BOMBARDIER Toronto (de Havilland) **Proprietary Information**	**PPS 9.17** **Production Process Standard (PPS)**

Encapsulation of Electrical Wire Harnesses and Cable Assemblies

Issue 12

- This standard supersedes PPS 9.17, Issue 11.
- This PPS is effective as of the distribution date.
- Validation of issue status is the responsibility of the user.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
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Issue 12 - Summary of Changes (over the previous issue)

The following summaries are not detailed and are intended only to assist in alerting PPS users to changes which may affect them; refer to the applicable section(s) of this PPS for detailed procedure and requirements.

- Added new sub-section 3.1 and para. 3.1.1, to ensure correct usage of reference specifications.
- Created new sub-section 3.2, to identify PPS document references as Bombardier Toronto (de Havilland) process specifications.
- Added new para. 4.1.1, to prevent inappropriate material substitution.
- Replaced reference to "Raychem" with reference to "TE Connectivity (Raychem)".
- Revised reference to hot air guns to add the Steinel HG 2520E hot air gun as an example.

Issue 12 - Summary of Changes (over the previous issue) continued

- Replaced all reference to S-1009, S-1030 and S-1125 adhesives with reference to S1009, S1030 and S1125 adhesives, respectively.
- Add reference to TE Connectivity (Raychem) S1017 and S1048 melt adhesive tapes.
- Added provisions for preparation, curing and storage of adhesives which may be specified by the engineering drawing, but are not specifically referenced in this PPS.
- Revised cure requirements for S1030 hot melt adhesive tape.
- Revised procedure for all encapsulation involving adhesives to remove instruction to wipe away excess adhesive to form a uniform fillet of adhesive after shrinking the boot, transition or tubing in place.
- Added procedure for encapsulation of individual electrical/electronic components.
- Revised procedure for removal of installed transitions and boots to also include removal of installed heat shrinkable tubing.
- Revised requirements to clarify/illustrate adhesive extrusion limits (i.e., insufficient, optimum and excessive).
- Added para. 7.1, to clarify applicability of the safety precautions specified herein.
- Moved safety considerations regarding hot air guns to section 7 (Safety Precautions).
- Added additional safety precautions.
- Revised storage provisions to specifically include hot melt adhesive tapes.

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1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for encapsulating electrical wire harnesses and cable assemblies using heat shrinkable tubing, boots and transitions and/or non-heat shrinkable convoluted tubing.

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 General

3.1.1 Unless a specific issue is indicated, the issue of the reference documents specified in this section in effect at the time of manufacture shall form a part of this specification to the extent indicated herein.

3.2 Bombardier Toronto (de Havilland) Process Specifications

3.2.1 PPS 13.26 - General Subcontractor Provisions.

3.2.2 PPS 13.28 - Storage Life of Adhesives, Sealants, Paints and Composite Products.

3.2.3 PPS 31.17 - Solvent Usage.

4 Materials and Equipment

4.1 Materials

4.1.1 Unless otherwise specified in this section, use only the materials specified; use of superseding or alternative materials is not allowed.

4.1.2 Heat-shrinkable encapsulation tubing, boots and transitions:

- Polyolefin - TE Connectivity (Raychem) WCSF.
- Elastomeric - TE Connectivity (Raychem) HCDR.

4.1.2.1 For the purposes of this PPS, encapsulation boots which are supplied with hot-melt adhesive pre-applied by the manufacturer are considered “pre-glued” boots.

4.1.3 Convoluted tubing to DSC 436 (e.g., TE Connectivity (Raychem) HCTE – XL-ETFE radiation crosslinked modified ethelyne tetrafluoroethylene).

4.1.4 Adhesive, 2 part epoxy:

- Polyolefin - TE Connectivity (Raychem) Thermofit S1009 Kit.
- Elastomeric - TE Connectivity (Raychem) Thermofit S1125 Kit.

4.1.5 Hot melt adhesive tape (e.g., TE Connectivity (Raychem) S1017, S1030 and S1048)

4.1.6 Guideline tape, fire resistant, filler - Freudenberg-NOK Inc. #52672 Guideline tape or insulation tape to A-A-59163 (e.g., Freudenberg-NOK Inc. #50215).

4.1.7 Abrasive paper, aluminum oxide, 180 - 220 grit.

4.2 Equipment

4.2.1 Hot air gun (e.g., Steinel HG 2520E or Steinel STEI-HG2310-BB) with interchangeable heat deflector attachments.

5 Procedure

5.1 General

5.1.1 Encapsulation components (i.e., tubing, boots and transitions) are available in polyolefin and elastomeric types. Refer to the engineering drawing for the type of system to be used on a particular assembly. Each component of the system has a part number designation and it is important that the correct components be used for each assembly.

5.1.2 Slip heat shrinkable boots and transitions onto the wire harness before the wires are terminated. Refer to Figure 1 for a general description of a fully encapsulated wire harness assembly.

5.1.3 Whenever using a hot air gun or heat gun (ref. para. 4.2.1) take care to ensure not to use too high a heat setting. The heat setting used must be appropriate to the task the hot air gun is being used for without causing damage to parts or surrounding structure. If necessary use heat guards to protect surrounding structure. If unsure what heat setting to use, start at a lower temperature setting and increase slowly to determine the proper setting.

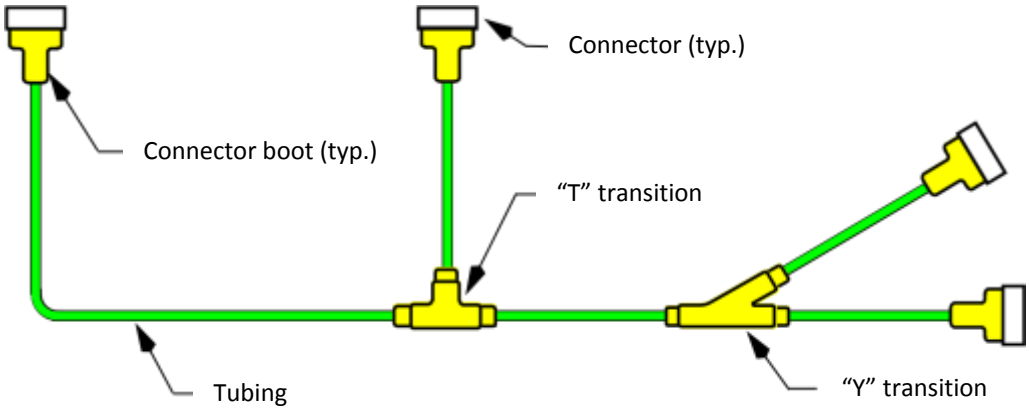


Figure 1. **Wire Harness Encapsulation System (Typ.)**

5.2 Preparation of Boots, Transitions, Tubing, Wiring and Filler Tape

5.2.1 Cut tubing to length. Allow 5% longitudinal shrinkage for polyolefin (WCSF) heat-shrinkable tubing and 10% longitudinal shrinkage for elastomeric (HCDR) heat-shrinkable convoluted tubing.

5.2.2 Prepare bonding surfaces on HCTE and PTFE (Teflon) convoluted tubing and elastomeric (HCDR) boots, transitions and tubing, as follows:

Step 1. Lightly abrade the bonding surfaces with 180 - 220 grit aluminum oxide abrasive paper.

Step 2. Solvent clean the bonding surfaces according to PPS 31.17.

5.2.3 For polyolefin (WCSF) transitions, tubing and boots (except "pre-glued" boots), solvent clean the bonding surfaces according to PPS 31.17. "Pre-glued" polyolefin (WCSF) boots do not require preparation before bonding (i.e., do not solvent clean).

5.2.4 Prepare bonding surfaces of wires or filler tape (ref. para. 4.1.5) by solvent wiping according to PPS 31.17.

5.3 Preparation and Curing of Adhesives

5.3.1 If the engineering drawing does not specify the adhesive, use the adhesive specified in Table 1.

Table 1. **Selection of Adhesives**

Bonding Surface	Adhesive
Heat-shrinkable, polyolefin encapsulation tubing (WCSF)	S1009 polyolefin adhesive (Thermofit 2 part epoxy kit) or S1030 hot melt adhesive tape
Heat-shrinkable, elastomeric encapsulation tubing (HCDR)	S1125 elastomeric adhesive (Thermofit 2 part epoxy kit) or S1030 hot melt adhesive tape
Convoluted tubing (HCTE)	S1125 elastomeric adhesive (Thermofit 2 part epoxy kit) or S1030 hot melt adhesive tape

Note 1. Use this table to select the adhesive to use only when the engineering drawing or wiring list does not specify the adhesive to be used. Do not use additional adhesive with “pre-glued” boots unless specified by the engineering drawing or wiring list.

5.3.2 Hot melt tape adhesives (i.e., S1017, S1030 and S1048, ref. para. 4.1.5) do not require any preparation before bonding. If bonding/sealing using hot melt adhesive tape, two complete turns of tape is recommended.

5.3.3 S1009 polyolefin adhesive and S1125 elastomeric adhesive come as self-contained kits, complete with sealed, pre-measured quantities of resin and hardener, a mixing stick, abrasive paper, and mixing instructions. Just before application, thoroughly mix the adhesive according to the manufacturer’s instructions. Discard unused adhesive which has exceeded the pot life specified in 5.3.2.

5.3.4 Refer to 5.3.2 for adhesive cure to handle and full cure requirements.

5.3.5 For adhesives specified by the engineering drawing, but which are not specifically referenced in this PPS, refer to the manufacturers’ instructions for adhesive preparation instructions.

Table 2. **Pot Life and Cure Times of Adhesives**

Adhesive	Pot Life	Cure Time	
		Cure To Handle	Full Cure
S1009 (2 part kit)	20 minutes	4 hours at room temperature	20 minutes at 350°F (177°C) or 24 hours at room temperature
S1017 hot melt tape	n/a	Allow to cool to room temperature	
S1030 hot melt tape	n/a	Allow to cool to room temperature	
S1048 hot melt tape	n/a	Allow to cool to room temperature	
S1125 (2 part kit)	90 minutes	24 hours at room temperature	15 minutes at 300°F (149°C) or 1 hour at 185°F (85°C)

Note 1. For “pre-glued” boots and transitions and when hot melt tape is used, allow the entire assembly to cool to room temperature before further handling or assembly.

5.4 Preparation of Wires

5.4.1 Ensure that wires to be encapsulated are free of burrs or nicks which may cause the tube to split during shrinking.

5.4.2 Ensure that the wires to be encapsulated are clean and free of oil and grease. Remove contaminants by solvent cleaning according to PPS 31.17.

5.4.3 Induce a slight twist into the wire loom so that the harness will maintain its shape at bends after encapsulation.

5.5 Encapsulation of Wire Harnesses

5.5.1 If the engineering drawing specifies encapsulation of a wire harness with heat shrinkable tubing, proceed as follows:

Step 1. Lay out the wire harness on the wiring board or bench according to the engineering drawing.

Step 2. Slide the tubing onto the wire harness. Position the tubing so as to provide a minimum 1/2" overlap of the transition onto the tubing after shrinking (see Figure 2).

Step 3. Starting at one end, shrink the tubing in place (see Figure 3). If possible, start at the transition end of the tube and work towards the connector end. Take care to avoid over heating the tubing.

Step 4. Install all transitions according to section 5.6.

Step 5. Install and encapsulate connectors as specified in section 5.7.

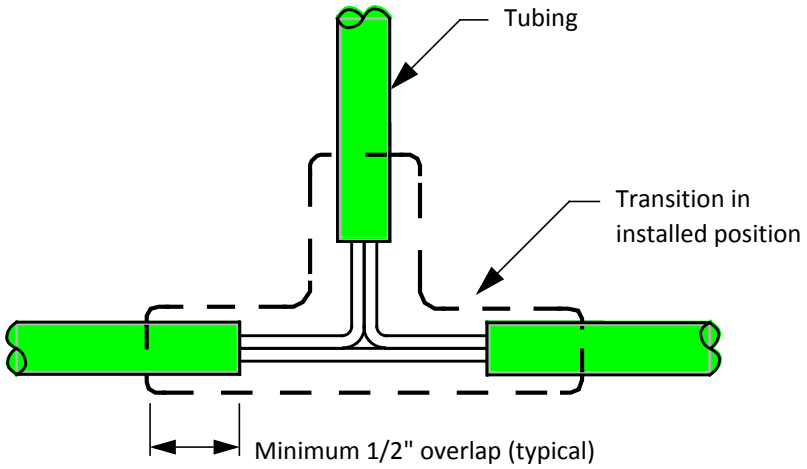


Figure 2. **Transition/Tubing Overlap**

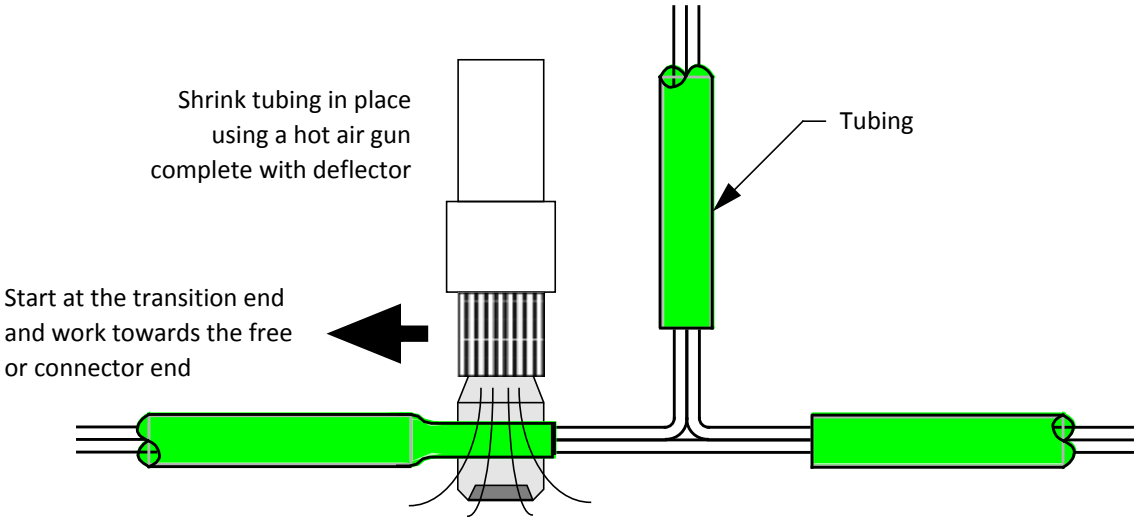


Figure 3. **Application of Tubing to Wire Harnesses**

5.6 **Installation of Transition Boots**

5.6.1 Each leg of the transition is identified by a letter designation. Make sure that the breakout is assembled into the correct transition leg, as it may not be obvious which leg is which in the expanded or as supplied condition (see Table 3).

5.6.2 Install encapsulation boots at transitions as follows:

Step 1. Prepare the bonding surfaces where the transitions will be placed according to section 5.2.

Step 2. Pass the wire bundles through the legs of the transition and locate the transition over the wire junction. If more than one transition is used, do not begin shrinking until all transitions are placed in position on the wire harness.

Step 3. Prepare a suitable quantity of adhesive. If the engineering drawing does not specify the adhesive, use the adhesive specified in Table 1.

Step 4. Apply heat around the center of the transition until a “mushroom” is formed on each of the legs of the transition.

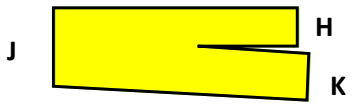
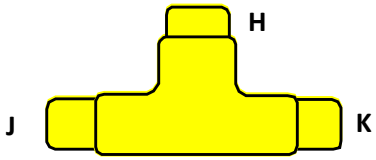
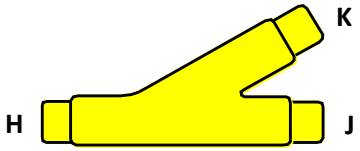
Step 5. Apply adhesive to the bonding surface within the “mushroom” of each of the legs of the transition and apply heat to complete the shrinking of each leg. Take care to avoid over heating while shrinking.

Step 6. Do not wipe away or otherwise interfere with the squeezed out adhesive bead.

Step 7. Apply adhesive and shrink the remaining legs of the transition in place according to the procedure specified in Step 5 and Step 6.

Step 8. Allow the adhesive to fully cure according to 5.3.2 before further working the assembly.

Table 3. **Transition Configurations**

	As Supplied	After Shrinking
"T" Transition		
"Y" Transition		

5.7 Encapsulation of Connectors

5.7.1 Encapsulate connectors as follows:

Step 1. Slip the boot onto the wire loom.

Step 2. Terminate the wires at the connector according to PPS 9.22.

Step 3. If the wire harness has been encapsulated in heat shrinkable tubing, trim the encapsulation tubing to a length which will cause the connector boot to overlap the tubing by at least 1/2" when the connector boot has been shrunk into place according to Figure 4.

Step 4. If only a few wires terminate at the connector and the boot will not shrink down to the wires completely, wrap the wires in filler tape (ref. para. 4.1.5) so that the boot shrinks down to the tape diameter. When positioning the tape, remember to account for longitudinal shrinkage of the boot.

Step 5. If the connector boot is being shrunk down onto conduit or heat shrinkable encapsulation tubing, prepare the bonding surfaces of the tubing or conduit where the connector boot will be placed according to section 5.2.

Step 6. For the following applications, prepare a suitable quantity of adhesive and apply a uniform coating to the connector backshell in the area to be covered with the boot.

- Apply adhesive when installing a non-"pre-glued" boot. If the engineering drawing does not specify the adhesive, use the adhesive specified in Table 1.
- Apply adhesive when the engineering drawing or wiring list specifies use of additional adhesive with a "pre-glued" boot. Do not use additional adhesive with a "pre-glued" boot unless this is specified by the engineering drawing or wiring list.

Step 7. Slide the boot into position, as shown in Figure 4.

Step 8. Apply heat to shrink the boot in place, working from the backshell end of the boot. If applying adhesive as per Step 6, pause at the wire end of the boot to form a "mushroom" and apply adhesive to the bonding surface within the "mushroom" before completing the shrinking operation. Take care to avoid over heating while shrinking.

Step 9. Do not wipe away or otherwise interfere with the squeezed out adhesive bead.

Step 10. Allow the adhesive to fully cure (e.g., according to 5.3.2) before further working the assembly.

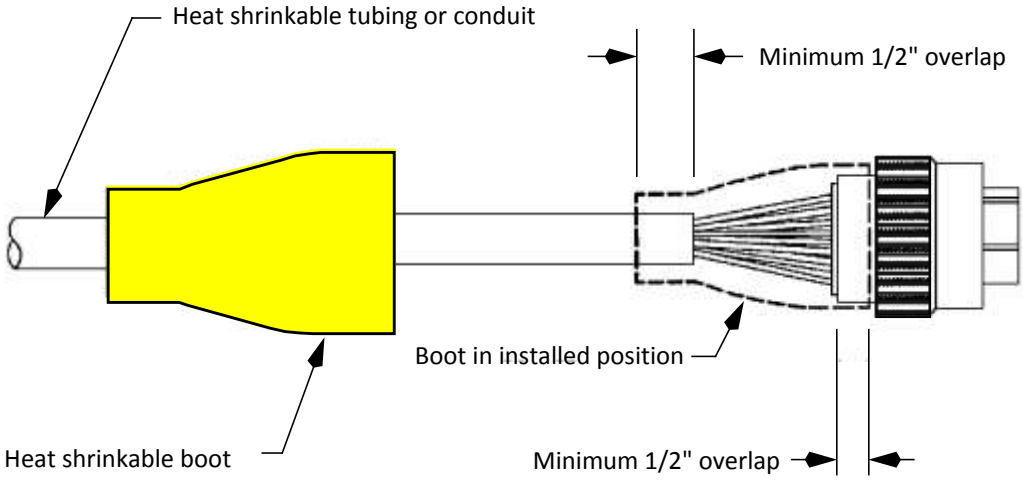


Figure 4. **Termination of Encapsulation Tubing or Conduit at Connectors**

5.8 Installation of Heat Shrinkable Boots on Conduit, Encapsulation Tubing or Harness

5.8.1 Where the engineering drawing specifies installation of a heat shrinkable boot in instances other than at a connector (e.g., instances where the harness, conduit or encapsulation tubing does not terminate at a connector; see Figure 5) install the boot as follows:

Step 1. Slip the boot onto the wire loom.

Step 2. Terminate the wires as specified by the engineering drawing.

Step 3. If the wire harness has been encapsulated in conduit or heat shrinkable tubing, trim the conduit or encapsulation tubing to a length which will cause the connector boot to overlap the tubing by the full length of the boot when the heat shrinkable boot has been shrunk into place.

Step 4. If necessary, wrap the conduit, wires or encapsulation tubing with filler tape (ref. para. 4.1.5) so that when the boot is shrunk down it will have a snug grip on the assembly. For example, if installing a 202A142-3/42-0 heat shrinkable boot on 3C-CML-INSNJ-0016 conduit, use filler tape to increase the diameter to at least 0.70" to ensure a snug fit of the boot when shrunk. When positioning the tape, remember to account for longitudinal shrinkage of the boot.

Step 5. Prepare the bonding surfaces of the wires, filler tape, encapsulation tubing or conduit where the connector boot will be placed according to section 5.2.

Step 6. For the following applications, prepare a suitable quantity of adhesive and apply a uniform coating to the conduit, wires or encapsulation tubing in the area to be covered with the boot.

- Apply adhesive when installing a non-“pre-glued” boot. If the engineering drawing does not specify the adhesive, use the adhesive specified in Table 1.
- Apply adhesive when the engineering drawing or wiring list specifies use of additional adhesive with a “pre-glued” boot. Do not use additional adhesive with a “pre-glued” boot unless so specified by the engineering drawing or wiring list.

Step 7. Slide the boot into position.

Step 8. Apply heat to shrink the boot in place. Work from the termination end of the boot. Take care to avoid over heating while shrinking.

Step 9. Do not wipe away or otherwise interfere with the squeezed out adhesive bead.

Step 10. Allow the adhesive to fully cure according to 5.3.2 before further working the assembly.

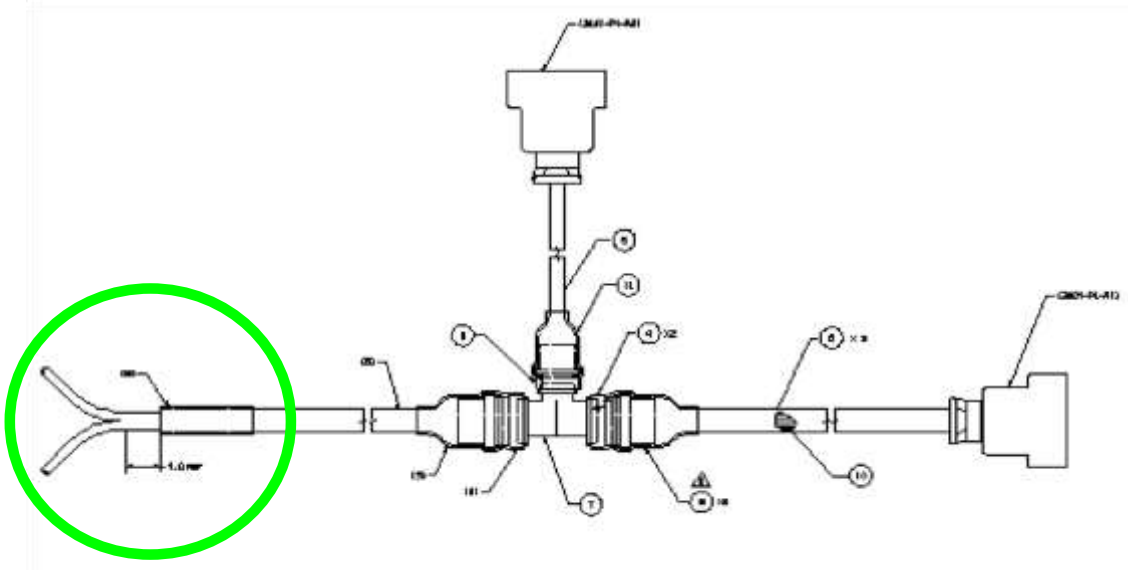


Figure 5. **Typical Installation of Heat Shrinkable Boots on Conduit** (no connector)

5.9 **Encapsulation of Individual Electrical/Electronic Components**

5.9.1 Where the engineering drawing or wiring list specifies encapsulation of an individual electrical/electronic component using heat shrinkable tubing and adhesive, encapsulate the component as follows:

Step 1. Slip a suitable length of the specified heat shrinkable tubing onto the wire loom.

Step 2. Terminate the wires at the electrical/electronic component as specified by the engineering drawing or wiring list.

Step 3. Prepare the bonding surfaces of the wires where the heat shrinkable tubing will be installed according to section 5.2.

Step 4. Prepare a suitable quantity of the adhesive specified on the engineering drawing. If the engineering drawing does not specify the adhesive, use the adhesive specified in Table 1. Ensure to use sufficient adhesive to ensure a uniform squeeze out bead but take care to avoid the application of an excessive amount of adhesive (see Figure 6).

Step 5. Keeping in mind longitudinal shrinkage of the heat shrinkable tubing, apply the adhesive to the bonding surfaces of the wires where the heat shrinkable tubing will be installed.

Step 6. Slide the heat shrinkable tubing into position.

Step 7. Shrink the heat shrinkable tubing in place, working from the middle of the tubing towards the ends, taking care to avoid over heating while shrinking.

Step 8. Allow the adhesive to fully cure according to 5.3.2 before further working the assembly. Do not wipe away or otherwise interfere with the squeezed out adhesive bead.

5.9.2 If hot melt tape adhesive was used, excessive flexing of a wire assembly with an encapsulated electrical/electronic component (e.g., during installation) may cause the tape edge to pull away from the harness. If an edge lifts up, reheat it with a heat gun and apply pressure to it until the edge stays down.

5.10 **Removal and Replacement of Installed Heat Shrinkable Tubing, Transitions or Boots**

5.10.1 If it is necessary to remove installed heat shrinkable tubing, transitions or boots (e.g., due to damage, incorrect placement or insufficient adhesive squeeze out), remove the installed tubing, transition or boot as follows:

Step 1. Score the tubing, transition or boot lightly without cutting all the way through.

Step 2. Apply heat to the tubing, transition or boot. The tubing, transition or boot should split with the application of the required heat.

Step 3. Once the tubing, transition or boot has split, remove it using a pair of pliers while it is still hot.

5.10.2 Install the replacement tubing, transition or boot according to section 5.6 or section 5.7, as applicable. Before installation of a replacement transition or boot, solvent clean the area to which it is to be installed according to PPS 31.17 to remove contaminants, if any; however it is not necessary to remove traces of residual adhesive before installation of the replacement transition or boot. After installation of the replacement transition or boot, remove any traces of residual adhesive by solvent cleaning according to PPS 31.17.

6 **Requirements**

6.1 After shrinking, examine sleeves, tubes, boots and transitions for signs of over-heating, cracks, looseness or edge peeling. Parts with any of these defects are unacceptable. When checking adhesion of transitions or boots to the tubing, do not subject the cable assembly to bending or stressing to a greater degree than the installed assembly would be subjected to in service.

6.2 Ensure that sleeves, tubes, boots and transitions are correctly positioned according to the engineering drawing.

6.3 Transition and connector boots must overlap heat shrinkable tubing or conduit by at least 1/2".

6.4 Connector boots must overlap the connector by at least 1/2".

6.5 Heat shrinkable tubing, boots and transitions must be fully shrunk in place on the encapsulated assembly and be uniform in shape.

6.6 Check all encapsulated assemblies to ensure a uniform unbroken extrusion of adhesive on the periphery of bonded heat shrinkable tubing, boots and transitions, as applicable. Evidence of insufficient extrusion of adhesive is not acceptable; excessive adhesive extrusion is acceptable but should be avoided. Refer to Figure 6 for visual representations of insufficient, optimum and excessive extrusion of adhesive.

6.7 Encapsulated assemblies must be allowed to full cure before further working of the assembly.

Insufficient - Not Acceptable | Optimum | Excessive – Acceptable (but should be avoided)

Figure 6. **Adhesive Extrusion** (typ.)

7 Safety Precautions

7.1 The safety precautions specified herein are specific to Bombardier Toronto (de Havilland) 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 Hot-air guns used in heat shrinking operations can develop temperatures of up to 500°F (260°C) at the screen nozzle. Exercise caution during handling to avoid burns.

7.4 It is recommended to use hot air guns which include a power interrupt reset feature which will prevent an unattended heat gun from resuming heat (e.g., after a power failure); for hot air guns which are not equipped with a power interrupt reset feature, take care to ensure turning the gun off immediately in the event of a power interruption.

7.5 After shrinking operations are completed, cool the heat gun by activating the switch to the cold position (if suitably equipped) until the nozzle is cool enough to handle.

7.6 Overheating heat shrinkable products to the point of charring or burning may produce vapors that may cause eyes, skin, nose or throat irritation. Persons with pre-existing eye, skin or respiratory disorders (e.g., asthma conditions) may be more susceptible to the effects of these vapors. Shrink products in a well-ventilated area.

7.7 Squeezed out hot melt tape and mixed adhesive will be very hot immediately after shrinking and could stick to unprotected skin, causing injury. Avoid any contact with the encapsulated assembly and squeezed out adhesive until cooled to a safe temperature.

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.

9 Storage

9.1 Store adhesive hot melt tape materials and/or adhesive components according to the precautions necessary for flammable materials.

9.2 Store adhesive resin and hardener, and hot melt adhesive tapes, at a temperature of 60°F - 80°F (16°C - 27°C). Where the engineering drawing specifies use of adhesives other than those specified herein, refer to the manufacturers' instructions for storage temperature requirements or recommendations.

9.3 Refer to PPS 13.28 to for the storage life of adhesive resin and hardener, and hot melt adhesive tapes. Where the engineering drawing specifies use of adhesive other than those specified herein, refer to the manufacturers' instructions for storage life requirements and/or recommendations.

9.4 Ensure that adhesive hot melt tape materials and/or adhesive containers of resin and hardener are clearly marked with the storage life expiry date, as applicable.