BOMBARDIER
Toronto (de Havilland)
PROPRIETARY INFORMATION

PPS 12.07

PRODUCTION PROCESS STANDARD

Installation of Bushings using the ForceMate Cold Expansion Process

Issue 8
- This standard supersedes PPS 12.07, Issue 7.
- 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)	March 7, 2014
	Production Process Standards (PPS)	
Approved By:	(L.K. John)	March 10, 2014
	Materials Technology	
	(Adam Gordon)	March 13, 2014
	Quality	

Table of Contents

Sections **Page**

Figures

Tables

1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and the requirements for the installation of bushings using the ForceMate cold expansion process.

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 PPS 1.09 - Drilling and Reaming.

3.2 PPS 13.26 - General Subcontractor Provisions.

3.3 PPS 21.16 - Aircraft Weather/Pressure Sealing.

3.4 PPS 32.02 - Manual Application of Chemical Conversion Coatings.

4 Materials and Equipment

4.1 Materials

4.1.1 ForceMate cold expansion bushings as specified by the engineering drawing.

4.1.2 DHMS S3.01/B2 sealant.

4.2 Equipment

4.2.1 ForceMate reamers as listed in Table 1 and cold expansion tools as listed in Table 2.

4.2.2 Forcemate Powerpak - FT-20 (TS. 672.04. 20), FT-200B (TS. 672.04. 30) or FT200 (TS.672.04.10).

5 Procedure

5.1 General

5.1.1 The ForceMate cold expansion (FmCx) process involves the cold working of a clearance fit bushing in a hole. The result is an interference fit bushing and an improved fatigue life of the structure.

5.1.2 The FmCx system consists of placing a specially sized, pre-lubricated bushing over a tapered mandrel, inserting the end of the mandrel into the puller unit, inserting the mandrel/bushing assembly into the hole, and then activating the puller unit to pull the mandrel through the bushing. Pulling the mandrel through the hole in the bushing causes the bushing to expand, thereby locking the bushing in place with high interference, as well as cold working the material surrounding the bushing creating residual compressive stresses which provide the improvement in fatigue life of the component. After expansion/installation the inside of the bushing is reamed to final size which also serves to remove any lubricant residue.

5.1.3 The bushing installation sequence as defined on the manufacturing documentation (e.g., assembly manual) must be strictly adhered to. In some cases it may be necessary to install one bushing and bore it to finish size before installing others. In other cases, it may be impossible to install the second bushing in the adjacent lug if the installation sequence is reversed.

5.1.4 The combination GO/NO-GO gauge (see Figure 1) is a dual purpose gauge used to check the starter hole diameter in the aircraft structure for standard size bushings as well as the final hole diameter in the bushing. The end with the larger diameter is used for testing the starter hole diameter in the aircraft structure whereas the end with the smaller diameter is used for testing the final bore diameter of the bushing. The GO portion of the gauge must fit into the hole and the NO-GO portion of the gauge must not fit into the hole (see Figure 2).

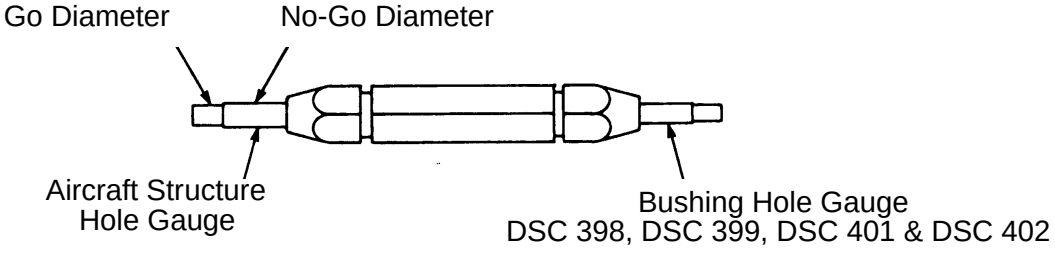

Figure 1 - Combination GO/NO-GO Gauge

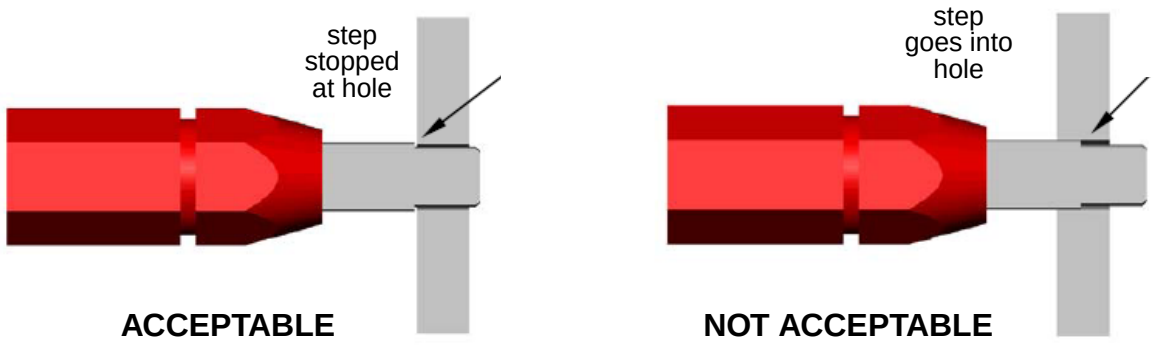

Figure 2 - Using the GO/NO-GO Gauge

5.2 Preparation of Holes

5.2.1 Preparation of holes for installation of bushings may be accomplished in several ways. These ways include the following examples:

- If starting from scratch (i.e., no hole exists), the starter hole may be prepared using a suitable starter drill and starting reamer (e.g., as supplied in the applicable tool kit). Alternatively, it is also acceptable to prepare the hole using a suitable pilot drill and piloted double margin drill.
- It is acceptable to prepare pilot holes for the starting reamer using N/C equipment. After the pilot holes have been prepared, use a starting reamer (e.g., as supplied in the applicable tool kit) to open the starting hole to the required size.
- If installing the bushing in an existing hole, use a starting reamer (e.g., as supplied in the tool kit), if applicable, or a piloted double margin drill to open the hole to the required size.
- Where Liaison Engineering has authorized installation of oversize bushings, open the hole using the appropriate reamer to the size specified.

5.2.1.1 Refer to PPS 1.09 for the procedure and requirements for drilling and reaming as well as a selection of drills and reamers available at Bombardier Toronto (de Havilland).

5.2.2 Prepare holes as follows:

Step 1. Drill and/or ream (ref. para. 5.2.1) the hole to meet the requirements specified in Table 1.

Step 2. Ensure that the hole is free from score marks, gouges, burrs, etc.

Step 3. Check the hole diameter (e.g., using the appropriate combination GO/NO-GO gauge specified in Table 1). If the hole diameter exceeds the maximum specified tolerance, refer to Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB for written authorization to install an oversize bushing.

Step 4. Manually brush apply chemical conversion coating to the bore of the hole according to PPS 32.02.

Step 5. If wet installation of the bushing is specified on the engineering drawing, immediately before installation of the bushing apply the primer or coating specified. Wipe the outside surfaces clean of runs or drips to help keep the tooling clean. Ensure all tooling is kept free of primer or coating build up.

Table 1 - Hole Size Requirements

BUSHING (Note 1)	**FORCEMATE STARTING REAMER** (Note 2)	**REQUIRED STARTING HOLE DIAMETER**	**COMBINATION GAUGE** (Note 3)
STANDARD			
DSC 398-1	n/a	1.4374" ± 0.0005"	FCG-119-6010-A
DSC 399-1	n/a	0.8124" ± 0.0006"	FCG-119-6050-A
DSC 401-1	n/a	1.1879" ± 0.0006"	FCG-119-6060-A
DSC 402-1	n/a	0.6250" ± 0.0005"	FCG-119-6040-A
DSC 586-1	FSR-1217-10010A	0.4378" ± 0.0010"	FCG-1217-65010A
DSC 587-1	FSR-1217-10010A	0.4378" ± 0.0010"	FCG-1217-65010A
DSC 588-1	FSR-1217-10030A	0.5003" ± 0.0010"	FCG-1217-65030A
1ST OVERSIZE			
DSC 398-1X	n/a	1.4530" ± 0.0005"	n/a
DSC 399-1X	n/a	0.8280" ± 0.0006"	n/a
DSC 401-1X	n/a	1.2035" ± 0.0006"	n/a
DSC 402-1X	n/a	0.6406" ± 0.0005"	n/a
DSC 586-1X	FSR-1217-10110A	0.4691" ± 0.0010"	FCG-1217-65110A
DSC 587-1X	FSR-1217-10110A	0.4691" ± 0.0010"	FCG-1217-65110A
DSC 588-1X	FSR-1217-10130A	0.5316" ± 0.0010"	FCG-1217-65130A

Note 1. -1 denotes a standard size bushing and -1X denotes a 1st oversize bushing. Written Liaison Engineering authority is required for installation of oversize bushings.

Note 2. The starting hole may be prepared using any of the methods specified in para. 5.2.1, including using the Forcemate starting reamer specified in this table. The designation of 'n/a' is used with regard to the listing of Forcemate starting reamers to indicate that a particular Forcemate reamer is not specified for that particular application.

Note 3. The designation of 'n/a' is used with regard to the listing of combination gauges to indicate that a particular Forcemate combination is not specified for that particular application.

5.3 Preparation of Tooling

5.3.1 Prepare tooling as follows (see Figure 3):

Step 1. Refer to Table 2 for the tools (i.e., puller unit, chuck assembly, etc.) required for the installation of each particular bushing. Ensure that all hydraulic and pneumatic line fittings are free of dirt, metal filings, etc. This process is tooling critical. The use of non-conforming tools can result in a significant reduction in fatigue life.

Step 2. Thread the chuck assembly onto the pull rod of the puller unit and hand tighten. Remove the LB threaded adapter, if installed; the LB threaded adapter is used only for removal of installed bushings.

Step 3. Thread the nose cap onto the puller unit and hand tighten.

Step 4. Thread the jaw into the nose cap and hand tighten.

Step 5. Check the mandrel for excessive wear using a mandrel check fixture; the mandrel check fixture is a gauge consisting of a steel plate with a NO-GO hole in the center, as shown in Figure 4. If the mandrel major diameter passes through the NO-GO hole, the mandrel is worn beyond the specification limit and must be replaced.

Step 6. For the purposes of verifying proper tool set-up and operation, insert the tang of the mandrel (**without a bushing**) into the chuck assembly. Note that the mandrel will be 'loose' in the chuck; it will only be gripped when the puller unit is activated.

Step 7. Connect the main hydraulic and the two pneumatic trigger control lines of the puller unit to the power pack.

Step 8. Connect a shop airline to the Forcemate power pack and activate the puller unit to verify proper operation. The puller unit is activated by depressing its trigger; continue depressing the trigger until the end of the mandrel has retracted completely below the face of the jaw. Do not release the trigger until the mandrel has fully retracted. When the mandrel has fully retracted, release the trigger and the mandrel should then return to its fully extended position. When using a new set of jaws, it is possible that the mandrel may stick in the jaws; if this occurs, unscrew the jaws so as to release the mandrel. If the proper operation of the puller unit cannot be verified, determine and correct the problem so that proper operation can be verified before proceeding.

Step 9. In preparation for bushing installation, remove the mandrel.

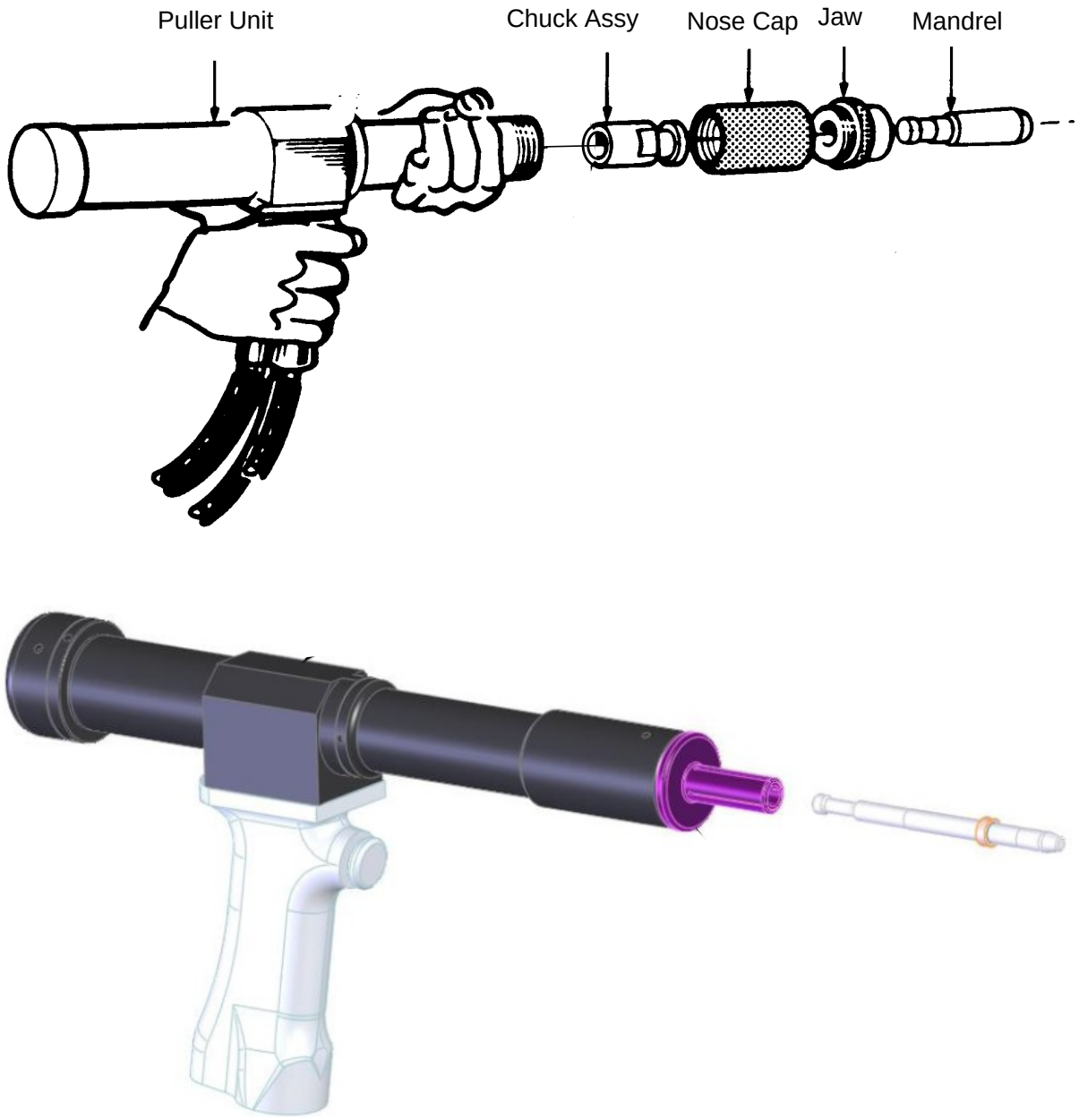

Figure 3 - Assembly of ForceMate Tooling

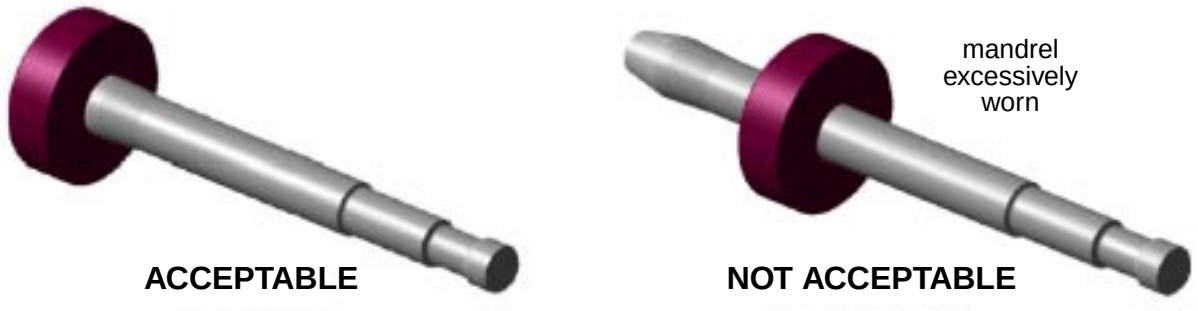

Figure 4 - Mandrel Check Fixture

Table 2 - ForceMate Tooling

	BUSHING (Note 1)			
	DSC 398	**DSC 399**	**DSC 401**	**DSC 402**
Tool Kit Number (Note 2)	TS.672.10.10 MK 4	TS.672.10.10 MK 1	TS.672.10.10 MK 3	TS.672.10.10 MK 2
Puller Unit	BB-30	LB-20	BB-30	LB-20
Chuck Assembly	BB-CA-16	LB-CA-A6	BB-CA-16	LB-CA-A6
Nose Cap	FMC-119-50010-A	FMC-119-50020-A	FMC-119-50010-A	FMC-119-50020-A
Jaws	FMJ-119-55010-A	FMJ-119-55050-A	FMJ-119-55060-A	FMJ-119-55040-A
Mandrel	FMM-119-25010-A	FMM-119-25050-A	FMM-119-25060-A	FMM-119-25040-A
Mandrel Gauge	FMG-119-30010-A	FMG-119-30050-A	FMG-119-30060-A	FMG-119-30040-A
Support Assembly	FSA-119-20010-A	---	---	---

	BUSHING (Note 1)		
	DSC 586	**DSC 587**	**DSC 588**
Tool Kit Number (Note 2)	TS.672.10.10 MK 5	TS.672.10.10 MK 6	TS.672.10.10 MK 7
Puller Unit	LB-20	LB-20	LB-20
Chuck Assembly	LB-CA-6	LB-CA-6	LB-CA-6
Nose Cap	FMC-L	FMC-L	FMC-L
Jaws	FMJ-1217-55010A	FMJ-1217-55010A	FMJ-1217-55030A
Mandrel	FMM-1217-25010A	FMM-1217-25010A	FMM-1217-25030A
Mandrel Gauge	FMG-1217-30010A	FMG-1217-30010A	FMG-1217-30030A

Note 1. -1 denotes a standard size bushing and -1X denotes a 1st oversize bushing. With the exception of the combination go/no-go gauge, use the same equipment for installation of standard and 1st oversize.

Note 2. The tool kits are made up of the puller unit, chuck assembly, nose cap, jaws, mandrel and mandrel gauge listed for installation of the applicable bushing.

5.4 Installation of Bushings

5.4.1 Installation of DSC 398 Bushings

5.4.1.1 Install DSC 398 bushings as follows (see Figure 5):

Step 1. Insert a DSC 398 bushing into each of the two lugs.

Step 2. Locate the support assembly between the two lugs. Ensure that the label 'PULL FROM THIS END' is facing towards the puller unit side. This ensures that the 0.005" detent on the opposite side of the support assembly locates the outer bushing 0.005" below flush.

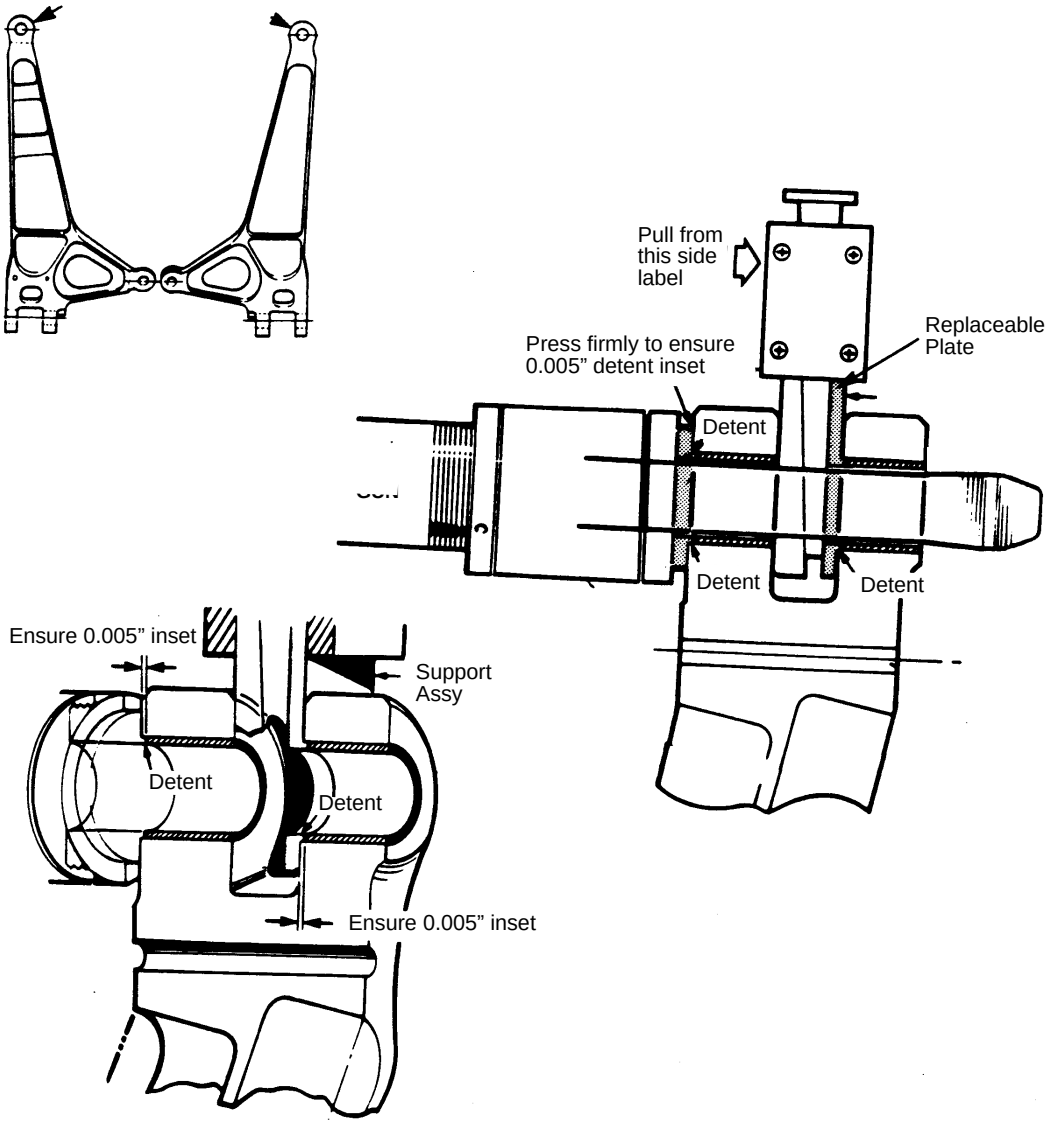

Figure 5 - Installation of DSC 398 Bushings

Step 3. Insert the mandrel, attachment end first, through the bushings in both lugs as well as the hole in the support assembly.

Step 4. Tap the sliding wedge portion of the support assembly with a plastic-faced hammer to firmly wedge the support assembly between the two lugs. The purpose of the support is to prevent deformation of the lugs during the cold expansion process.

Step 5. Connect the shop airline to the power pack.

Step 6. Locate the puller unit over the attachment end of the mandrel and push the jaw firmly against the lug. The 0.005” detent on the face of the jaw will locate the inner bushing 0.005” below flush.

Step 7. Activate the puller unit to withdraw the mandrel thereby cold expanding the bushings.

Step 8. Remove the mandrel from the puller unit, disconnect the shop airline from the power pack and remove the support assembly.

5.4.2 Installation of DSC 399 Bushings

5.4.2.1 Install DSC 399 bushings as follows (see Figure 6):

Step 1. Slide a DSC 399 bushing onto the mandrel and insert the attachment end of the mandrel into the puller unit.

Step 2. Connect the shop airline to the power pack.

Step 3. Insert the mandrel/bushing into the lug and push the jaw firmly against the lug. The 0.005” detent on the face of the jaw will locate the bushing 0.005” below flush.

Step 4. Activate the puller unit to withdraw the mandrel thereby cold expanding the bushing.

Step 5. Remove the mandrel from the puller unit and disconnect the shop airline from the power pack.

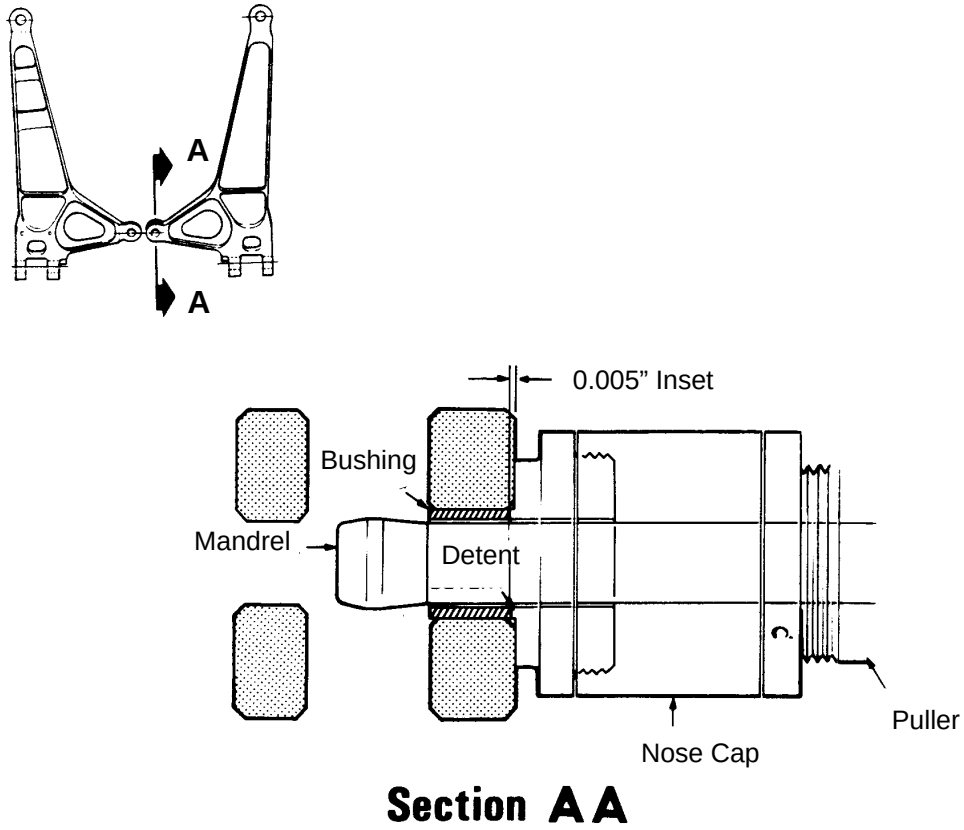

Figure 6 - Installation of DSC 399 Bushings

5.4.3 Installation of DSC 401 Bushings

5.4.3.1 Install DSC 401 bushings as follows (see Figure 7):

Step 1. Insert a DSC 401 bushing into the lug. The flange on the bushing must be located on the side shown in Figure 7.

Step 2. Insert the mandrel, attachment end first, through the bushing.

Step 3. Connect the shop airline to the power pack.

Step 4. Locate the puller unit over the attachment end of the mandrel and push the jaw firmly against the lug.

Step 5. Activate the puller unit to withdraw the mandrel thereby cold expanding the bushing.

Step 6. Remove the mandrel from the puller unit and disconnect the shop airline from the power pack.

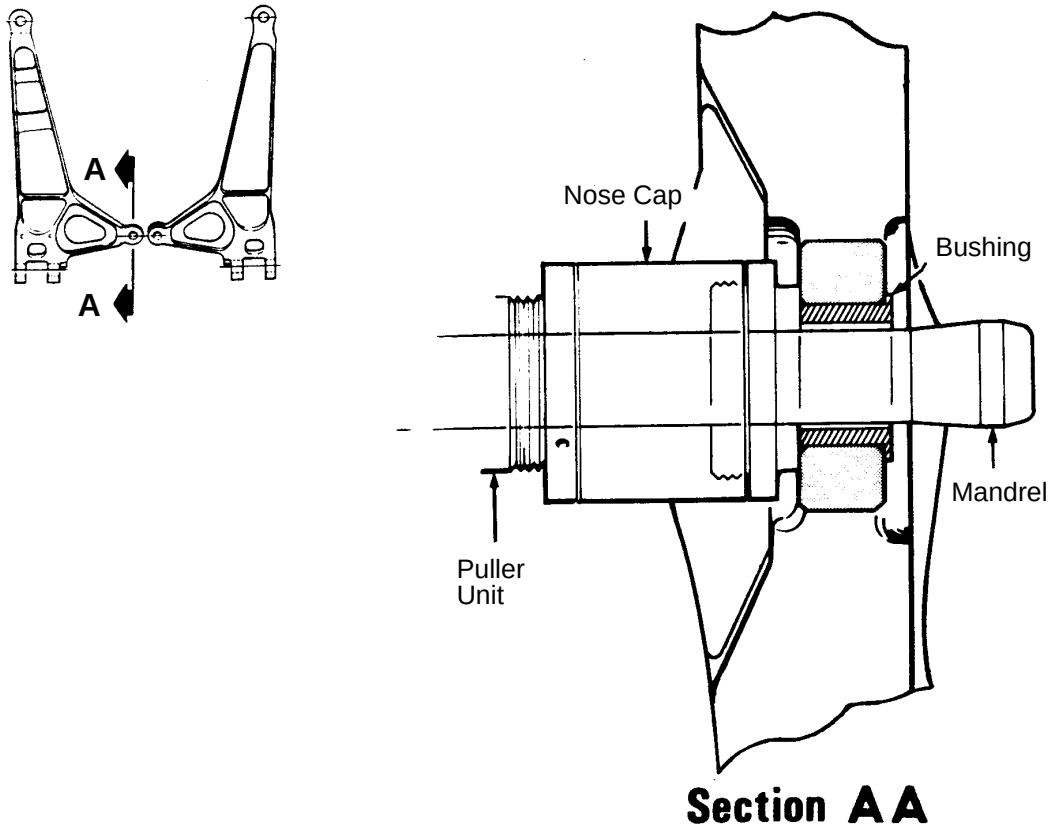

Figure 7 - Installation of DSC 401 Bushing

5.4.4 Installation of DSC 402 Bushings

5.4.4.1 Install DSC 402 bushings as follows (see Figure 8):

Step 1. Insert a DSC 402 bushing into the lug. The flange of the bushing must be located between the two lugs as shown in Figure 8.

Step 2. Insert the mandrel, attachment end first, through the bushing.

Step 3. Connect the shop airline to the power pack.

Step 4. Locate the puller unit over the attachment end of the mandrel and push the jaw firmly against the lug.

Step 5. Activate the puller unit to withdraw the mandrel, thereby cold expanding the bushing.

Step 6. Remove the mandrel from the puller unit and disconnect the shop airline from the power pack

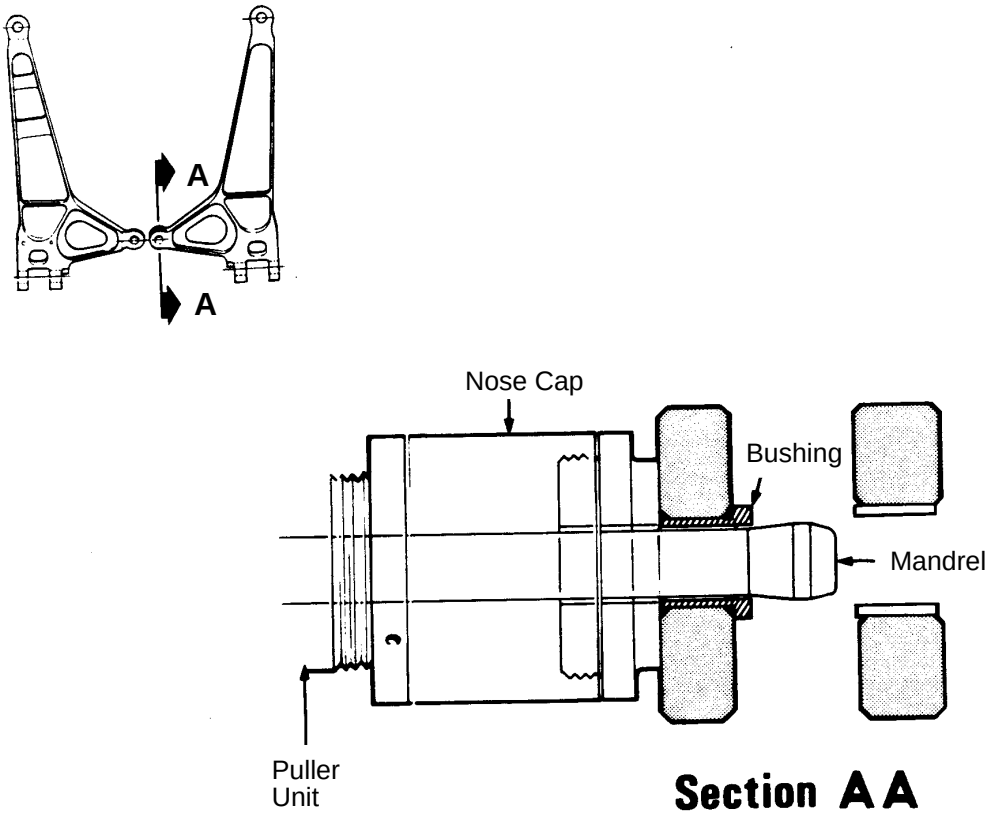

Figure 8 - Installation of DSC 402 Bushings

5.4.5 Installation of DSC 586, DSC 587 and DSC 588 Bushings

5.4.5.1 Install DSC 586, DSC 587 and DSC 588 bushings as follows (see Figure 9):

Step 1. Slide the applicable bushing onto the mandrel.

Step 2. Insert the tang end of the mandrel through the jaw into the puller unit.

Step 3. Slide the mandrel/bushing into the prepared starting hole. Depending upon the orientation of the mandrel/bushing and hole, it may be necessary to hold the mandrel/bushing in place with a finger tip or tool from the other side of the hole to prevent the mandrel/bushing from dropping through the hole as the mandrel will not be gripped by the puller unit until the pull cycle begins.

Step 4. Press the puller unit jaw firmly against the structure, square to the work, ensuring that the jaw detent (i.e., the raised ridge or boss, on the face of the jaw) is completely engaged within the hole and the bushing is flush to underflush.

Step 5. Activate the puller unit by pressing and **holding** the trigger to retract the mandrel and expand the bushing into the prepared hole. If holding the mandrel/bushing in position with a fingertip or tool, as soon as pressure is applied to the trigger simultaneously release the mandrel/bushing. Do not release the trigger until the mandrel fully retracts. Interruption of mandrel retraction could result in damage to the tooling and/or aircraft structure.

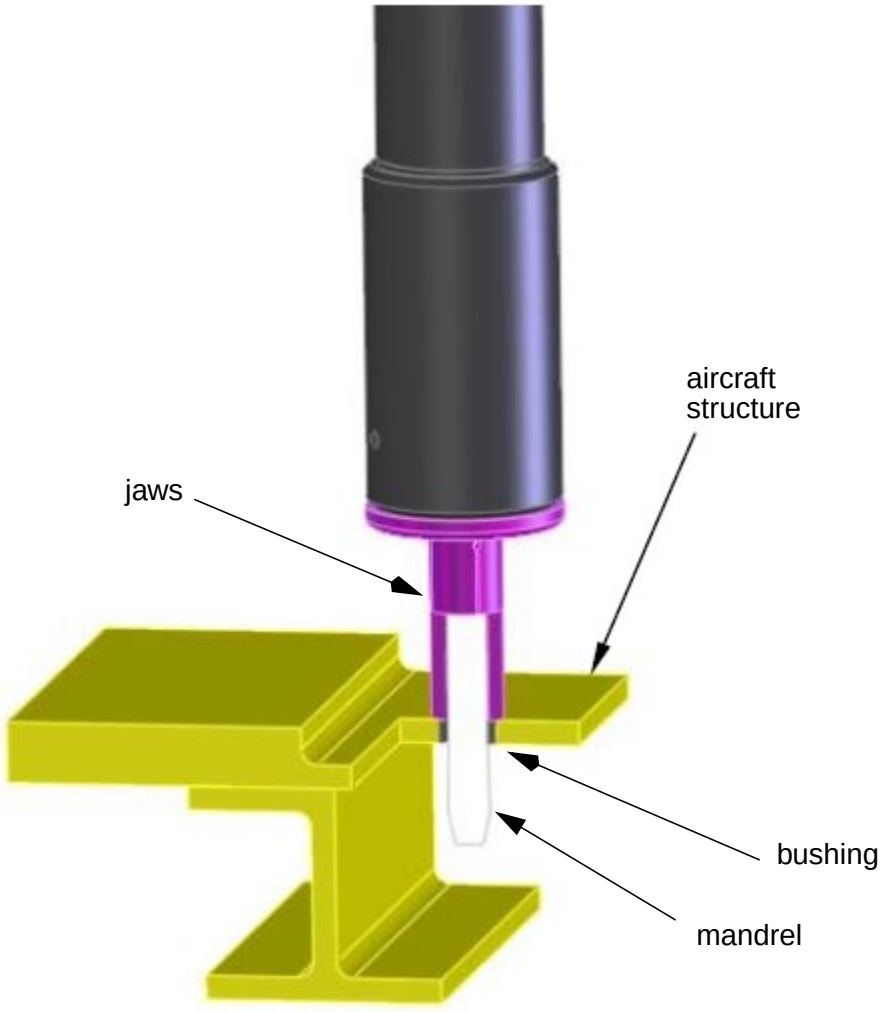

Figure 9 - Installation of DSC 586, DSC 587 & DSC 588 Bushings

5.5 Preparation of Bushing Holes (i.e., Bushing Inside Diameter)

5.5.1 For DSC 398, DSC 399, DSC 401 and DSC 402 bushings only, prepare the hole in the installed bushing to the final size specified in Table 3. Prepare the inside diameter of DSC 398, DSC 399, DSC 401 and DSC 402 bushings as follows:

Step 1. Drill and/or ream the bushing inside diameter according to PPS 1.09.

Step 2. Check the final bushing inside diameter (e.g., using the combination go/no-go gauge specified in Table 3).

Step 3. Manually brush apply chemical conversion coating to the bushing inside diameter according to PPS 32.02.

Table 3 - Boring of Bushing Inside Diameter

BUSHING	REQUIRED BUSHING INSIDE DIAMETER	COMBINATION GAUGE
DSC 398	1.2210" ± 0.0015"	FCG-119-6010-A
DSC 399	0.6009" ± 0.0007"	FCG-119-6050-A
DSC 401	0.8514" ± 0.0010"	FCG-119-6060-A
DSC 402	0.4779" ± 0.0007"	FCG-119-6040-A
DSC 586	See para. 5.5.2	
DSC 587		
DSC 588		

Note 1. The required bushing inside diameter is the same for both standard (-1) and 1st oversize (-1X) bushings.

5.5.2 The inside diameter of DSC 586, DSC 587 and DSC 588 bushings does not need to be opened up after bushing installation; however, if necessary to facilitate assembly of mating parts, it is acceptable to ream the bushing inside diameter up to the maximum final hole size specified by the engineering drawing.

5.6 Oversize Holes

5.6.1 Oversize holes in the part in which the bushing is to be installed may be salvaged by installation of oversize bushings only if authorized in writing (e.g., via fastpath RNC) by Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB.

5.7 Post Installation Procedure - Sealing

5.7.1 Unless otherwise specified by the engineering drawing, seal the periphery of DSC 398, DSC 399, DSC 401 and DSC 402 bushings with a bead of DHMS S3.01/B2 sealant according to PPS 21.16. Do not seal the periphery of DSC 586, DSC 587 or DSC 588 bushings.

5.8 Removal and Replacement of Installed Bushings

5.8.1 If necessary, remove DSC 398, DSC 399, DSC 401 or DSC 402 bushings using an arbour press, gear/bushing puller, or similar tool.

5.8.2 Remove installed DSC 586, DSC 587 or DSC 588 bushings using a puller unit fitted with the removal tools specified in Table 4 as follows:

Step 1. Remove the jaw, nosecap and chuck assembly from the puller unit.

Step 2. Install the LB threaded adapter onto the pull rod of the puller unit.

Step 3. Thread the removal rod into the threaded adapter.

Step 4. Thread the long threaded end of the nosecap completely onto the end of the puller unit.

Step 5. Thread the removal jaw into the short thread end of the nosecap.

Step 6. Connect the air hoses to the PowerPak.

Step 7. Bring the puller assembly to the structure and insert the removal rod through the bushing to be removed with the removal jaw flush against the structure.

Step 8. Hold the removal jaw firmly and squarely against the structure and visually verify that the removal jaw is flush with the structure and that the jaw counterbore fully encloses the bushing to be removed.

Step 9. Holding the jaw flush against the structure, thread the removal collar onto the removal rod from the other side of the bushing until the collar rests against the bushing, **without tightening**.

Step 10. Activate the puller unit to remove the bushing.

Step 11. Release the trigger and withdraw the puller assembly when the bushing has been removed. Should the puller bottom out just after the point of removal, it is not cause for alarm.

Step 12. Discard removed bushings; removed bushings cannot be re-installed.

5.8.3 After removing the bushing, check the hole for damage and measure the diameter; if the hole is free from damage (i.e., score marks, gouges, etc.) and the hole diameter is within the limits specified in Table 1, it is acceptable to re-install a standard size bushing. If the hole has been damaged or the hole diameter is greater than specified in Table 1, refer to Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB for authority to install an oversize bushing according to section 5.6. Discard removed bushings; removed bushings cannot be re-installed.

Table 4 - Removal Tools for DSC 586, DSC 587 and DSC 588 Bushings

REMOVAL TOOLS	BUSHING TO BE REMOVED (Note 1)		
	DSC 586	DSC 587	DSC 588
Removal Collar	BRC-1217-86010A	BRC-1217-86010A	BRC-1217-86030A
Removal Jaw	BRJ-1217-87010A	BRJ-1217-87010A	BRJ-1217-87030A
Removal Rod	BRR-1217-90010A	BRR-1217-90010A	BRR-1217-90030A
LB Threaded Adapter	2340-001	2340-001	2340-001
Note 1. The same removal tools can be used for both standard (-1) and 1st oversize (-1X) bushings.			

6 Requirements

6.1 On flanged bushings, the maximum permissible gap between the installed bushing flange and the face of the attachment lug is 0.002".

6.2 On plain bushings, the ends of the bushings must be flush or below flush with the face of the structure.

6.3 All other dimensions must meet the requirements of the engineering drawing.

6.4 Ensure that the inside surface of installed bushings is free of defects/damage (e.g., adequate surface finish and without scoring).

7 Safety Precautions

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

7.2 Forcemate tooling requires the use of very high hydraulic and air pressure. Disconnect air and hydraulic lines when changing mandrels, jaws, etc. on the puller unit. Disconnect the air supply from the PowerPak whenever it is not in use, when the hydraulic hose is disconnected from the pump and whenever maintenance is performed.

7.3 Wear safety glasses at all times during the cold expansion process.

7.4 Before operation of the puller unit make sure all screws, fittings and caps are properly tight.

7.5 In the event of a ruptured or leaking hydraulic hose, hydraulic fitting or the puller unit, immediately release the trigger and disconnect the air supply line from the PowerPak. Never use your hands to grasp a leaking hose under pressure as the force of escaping hydraulic fluid can cause serious injury.

7.6 Periodically check hoses for wear or damage that could cause failure and possibly result in injury.

7.7 Do not attempt to disconnect the hydraulic hose while the PowerPak is running.

7.8 Do not expose hoses to potential hazards such as extreme heat or cold, sharp surfaces, heavy impact, vehicular traffic or toxic materials or paints.

7.9 Do not allow hoses to kink, twist curl or bend so tightly that the oil flow within the hose is blocked or reduced.

7.10 Do not mix tooling from other manufacturers. Always use the complete set of compatible tooling.

7.11 Do not use excessively worn equipment.

8 Personnel Requirements

8.1 Personnel must have a good working knowledge of the applicable procedure and requirements as specified herein and must have exhibited their competency to their supervisor.