

AEROSPACE HEAT TREATING:
**PROCESSES, ALLOYS,
AND CERTIFICATION
REQUIREMENTS**

It takes a lot of science and a ton of organization to turn drawings and documents into commercial, civilian and military aircraft. The firms who do it well make it seem more like an art form.

It's hard work—and it's getting harder. Prices are rising. Supply chains are unpredictable. Maintaining safety is paramount.

At a time when OEMs are under great pressure to meet their obligations while preserving part quality and safety, strong supplier partnerships—including those with thermal processors—can change the game.

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PART 1

WHY PRECISION MATTERS IN AEROSPACE HEAT TREATING

The pursuit of faster, lighter, more efficient aircraft has spurred the development of countless complex alloys. And for those alloys to perform as designed, equally complex heat treatments have emerged.

The development of these parts and the advanced heat treatments necessary for them to achieve superior mechanical properties have made precision critical at every point in the supply chain.

WHAT ARE COMMON ALLOYS USED IN AEROSPACE COMPONENTS?

Aircrafts feature a wide variety of complex materials. Manufacturers must balance important design and material selection concerns to produce long-lasting parts at reasonable costs.

In a game of tradeoffs, the options are almost endless. Heat treaters can play an important part in sorting through the choices to achieve the right balance of a diverse array of alloys.

Complex thermal processes have emerged to match the complexity of alloys developed in the pursuit of faster, lighter and more efficient aircraft.

aluminum alloys

Aluminum alloys have been crucial to aerospace material and design advances for decades. As production techniques matured, aluminum alloys like 6061 helped make aircraft lighter and sturdier.

Today, modern aluminum alloys remain integral in some aerospace applications due to their high strength-to-weight ratio. Common types include:

- 5xxx alloys featuring silicon and manganese that are relatively workable and feature high hardness and high tensile strength despite low density.
- 2xxx alloys commonly used for structural service and as fasteners and rivets.
- 7xxx alloys that also perform well in structural applications and which boast high toughness and resistance to stress corrosion cracking.

Learn more about aluminum alloys [here](#).

titanium alloys

Titanium and titanium alloys are commonly used in critical aircraft applications where resistance to constant stress is necessary.

Ti6Al4V, a titanium formula containing aluminum and vanadium as alloying elements, is the most popular. It's known for its performance under constant severe motion in the cold sections of jet engines. Ti6Al4V is often specified for discs, ducts, turbine blades and bearing housings. Slight tweaks to the formula result in excellent performance in cryogenic temperatures. It's also sometimes used to make fasteners.

Titanium performs well in many aerospace settings, but it's not as widely used as many in the industry would like. That's because the element is hard to mine and process. It may become more widely used as mining and processing techniques improve.

nickel alloys

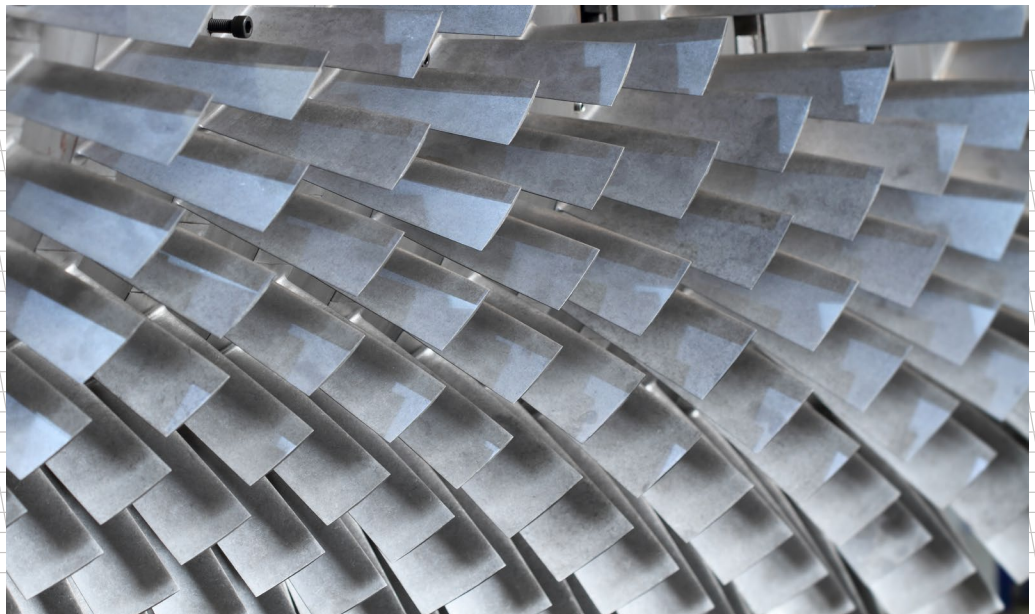
Nickel alloys are also lauded for their performance in high-stress service environments. They're also generally very resistant to corrosion, making them ideal for use in jet engine components in constant motion and subject to high heat and corrosive gases. Common aerospace nickel alloys include:

- WASPALOY and its variants, which are very strong at high temperatures.
- Inconel 718 and Inconel 625, each of which boast high strength in hot environments; 718 is stronger than 625 but 625 is more corrosion-resistant.
- Alloy 36, which retains dimensional properties in high temperatures and is often specified for complex aircraft instrumentation.
- Alloy 230, which resists corrosion under high stress and is suited for cold-section service.
- PWA 1484, a formula which is very resistant to high temperature creep. Alternatives include the René alloys N5 and N636 among others.

Nickel alloys are widely used in critical service environments due to their corrosion resistance and performance under high stress.

cobalt alloys

Cobalt alloys such as L-605 exhibit good oxidation resistance and high strength at elevated temperatures. They're commonly used in turbine rotors, nozzle diaphragm valves, springs and other components.



stainless steel alloys

Stainless steel alloys are among the most versatile in modern industry. From automotive to power generation to pharmaceutical applications and beyond, stainless steel alloys are widely specified for their excellent corrosion resistance.

The following stainless steel formulas are widely used in a broad range of aerospace settings:

- 304, used in fuel tanks and some structural components not subject to very hot temperatures.
- 309, a heat-resistant formula containing extra chromium and nickel.
- 316, 316L, 321, S30415 and S30815, all of which are more heat-resistant and suitable for use in exhaust systems, engines and some high-temperature structural service.
- 17-4Ph, a formula containing copper and niobium alloys that is comparable to 304 stainless but chosen when extra corrosion resistance is desired.

HOW AEROSPACE ALLOYS ARE HEAT TREATED

Many aerospace components sustain constant strain and motion and serve in extremely hot or cold environments. For parts like these, complex and precise heat treatments are necessary.

[Vacuum furnaces](#) are ideal for hardening and strengthening aerospace components for a couple reasons. First, parts treated in vacuum furnaces cannot oxidize or become otherwise contaminated when atmosphere is removed from the chamber. Second, these furnaces are built to include process controls that allow metallurgists to design the complicated treatment cycles that fulfill the industry's incredibly strict specs.

Process control is crucial. In aerospace, there's no room for error.

Some projects come with specs that dictate the exact treatment parameters we must follow. Other orders specify treatments based on the properties parts must exhibit, and it's up to us to develop the treatment that makes it happen. Either way, we rely on our experienced team of metallurgists and the industry's most advanced equipment.

**Process control is crucial.
In aerospace, there's
no room for error.**

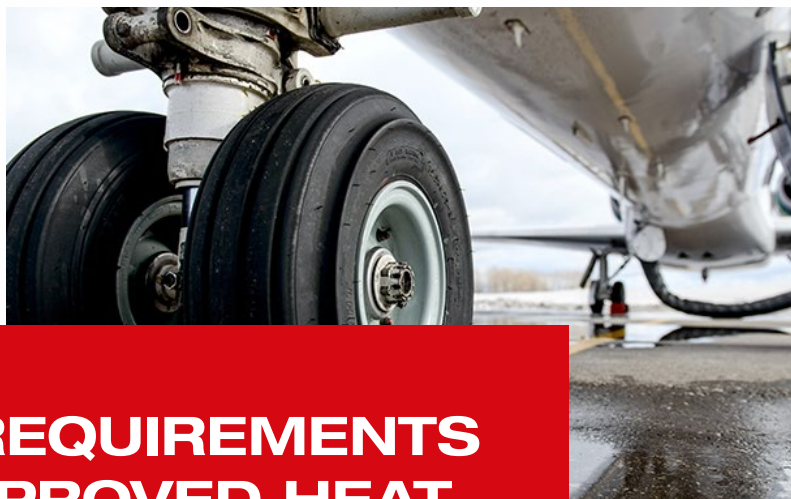
Vacuum furnaces operating in Paulo's Cleveland Division routinely execute complex day-long treatments that top 2,400 degrees Fahrenheit. Consider these notable process control capabilities:

- We can create treatments that feature very slow ramp rates (down to around 1 degree per minute). This ensures that parts reach the required treatment temperature slowly and evenly, which promotes proper solutionizing.
- Fine-tuned thermocouples help our furnaces sustain temperatures to within +/- 2 degrees for an extended period.
- Using programmable logic controllers (PLCs), we can apply correction factors to treatments in progress.
- Dozens of sensors monitor around 1,000 different variables in real time and trigger alarms if out-of-spec conditions are observed.

Earning and maintaining key certifications is just as important for aerospace thermal processors as understanding materials and metallurgy.

There's more to thermal processing for the aerospace industry than an in-depth understanding of materials and metallurgy. Earning and maintaining key certifications is equally critical. Read on to learn about the industry's most rigorous certification—and the benefits of working with providers who've earned it.





PART 2

WHAT ARE THE REQUIREMENTS FOR NADCAP-APPROVED HEAT TREATERS?

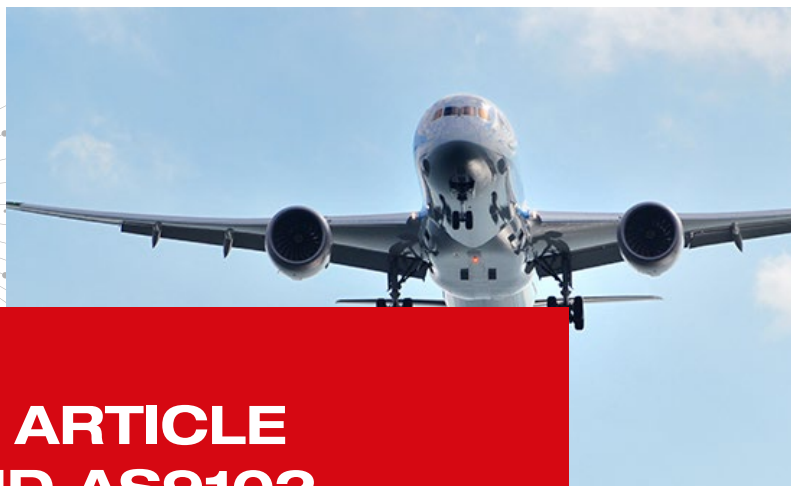
Nadcap requirements are quite prescriptive. Other industry standards programs give suppliers varying amounts of leeway en route to achieving the benchmarks they set. Nadcap features no such liberty. It's their way or the highway.

Nadcap-approved heat treaters must meet requirements regarding all aspects of their operation, including:

- The types, sizes and capabilities of [heat treating equipment](#) used to treat aerospace and defense components.
- The details of how certain components must be treated (for instance, we need documentation showing our [vacuum brazing](#) or other [solution treating](#) operations meet muster according to the Nadcap program).
- The degree of precision in pyrometry (remote temperature measurement) that must exist in heat treatment furnaces.
- Ensuring furnace repairs are executed in accordance with the standards.
- The properties of appropriate quench oils and the quality tests the oils must pass before use.
- The training of personnel operating the equipment used in aerospace and defense heat treating.

Nadcap starts as a crucial requirement and ends as a mutually beneficial asset.

Becoming a Nadcap-approved heat treater requires proving you have the equipment and processes in place to treat safety-critical aerospace and defense components. Keeping the certification is all about maintaining the mountain of documents showing you're continually able to meet the strict requirements.

**PART 3**

WHAT ARE FIRST ARTICLE INSPECTIONS AND AS9102 REQUIREMENTS IN HEAT TREATING?

One of the industry's most important quality assurance principles is first article inspection (FAI)—the systematic inspection of new parts to ensure they'll perform as designed.

The aerospace, automotive, medical and other industries all feature FAI requirements. In general, these inspections (and the exhaustive documentation supporting them) entail the thorough investigation of parts pulled from the first-ever batch to verify that:

- The exact material specified for a given part was used.
- Manufacturing or finishing methods detailed in the specs were followed.
- Part characteristics that result from manufacturing or processing are within tolerances stated in the specs.

In the aerospace industry, [SAE AS9102](#) standardizes the documentation that industry suppliers must provide to meet OEMs' FAI requirements. According to SAE, the standard is meant to provide “objective evidence that all engineering design and specification requirements are properly understood, accounted for, verified and documented.”

REDUCE RISK WITH THE RIGHT NADCAP-CERTIFIED HEAT TREATER

When it comes to managing quality for aerospace components, every detail must be documented and scrutinized. Nothing can be left unplanned.

At AST-Paulo, our cross-functional team applies its heat treatment expertise to the information we gather about part design, material and manufacturing. This intensive review allows us to flag potential problems earlier in the process and, when possible, recommend upstream tweaks that will result in parts that pass inspection.

Our advanced process tracking system ensures nothing slips through the cracks by recording process information in real time and alerting operators if furnace conditions such as pyrometry slip outside of the tolerances defined in treatment specs.

Together, with a team of expert metallurgists and advanced equipment, we provide heat treatments that are successful and highly repeatable.

Ready to make your heat treating more precise and repeatable? Partner with AST-Paulo on your next project.

