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**Aerospace Aluminum Brazing and Compliance: Meeting AMS 2750E and Nadcap Certifications**

By Jim Grann and Craig Moller



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# Aerospace Aluminum Brazing and Compliance

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## Abstract

Removing the fear from the phrase, *Aerospace Aluminum Brazing and Compliance*, can be significantly simplified with increased knowledge, understanding and proper implementation of the requirements and adherence to required guidelines and checklists.

In the past, the majority of aluminum brazing processes have managed to escape the critical eye of AMS 2750E and Nadcap certifications. In general, we must first understand the differences between Aerospace Materials Specifications (AMS) 2750E and Nadcap certification from a topical view. While the two normally form a synergistic bond, they first must be separated in order to understand the fundamental differences between the two. For aerospace aluminum brazing, this understanding is critical, because most Nadcap inspectors require adherence to AMS 2750E before granting consideration of your specific aerospace-related processes.

## Introduction

### Clarification of Definition of AMS 2750E and Nadcap

AMS 2750E is a pyrometry (temperature driven) specification that employs procedures, timelines, calibration data, record archiving, SAT (System Accuracy Testing), TUS (Temperature Survey Surveys) and thermocouple guidelines and applications. According to Nadcap's website they are defined as,

“The leading worldwide cooperative program of major companies designed to manage a cost-effective consensus approach to special processes & products and provide continual improvement within the aerospace & automotive industries.” [1]

Nadcap is considered a systematic approach of checkpoints that confirm proven control and repeatability of a given process for which approval is being sought. When an organization claims they are Nadcap accredited, it generally means that they have been complying with AMS 2750E [2], AWS C3.7M/C3.2005 [5] and in some cases AMS 2769B [3], but there can be other internal customer specifications dependent on processes and other factors\*.

There are many heat treating processes for which Nadcap accreditation may be sought. Normally speaking, most heat treating companies will seek acceptances that relate specifically to their actual processes for Aerospace; for instance, in the aluminum vacuum brazing arena, it is common to see customers seeking Nadcap approval on:

- **AC7102/1 (If seeking brazing approval)**
- **AC7102/2 (If seeking aluminum approval)**

With possible additional adherence to:

- **AWS C3.7M/C3.2005 [5]**
- **AMS 2769A**
- **PRI Introduction to Pyrometry**
- **AMS 2759**
- **AWS C3.7M/C3.7:2005**
- **An American National Standard**

**\*Aerospace primes may have their own specifications.**

## Understanding AMS 2750E & Nadcap

With a clearer definition of AMS 2750E and Nadcap certification, it is now important to gain a better understanding of each. Nadcap is a certification process linked closely with AMS 2750E, so it is imperative to explore these requirements in more depth.

When attempting to comply to AMS 2750E one must consider their process, the configuration of their equipment and the classification of their equipment. Normally speaking, these are the guidelines set forth within AMS 2750E to insure the validation, calibration and verification of the ability of the heat treatment equipment to demonstrate process repeatability.

## Process

The first thing to consider when attempting compliance with AMS 2750E is your process. It extremely important to understand the parts that you will be processing and what specifications you need to meet for that particular process.

## Configuration of Equipment

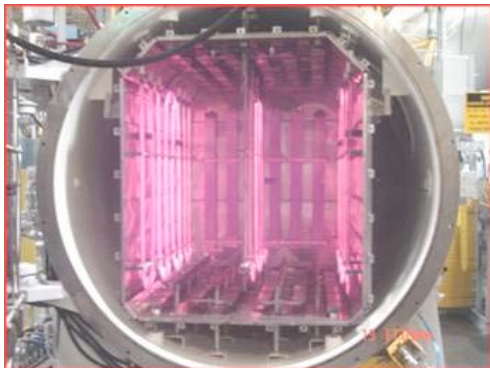
Once the process and specifications are understood, the selection of the actual vacuum heat treatment system is considered. It's important to have a thorough understanding of your process in order to make the correct selection of furnace. The furnace you choose must be able to achieve the necessary requirements for the parts you are processing to ensure compliance is achievable.

While reviewing furnace options and abilities, many things must be taken into consideration, for example total desired cycle times, resting metallurgy of processed parts, uniformity of heat treatment, cooling, sublimation of alloy control, ease of operation and total component compliance to AMS 2750E.

### Furnace Classification

Another factor that affects compliance is the class of your furnace. Figure 1 shows an internal view of a aluminum vacuum brazing furnace. While many claim to be AMS 2750E compliant, there are actually several different versions that constitute compliance in regards to vacuum heat treatment systems. Therefore, it is again imperative that you know the process for which you need compliance in order to make sure the furnace classification meets the specifications.

You must know what class you are attempting to subscribe to as predicated by your metallurgy specifications. AMS 2750E requires two categories for furnaces - class and instrumentation type. Temperature uniformity range determines furnace class, and the number, location, and function of the sensors within the furnace determine furnace instrumentation type.



**Figure 1** Vacuum Aluminum Brazing Furnace (Ipsen R&D)

AMS 2750E outlines furnace class by numbers one through six, with one being the highest class rating. Instrument class is qualified by letters A through E, with A

being the tightest tolerance rating. [2]

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

- Parts' weight, materials and geometry
- Geographical location of end user's facility
- Control of retained water vapor from stamping to brazing
- Furnace vacuum levels during braze
- 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
- 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 methodologies)

### Aerospace Prime Specifications

In addition to AMS 2750E and Nadcap, most Aerospace manufacturers have their own specifications that you must meet in order to run their parts. In many cases, the Aerospace prime specifications are stricter than that required for AMS 2750E and Nadcap certification. Best practice would be to make sure you are certified to the strictest specifications related to your customer's requirements and processes. [3]

### AMS 2750E Vacuum Specifications

There seems to be a bit of confusion in the area of AMS 2750E as it relates to vacuum processes, so it is worth delving into this topic in order to reach a better, more thorough understanding. While AMS 2750E remains a pyrometry specification, there are many field inspectors who have annexed in the requirement for vacuum gauge calibration.

Section 3.5.12 of AMS 2750E says 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." [2]

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.

The thoughts behind this relate to the production parts: if they are processed at or below one micron, vacuum gauge calibration is not an issue with AMS 2750E. If the production parts are normally processed in a partial pressure environment the vacuum gauge system by default becomes a part of the process; thus, the requirement for calibration being drawn into AMS 2750E. AMS 2759 and AWS C3.7M/C3.2005 often make reference to vacuum levels.

Ancillary to the above, some inspectors mandate that system accuracy tests (SAT) and temperature uniformity surveys (TUS) be 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 recent changes in AMS 2750E 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. When generally summarized it comes down to the end user being able to prove that they maintain their equipment, follow basic guidelines of AMS 2750E, have proper work instructions in place, history (records) being maintained in accordance with guidelines, process repeatability, trained operators and so fourth prior to accreditation.

The Nadcap team has published a paper to help heat treaters to better understand the reason for their failures and offer guidance to achieve successful certification. Key factors that are often overlooked by those seeking certification include the pre-certification checklist and successful completion of the self-audit, both of which must be done prior to seeking resting Nadcap accreditation.

An excerpt from the Nadcap guidance paper:

“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 practice.

We have prepared this guide to improve the understanding of pyrometry and the performance of pyrometric functions. It provides guidance and interpretations of AMS2750E, 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 2750E 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.” [1]



**Figure 3** TUS Fixture (Ipsen R&D)



**Figure 4** TUS Fixture in Furnace (Ipsen R&D)

### *System Accuracy Tests (SAT) & Temperature Uniformity Surveys (TUS)*

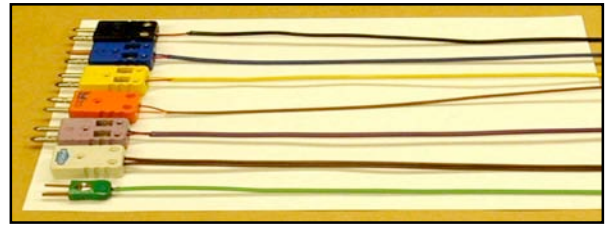
As mentioned earlier, the self-audit and checklists need to be performed before the Nadcap auditor arrives on-site. Part of this self-audit is the testing of your equipment to document that it does comply with the required specifications for your particular processes. SAT and TUS validate the furnace performance criteria of the system proving accurate, repeatable results that fall within the guidelines. TUS fixtures can be seen in Fig. 3, 4, 6 and 7.

SAT is a simple test performed in order to determine that the thermocouples and instruments are giving an accurate depiction of temperature. These tests provide information as to 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 the age and classification of the instrumentation. Types of thermocouples (TC), seen in Figure 5, utilized for SAT and TUS are also important to consider when testing for compliance.

Types of commonly used load TCs:

- 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 5** Types of Thermocouples

The next thing to consider is the number of TC penetrations you need in order to perform SAT testing for the desired compliance. AMS 2750E 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 and 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 shall 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 shall also be performed on additional systems that qualify instrumentation as types A, B or C. [2]

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.



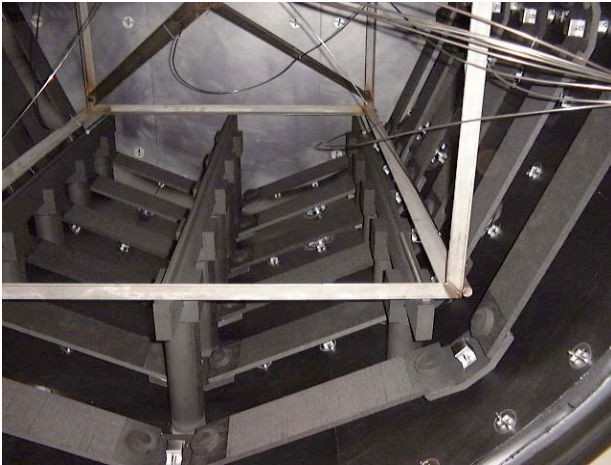
**Figure 6** Vacuum Aluminum Brazing Furnace (Ipsen R&D)

## Aluminum Brazing is a dirty process

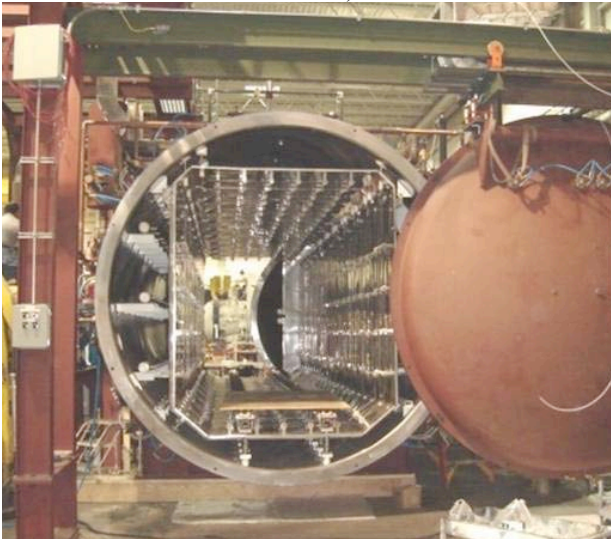
A vacuum aluminum brazing furnace needs magnesium to be able to braise, but conversely an excessive buildup of magnesium oxide (residue left over from the brazing process) prevents the furnace from being able to braise. There is a synergistic bond and balancing act between the two thresholds.

Cleaning is mainly done via mechanical scraping and a combination of air and vacuum burn-out cycles. Figure 8 shows the front and back doors of Ipsen's aluminum brazing furnace open for cleaning. Figures 9 through 11 show various levels of magnesium buildup.

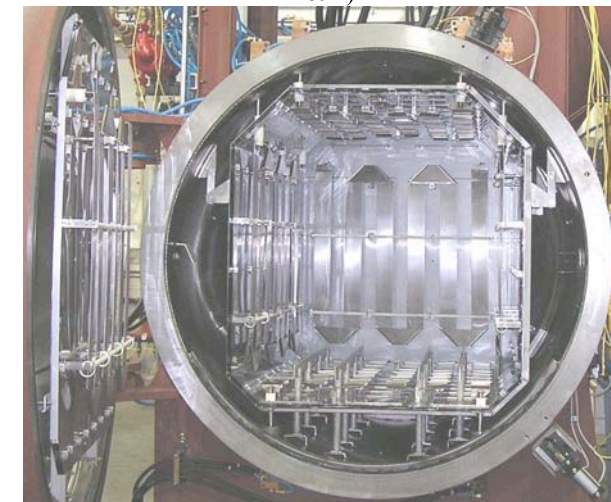
Customers that are new to the aluminum brazing arena are often taken aback by the condition of the hot zone and furnace after a few short months of operation. Only with time and experience will one be able to fully realize what is considered normal, and how to best maintain the proper balance of magnesium in the furnace.



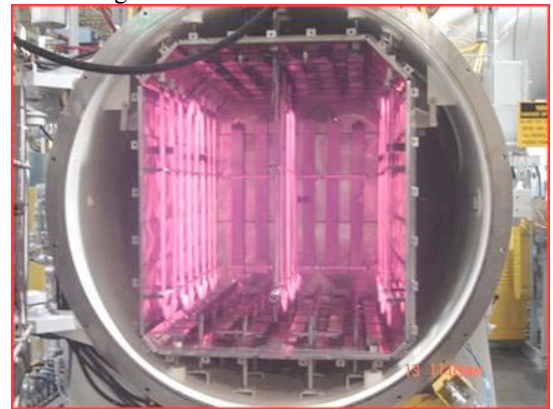
**Figure 7** Vacuum Aluminum Brazing Furnace (Ipsen R&D)



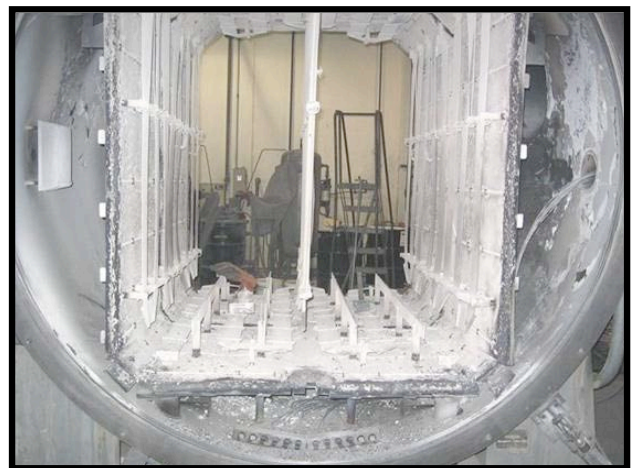
**Figure 8** Vacuum Aluminum Brazing Furnace (Ipsen R&D)



**Figure 9** Vacuum Aluminum Brazing Furnace (Ipsen R&D)



**Figure 10** New Aluminum Brazing Furnace (Ipsen R&D)



**Figure 11** Four Year Old Aluminum Brazing Furnace – Normal (Ipsen R&D)

## Typical Aluminum Brazed components

Various components that utilize aluminum brazing are seen in Figures 12 through 15 below.



**Figure 12 Condenser systems** (Photo courtesy of API TECH)



**Figure 13 Large Heat Exchangers** (Photo courtesy of Chart Industries)



**Figure 14 Flat Plate Coolers** (Photo courtesy of API TECH)



**Figure 15 Large Automotive Radiator** (Photo courtesy of API TECH)

## Conclusion

Aerospace aluminum brazing has been around for decades. It continues to evolve and fractionate into different Aerospace niches. At the same time, the continual demand for lower brazing costs, system throughput enhancements and furnace capabilities to process complicated part geometries increase, and hence the need for stricter guidelines and procedure adherence. Understanding of the specifications and requirements set out by AMS 2750E and Nadcap that pertain to your processes will help to simplify certification.

## References

- [1] Performance Review Institute, "Nadcap," 2011. Web. 16 October 2011. <<http://www.pri-network.org/Nadcap/>>.
- [2] SAE International, "AMS 2750E : Pyrometry," 2005.
- [3] SAE International, "AMS 2769B : Heat Treatment of Parts in a Vacuum," 2009.
- [4] SAE International, "AMS 2759E : Heat Treatment of Steel Parts, General Requirements," 2008.
- [5] American Welding Society, Brazing Handbook, American Welding Society, 1991.
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