Aerospace Aluminum Brazing: Complying with AMS 2750 and Nadcap Requirements

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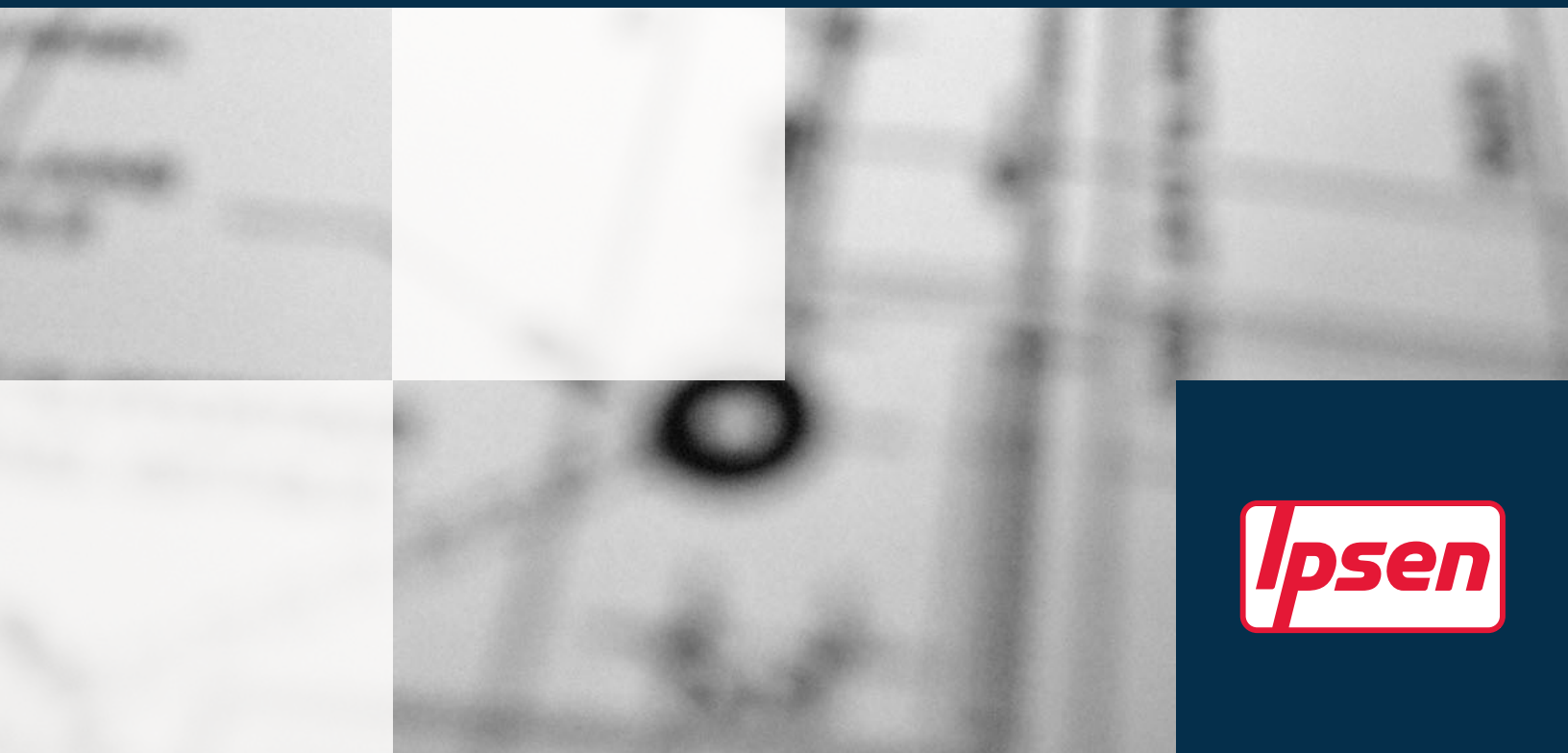

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by Jim Grann and Craig Moller

Abstract

Aluminum brazing has been used in the aerospace industry for decades and continues to evolve to meet the complex needs of the industry. As demand increases for lower brazing costs, system enhancements and advanced furnace capabilities, the need for stricter guidelines also becomes more important. Understanding the specifications and requirements set out by Aerospace Materials Specifications (AMS) and Nadcap will help simplify the certification process.

AMS and Nadcap each provide a set of requirements for heat treating as it relates to the aerospace industry. If you are looking to obtain Nadcap accreditation for your process, most auditors will require adherence to AMS 2750 (pyrometry requirements). This paper will help to increase your knowledge and understanding of aerospace brazing requirements, including proper implementation and adherence to guidelines and checklists.

Introduction

AMS 2750G "covers pyrometric requirements for equipment used for the thermal processing of metallic materials. Specifically, it covers temperature sensors, instrumentation, thermal processing equipment, correction factors and instrument offsets, system accuracy tests (SAT), and temperature uniformity surveys (TUS)." [1]

Nadcap defines itself as, "an industry-managed approach to conformity assessment that brings together technical experts from both Industry and Government to establish requirements for accreditation, accredit Suppliers and define operational program requirements." [2]

Nadcap is considered a standardized approach to quality assurance that confirms control and repeatability of a given process. Nadcap accreditation can be sought for many heat-treating processes. Most companies will seek acceptances that relate to their specific processes for Aerospace. With vacuum aluminum brazing, it is common to see customers seeking Nadcap approval on:

- **AC7102** – Suppliers obtaining Nadcap accreditation in heat treating must include this checklist regardless of the process being performed. Additional checklists are added depending on what thermal processes a supplier wishes or is required to include in their scope. [3]
    - AC7102/1 – Brazing
    - AC7102/2 – Aluminum heat treating
- **AWS C3.7M/C3.7:2011** – "This specification presents the minimum fabrication, equipment, material, process procedure, and inspection requirements for the brazing of aluminum." [4]
- **AMS 2769D** – "This specification establishes the requirements and procedures for heat treating parts in vacuum/partial pressure." [5]
- Additional specifications as required by aerospace primes.

Understanding AMS 2750G and Nadcap Requirements

The guidelines set by AMS 2750G ensure process repeatability through validation, calibration and verification of heat-treatment equipment. To comply with AMS 2750G, it is important that you understand your process, the parts you will be heat treating and the specifications you need to meet for that particular process.

If you are in the market for new heat-treating equipment, make sure the furnace you choose is able to achieve the necessary requirements for the parts you will be processing. While reviewing furnace options, take into consideration desired cycle times, desired metallurgy of processed parts, temperature uniformity, cooling rates, sublimation of alloy control, ease of operation, and overall compliance to AMS 2750G.

Figure 1 *Ipsen Vacuum Aluminum Brazing Furnace*

Furnace Classification

Another factor that affects compliance is the class and instrumentation type of your furnace. Temperature uniformity range determines furnace class; and the number, location, and function of the sensors within the furnace determine furnace instrumentation group.

AMS 2750G outlines furnace class by numbers "one through six," with one being the tightest class rating. Instrument type is qualified by letters "A through E." [1]

When selecting a furnace for aerospace aluminum brazing, consider the following:

- Part weight, material and geometry
- Geographic location of end user's facility
- Control of retained water vapor and forming oils from stamping to brazing
- Furnace vacuum levels during brazing process
- Furnace pumping systems and time required to evacuate
- Temperature uniformity regulation and zones of control
- Temperature zone offset abilities
- Optional part (in furnace) cooling systems
- Slow pumping bypass event to negate core shifting and water vapor freeze over
- Cold-wall temperature regulation (water vapor)
- Double-ended opening door systems (ease of cleaning)
- Brazing furnace tuned for core and/or flat plate brazing processes (same furnace, different tuning methods)

Aerospace Prime Specifications

In addition to AMS 2750G and Nadcap, many aerospace manufacturers have their own specifications that you must meet to process their parts. In many cases, the aerospace prime specifications are stricter than those required by AMS 2750G and Nadcap. Best practice is to make sure you are certified to the strictest specifications related to your customer's requirements and processes.

AMS 2750G Vacuum Specifications

There has been some confusion in the area of AMS 2750G as it relates to vacuum processes, so it is worth exploring this topic in order to reach a better, more thorough understanding. While AMS 2750G remains a pyrometry specification, customers have found that some field inspectors will include the requirement for vacuum gauge calibration.

AMS 2750G states that, "Furnace vacuum level during TUS shall be run at the lowest vacuum level used in production, but need not be less than 1 micron Hg." [1]

Translation: according to several inspectors, if your processes utilize argon or nitrogen gas in the form of partial pressure above one micron, the vacuum gauge must be part of the certification and calibration of your vacuum furnace systems (while this is assumed, it is not officially written in the guidelines).

The thought behind this relates to the production parts: if they are processed at or below one micron, vacuum gauge calibration is not an issue with AMS 2750G. If the production parts are normally processed in a partial pressure environment, the vacuum gauge system by default becomes a part of the process; so, the requirement for calibration is included in AMS 2750G. AMS 2759 and AWS C3.7M/C3.7:2011 often refer to vacuum levels as well.

Additionally, some inspectors mandate that system accuracy tests (SAT) and temperature uniformity surveys (TUS) are run in partial pressure as well. This best emulates the furnace calibrations to the actual production process when validating the furnace for compliance.

Due to changes in AMS 2750G and Nadcap requirements, it is possible to encounter auditors who subscribe to this theory and those who do not. It has been a grey area in certain regions of the world, but being prepared for it is better than being surprised.

Figure 2 *Vacuum Gauge*

Nadcap Certification

Several heat treaters have failed Nadcap audits simply because they lack understanding of the basic requirements. Nadcap accreditation is based on many factors, but it comes down to the end user being able to prove that they maintain their equipment, follow basic guidelines of AMS 2750G, have proper work instructions in place, maintain records in accordance with guidelines, have process repeatability, train operators, and so forth, prior to accreditation.

The Performance Review Institute (PRI) published a reference guide to help heat treaters better understand the reason for their failures and offer guidance to achieve successful certification. Key factors that are often overlooked include the pre-certification checklist and successful completion of the self-audit, both of which must be done prior to the Nadcap audit.

Excerpt from the Heat Treating Task Group Pyrometry Reference Guide:

"During the period that the Nadcap Heat Treat Task Group has been reviewing audits, we have found Pyrometry to be the least understood and the causes of the most problems and confusion. A recent study indicated, aside from job audit non-conformance reports (NCR), eight of the top ten NCR causes are related to pyrometry. However, pyrometry is also the core and basis of all heat-treatment practices.

We have prepared this guide to improve the understanding of pyrometry and the performance of pyrometric functions. It provides guidance and interpretations of AMS 2750[G], as well as fundamental pyrometry principles and tells you what a Nadcap auditor will expect to see during an audit.

SCOPE: This guide is not intended to replace AMS 2750[G] or waive any of its requirements or those imposed by customers. The following are Nadcap interpretations of the specification and these interpretations must be used only as guidance to the specification. Customer requirements may exceed those discussed here. It is the responsibility of the supplier to understand and comply with all customer requirements." [6]

Figure 3 *Vacuum Furnace with TUS Fixture*

System Accuracy Tests & Temperature Uniformity Surveys

As mentioned earlier, the self-audit and checklists need to be performed before the Nadcap auditor arrives on-site. Part of this self-audit includes testing your equipment to document that it complies with the required specifications for your particular processes. SAT and TUS validate the performance of the furnace, ensuring that it provides accurate, repeatable results that fall within the guidelines. TUS fixture can be seen in Figure 3.

SAT is a simple test performed in order to determine that thermocouples (TC) and instruments are giving accurate temperature readings. These tests provide information on changes over time, by comparing temperature control and recording systems in each control zone with a separate test instrument and thermocouple combination.

Considerations when testing include age of the furnace and hot zone, as well as age and classification of the instrumentation. TC types, seen in Figure 4, utilized for SAT and TUS are also important to consider when testing for compliance.

Commonly Used Load TC Types:

- Type K - Positive leg of chromel (90% nickel, 10% chromium) and a negative leg of alumel (95% nickel, 5% aluminum and silicon)
- Type N - Positive leg of nicrosil (84.5% nickel, 14% chromium, 1.5% silicon) and a negative leg of nisil (95.4% nickel, 4.5% silicon, 0.1% magnesium)

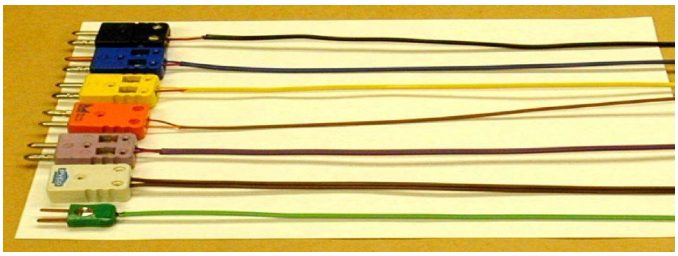

Figure 4 *Types of Thermocouples*

The next thing to consider is the number of TC penetrations you need in order to perform SAT testing for compliance. AMS 2750G requires three penetrations: control TC, over temp TC and SAT TC. The commonly used control and over temp TCs are the R, S, and B family, because these TCs have minimal drift in thermal electromagnetic frequencies (EMF) when exposed to high temperatures, oxidizing and reducing atmospheres.

SAT TCs must be of a different family from the furnace control TC. Normally type K and type N are utilized. SATs should be performed on the temperature control and recording systems in each control zone of each piece of thermal processing equipment that is used for production heat treatments. The SATs should also be performed on additional systems that qualify instrumentation as types A, B or C. [1]

A TUS is done utilizing a fixture that enables the precisely placed TCs to validate the uniformity throughout the heating zones within the hot zone environment. When selecting survey TCs it is important to ensure that the maximum correction factor of the TCs being utilized is less than the specification you are attempting to achieve within the vacuum furnace.

Aluminum Brazing is a Dirty Process

A vacuum aluminum brazing furnace needs magnesium to braze; however, an excessive buildup of magnesium oxide (residue left over from the brazing process) prevents the furnace from functioning properly. Therefore, it is important to maintain a balanced brazing environment within the furnace.

Cleaning is mainly done via mechanical scraping and a combination of air and vacuum burnout cycles. Ipsen's VAB furnace is built with both a front and back door for ease of cleaning (Figure 6).

Customers that are new to aluminum brazing are often surprised by the condition of the hot zone and furnace after a few short months of operation. With time and experience, you will better understand what is considered normal, and how to best maintain the proper balance of magnesium in the furnace.

Figure 5 *A typical vacuum aluminum brazing hot zone after use*

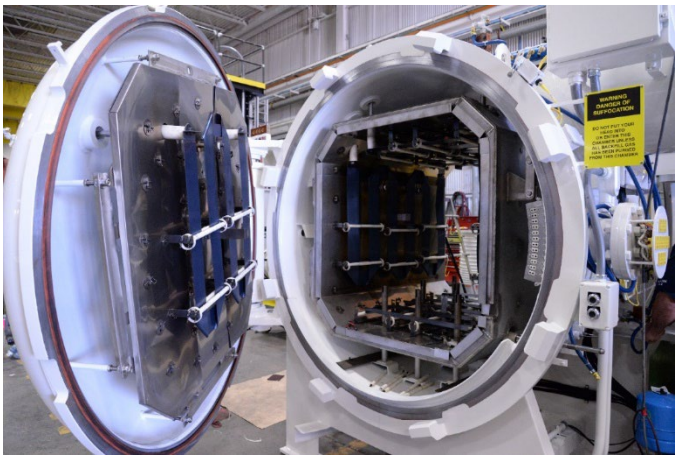

Figure 6 *Small Ipsen VAB furnace with front and back door open*

Typical Aluminum Brazed components

Various components that utilize aluminum brazing are seen in Figures 7 through 10 below.

Figure 7 *Condenser systems (Photo courtesy of API TECH)*

Figure 8 *Large Heat Exchangers (Photo courtesy of Chart Industries)*

Figure 9 *Flat Plate Coolers (Photo courtesy of API TECH)*

Figure 10 *Large Automotive Radiator (Photo courtesy of API TECH)*

References

[1] "Pyrometry AMS2750G." *SAE International*, 29 June 2022, https://www.sae.org/standards/content/ams2750g/.

[2] "Nadcap." *Performance Review Institute*, 2 Nov. 2021, https://p-r-i.org/nadcap/.

[3] Schulze, Jason. "AC7102 Checklist Review, Part 1." *Thermal Processing Magazine*, 4 Mar. 2021, https://thermalprocessing.com/ac7102-checklist-review-part-1/.

[4] "Specification for Aluminum Brazing." *American Welding Society*, 5 Oct. 2011.

[5] "Heat Treatment of Parts in a Vacuum AMS2769D." *SAE International*, 22 Sept. 2020, https://www.sae.org/standards/content/ams2769d/.

[6] Performance Review Institute. Heat Treating Task Group Pyrometry Reference Guide. Retrieved November 16, 2021, from https://pdfcoffee.com/pyrometry-guide-20-nov-12-4-pdf-free.html.

Originally published in April 2012, updated in 2023 for clarity and to reflect specification changes.

About Ipsen

Ipsen designs and manufactures industrial vacuum and atmosphere heat-treating systems, supervisory controls and predictive maintenance software for many industries including Aerospace, Automotive, Commercial Heat Treating, Energy and Medical. Leading the industry with more than 10,000 furnaces installed worldwide, with production locations on three continents and representation in 34 countries, Ipsen is committed to providing 360° support for customers.

Ipsen Customer Service provides aftermarket support for any brand of vacuum furnace through process development, factory layout planning, installation and start-up assistance, training, replacement parts, hot zones, controls and instrumentation upgrades, mechanical retrofits and furnace refurbishments. With a global team of more than 120 field service technicians, Ipsen employs the largest and most skilled aftermarket team in the business providing quick and easy access to troubleshooting, maintenance, repairs, instrument calibrations and temperature uniformity surveys. Ipsen's aftermarket support helpline also provides remote assistance for customers in any location.

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