BOMBARDIER
Toronto Site
PROPRIETARY INFORMATION

PPS 10.21

PRODUCTION PROCESS STANDARD

CERTIFICATION OF AUTOCLAVES

Issue 7
- This standard supersedes PPS 10.21, Issue 6.
- Vertical lines in the left hand margin indicate changes over the previous issue.
- Direct PPS related questions to christie.chung@aero.bombardier.com or (416) 375-7641.
- This PPS is effective as of the distribution date.

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	Quality	

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

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1 SCOPE

1.1 The purpose of this Production Process Standard (PPS) is to identify the equipment and operating requirements of autoclaves used by Bombardier Toronto or its subcontractors for metal bonding and fabrication of composite structures.

1.1.1 This PPS complements the engineering drawings that specify its use as an authorized instruction. The procedure specified in this PPS shall 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. Similarly, the procedure and requirements specified in this PPS are not applicable when use of a BAPS, MPS, LES or P. Spec. is specified.

2 HAZARDOUS MATERIALS

2.1 Before receipt at Bombardier Toronto, all materials shall be approved and assigned Material Safety Data Sheet (MSDS) numbers by the Bombardier Toronto 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 Environment, Health and Safety Department.

3 REFERENCES

3.1 PPS 10.28 - Assembly of Wire Thermocouples.

3.2 PPS 13.26 - General Subcontractor Provisions.

3.3 PPS 13.39 - Bombardier Toronto Engineering Process Manual.

3.4 QAPI 3.8.7.20 - Control of Inspection, Measuring and Test Equipment - *Bombardier Toronto internal Quality procedure.*

4 MATERIALS AND FACILITIES

4.1 Materials

4.1.1 Thermocouples prepared according to PPS 10.28.

4.2 Facilities

4.2.1 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 utilize the autoclaves specified herein for metal bonding and fabrication of composite structures according to the applicable fabrication PPS (i.e., PPS 10.xx series or PPS 36.xx series).

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

4.2.3 Facility approval shall be based on a facility report, a facility survey and completion of a qualification test program, if required. The facility report shall 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 shall be detailed in the facility report. Based upon the facility report, Bombardier Toronto Materials Technology may identify additional qualification and/or process control test requirements. During the facility survey, the facility requesting qualification shall 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.

4.2.3.1 Unless otherwise specified by Bombardier Aerospace Toronto Materials Technology, for approval of subcontractor facilities to utilize the autoclaves specified herein for metal bonding and fabrication of composite structures according to the applicable PPS’s, completion of a test program and submission of suitable test samples representative of production parts is required. Test samples shall meet the requirements of the applicable fabrication PPS (i.e., PPS 10.xx series or PPS 36.xx series). Certification and re-certification of the autoclave shall be as specified in section 6.

5 PROCEDURE

5.1 General

5.1.1 Autoclaves meeting the requirements of this standard will be certified for curing and bonding both composites, and metal bonding.

5.1.2 Autoclaves may receive a partial certification for curing composite parts at 260°F ± 10°F or metal bonded parts at 250°F ± 10°F, if the autoclave will not be used for curing parts at higher temperatures.

5.1.3 The autoclave control mode may be either manual or automatic, or combinations thereof. The control mode selected to run operational tests shall also be used in production. If a different control mode is later implemented, test and certify the autoclave to that mode.

5.1.4 The autoclave interior shall be clean and free from dirt, oil or any material detrimental to bonded structure.

5.1.5 Prepare and calibrate thermocouples according to PPS 10.28.

5.2 Autoclave Equipment Checks and Calibration

5.2.1 General

5.2.1.1 The pressure, thermal input, and cooling capacity of the autoclave shall be adequate to meet the cure schedules specified in the applicable fabrication PPS when operating in a fully loaded condition.

5.2.2 Temperature

5.2.2.1 Calibrate the autoclave temperature set-point controller and monitoring equipment (hardware and software) (e.g., QAPI 3.8.7.20).

5.2.2.2 Equip the autoclave with a sufficient number of thermocouple connectors to monitor part temperatures according to the requirements of the applicable fabrication PPS.

5.2.2.3 Temperature recording equipment shall be capable of continuously recording each operating thermocouple throughout the cure cycle. However, multi-point recorders are acceptable, providing that each operating thermocouple is monitored at least once every 6 minutes.

5.2.2.4 The combined accuracy of the thermocouple, junction box, and recorder, shall be ± 5°F from 100°F to 365°F.

5.2.3 Vacuum

5.2.3.1 Calibrate the autoclave vacuum set-point controller, monitoring equipment (hardware and software) (e.g., QAPI 3.8.7.20).

5.2.3.2 Equip the autoclave with a sufficient number of vacuum monitors to accurately monitor pressure under the vacuum bag and to permit checking for leaks according to the requirements of the applicable fabrication PPS.

5.2.3.3 Vacuum monitors shall be independent of vacuum source lines.

5.2.3.4 Vacuum monitoring equipment shall register over a range from 30" Hg vacuum to at least 15 psig pressure. Certify sensor accuracy as follows:

0 to 30 inches Hg . . . . . .± 0.6 inches Hg
0 to 15 psig . . . . . .± 0.3 psig
above 15 psig . . . . . .± 4% of reading

5.2.3.5 Equip the autoclave with a sufficient number of vacuum sources to maintain a minimum vacuum of 24" Hg on the parts according to the requirements of the applicable fabrication PPS.

5.2.3.6 Provide valving for venting the bags directly to the atmosphere (not into a vacuum header).

5.2.4 Pressure

5.2.4.1 Calibrate the autoclave pressure set-point controller and monitoring equipment (hardware and software) (e.g., QAPI 3.8.7.20).

5.2.4.2 Pressure recording equipment shall be capable of continuously recording each operating vacuum monitor throughout the cure cycle. If the autoclave is not equipped with a pressure monitor system, the autoclave shall be capable of checking the pressure under the vacuum bag by the combination vacuum/vent/pressure sensing method (see paragraph 5.4.2).

5.2.4.3 Certify pressure recording equipment accuracy as follows:

0 to 100 psig . . . . . .± 2 psig
above 100 psig . . . . . .± 2% of reading

5.2.4.4 Pressure graduations shall not exceed 5 psi increments.

5.2.5 Elapsed Time Measurement Equipment

5.2.5.1 Equip the autoclave with elapsed time measurement equipment capable of continuously monitoring and logging the lapsed time during the heat-up, curing period, and cool-down of the autoclave cycle. However, the heat-up rates of leading and lagging thermocouples may be determined by a multi-point recorder printout.

5.2.5.2 Chart timing accuracy shall be within ± 2% of the actual elapsed time.

5.2.5.3 Calibrate elapsed time measuring equipment according to (e.g., QAPI 3.8.7.20).

5.3 Operational Test - Empty Autoclave

5.3.1 Perform the empty autoclave operational test as follows:

Step 1. Except as noted, position thermocouples within the working zone as shown in Figure 1. Alternative placement to that shown in Figure 1 is acceptable provided that the thermocouple placement is such that a representation of the entire working zone is obtained. When using an alternative placement, use at least 9 thermocouples in autoclaves with a volume **up to** 10,000 ft^3 and at least 14 thermocouples in autoclaves with a volume **over** 10,000 ft^3.

Step 2. Perform a leak test as follows:

(a) Attach the autoclave vacuum sources to the corresponding vacuum monitor connectors.

(b) Pressurize the autoclave to 45 ± 5 psig.

(c) Apply full vacuum (24" Hg minimum).

(d) Close all vacuum and vent lines.

(e) Monitor the line vacuum sensors for 5 minutes. If a vacuum drop in any vacuum monitor greater than 5" Hg over the 5 minute period is observed, abort the test and correct the leaks before re-testing.

(f) Vent the vacuum lines to atmosphere.

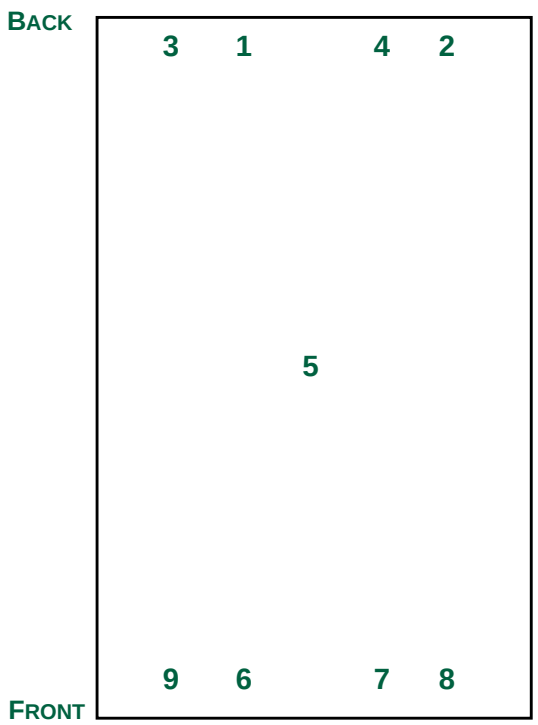
Step 3. Continue pressurization of the autoclave to 100 ± 5 psig.

Step 4. Heat the autoclave at approximately 10°F per minute to 260°F. Within 10 minutes after the leading thermocouple has reached the 260°F dwell temperature, each thermocouple shall read 260°F ± 10°F.

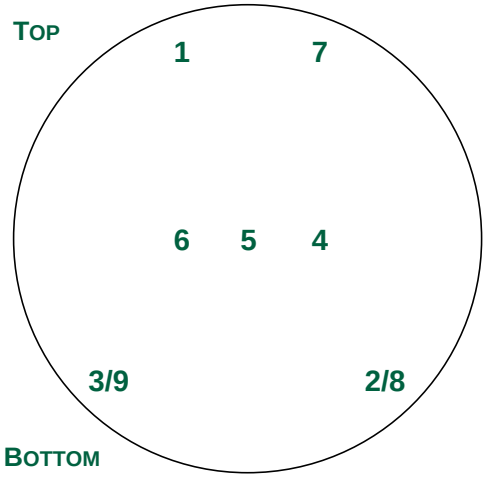
Step 5. If certification to 350°F cure is required, continue heating at approximately 10°F per minute to 355°F. Within 10 minutes after the leading thermocouple has reached the 355°F dwell temperature, each thermocouple shall read 355°F ± 10°F.

Step 6. Cool the autoclave down to ambient temperature and depressurize using normal operating procedures.

AUTOCLAVE VOLUME UP TO 10,000 FT^3

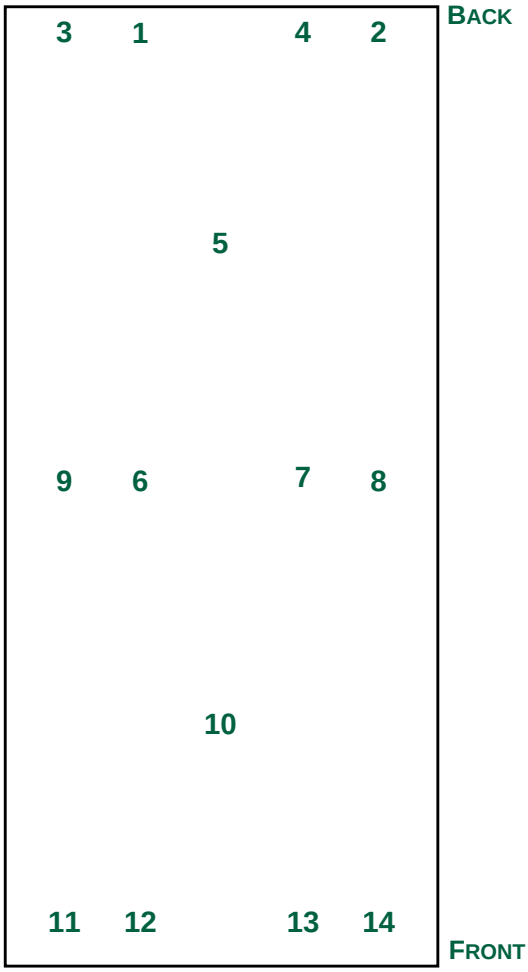


TOP VIEW

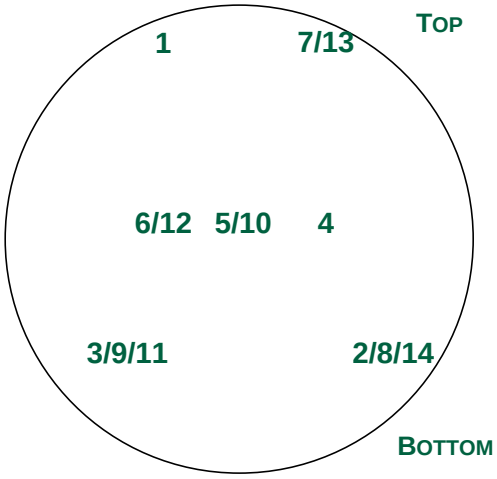


END VIEW

AUTOCLAVE VOLUME OVER 10,000 FT^3



TOP VIEW



END VIEW

FIGURE 1 - STANDARD DISTRIBUTION OF AUTOCLAVE TEST THERMOCOUPLES

5.4 Operational Test - Dummy Load

5.4.1 Prepare a dummy load for the operational test that will meet the following:

- The heat sink capacity of the dummy load shall be at least equal to the maximum heat sink capacity that could occur under production conditions and the thermal conductivity of the dummy load shall be similar to the thermal conductivity of the parts that will be made at that facility.
- For composite structures, the material of the dummy load shall consist of cured or uncured fiberglass or composite structure or scrap that would represent a typical construction. For metal bonding, the material of the dummy load shall consist of racks, tools, platens, and cured or uncured scrap metal laminates.
- Included in the dummy load there shall be at least 2 vacuum bag assemblies. Form the vacuum bag assembly using standard bagging film, release film and bleeder cloth materials according to the applicable fabrication PPS. Each vacuum bag assembly shall contain at least one vacuum monitor outlet. Position at least 6 thermocouples under each vacuum bag. Place the thermocouples in actual or simulated edge breathers and part excesses for composite structure loads and in bondlines or simulated bondlines for metal bonding loads. Position thermocouples within the vacuum bags in the autoclave so that the structures with the greatest and the least mass (including the tool) are measured.
- Position the dummy load on caul plates or bonding fixtures.

5.4.2 Perform the dummy load operational test as follows. During the test, verify that the pressure under the vacuum bag does not exceed 5 psi by either the dead end pressure gauge method (see paragraph 5.4.2.1) or by the combination vacuum/vent/pressure sensing method (see paragraph 5.4.2.2).

Step 1. Place the dummy load in the autoclave.

Step 2. Connect the thermocouples to the autoclave recorder.

Step 3. Connect vacuum lines to vacuum outlets.

Step 4. With the vent lines open or under vacuum, pressurize the autoclave. Unless honeycomb panels are present, pressurize to 85 ± 5 psig; if honeycomb panels are present, pressurize the autoclave to 45 ± 5 psig. Autoclave pressure shall be stable at either 85 ± 5 psig or 45 ± 5 psig, as applicable, throughout the simulated cycle.

Step 5. Heat the autoclave, ensuring that the following requirements are met:

- Minimum permissible heat-up rates calculated from lagging part thermocouple data are as follows:
  130°F to 190°F . . . . . .2°F/minute
  190°F to 230°F . . . . . .1°F/minute
  230°F to 250°F . . . . . .0.3°F/minute
- The leading part thermocouple shall not exceed a heat-up rate of 8°F per minute.
- Calculate heat-up rates for each 5 minute interval.

After the leading part thermocouple reaches 250°F, allow up to 60 minutes for the remaining thermocouples to reach 260°F ± 10°F. Each part thermocouple shall then maintain 260°F ± 10°F for a minimum of 30 minutes.

Step 6. If certification to 355°F capability is desired, continue heating the autoclave ensuring that the following part temperature requirements are met:

- Minimum permissible heat-up rates calculated from lagging part thermocouple data are as follows:
  270°F to 330°F . . . . . .1°F/minute
  330°F to 345°F . . . . . .0.3°F/minute
- The leading part thermocouple shall not exceed a heat-up rate of 5°F per minute.
- Calculate heat-up rates for each 5 minute interval.

After the leading part thermocouple reaches 345°F, allow up to 60 minutes for part temperatures to reach 355°F ± 10°F. Each part thermocouple shall then maintain 355°F ± 10°F for a minimum of 30 minutes.

Step 7. Cool the autoclave to 125°F using a cooling rate not exceeding 5°F per minute. Maintain a minimum pressure of 40 psig to 160°F and a minimum pressure of 10 psig to 125°F. Release remaining pressure at 125°F and terminate the run.

Step 8. Save pressure and temperature plots. Maintain adequate records to clearly document the results of the test run.

5.4.2.1 When pressure sensing using the dead end pressure gauge method, position at least one pressure sensing line at a maximum distance from the nearest vent line and do not vent the pressure sensing line in any manner.

5.4.2.2 When pressure sensing using the combination vacuum/vent/pressure sensing method, close the vents for a minimum of 30 seconds and log or record pressure readings. Ensure that the vacuum bag remains vented throughout the cure except when taking pressure readings. Check the pressure at each of the following:

- At the time the autoclave reaches full pressure.
- At the start of the 250°F or 355°F dwell period.
- at the middle of the dwell period.
- At the end of the dwell period, before cool down.

6 REQUIREMENTS

6.1 Refer to Table I for a listing of the checks and operational tests required for initial certification and re-certification.

TABLE I - CERTIFICATION AND RE-CERTIFICATION REQUIREMENTS

	SECTION	INITIAL CERTIFICATION	RE-CERTIFICATION (Note 1)
Autoclave Equipment Checks and Calibration	5.2	yes	every 6 months
Operational test - Empty Autoclave	5.3	yes	every 6 months
Operational test - Dummy Load	5.4	yes	not required

Note 1. When the autoclave has been overhauled or there has been an increase in the maximum production heat sink load, re-certify the autoclave by the performance of the autoclave equipment checks and calibration and both operational tests before further fabrication of production parts.

7 SAFETY PRECAUTIONS

7.1 Safety precautions applicable to the materials and procedures specified herein shall be defined by the subcontractor performing the work for Bombardier Toronto.

8 PERSONNEL REQUIREMENTS

8.1 This PPS has been categorized as a “Controlled Special Process” according to PPS 13.39. Refer to PPS 13.39 for additional personnel requirements. Certified and/or qualified personnel shall have a good working knowledge of the following, as applicable:

- have a working knowledge of autoclave equipment checks and calibration requirements
- understand the requirements for thermocouple placement for empty autoclave operational tests
- understand the requirements for preparing and placing dummy loads
- know how to vacuum bag dummy load parts for the operational test
- have a working knowledge of the dead end pressure gauge and combination vacuum/vent/pressure sensing methods
- have a working knowledge of the operation of the autoclave during certification tests

9 ADDITIONAL INFORMATION

9.1 Over-pressurization and high temperature alarms on the autoclave are recommended.

9.2 If combustible materials are being used in the autoclave, or cure temperatures are above 250°F, it is recommended that an inert gas such as CO_2 or N_2 be available for pressurization rather than compressed air.