Nabertherm
MORE THAN HEAT 30-3000 °C

Additive Manufacturing

Heat Treatment as Key for Good Product Properties

Yverdon-les-Bains
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Nabertherm GmbH
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Nabertherm
MORE THAN HEAT 30-3000 °C

Company

Headquarters:	Nabertherm GmbH
Core Business:	Furnace manufacturing, custom-made, innovate solutions for thermal processes
Foundation/Ownership:	1947, family-owned
Turnover:	60 Mio EUR
Employees:	550
Customers:	150.000 world-wide
Sales Organisation:	Nabertherm Ltd. (Shanghai) Nabertherm SARL, France Nabertherm Italia, Italy Nabertherm Switzerland AG Nabertherm Ltd., UK Nabertherm Inc., USA Nabertherm Ibérica, Spain Nabertherm Benelux, The Netherlands
Management:	Managing Director: Friedrich-Wilhelm Wentrot

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Contents

1 Introduction

Additive manufacturing allows for the direct conversion of design construction files to fully functional objects.

With 3D-printing objects from metals, plastics, ceramics, glass, sand or other materials will built-up in layers until they have reached their final shape.

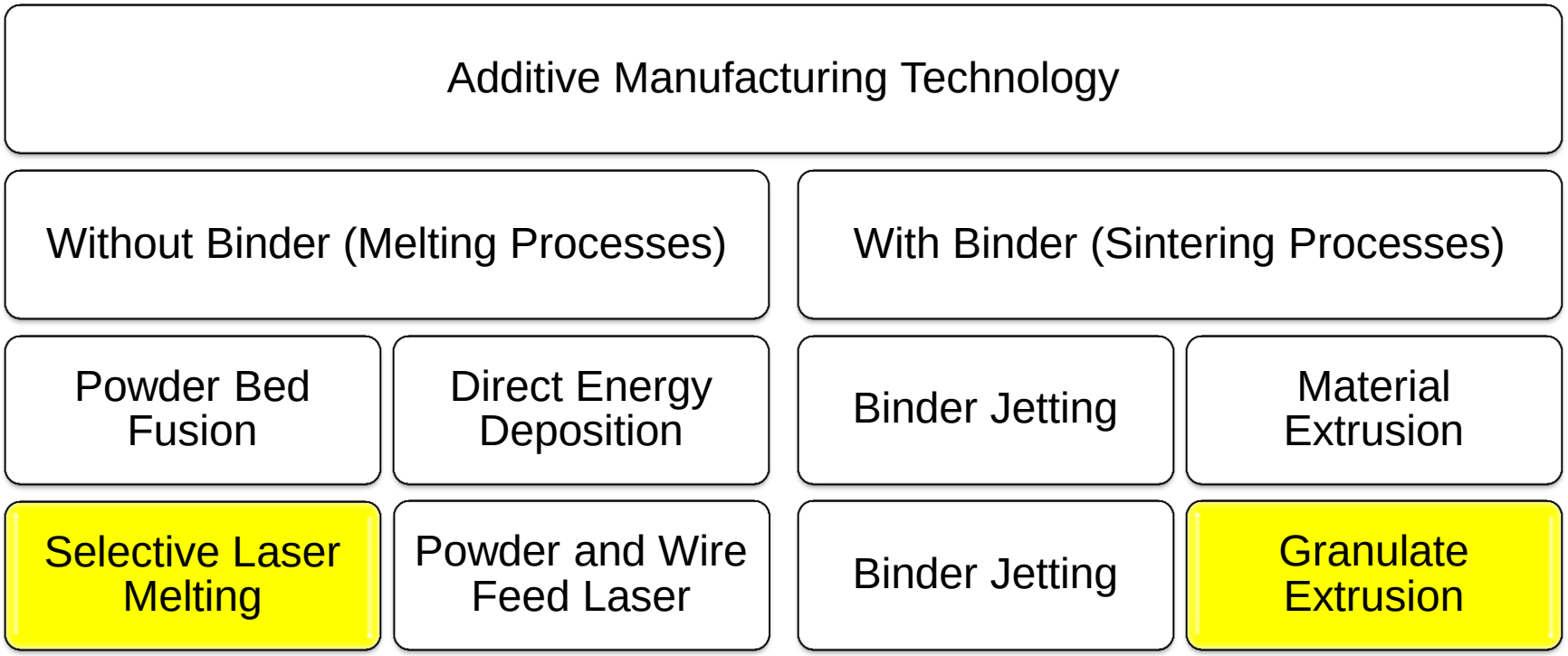
Depending on the material, the layers are interconnected by means of either a binder system or by laser or other technology.

As a part of the complete process chain many additive manufacturing processes require subsequent heat treatment of the printed parts.

Process Chain

1 Introduction

Additive Manufacturing Technology



1 Introduction

Additive Manufacturing Technology Selection

The selection of the additive manufacturing technology depends among the total costs on several factors:

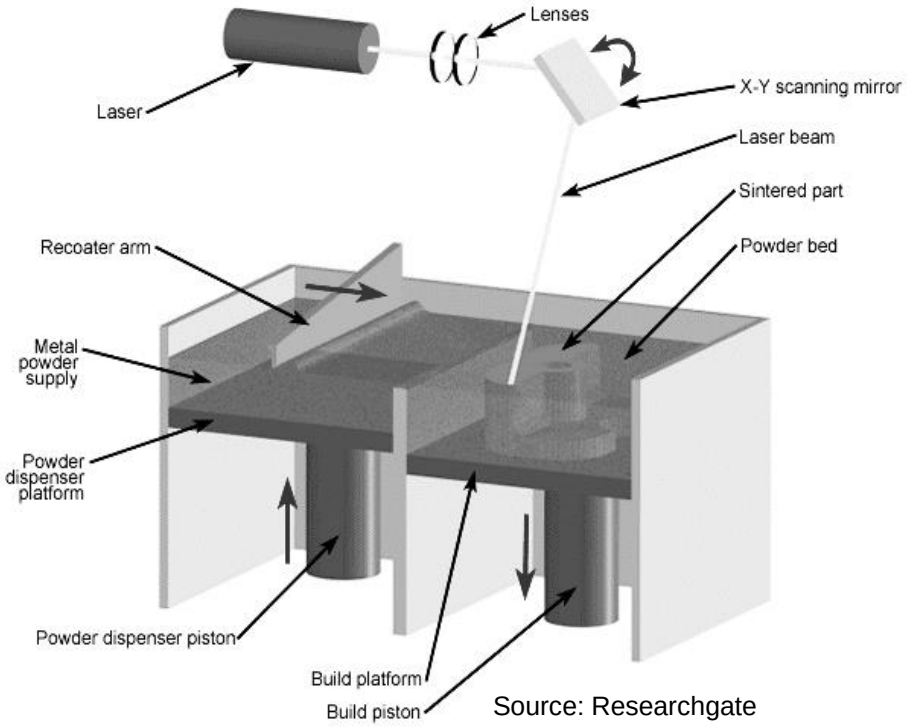
- Part material
- Production volume
- Part complexity
- Dimensions accuracy
- Surface quality
- Material properties

The heat treatment requirements depend on the printed material, working temperatures, the atmosphere in the furnace and, of course, the additive manufacturing method.

2 Processes without Binder

Selective Laser Melting

A powder coating is selectively laser melted for fusion.



Source: Researchgate

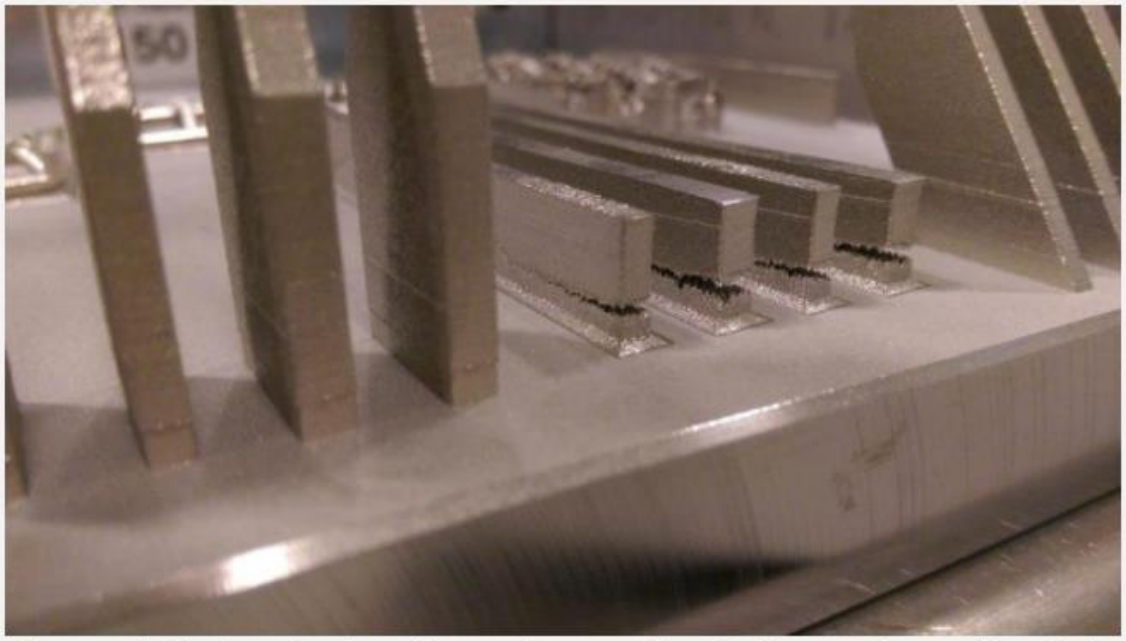
Manufacturer CETIM CERTEC on SUPCHAD platform

2 Processes without Binder

Selective Laser Melting

Reasons for heat treatment of parts that are built-up by a laser

1) It is necessary to perform stress relief heat treatment in order to prevent from bending or cracking of the parts before they are separated from the platform.



Here, stress buildup shows the collapse of four metal bars created through additive manufacturing. [Photo Credit: Albert To / University of Pittsburgh's Swanson School of Engineering]

2 Processes without Binder

Selective Laser Melting

Reasons for heat treatment of parts that are built up by a laser

2) It might be necessary to perform other heat treatment types after the part is ready machined in order achieve the required material properties

- Titan HIP Hot Isostatic Pressing
- 316L Solution treatment
- 17-4PH Precipitation hardening

2 Processes without Binder

Heat Treatment Process

Selection of the suitable heat treatment process parameters

- Material (Aluminum, stainless steel, titanium,…)
- Additive Manufacturing Process (Laser Melting, EBM)
- Purpose of heat treatment (Stress relieving, hardening,…)
- Requirements from the final product (Surface quality,…)
- Manufacturer (System provider, powder type,…)

Subject to the achieved quality, the heat treatment process will be proceeded either in air, under protective gas or vacuum.

2 Processes without Binder

Process atmosphere

Laser melted parts

Protective gas, reactive gas or vacuum e.g. titanium			Air e.g. aluminum	
Chamber furnace (sealed) up to 2000 ppm	Furnace with process box < 200 ppm	Retort furnaces O ppm / 10^{-5} mbar	Forced convection furnace	Furnace with radiation heating

2 Processes without Binder

Process atmosphere e.g. for heat treatment of Titanium

Selection criteria's furnace atmosphere

- Manufacturer or material specification
- Purpose of the heat treatment
- Requirements for the component and the surface
- Further requirements

What is the expected result after the heat treatment process?

- Surface without oxidation → no further mechanical treatment
- Oxidation allowed → parts will get a surface finishing or further treatment

2 Processes without Binder

Process atmosphere e.g. Titanium

Protective gas or vacuum

Chamber furnace (sealed)	Furnace with protective gas box	Retort furnace

2 Processes without Binder

Chamber furnace with protective gas box

Chamber furnaces offer a good price / performance ratio for applications that are carried out under a non-flammable protective gas atmosphere.

By using a protective gas box with the corresponding gas a standard chamber furnace can be converted into a protective atmosphere furnace.

Depending on the process gas, gas flow rate and condition of the box, the residual oxygen contents can be achieved in a low ppm range.

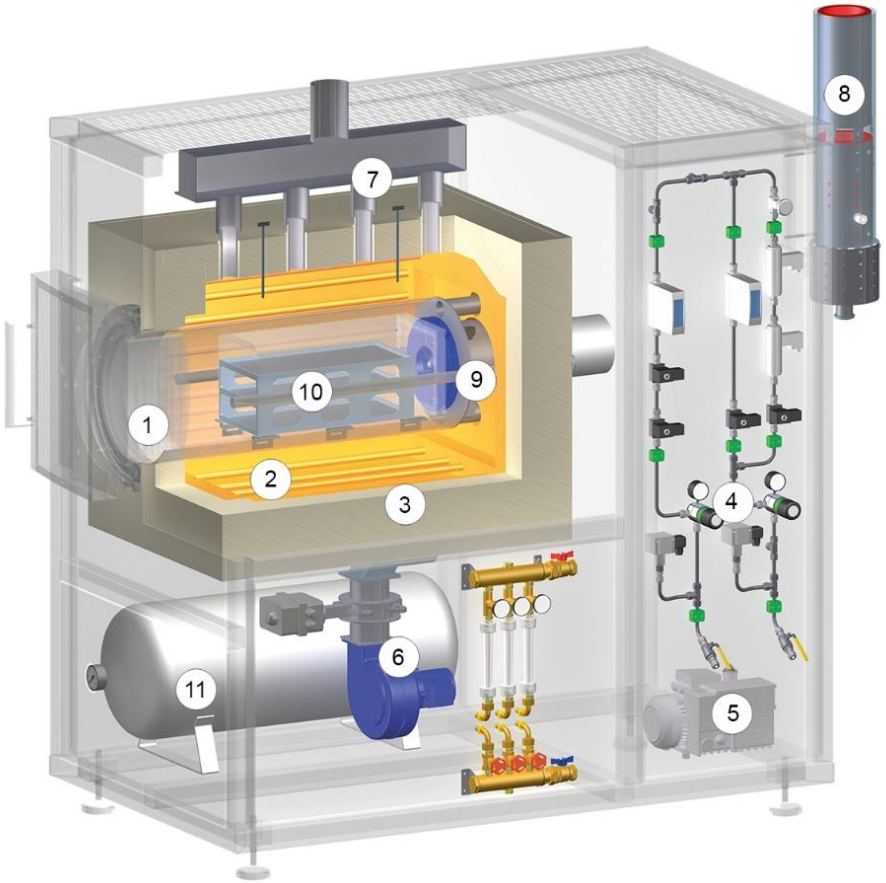
Available for temperatures up to 1150°C

LH 60/12

2 Processes without Binder

Hot-Wall Retort Furnace

These retort furnaces are ideal for heat treatment processes which require a vacuum up to 600°C or a defined protective or a reaction gas atmosphere up to 1150°C.

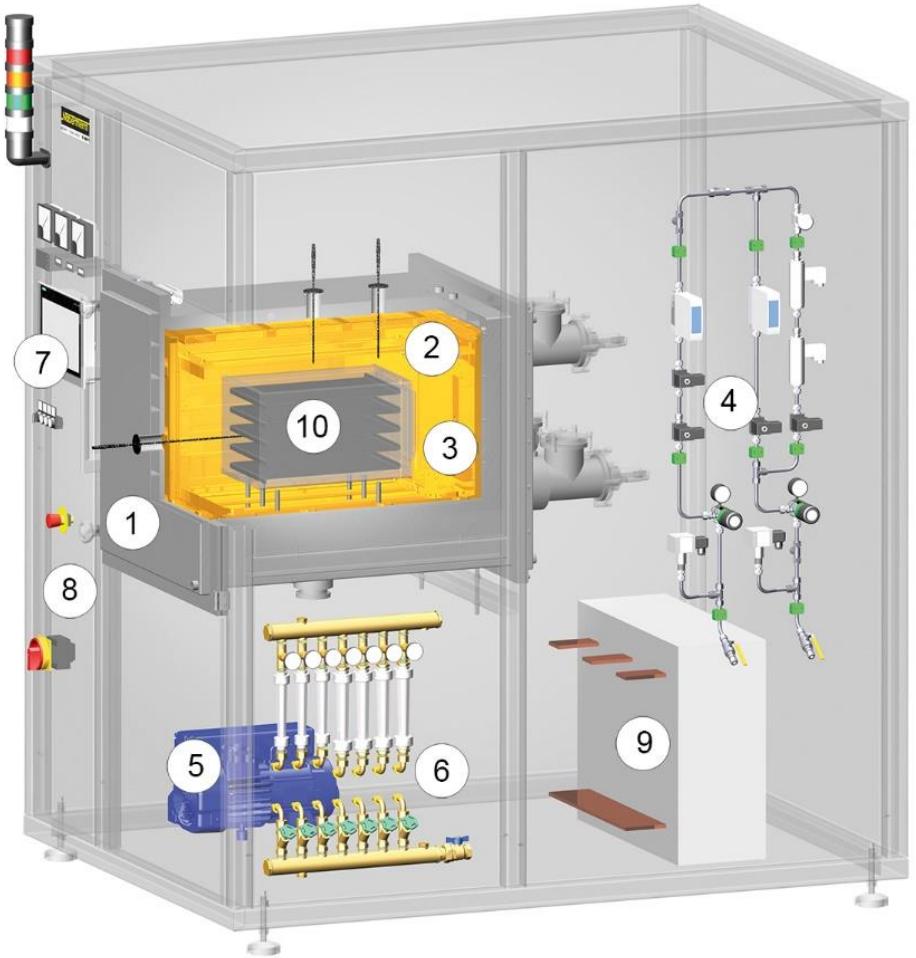


2 Processes without Binder

Cold-Wall Retort Furnace

These retort furnaces can be used for heat treatment processes either in protective and reaction gas atmospheres above 1150°C or in a vacuum down to 10^{-5} mbar up to Tmax.

VHT 100/12 MO



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2 Processes without Binder

Chamber furnaces for operation in Air

Many kinds of materials like aluminum, some steel alloys as well as plastics have to be heat treated in air in order to achieve the required material properties.

For processes below 850°C furnaces with a forced air convection are the best choice. Due to the very good temperature uniformity, forced convection chamber furnaces are suitable for processes such as tempering, aging, stress-relief or preheating.

If the required temperature is above 850°C radiation furnaces will be used. Hardening of steel under ambient atmosphere with an external quench bath is just one example.

NA 250/45

N 41/H

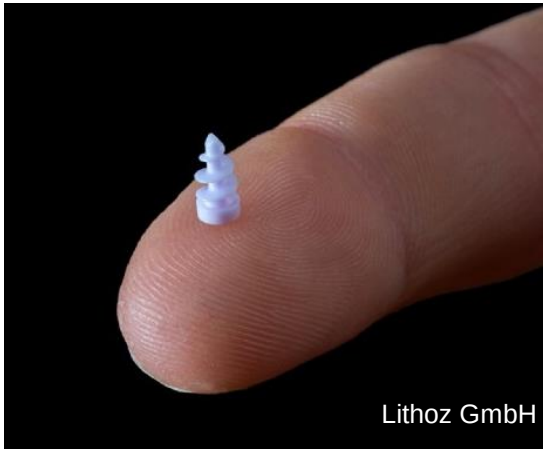
3 Processes with Binder

Binder containing process (Sintering processes)

Typical materials are metals, ceramics, sand and plastics, but also other materials are possible to ‘print’ depending on the printing technology.

Digital Metal

Voxeljet



Lithoz GmbH

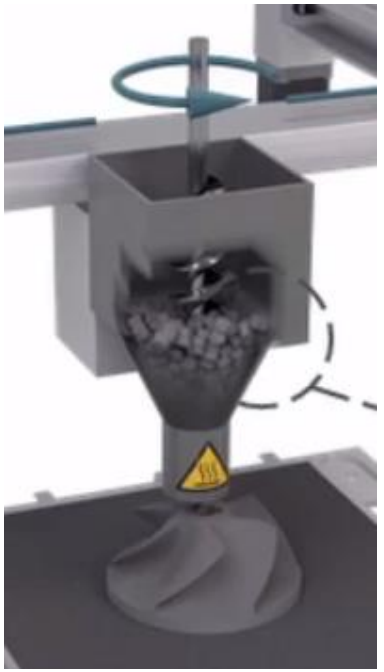
3 Processes with Binder

Binder containing process (Sintering processes)

Build up processes with binder (Sintering Processes)

Binder Jetting	Granulate Extrusion
Inkjet print heads apply a liquid bonding agent onto thin layers of powder. By gluing the particles together, the part is built up layer by layer.	CEM process (composite extrusion modeling) is a simple process based on pellets, which were originally designed for injection molding.

Feedstock (MIM)



AIM 3D ExAM 255

3 Processes with Binder

Binder Containing Process (Sintering Processes)

Independent from the printing process, the printing material and the machine provider, the subsequent heat treatment processes are similar.

green part

1. Debinding

Most of the organic binder is removed during debinding. There are various debinding methods. Such as thermal debinding, catalytic debinding or solvent debinding.

brown part

2. Sintering

In the next step, the component is sintered at above 1300°C. Depending on the feedstock, the component shrinks by up to 20%.

sintered part

3 Processes with Binder

Heat Treatment Processes

Build up processes with binder (Sintering Processes)

Metals	*Ceramics*
Protective or reactive gas or vacuum	Air

Debinding	*Sintering*	*Debinding*	*Sintering*	*Debinding & Sinterimg*
Hot-Wall retort furnace	Cold-Wall retort furnace	Various Systems	Various Systems	Combi Furnaces

3 Processes with Binder

Thermal Debinding

Debinding is a critical process due to the released hydrocarbons which subject to the corresponding concentration can cause a formation of an ignitable mixture inside the furnace. Depending on the process and the quantity of binder, Nabertherm provides for tailored safety packages to ensure a safe operation of the furnace.

Conditions for critical atmosphere inside the furnace:

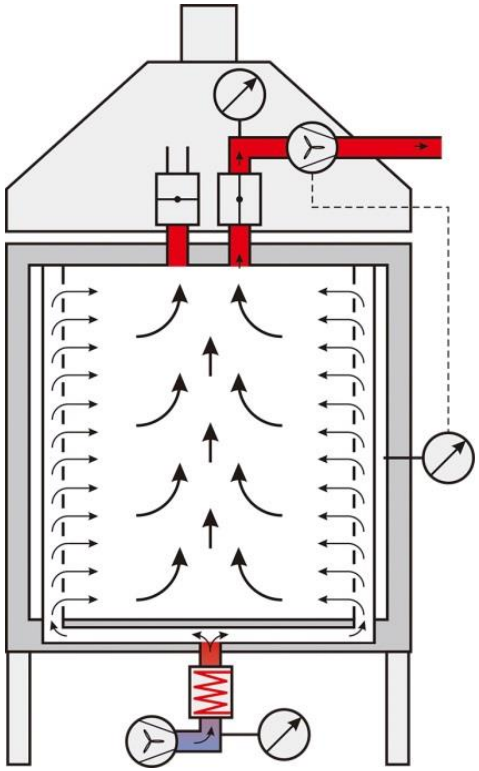
- Flammable organics (binder, wax, solvents,..)
- Oxygen (ambient atmosphere)
- Ignition source (heating system)

3 Processes with Binder

Thermal Debinding in Air

Fresh air will be blown-in the furnace in order to reduce the exhaust gas concentration from the charge to an non-ignitable atmosphere.

- Passive safety concept DB
  - Fresh air injection
  - Monitoring



DB 200

3 Processes with Binder

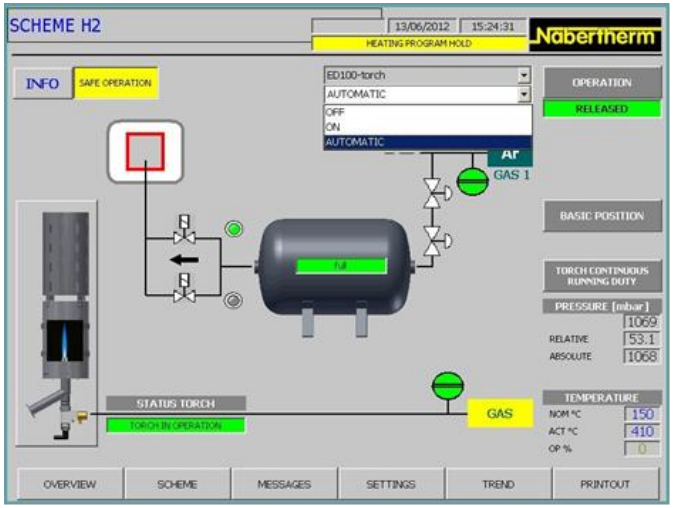
Thermal Debinding in Process Atmosphere

Safety Concept:

No oxygen inside the process chamber before the heating process can be started!

- Cold evacuation of the furnace
- Flushing the furnace retort with protective or reactive gas
- Monitoring of gas supply

Safe operation under positive pressure



3 Processes with Binder

Thermal Debinding in Process Atmosphere

Typically, hot-wall retort furnaces are used as debinding furnaces

Inert Debinding (IDB) under non-flammable gases like argon, nitrogen or non-flammable forming gases at a positive pressure of approx. 35 mbar relative

Debinding under hydrogen (H_2) atmosphere at an over-pressure of approx. 35 mbar relative.

Catalytic debinding (CDB) where the polyoxymethylene (POM) of the binder will be removed from the green part and chemically decomposed under the influence of nitric acid.

Further debinding methods are in vacuum or in liquids like water or solvents.

NRA 400/03-IDB

NRA 40/02-CDB

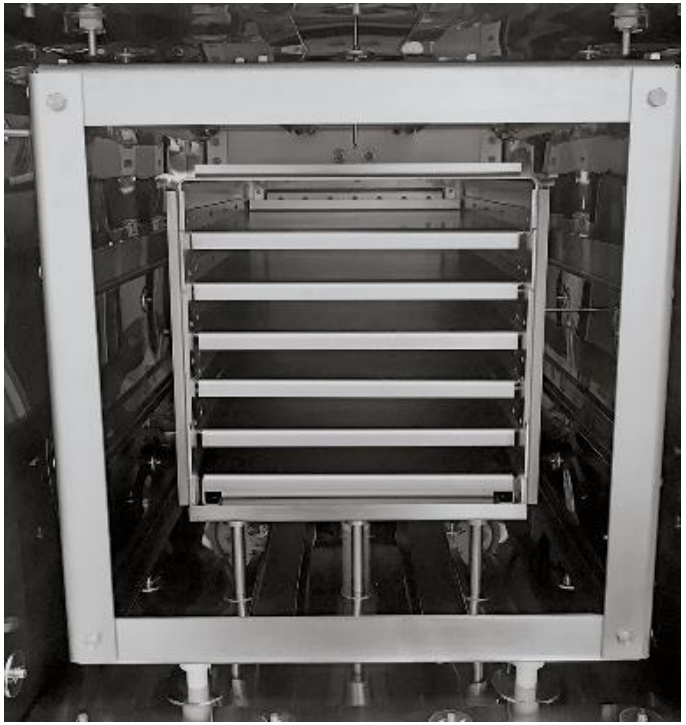
3 Processes with Binder

Sintering in Process Gas Atmosphere

Cold-wall retort furnaces are used for the residual debinding step, followed by the final sintering cycle.

The furnace chamber is equipped with an additional inner process chamber (box in the box) that has a direct outlet to the exhaust gas torch. The exhaust gas will be directly lead-out.

This system significantly reduces the furnace chamber contamination caused by the exhaust gases generated during debinding.



4 Discussion

Any Questions?

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Thank you for your attention!

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