BOMBARDIER Toronto (de Havilland) **PROPRIETARY INFORMATION**	**PPS 17.04** **PRODUCTION PROCESS STANDARD**

Shot Peen Forming

Issue 15 - This standard supersedes PPS 17.04, Issue 14.
- Vertical lines in the left hand margin indicate technical changes over the previous issue.
- This PPS is effective as of the distribution date.
- Validation of issue status is the responsibility of the user.

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Issue 15 - 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 sections of this PPS for detailed procedure and requirements.

- Clarified facility approval requirements to specify explicitely that facilities approved to perform shot peen forming according to BAPS 185-003 are also considered approved to perform shot peen forming according to PPS 17.04 without further approval needed (i.e., approval according to PPS 13.39 is not required).

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1 Scope

1.1 This Production Process Standard (PPS) specifies the procedure and requirements for shot peen forming.

1.1.1 As an alternative to the procedure and requirements specified herein, it is acceptable to perform shot peen forming according to BAPS 185-003.

- Perform shot peen forming according to the procedure and requirements of either BAPS 185-003 or this PPS in their entirety; a piecemeal approach utilizing certain sections or portions of BAPS 185-003 and this PPS is **not** acceptable.
- Subcontractor facilities which have been approved by Bombardier to perform shot peen forming according to BAPS 185-003 are considered approved to perform shot peen forming according to this PPS without further approval needed.
- PPS Process Standard Deviations (PSD's) issued against this PPS are **not** applicable to BAPS 185-003. Likewise, requests for deviation (RFD's) allowed against BAPS 185-003 are not applicable to this PPS.
- When processing parts according to BAPS 185-003 as an alternative to processing parts according to PPS 17.04, deviations allowed by an approved RFD against BAPS 185-003 may be used unless a specific limitation regarding program applicability is specified by the RFD comments/restrictions.

1.1.2 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS (or BAPS 185-003, as referenced in para. 1.1.1) must be followed to ensure compliance with all applicable specifications and to fulfil the engineering design and reliability objectives. In general, if this PPS (or BAPS 185-003) conflicts with the engineering drawing, follow the engineering drawing.

1.1.3 Refer to PPS 13.26 for the subcontractor provisions applicable to 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 13.39 - Bombardier Toronto Engineering Process Manual.

3.2.3 PPS 17.03 - Saturation Shot Peening.

3.2.4 PPS 27.01 - Repair of Surface Defects in Aluminum Alloy Sheet.

3.2.5 PPS 27.05 - Manual Edge Finishing Equipment.

3.2.6 PPS 31.04 - Degreasing Processes.

3.2.7 PPS 31.17 - Solvent Usage.

3.3 Bombardier Aerospace Process Specifications

3.3.1 BAPS 185-003 - Peen Forming of Metal Parts.

3.4 Industry Specifications

3.4.1 AMS 2431 - Peening Media General Requirements.

3.4.2 RR-S-366 - Sieves, Test.

3.4.3 SAE J441 - Wire, Cut, Shot.

3.4.4 SAE J442 - Test Strip, Holder and Gauge for Shot Peening.

3.4.5 SAE J827 - High-Carbon Cast-Steel Shot.

4 Materials, Equipment and Facilities

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 Burnishing balls, 1/8", 3/16" and 1/4" nominal diameter, SAE 52100, Rc 60/65.

4.1.3 Cast steel shot to SAE J827.

4.1.4 Cut wire shot to SAE J441. Cut wire shot must be “conditioned” before use on production parts (i.e., cut edges must be pre-rounded by suitable means before shot use).

4.1.5 Glass bead shot to AMS 2431.

4.1.6 Masking materials: Mask surfaces that are required to remain unpeened by means of tape or film of adequate thickness to protect the surfaces. For example, expandable protective sleeving (e.g., Dupont VEXAR) or 1/4" thick polyethylene bags/foam sheet (e.g. Cellaire CA-250). Holes may be masked by means of rubber plugs or other means that provide adequate protection without interfering with the peening of adjacent areas.

4.1.7 Almen test strips to SAE J442.

4.2 Equipment

4.2.1 The shot peen forming machine must be capable of consistently reproducing the shot peening intensities required and shall include a separator for the continuous removal of broken or defective shot during shot peening.

4.2.2 Part holding and pre-stressing fixtures as required.

4.2.3 Contour checking fixtures and gauges as required.

4.2.4 Almen #2 test gauge to SAE J442.

4.2.5 Almen test strip holding fixtures to SAE J442. For roto peening, use a magnetic Almen strip holder suitable for determining roto peen intensity.

4.2.6 Roto peening mandrels (e.g., 3M 7210 and 7211 for use with 9/16" x 1 1/4" and 1" x 2" flap sizes, respectively).

4.3 Facilities

4.3.1 This PPS has been categorized as a “Controlled Critical Process” according to PPS 13.39. Except as noted in para. 4.3.1.1, only facilities specifically approved according to PPS 13.39 are authorized to perform shot peen forming according to this PPS.

4.3.1.1 Facilities approved to perform shot peen forming according to BAPS 185-003 are also considered approved to perform shot peen forming according to this PPS without further approval needed (i.e., approval according to PPS 13.39 is not required).

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 shot peen forming 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 8.

5 Procedure

5.1 General

5.1.1 The shot peen forming machine provides a means of propelling shot by air pressure or centrifugal force against the part. Shot peen forming consists of contour forming by shot peening of the part surfaces. The extent of contour or curvature which can be accomplished by shot peen forming is related to the degree of surface deformation which is controlled by the shot size, velocity, angle of impingement and coverage.

5.1.2 Carry out shot peen forming only where specified on the engineering drawing, or if authorized by Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB as rework for correcting machining or heat treat distortion.

5.1.3 Unless otherwise specified on the engineering drawing, shot peen forming should be performed after the following operations, as applicable, and before the application of any final surface finishes or treatments.

- heat treatment
- straightening
- magnetic particle inspection
- removal of gouges, dents, scratches or burrs
- part edges shall be broken.
- forming
- machining; polishing
- fluorescent penetrant inspection
- fillets shall be properly formed and broken

5.1.4 Before initial production, forming schedules for parts prepared for the Learjet Model 45 wing must be approved by Bombardier Toronto (de Havilland). Approved forming schedules may not be changed without Bombardier Toronto (de Havilland) approval.

5.1.5 Ensure that all parts meet the dimensional and surface finish requirements of the engineering drawing before shot peen forming.

5.2 Preparation of Parts

5.2.1 Strip areas to be subjected to shot peen forming of all protective coatings (e.g., paint, primer, etc.).

5.2.2 Immediately before shot peen forming, degrease parts according to PPS 31.04 or solvent clean according to PPS 31.17.

5.2.3 Mask off all areas which are not to be shot peened, as shown on the engineering drawing, with suitable tape, bags, sleeving, pads or shields, as applicable (see Materials section, para. 4.1.6).

5.3 Set-Up Procedure

5.3.1 Before processing an initial batch of parts, establish a forming schedule (based on calculations, forming of samples or trial parts) and maintained on file for each part number being shot peen formed. When establishing a forming schedule, validate machine settings to ensure that the maximum intensity per thickness peened is not exceeded. Maintain forming schedules for each part number and machine used. Revise forming schedules if the configuration of the part changes or machine modifications are made. If requested, submit forming schedules to Bombardier Toronto (de Havilland) for approval. The forming schedule must, as a minimum, include the following information:

- Issue date and revision number.
- Part number.
- Alloy, temper, and material specification of the part.
- Part description as called out on the drawing.
- Intensity per thickness peened. Refer to Table 1 for the maximum allowable peening intensity.
- Shot peen machine set-up (i.e., air pressure or wheel speed, travel or rotation speed of table, number of nozzles, nozzle positions, nozzle sizes, etc.).
- Shot peen forming time or number of passes.
- Sequence of operations.
- Any fixtures required to hold the part during peening and pre-loading procedures.
- Any areas to be masked during peening.
- Shot size, type, and hardness.
- Machine number.

5.3.2 Mount and, if required, pre-stress parts to induce an elastic strain before contour forming. Pre-stressing must not exceed the elastic limit of the material being formed (i.e., material should recover the original configuration if unloaded from the pre-stressed condition before shot peening). Additional tooling may be provided to restrain parts locally during shot peening to prevent adverse bowing or an abrupt change in contour, where material thickness transition occurs.

Table 1 - Maximum Peening Intensity for Various Gauges

Material Thickness	Maximum Intensity	Material Thickness	Maximum Intensity
0.060" - 0.069"	0.004A	0.190" - 0.214"	0.013A
0.070" - 0.079"	0.005A	0.215" - 0.239"	0.014A
0.080" - 0.089"	0.005A	0.240" - 0.269"	0.016A
0.090" - 0.114"	0.006A	0.270" - 0.309"	0.018A
0.115" - 0.139"	0.008A	0.310" - 0.369"	0.021A
0.140" - 0.164"	0.010A	0.370" - 0.449"	0.007C
0.165" - 0.189"	0.011A	0.450" and over	0.009C

Note 1. For rework forming, if shot peening below the maximum allowable intensity does not result in an acceptable forming profile or correction of distortion, refer the part to Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB for disposition.

Note 2. For production shot peen forming, submit any new or revised forming schedule which specifies peening intensities greater than specified herein to Bombardier Toronto (de Havilland) for approval.

Note 3. Alternatively, the intensities specified above may be expressed in multiples of 0.001" for the test strip type specified (e.g., an Almen “A” intensity may be expressed as either 0.010A or 10A).

5.4 Shot Peen Forming Operation

5.4.1 Perform shot peen forming of parts as follows:

Step 1. Set up the shot peening machine according to the approved forming schedule.

Step 2. Validate the machine settings on the lowest and highest intensities specified by the approved forming schedule to ensure that in each case the specified intensity will be met.

Step 3. Shot peen form according to the approved forming schedule. Except when the coverage extends to the part edge or step, apply a minimum 1/4" fade out (shot intensity diminishes to zero) to the perimeter of any shot peened area where 75% or greater coverage has resulted.

5.5 Rework

5.5.1 If parts have been over-formed by shot peening, apply localized shot peening on the opposite surfaces to correct the contour. Localized shot peen forming to correct machine or heat treat distortion may be carried out using manual equipment.

5.5.2 Except for aluminium alloy parts, refer parts with any dents, gouges or scratches deeper than 0.002" to Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB for disposition. For aluminum alloy parts only, it is acceptable to repair dents, gouges or scratches deeper than 0.002" according to PPS 27.01 followed by local shot peening of the reworked area according to PPS 17.03.

5.5.3 Validate the shot peen settings to ensure the maximum intensity specified in Table 1 is not exceeded. If shot peening below the maximum allowable intensity does not result in an acceptable forming profile or correction of distortion, refer the part to Bombardier Toronto (de Havilland) MRB or Bombardier Toronto (de Havilland) delegated MRB for disposition.

5.5.4 If shot peen forming results in local erosion of the surface, use larger shot to minimize the dwell time in a given area while achieving the required contour.

5.6 In Situ Repair

5.6.1 Perform in situ repair for contour correction using a roto peen flap assembly as follows only if specifically authorized by Liaison Engineering:

Step 1. If Liaison Engineering has specified a maximum standard Almen A intensity for the repair, refer to Table 1 to convert standard Almen “A” intensity to the roto peen intensity. Conversion is necessary since the Almen strip will bend more when using the roto peen strip holder.

Step 2. Determine the appropriate flap size required based on the specific repair need. For example:

- for larger areas with no obstructions or restrictions, use of a 1" x 2" flap assembly is recommended
- for smaller areas, use of a 9/16" x 1 1/4" flap assembly is recommended
- in restricted areas, use whichever size fits; if necessary, it is acceptable to cut the flaps narrower with scissors.

Step 3. Set the mandrel to the desired speed using a non-contacting or strobe light tachometer while the flap is in contact with the surface of a piece of suitable scrap material. Refer to Table 2 for the recommended mandrel speed:

Step 4. Mount an unpeened Almen test strip on a special magnetic Almen strip holder suitable for determining roto peen intensity. Do not use a standard Almen strip holder.

Step 5. Roto peen the Almen test strip in the holder. To ensure proper flap deflection, maintain the height of the mandrel above the surface of the test strip as shown in Figure 2. If the mandrel is too high, there will be an uncomfortable vibration or bounce to the tool. To ensure uniform peening coverage, use a circular or oscillating motion from side to side over the entire area.

Step 6. Check for saturation according to Flow Chart 1. Always check the intensity using the Almen gauge on the unpeened side of the Almen strip.

Step 7. Solvent clean the area to be shot peened as specified in PPS 31.17.

Step 8. Roto peen form the repair area to the desired contour. To ensure proper flap deflection, maintain the height of the mandrel above the surface of the repair area as specified in Step 5. To ensure uniform peening coverage use a circular or oscillating motion.

Table 2 - Conversion of Almen "A" Intensity to Roto Peen Intensity

Almen "A" Intensity Specified	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Required Roto Peen Intensity	3	4	5	6	7	10	12	14	15	17	18	20	22	23	25	26	28	30

Note 1. The intensities specified above represent the intensity expressed in multiples of 0.001" for the test strip type specified (e.g., an Almen "A" intensity may be expressed as either 10A or 0.010A).

Table 3 - Recommended Roto Peen Mandrel Speeds

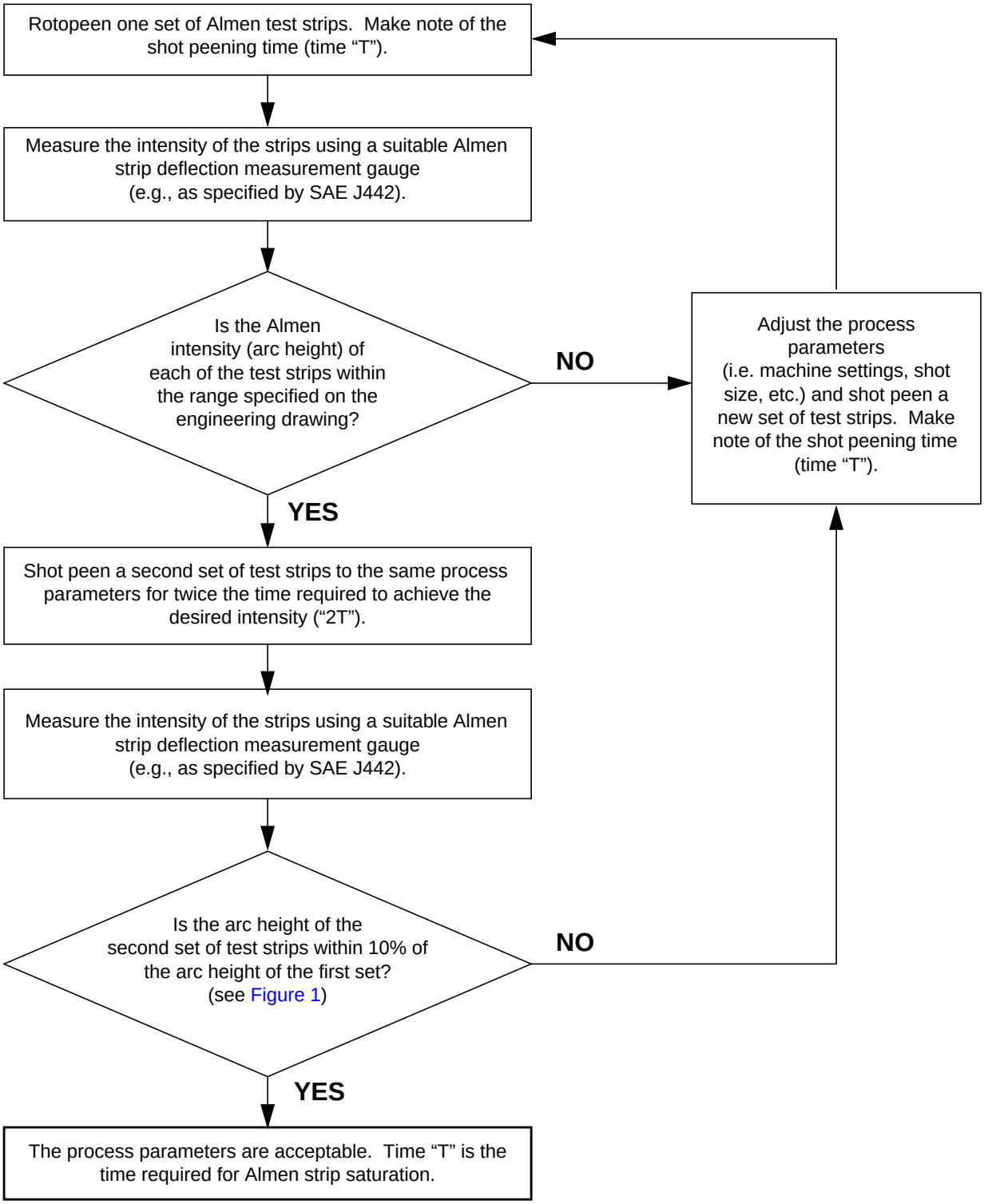
Almen "A" Intensity	Flap Size		Almen "A" Intensity	Flap Size	
	9/16" x 1 1/4"	1" x 2"		9/16" x 1 1/4"	1" x 2"
8	3200 RPM	2100 RPM	15	6500 RPM	3800 RPM
9	3600 RPM	2400 RPM	16	6800 RPM	3900 RPM
10	4300 RPM	2700 RPM	17	7300 RPM	4200 RPM
11	4600 RPM	2800 RPM	18	7600 RPM	4300 RPM
12	5100 RPM	3100 RPM	19	8100 RPM	4600 RPM
13	5400 RPM	3200 RPM	20	8700 RPM	4800 RPM
14	6000 RPM	3500 RPM			

Note 1. The mandrel RPM recommended in this table is based on an Almen strip saturation time "T" of 2 minutes (120 seconds) and should only be used as a guide. Tool and operator variability may require speed adjustments to obtain the required intensity. For longer Almen strip saturation times, a lower mandrel RPM is recommended.

Note 2. For cut down flaps, increase the mandrel speed accordingly.

Note 3. The intensities specified above represent the intensity expressed in multiples of 0.001" for the test strip type specified (e.g., an Almen "A" intensity may be expressed as either 10A or 0.010A).

Flow Chart 1 - Determination of Shot Peening Parameters



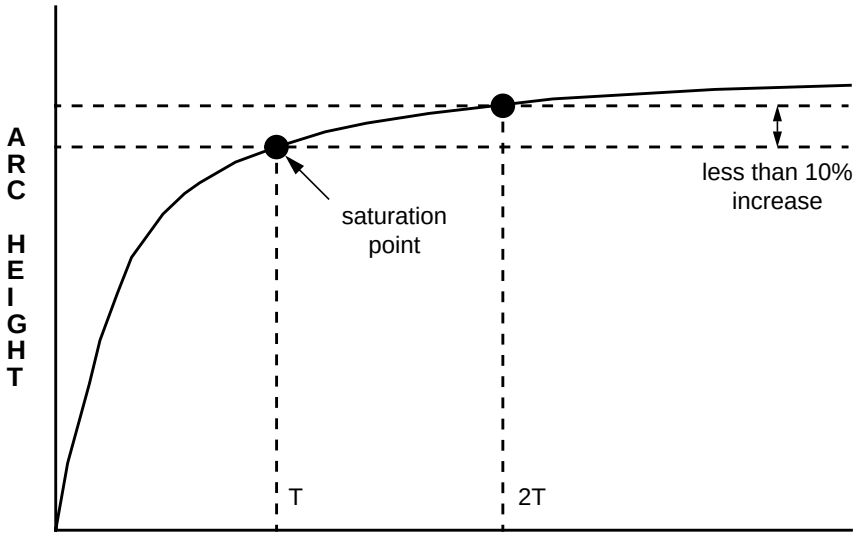
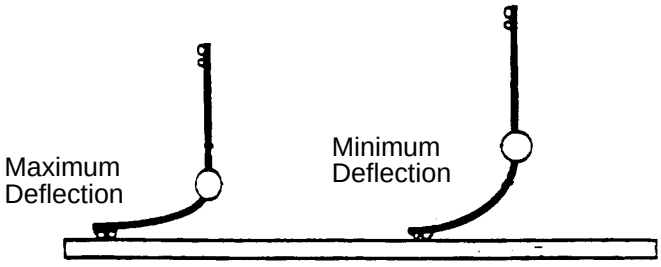


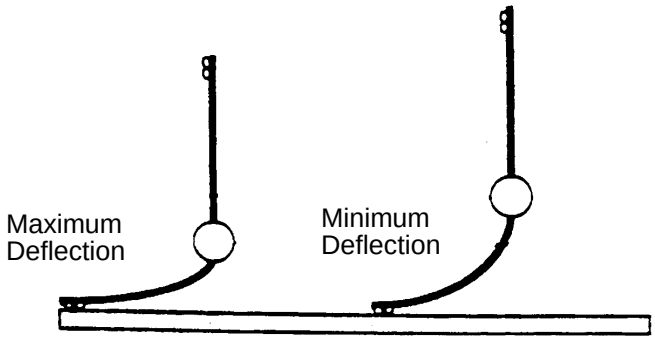
Figure 1 - Saturation Intensity Curve



9/16" X 1 1/4" FLAP ASSEMBLY

For 9/16" X 1 1/4" flap assemblies, maintain the mandrel approximately 3/16" above the surface to be roto peened.

Note: If the mandrel is too high, there will be an uncomfortable vibration or bounce to the tool.



1" X 2" FLAP ASSEMBLY

For 1" X 2" flap assemblies, maintain the mandrel approximately 5/16" above the surface to be roto peened

Figure 2 - Roto Peen Flap Deflection

5.7 Post Shot Peening Procedure

5.7.1 Remove rollover on the part edge resulting from shot peen forming by edge finishing according to PPS 27.05.

5.7.2 Except as noted in para. 5.7.2.1, after shot peen forming saturation shot peen the part to the specified Almen intensity according to PPS 17.03. Saturation shot peening may extend beyond shot peen formed areas, necessitating re-masking of part surfaces.

5.7.2.1 Unless otherwise specified by Liaison Engineering, areas repaired using in situ roto peen forming according to section 4.2 do not require saturation shot peening after shot peen forming.

5.7.3 After saturation shot peening, surface roughness improvement to all shot peen formed parts shall be accomplished by light honing, lapping, hand sanding or abrasive belt polishing. Unless otherwise specified on the engineering drawing, do not remove more than 10% of the nominal Almen A intensity to which the part was shot peened during surface roughness improvement.

6 Requirements

6.1 Check all shot peen formed parts against the appropriate checking template to ensure that the correct contour has been obtained. Deviation from required contour must not exceed the tolerances specified on the engineering drawing or engineering order.

6.2 The shot peening settings must be verified and recorded as specified in Step 2 of para. 5.4.1.

6.3 Straightening of shot peen formed parts shall only be accomplished by localized manual shot peen forming as specified herein.

6.4 A minimum 1/4" fade out shall have been applied to the perimeter of any shot peened area where 75% or greater coverage has resulted. Where a 75% or greater coverage extends to the part edge or step, fade out on that edge is not required.

6.5 Part edges shall be free of rollover.

6.6 Parts shall not exhibit indications of erosion.

6.7 At the beginning of processing each production batch of parts and after each 8 hours of continuous machine operation, check the shot for size and uniformity. Shot size shall be as specified on the forming schedule for the part numbers being processed. Only one size of shot shall be used in the shot peening machine at any one time. Shot uniformity shall be maintained according to the screening tolerance shown in Table 4, Table 5 or Table 6, as applicable.

Table 4 - Uniformity of Burnishing Balls

Ball Size	First Sieve	Second Sieve	Amount of Broken Balls
1/8"	5	8	none
3/16"	4	5	none
1/4"	3	4	none

Note:
- U.S. sieves according to RR-S-366
- Refer to Table 7 for a listing of the sieve opening size for each sieve number.

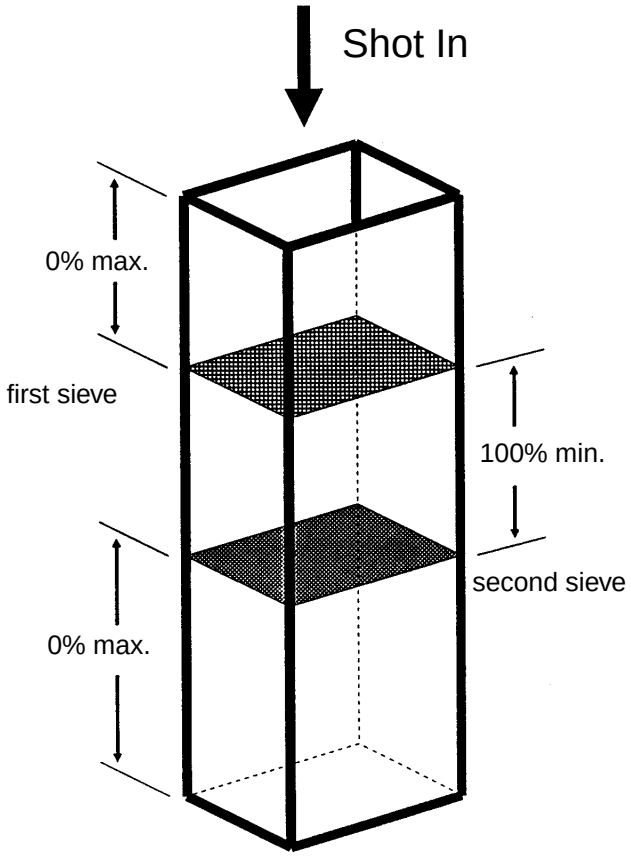


Table 5 - Uniformity of Cut Wire & Cast Steel Shot

Shot	First Sieve	Second Sieve	Maximum Number of Deformed Shot
CS230	25	30	20 per 1/2" square
CS330	18	20	20 per 1/2" square
CS550	12	14	12 per 1" square

Note:
- U.S. sieves according to RR-S-366.
- Refer to Table 7 for a listing of the sieve opening size for each sieve number.
- Deformed shot has a length greater than twice the diameter.

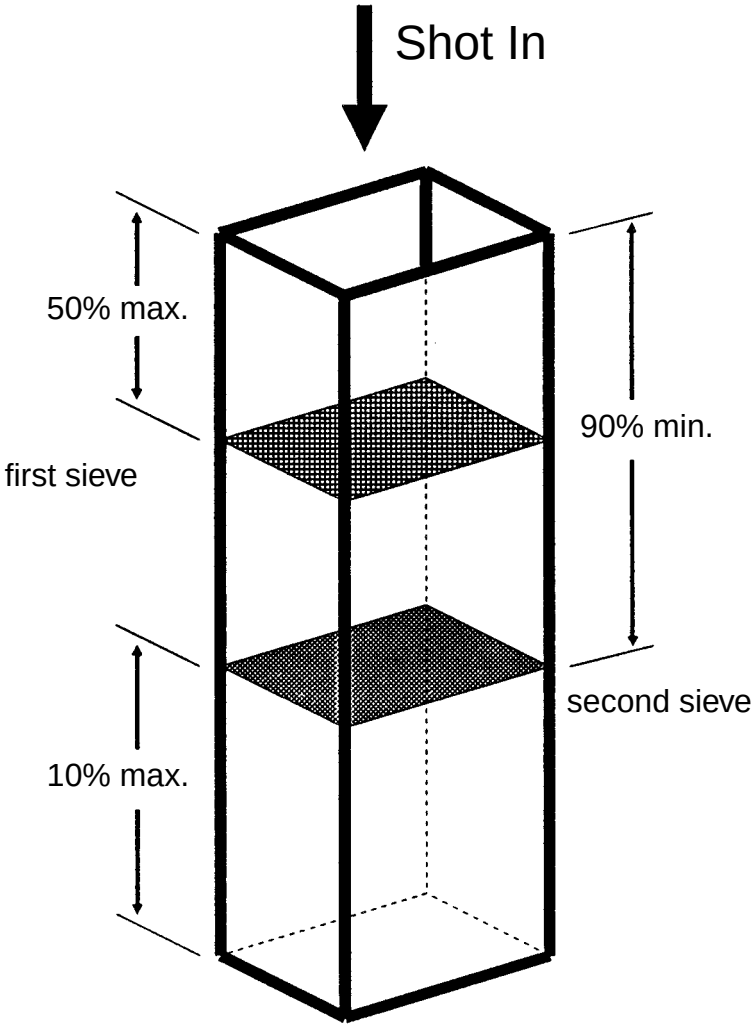


Table 6 - Uniformity of Glass Bead Shot

Glass Beads	First Sieve	Second Sieve	Third Sieve
GP100	50	80	100
GP165	35	50	60
GP234	25	40	45

Note:
- U.S. sieves according to RR-S-366.
- Refer to Table 7 for a listing of the sieve opening size for each sieve number.

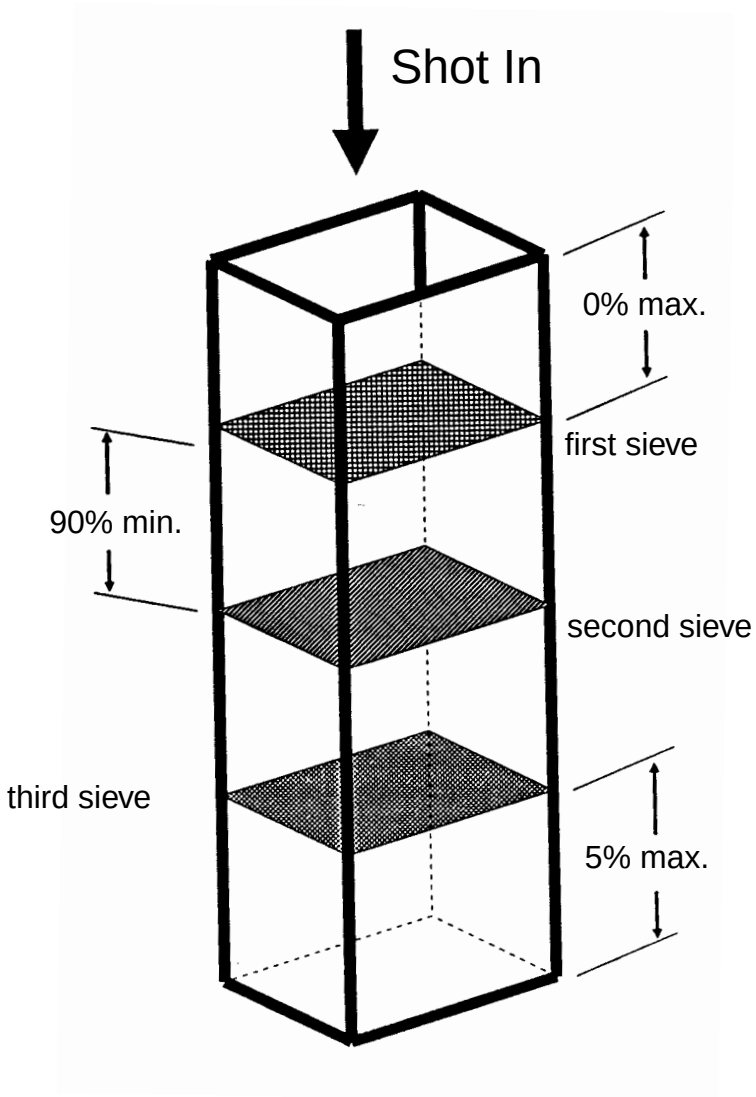


Table 7 - Sieve Opening Sizes for U.S. Sieves according to RR-S-366

Sieve Number	Sieve Opening	Sieve Number	Sieve Opening	Sieve Number	Sieve Opening
100	0.0059"	35	0.0197"	12	0.0661"
80	0.0070"	30	0.0232"	8	0.0937"
60	0.0098"	25	0.0280"	5	0.1590"
50	0.0117"	18	0.0394"	4	0.2020"
45	0.0138"	16	0.0469"	3	0.2790"
40	0.0165"	14	0.0555"		

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 Take care to keep the shop area free of excessive amounts of loose shot.

8 Personnel Requirements

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

9 Additional Information

9.1 Except as noted in para. 9.1.1 or para. 9.1.2, ensure that shot peen formed parts are not subjected to processing temperatures above the following limits:

- Steel Parts: 475°F (246°C)
- Aluminum Parts: 200°F (93°C)

9.1.1 Shot peened aluminum parts, which are to be F19 primed, may be subjected to a maximum of two oven curing cycles at 215°F ± 15°F(102°C ± 8°C) for 5 - 6 minutes according to PPS 34.08.

9.1.2 If the engineering drawing requires shot peen formed parts be subjected to processing temperatures in excess of the maximum temperatures specified in para. 9.1, the engineering drawing shall govern.

9.2 Unless otherwise noted on the engineering drawing, do not subject shot peen formed parts to hardness testing, grinding, stress relief or etching after shot peen forming.