WHITE PAPER

AluVaC®: All-Aluminum CF Components and Chambers
Part 3 – EN

Baking Aluminum for Ultrahigh Vacuum (UHV) Applications

- UHV conditions after baking at 120 °C
- Reliable knife edge stability at 180 °C
- AluVaC®-stainless steel connections safely bakeable

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10^-n mbar VACOM®

Baking Aluminum for Ultrahigh Vacuum (UHV) Applications

UHV components made of aluminum materials are an energy-efficient and lightweight alternative to CF components made of stainless steel. However, due to their lower melting temperatures skeptics are concerned about their use in bakeable UHV systems. The results of baking AluVaC components in UHV applications presented here show that these fears are ungrounded.

Aluminum as a vacuum material

Due to its low density (2.7 g/cm^3) as well as excellent machinability, aluminum is known as a very attractive construction material. Therefore, the use of aluminum materials in general mechanical engineering, automotive industries and building technologies has dramatically increased over recent decades.

Aluminum materials offer additional attractive properties for vacuum applications, e.g. a very low magnetic permeability ($\mu_r < 1.00002$) and a low material activation under radiation. In addition, aluminum shows extremely low outgassing in ultrahigh vacuum. Corresponding experiments and results are presented in detail in the second part of the AluVaC whitepaper (*„Outgassing Rates of Aluminum compared to Stainless Steel“* [1]).

Despite all the advantages mentioned above, stainless steel still is the preferred material in UHV technology. Among other things, reasons for this are reservations about the mechanical and thermal stability of the aluminum knife edges. Results presented in the first part of the AluVaC whitepaper (*„Knife Edge Stability of CF Components made of Lightweight Aluminum“* [2]) show that the CF knife edges of the AluVaC components remain mechanically stable even after extensive use in more than 100 sealing cycles.

In this third part of the AluVaC whitepaper, results for the usability and knife edge stability of AluVaC systems under thermal stress (e.g. occurring during vacuum baking processes) are introduced.

Manufacturer specifications on operating temperatures

Precipitation hardened aluminum alloys, such as series 6000 (type Al-Mg-Si), can lose their previously obtained strengths when excessively heated above defined temperature limits. Depending on the alloy and duration of heat load, manufacturer specifications for maximum operating temperatures range from 120 °C (permanent) to 160 … 180 °C (short-term). Below these temperatures, alloys reliably maintain their stated strengths values after re-cooling. The recommended operating temperatures were taken into account in the studies on optimal baking procedures for AluVaC components.

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Bakeouts in ultrahigh vacuum applications

Material	H_2-annealing		In-situ bake-out	
	T [°C]	t [h]	T [°C]	t [h]
AluVaC®	-		≤ 120	≥ 24
1.4301 (304)	-		≥ 200	≥ 24
1.4404 (316L)	> 850	> 2	≥ 200	≥ 24
1.4429 (316LN-ESU)	> 850	> 2	≥ 200	≥ 24

Table 1: Established baking procedures for AluVaC and commonly used stainless steels

Baking in UHV applications is particularly necessary to achieve UHV conditions within practicable amounts of time. With that, particular conditioning times range from a few hours to a few days depending on numerous system parameters. By baking the vacuum system, desorption processes of previously adsorbed particles on the inner surfaces are accelerated. These primarily atmospheric constituents, especially water, become detached from the surface, move into the gaseous phase and can be pumped off. The article *„Thermal Outgassing"* by Karl Jousten from the National Metrology Institute of Germany (PTB), Berlin [3] provides a profound overview of thermal desorption processes in vacuum systems.

Temperatures and baking times ultimately necessary for achieving desired process pressures in a particular vacuum system depend on numerous factors. In addition to the materials in use, applied pump technology, sealing types, geometry and size of the vacuum chamber and in particular its inner surface play a decisive role for conditioning. The inner surface is chemically and physically characterized by the raw material, its industrial processing and subsequent treatments. In order to ensure reproducible quality of UHV chambers and components, profound practical knowledge and the strict adherence of defined processes in manufacturing and finishing are indispensable.

Baking of AluVaC® and ConFlat® systems

Investigations on the outgassing behavior of AluVaC components and identical, compatible stainless steel components [1] show: AluVaC components can achieve comparable or, in some cases, even significantly lower outgassing rates than vacuum fired stainless steel components. The lowest outgassing rates in AluVaC systems were achieved by baking for 24 hours at 120 °C. In contrast to this, general baking processes for stainless steel range from 24 to 72 hours at temperatures of 200 °C to 250 °C [4]. For applications in the lowest pressure ranges, stainless steel parts additionally undergo a vacuum firing process (also known as low hydrogen annealing). Table 1 provides an overview of established UHV baking procedures for AluVaC components and commonly used stainless steels.

Performance of baked AluVaC® systems

During several studies on optimal conditioning parameters and outgassing characterization, AluVaC chambers and components were extensively and cyclically baked.

For example, a DN200CF AluVaC chamber (Fig. 1, left) was repeatedly heated to 120 °C, held for two hours, and cooled down to room temperature. After cooling-off, the next heating cycle was started. Heating characteristics are schematically shown in Fig. 1, on the right.

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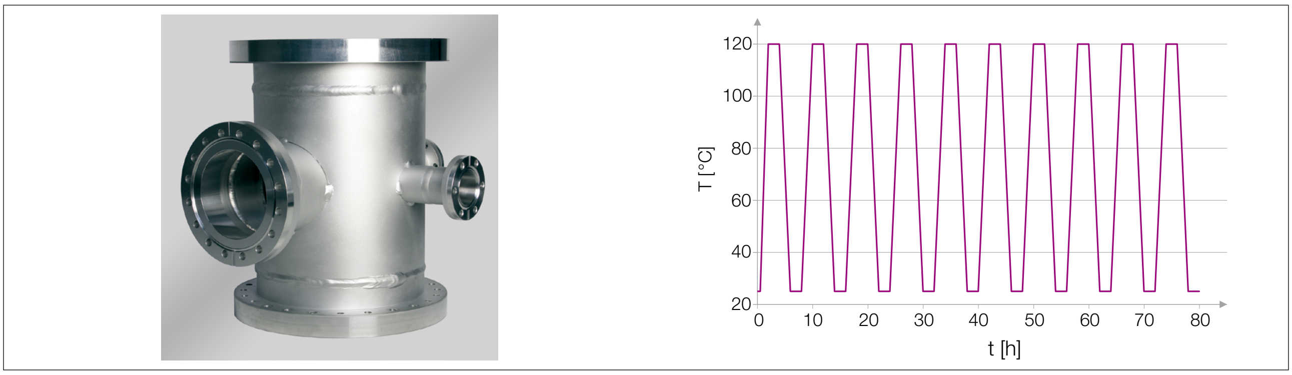

Figure 1: DN200CF AluVaC® chamber under test (left) and schematic heating curve (right)

Chamber pressure was recorded throughout the entire run in order to detect possible leakages instantly and directly during operation.

The result: the AluVaC system including all seals and connections remained durably and reliably leak-tight. After each cool-down, the vessel pressure was well within the ultrahigh vacuum range ($p < 1 \cdot 10^{-9}$ mbar). In addition to AluVaC-AluVaC connections, also AluVaC-stainless steel connections were used in the set-up.

In another set-up, peak baking temperatures for an AluVaC system were successively increased (Fig. 2, left). In addition to AluVaC blind flanges, the chamber was also connected to several components with knife egdes made of stainless steel (including an ion getter pump shown in the picture on the left and an angled valve in the picture on the right). Fig. 2, on the right shows the schematic heating characteristics: Beginning at 110 °C, the temperature was gradually increased with each baking cycle. Temperatures measured directly at the AluVaC flange reached a maximum value of 210 °C. Each time, the temperature was held for 48 hours.

Throughout the extensive baking process up to 210 °C, the AluVaC chamber reliably maintained its functionality – even well above the recommended operating temperatures.

Further characterization has been made on the knife edge contours of the AluVaC flanges in use. After each baking cycle, a DN40CF AluVaC blind flange was demounted to record its

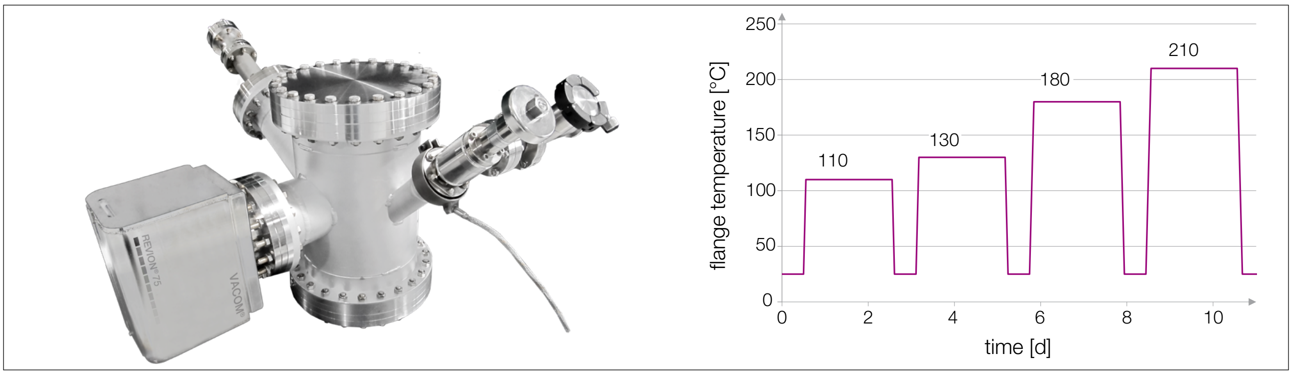

Figure 2: AluVaC® chamber under test (left) and schematic heating curve (right)

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knife edge contour. The results (Fig. 3) show no significant deformation after several days of heating at 110 °C and 130 °C as well as at 180 °C. The knife edge geometry persistently lies within the tolerances of ISO / DIS 3669 (see [2] for details).

Conclusion

The AluVaC knife edge, which is necessary for leak-tight sealing, remains reliably stable at recommended operating temperatures of 120 °C. Moreover, UHV conditions in the chamber are safely maintained even well above the recommended operating temperatures. In particular, the results show that knife edge stability of the AluVaC components is also ensured in the case of multi-day exposure at 120 °C and at peak temperatures of 180 °C.

The presented results complement the comprehensive studies on AluVaC chambers and components with their usability in baked UHV systems. It becomes clear that the extremely low outgassing and mechanically stable AluVaC components also retain their functionality under extensive thermal loads. Due to their proven advantageous properties, AluVaC components are outstandingly suited for applications in the lowest vacuum range.

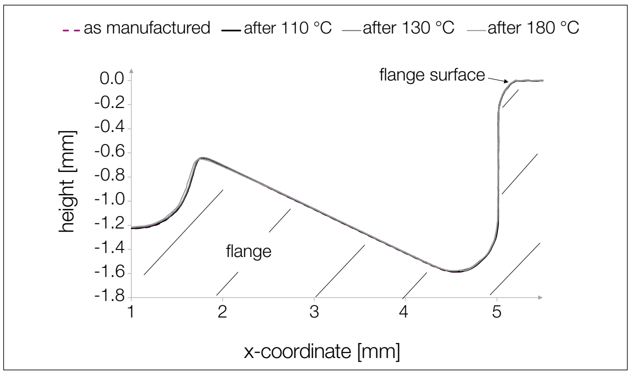

Figure 3: Knife edge contour as manufactured and after heating several days at 110 °C, 130 °C, and 180 °C.

References

[1] VACOM GmbH: Outgassing Rates of Aluminum compared to Stainless Steel, 2016. (www.vacom.de/en/downloads/white-papers).

[2] VACOM GmbH: Knife Edge Stability of CF Components made of Lightweight Aluminum, 2016. (www.vacom.de/en/downloads/white-papers).

[3] Jousten, K.: Thermal outgassing. In: Proceedings CAS CERN Accelerator School Vacuum Technology, 1999, 111-124, ISBN 92-9083-149-9.

[4] Jousten, K.: Wutz Handbuch Vakuumtechnologie, 10. überarb. Aufl. Wiesbaden: Vieweg u. Teubner, 2010.steel connections were used in the set-up.

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