Additive Manufacturing, 3D-Printing

Retort furnace NR 150/11 for annealing of metal parts of 3D-printing

Additive manufacturing allows for the direct conversion of design construction files fully functional objects. With 3D-printing objects from metals, plastics, ceramics, glass, sand or other materials are built-up in layers until they have reached their final shape.

Depending on the material, the layers are interconnected by means of a binder system or by laser technology.

Many methods of additive manufacturing require subsequent heat treatment of the manufactured components. The requirements for the furnaces for heat treatment depend on the component material, the working temperature, the atmosphere in the furnace and, of course, the additive production process.

Nabertherm offers solutions from curing for conservation of the green strength up to sintering in vacuum furnaces in which the objects of metal are annealed or sintered.

Oven TR 240 for drying of powders

Chamber oven KTR 2000 for curing after 3D-printing

Compact tube furnace for sintering or annealing under protective gases or in a vacuum after 3D-printing

HT 160/17 DB200 for debinding and sintering of ceramics after 3D-printing

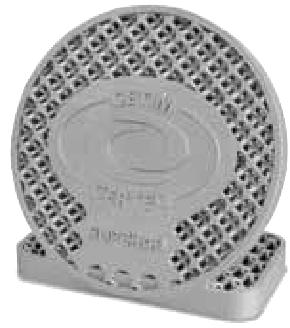
Metals	Ceramics, Glass, Composites, Sand	Plastics
Debinding Sintering Stress-relieving Solution annealing Hardening	Debinding Sintering Drying Curing	Curing Tempering Drying
under Protective Gases, Reaction Gases or in Vacuum	**in Air**	**in Air**
Chamber furnaces with protective gas boxes	Debinding in chamber furnaces with air circulation Sintering in chamber furnaces Debinding and Sintering in combi furnaces Dewaxing Furnaces	Ovens Chamber dryers Forced convection chamber furnaces
Hot-wall retort furnaces		See als concepts for drying, debinding, thermal cleaning and wax burnout in catalog Advanced Materials as well as catalog Thermal Process Technology I
Cold-wall retort furnaces	See also concepts for drying, debinding, thermal cleaning and wax burnout in catalog Advanced Materials	

Also, concomitant or upstream processes of additive manufacturing require the use of a furnace in order to achieve the desired product properties, such as heat treatment or drying the powder.

In additive manufacturing, a distinction is made between printing with and without binder. Depending on the manufacturing process, different furnace types are used for the subsequent heat treatment.

Apart from the factors described above, the previous processes from the heat treatment also have an influence on the overall result. One important criteria for a good surface quality is that the components are cleaned properly before the heat treatment.

This also applies to processes that are carried out in vacuum or in furnaces where a low residual oxygen concentration is important. For these furnaces, it is important that they are cleaned and maintained regularly. Even the smallest leak or contamination can produce an unsatisfactory result.



Printed aluminum part, heat treated in model N 250/85 HA (Manufacturer CETIM CERTEC on SUPCHAD platform)

Binder-Free Systems

In binder-free additive manufacturing, in most cases, the components are produced in a laser melting process.

The tables below show typical materials and construction platform sizes of laser-based systems that are available on the market with suggestions with respect to furnace sizes, required temperature and atmosphere in the furnace.

Aluminum Components
Generally, aluminum is heat treated in air at temperatures between 150 °C and 450 °C.

Due to the very good temperature uniformity, forced convection chamber furnaces are suitable for processes such as tempering, aging, stress-reliefing or preheating.

Forced convection chamber furnace NA 250/45 for heat treatment in air

Examples for max platform sizes	Forced convection chamber furnaces, see page 60 up to 450 °C[1]
210 x 210 mm	NA 30/45
280 x 280 mm	NA 60/45
360 x 360 mm	NA 120/45
480 x 480 mm	NA 250/45
600 x 600 mm	NA 500/45

[1]Also available for 650 °C and 850 °C

Stainless Steel and Titanium Components
In many cases, certain stainless steels and titanium are heat treated in a protective gas atmosphere at temperatures below 850 °C.

By using a protective gas box with the corresponding process gas supply, a standard furnace can be upgraded to a protective gas furnace. Depending on the type of process gas, the preflushing rate, the process flushing rate, and the condition of the box, it is possible to achieve residual oxygen concentrations of up to 100 ppm.

The forced convection chamber furnaces with protective gas boxes described below have a working temperature range between 150 °C and 850 °C. If the protective gas boxes are removed from the furnace, aluminum components can also be heat treated in air.

Forced convection chamber furnace N 250/85 HA with protective gas box for heat treatment in a protective gas atmosphere

Examples for platform sizes	Forced convection chamber furnaces, see page 60 up to 850 °C with protective gas box
100 x 100 mm	N 30/85 HA
200 x 200 mm	N 60/85 HA
280 x 280 mm	N 120/85 HA
400 x 400 mm	N 250/85 HA
550 x 550 mm	N 500/85 HA

Hot-wall retort furnace NRA 150/09 for heat treatment in a protective gas atmosphere

With sensitive materials, such as titanium, the component may still oxidize due to the residual oxygen concentration in the protective gas box.

In these cases, hot-wall retort furnaces with a maximum temperature of 950 °C or 1100 °C are used. These gas tight retort furnaces are ideal for heat treatment processes that require a defined protective or reaction gas atmosphere. The compact models can also be designed for heat treatment under vacuum up to 600 °C. The risk of oxidation on the component is considerably reduced with these furnaces.

Examples for platform sizes	Hot-wall retort furnaces see page 16
180 x 180 mm	NR(A) 17/..
280 x 280 mm	NR(A) 50/..
400 x 400 mm	NR(A) 150/..

Titanium rods after heat treatment in NR 50/11 in argon atmosphere

Chamber furnace LH 60/12 with protective gas box for heat treatment in a protective gas atmosphere

Inconel or Cobalt-Chromium Components

Materials such as Inconel and cobalt-chromium are generally heat treated at temperatures from 850 °C up to between 1100 °C and 1150 °C. Various furnace families are used for these processes. In many cases, the chamber furnaces of the LH .. or NW .. series with protective gas boxes are sufficient to provide an outstanding price/performance ratio. Both furnace groups are suitable for temperatures between 800 °C and 1100 °C.

Examples for platform sizes	Chamber furnaces see page 54 and 58 up to 1100 °C with protective gas box
100 x 100 mm	LH 30/12
250 x 250 mm	LH 120/12
400 x 400 mm	LH 216/12
420 x 520 mm	NW 440
400 x 800 mm	NW 660

Cold-wall retort furnace VHT 100/12-MO for processes in high vacuum

Cold-wall retort furnaces are used for processes in protective gas at temperatures above 1100 °C or under vacuum above 600 °C.

Examples for platform sizes	Cold-wall retort furnaces see page 26
100 x 100 mm	VHT 8/12-MO
250 x 250 mm	VHT 40/12-MO
400 x 400 mm	VHT 100/12-MO

Systems with Binder

In 3D printing, organic binders, which evaporate during heat treatment, are used to build-up the part. The printed parts can be made of ceramic, metal, glass or sand. Depending on the evaporation volume, furnaces with graduated safety systems for debinding and sintering are used.

Muffle furnace L 40/11 BO with passive safety system and integrated post combustion for thermal debinding in air

Debinding and Sintering in Air

This table shows examples of furnaces with the respective safety technology for debinding in air and the corresponding sintering furnaces for high temperatures, which are suitable, for example, for sintering many oxide ceramics.

Printing dimensions up to	Debinding furnaces[1] see catalog Advanced Materials	Sintering furnaces[2] see catalog Advanced Materials
100 x 100 x 100 mm	L 9/11 BO	LHT 4/16
200 x 200 x 150 mm	L 9/11 BO	HT 40/16
300 x 400 x 150 mm	L 40/11 BO	HT 64/17

[1] Values for debinding like max. organic content, or evaporation rate have to be considered
[2]The furnaces are available with different max. furnace chamber temperatures

High-temperature furnace HT 64/17 DB100 with passive safety system for debinding and sintering in air

Debinding and Sintering in Protective or Reaction Gas or under Vacuum

To protect metal components that were printed using a binder-based system against oxidation, two process steps, debinding and sintering, are carried out in an oxygen-free atmosphere.

Depending on the material and the binder system, debinding is carried out either in a non-flammable protective gas (IDB), under hydrogen (H_2), or catalytically in a mixture of nitric acid and nitrogen. Adapted safety systems are used to ensure the safety of these processes.

The table contains examples of furnaces which can be equipped with suitable safety technology. Hot-wall retort furnaces are used as debinding furnaces and cold-wall retort furnaces as sintering furnaces. Under certain circumstances, depending on the application, it is possible to use the same furnace for both processes.

Printing dimensions up to	Hot-wall retort furnaces[1] see page 16	Cold-wall retort furnaces[2] see page 26
150 x 150 x 150 mm	NRA 17/09	VHT 8/16-MO
300 x 300 x 300 mm	NRA 50/09	VHT 40/16-MO
400 x 400 x 400 mm	NRA 150/09	VHT 100/16-MO

[1]Safety systems see page 18
[2]Parts without residual binder. In case of a low content of residual binder we recommend an inner process chamber.

The models listed in the table above are just a few examples.