Designation: B998 – 17

Standard Guide for Hot Isostatic Pressing (HIP) of Aluminum Alloy Castings[1]

This standard is issued under the fixed designation B998; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This guide presents requirements for hot isostatic pressing (HIP) of aluminum alloy castings. HIPing is a process in which components are subjected to the simultaneous application of heat and high pressure in an inert gas medium. The process is to be used for the reduction of internal (non-surface connected) porosity. The document is to describe the general parameters of the HIP process, describe certification procedures and a description that the process has been followed. It is not intended to be a description of a heat treating procedure. This is not meant to supersede an end user's specification where one exists.[2]

1.2 *Units*—The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 The following documents of the issue in effect on the date of casting purchase form a part of this practice to the extent referenced herein:

2.2 *ASTM Standards:*

E230/E230M Specification for Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples

2.3 *AMS Standards*

AMS 2750 Pyrometry

3. Terminology

3.1 *Definitions of Terms Specific to This Standard:*

3.1.1 *autoclave, n*—a pressure vessel used in the HIP process.

3.1.2 *hold time, n*—time at required temperature and pressure as specified on the drawing or applicable specification. Hold time to start when pressure and all temperature hold time load monitoring thermocouples are within specified requirements.

3.1.3 *hot isostatic pressing (HIP), n & v*—a solid state process whereby heat and pressure are simultaneously applied to objects in an autoclave by way of an inert gas to reduce internal voids and obtain desired properties. Also used as a verb to describe application of the process to an object, hence HIPing, HIPed.

3.1.4 *inert gas, n*—a non-reactive gas, used in HIP vessel during pressurization.

3.1.5 *on-line gas analysis, n*—analysis of process gas emanating from the autoclave. Refer to 7.6 ("Inert Gas Purity").

3.1.6 *working zone, n*—the volume of the heated region of an autoclave which may be occupied by castings to be hot isostatically pressed.

4. Significance and Use

4.1 HIP of castings should be performed in the as cast condition. Post HIP inspection of castings should result in a reduction of porosity that is evident in x-ray grade and properties.

4.2 HIP will not eliminate inclusions or surface-connected porosity in a casting.

5. Ordering Information

5.1 Orders for HIPing of aluminum castings under this guide should include the following information:

5.1.1 This guide designation (which includes the number, year and revision letter, if applicable).

[1] This guide is under the jurisdiction of ASTM Committee B07 on Light Metals and Alloys and is the direct responsibility of Subcommittee B07.01 on Aluminum Alloy Ingots and Castings.

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[2] The HIP practice described in this guide is not intended to be substituted for the heat treat requirements for aluminum alloy castings, which are provided in Practice B917/B917M Standard Practice for Heat Treatment of Aluminum-Alloy Castings from All Processes. This standard Guide is not meant to supersede an end user's specification where one exists.

5.1.2 The quantity in pieces.

5.1.3 Alloy.

5.1.4 Temperature, pressure, hold time, including tolerances.

6. Equipment

6.1 *Autoclave:*

6.1.1 Autoclaves should be of the inert gas pressurization type, internally heated, cold wall pressure vessel.

6.2 *Fixtures:*

6.2.1 Suitable jigs, trays, or other fixtures should be provided as necessary for proper handling and positioning of parts to be hot isostatic pressed. All fixtures should be made of suitable material which is compatible with the parts to be treated.

6.3 *Temperature Measurement and Control Devices:*

6.3.1 *Temperature Measurement*—Temperature measuring and recording devices should be provided for the autoclave. The devices should be of the potentiometric type, should use thermocouple sensors, and should provide permanent records of the temperature during the entire treatment.

6.3.2 *Temperature Control*—A sufficient number of suitable temperature control devices should be provided and properly arranged in the autoclave to assure the required temperature control in the working zone. The devices should be of the potentiometric type and should use thermocouple sensors.

6.4 *Pressure Measurement Devices:*

6.4.1 Pressure measurement devices should be accurate to within ±2 % at the specified operating pressure for parts being processed. The device should be capable of continuously monitoring and recording the pressure throughout the process.

7. General

7.1 All HIP equipment qualifications should be the responsibility of the hot isostatic pressing HIP Vendor. The Vendor should be responsible for any testing required for HIP equipment and should sign all necessary forms which certify that qualification, in accordance with this guide, has been attained.

7.2 *Cleaning:*

7.2.1 Castings to be treated, including fixtures, should be delivered to the Vendor clean and free of all surface contaminants which may be detrimental to the material being treated or to autoclave components. Prior to subsequent processing cycles the Vendor should ensure that fixtures, jigs, or tooling should be kept free of all surface contaminants which may be detrimental to the material being treated or to the autoclave components.

7.3 *Instrumentation:*

7.3.1 A minimum of three thermocouples should accompany the material during treatment. They should be located in the hottest, coldest, and nominal temperature the castings. An alternate instrumentation plan may be used with prior approval from the purchaser.

7.4 *Pressure Environment:*

7.4.1 *Equipment*—All pressure recording equipment should be calibrated in accordance with the instrument manufacturer's instructions.

7.4.2 *Pressure*—The chamber pressure during treatment should be as specified on the drawing or applicable specification. During the heat up and hold, the chamber pressure should be continuously monitored and data should be recorded at a maximum interval of no more than five (5) minutes.

7.5 *Thermal Treatment:*

7.5.1 The times and temperatures for the thermal cycle should be as specified on the drawing, applicable specification, or in Table 1. Note that HIP is a solid state process and should always occur below an alloy's solidus temperature or below any incipient melting temperature, whichever is lower. The temperatures should be continuously monitored and data should be recorded at an interval that is no greater than five (5) minutes. The use of multipoint recorders with a periodic recording of five (5) minutes maximum per thermocouple is permitted.

7.6 *Inert Gas Purity:*

7.6.1 Prior to hot isostatic pressing, the inert gas purity emanating from the autoclave should be greater than 99.70 % by volume and should satisfy the impurity limit requirements provided in Table 2.

7.6.1.1 The inert gas emanating from the autoclave, before hot isostatic pressing, which meets the impurity requirements of 7.6.1, should give a dew-point of -50°F, (-46°C) (66 ppm) or colder at ambient temperature and pressure.

7.6.1.2 Methods of gas dilution, replenishment, reuse, and purification are allowed.

7.6.2 Indication of conformance to the requirements for gas purity should be determined by on-line gas analysis of the process gas.

7.7 *Inspection and Tests:*

TABLE 1 Typical Mean HIP Cycles Guidelines for Aluminum Alloys

Aluminum Casting Alloys	Maximum Temperature in HIPing Furnace[A]	Recommended Furnace Set Point Temperature °F ± 25°F (°C ± 14°C)[B]	Pressure psi ±500 psi (MPa ± 3 MPa)	Hold Time (Mnutes, +15/-0)
A201.0, A206.0	960°F (516°C)	925–935°F (496–502°C)	15 000 (103)	120–360
355.0, C355.0	990°F (532°C)	925–965°F (496–518°C)	15 000 (103)	120–360
356.0, A356.0, 357.0, A357.0, E357.0, F357.0	1000°F (538°C)	925–975°F (496–524°C)	15 000 (103)	120–360

[A] Eutectic melting may occur if the maximum temperature in the furnace is exceeded.

[B] The recommended furnace temperature set point is based on a furnace temperature uniformity of ±25°F (°C ± 14°C) (see 8.2.1.2). The furnace set points may be adjusted for furnaces that demonstrate greater control of temperature variation as long as temperatures in the furnace do not exceed the maximum temperature.

TABLE 2 Allowable Inert Gas Impurities

Impurity	Maximum Volume Present	PPM (Vol/Vol)
Nitrogen	0.0050	50
Hydrogen	0.0125	125
Oxygen	0.0025	25
Hydrocarbons (Methane, CH_4)	0.0025	25

7.7.1 All inspections or tests required by the drawing or applicable specifications should be performed. The results of these inspections or tests should meet the requirements of the drawing or applicable specifications.

7.8 *Records:*

7.8.1 All records and test results for each hot isostatic pressing treatment should be maintained for purchaser surveillance as required by the customer, contract, or purchase order. These records should include at least the following information:

(a) Purchaser identification of parts or material treated.

(b) Part or material alloy designation.

(c) Autoclave identification.

(d) Loading procedures and part placement.

(e) Instrumentation procedures including thermocouple type and placement.

(f) Pressure records.

(g) Temperature records.

(h) Pressure media.

(i) Gas analysis records.

(j) Dew-point measurement records.

(k) Test results.

8. Quality Assurance Provisions

8.1 *General:*

8.1.1 All HIP equipment qualifications should be the responsibility of the hot isostatic pressing HIP Vendor. The Vendor should be responsible for any testing required for HIP equipment and should sign all necessary forms which certify that qualification, in accordance with this guide, has been attained.

8.2 *Autoclave Qualification:*

8.2.1 *Temperature Uniformity:*

8.2.1.1 All autoclaves should be qualified for working zone temperature uniformity prior to use for production hot isostatic pressing. All autoclaves should be requalified at least once per year after initial qualification. Qualification may be performed on a production load in accordance with 8.2.1.3. The procedure for qualification, requalification, and qualification after major change are all the same.

8.2.1.2 After thermal equilibrium is reached, the maximum temperature variation of any load thermocouple should not deviate from the selected control temperature by more than ±25°F (±14°C).

8.2.1.3 *Qualification Procedure*—Qualification procedure for temperature uniformity should be documented, using a furnace load containing a representative production load of parts. Furnace qualification should conform to the requirements of AMS 2750 using customer accepted temperature uniformity survey(s) done by the HIP vendor. After initial qualification the furnace should be requalified at least every six (6) months using an agreed upon procedure between purchaser and HIP vendor.

8.3 *Temperature Measurement and Control Qualification:*

8.3.1 *Instruments*—The temperature control system should have an accuracy of ±0.5 % of the maximum operating temperature. The temperature accuracy of each instrument should be determined in accordance with the equipment manufacturer's recommendations. After the initial qualification, all instruments should be requalified at least every 90 days.

8.3.2 *Thermocouples*—Before each use, all thermocouples should be capable of meeting the temperature/electromotive force requirements of Specification E230/E230M tables for special grade wire as determined by suitable test methods and requalification intervals.

8.4 *Pressure Indicating Instrument Qualification*—All pressure indicating instruments should be checked in accordance with the equipment manufacturer's recommendations. The equipment's performance should be within the limits supplied by the equipment manufacturer. After the initial qualification, each instrument should be requalified at least every 90 days or the controlling specification requirement.

8.5 *Process Qualification:*

8.5.1 Castings should be processed only by a HIP source approved by the purchaser.

8.5.2 If required, before production processing, detailed process procedures and results of test samples may be submitted to the purchaser for approval.

8.5.3 Process procedures should include the same information as required in 7.8.1.

9. Keywords

9.1 aluminum casting; autoclave; densification; HIP; HIPing; hot isostatic pressing; internal voids; inert gases; porosity; pressure; thermal couple; thermal treatment