1" for 3/8-18 Thread (Tap 0.8" deep)	1.00"	0.687"	Same as the tube diameter
1.0625" - 1.510"	Drill 1" for 5/8-18 Thread (Tap 0.8" deep)	1.00"	0.875"	Same as the tube diameter



Typical Push Rod End Fitting



Typical Torque Tube End Fitting

Bombardier Toronto (de Havilland)
Methods Ref. PPS1-08FIG1

Note 1. Use the same material, finish, groove diameter and configuration for the test fitting as the represented part.
Note 2. Torque flats and torque grooves are applicable only to torque tube specimens.
Note 3. Whenever expedient, use production end fittings to make up test specimens.

6.9.2 Tension load **push rod** test specimens until failure of the assembly occurs. The *failure* load is the highest load obtained before separation of the end fitting from the tube.

6.9.3 Torsion load **torque tube** test specimens using a suitable torque test rig (see paragraph 4.2.4) until failure of the assembly occurs. Carry out failure testing of torque tube specimens in the same direction as proof loading. The *failure* load is the highest load obtained before differential rotations of approximately 180° between end fittings.

6.9.4 If any of the test specimens fail to meet the minimum acceptable *failure* load, determine and correct the cause of the failure and re-test according to this section. Refer to the magneforming schedule for the minimum acceptable *failure* load. The minimum acceptable *failure* load is 110% of the *breaking* load specified on the engineering drawing.

7 Safety Precautions

7.1 The safety precautions specified herein are specific to Bombardier Toronto to meet Canadian Federal and Provincial government environmental, health and safety regulations. It is recommended that other facilities consider these safety precautions; however, suppliers, subcontractors and partners are responsible for ensuring that their own environmental, health and safety precautions satisfy the appropriate local government regulations.

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

7.3 Ensure that the safety cover on the machine remains closed while the magneforming operation is taking place.

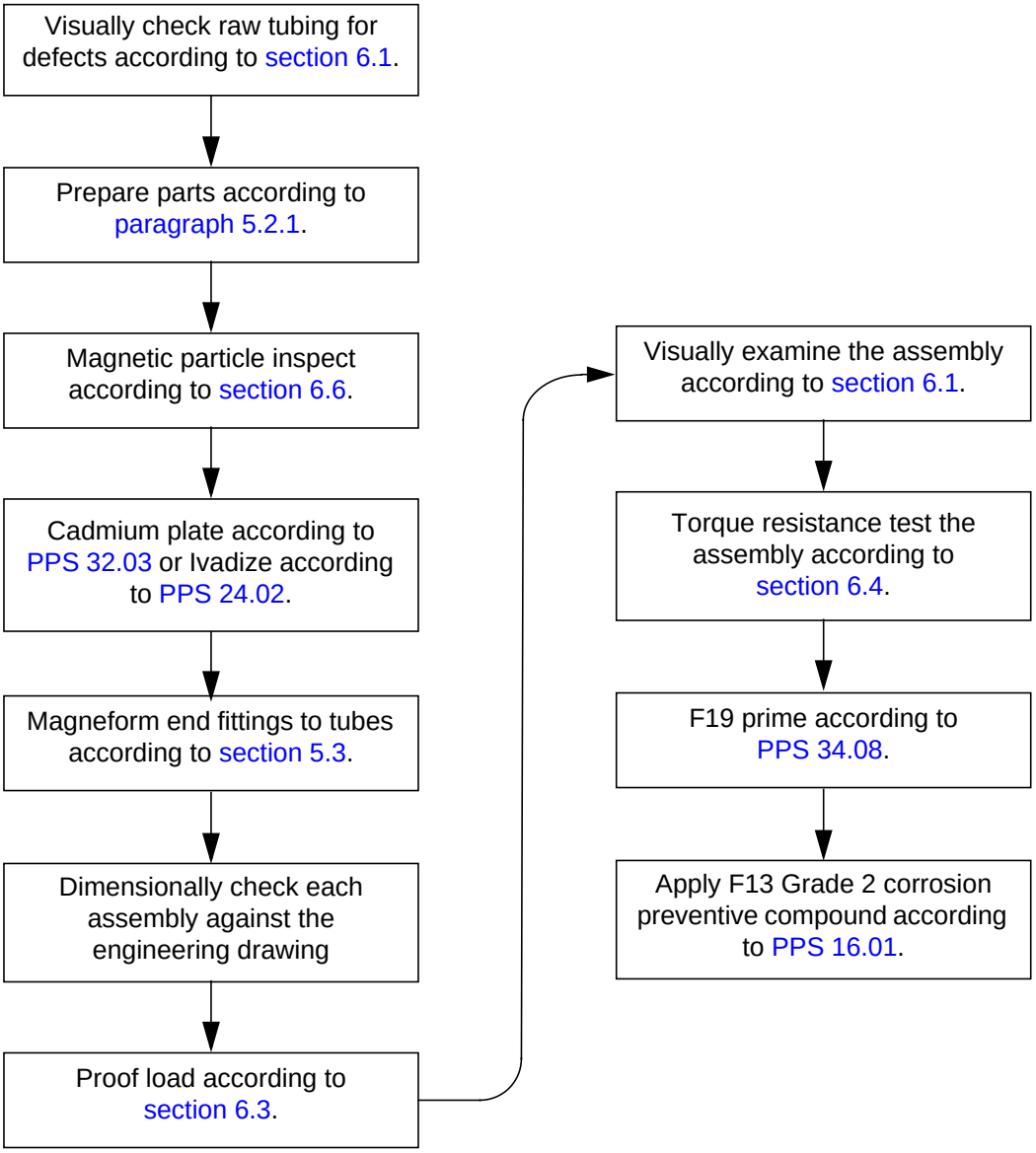
8 Personnel Requirements

8.1 This PPS has been categorized as a “Controlled Special Process” by PPS 13.39. Refer to PPS 13.39 for personnel requirements.

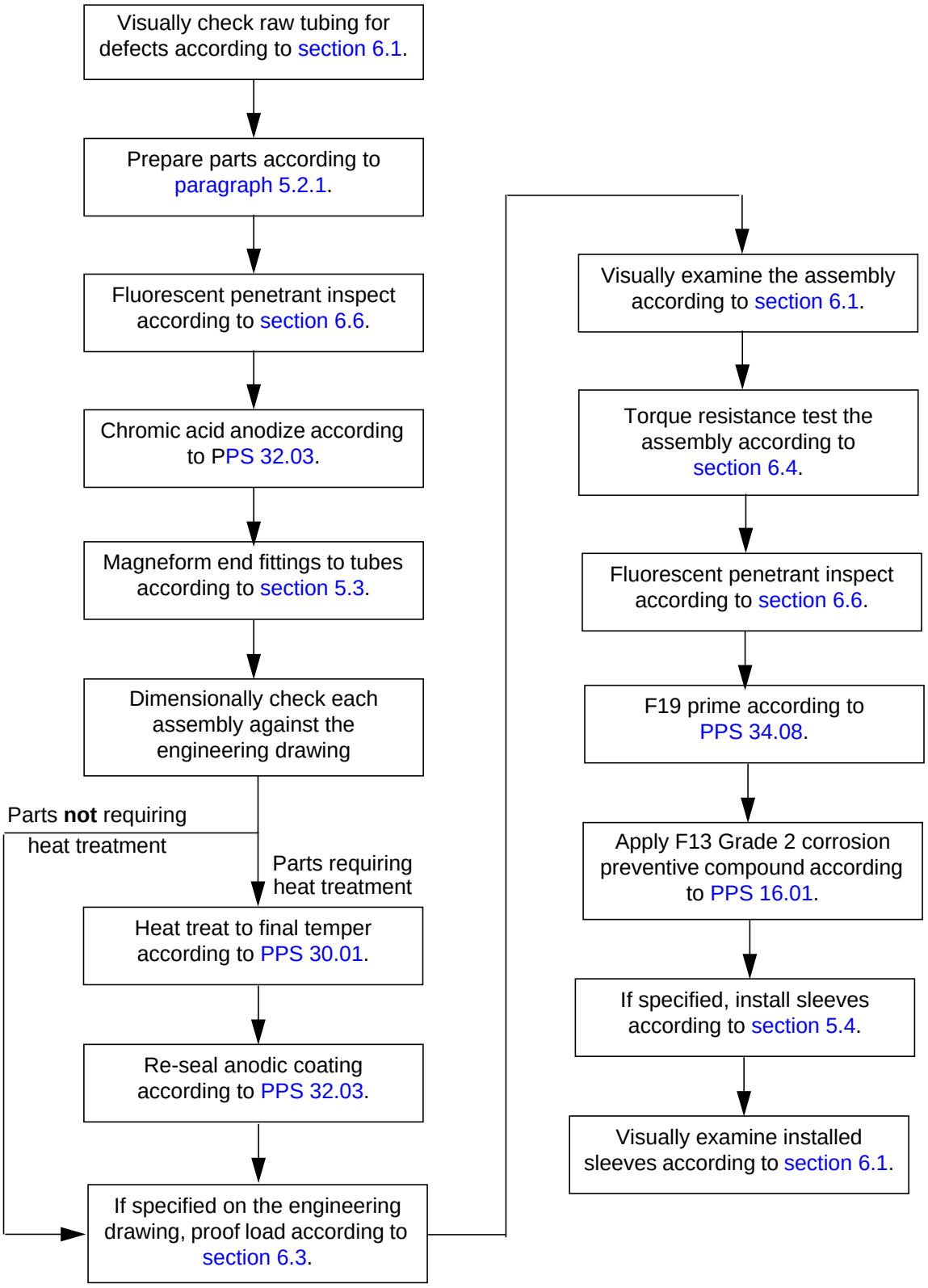
9 Maintenance of Equipment

9.1 It is recommended that magneform machines receive regular maintenance.

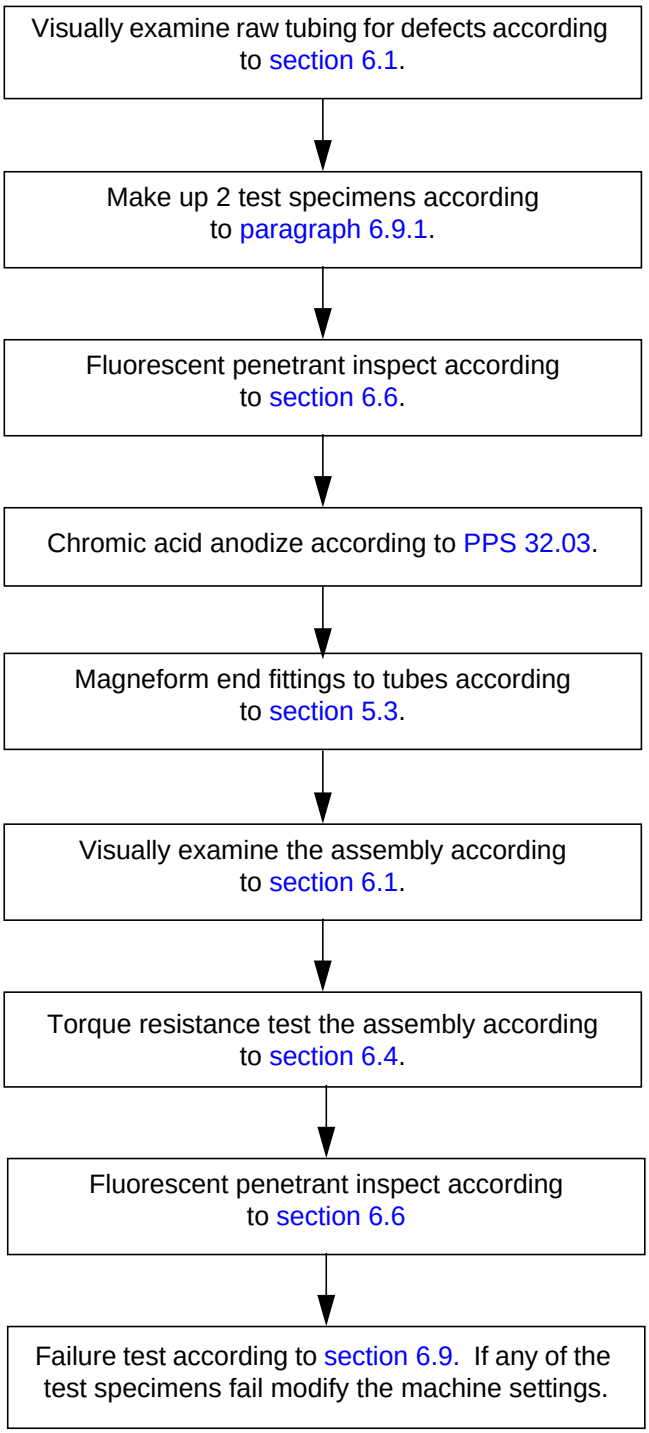
Flow Chart 1 - Processing of Steel Tube Assemblies



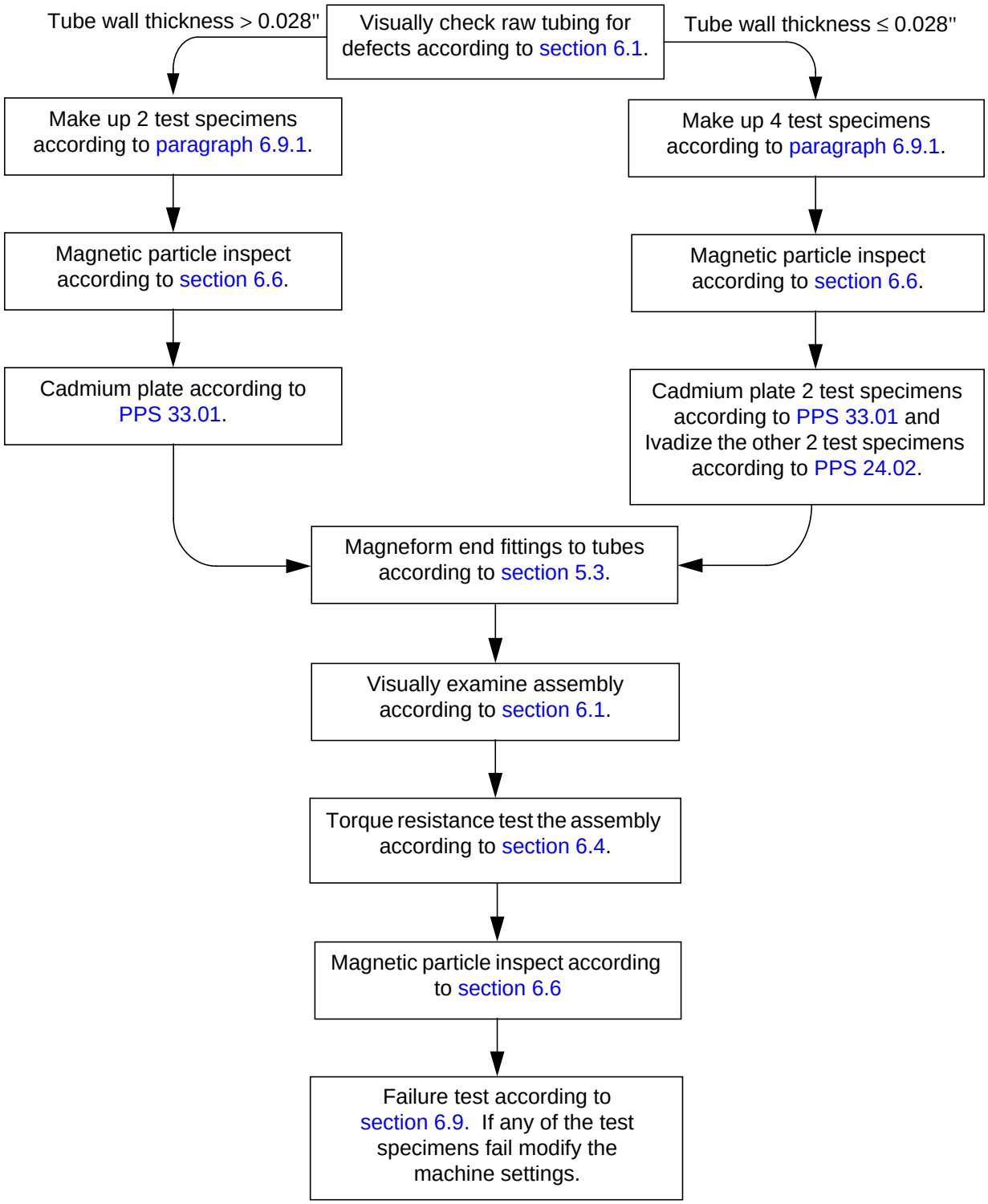
Flow Chart 2 - Processing of Aluminum Alloy Tube Assemblies



Flow Chart 3 - Certification of Magneform Schedules for Aluminum Tube Assemblies Without Sleeves



Flow Chart 4 - Certification of Magneform Schedules for Steel Tube Assemblies Without Sleeves



Flow Chart 5 - Certification of Magneform Schedules for Aluminum or Steel Tube Assemblies With Sleeves