Safety Concept for Debinding

Debinding of technical ceramics 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 offers tailored passive and active safety packages to ensure a safe operation of the furnace.

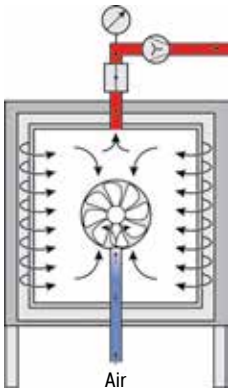
I. Debinding in Air

1. Debinding in an Electrically Heated Furnace

For debinding in air with electric heating Nabertherm offers various debinding packages tailored to the individual process requirements. All debinding packages have professional integrated safety technology. Passive or active safety concepts are available, depending on the specific requirements. The passive safety concepts differ upon the requirements for the quantity of organic materials, process reliability, and temperature distribution.

1.1. Passive Safety Concept

Nabertherm debinding furnaces are generally equipped with a passive safety concept to allow for a slow vaporization of flammable substances. The electrically heated furnaces work according to the dilution principle by introducing fresh air to reduce the degassing from the charge to a non-ignitable atmosphere in the furnace. The customer has to define the quantity of organic materials as well as the temperature curve, to make sure that the maximum permissible rate of vaporization is not exceeded. Thus, the customer is responsible for the function of the safety concept. The furnace DB safety package monitors all safety-relevant process parameters and initiates a respective emergency program in case of a malfunction. The passive safety concept has proven itself in practice due to its good price performance ratio. Depending on the process requirements, the following equipment packages are available.

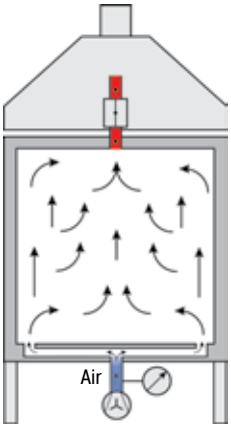


DB10 Debinding Package for Air Circulation Furnaces (Convection Heating) up to 450 °C

The DB10 debinding package is the basic option for safe debinding in air circulation furnaces up to 450 °C. The furnace is equipped with an exhaust gas fan providing for a defined volume of air which is extracted from the furnace, thus allowing the volume of fresh air required for the debinding process to enter the furnace. The furnace is operated with negative pressure, which prevents an undefined emission of vaporization products.

Monitored process states for safe operation:

- Exhaust gas volumetric flow rate
- Function of air circulation
- Temperature gradient: If the heating gradient, selected by the customer is exceeded, the furnace is immediately switched off.



DB50 Debinding Package for Laboratory Furnaces

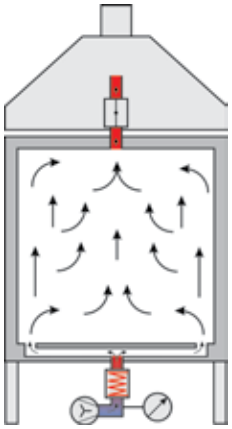
The DB50 debinding package is especially suitable for laboratory furnaces and for processes with low vaporization rates. The furnace is equipped with a fresh air fan. The fresh air fan is pre-set in the factory for the minimum volume of fresh air required for the debinding process. The furnace is operated with overpressure during the debinding process.

Monitored process states for safe operation:

- Fresh air volumetric flow rate

DB100 Debinding Package for Production Furnaces with Radiation Heating

The DB100 debinding package is the basic option for safe debinding in furnaces with radiation heating. The furnace is equipped with a fresh air fan and a fresh air preheater. The fresh air fan is pre-set in the factory for the minimum volume of fresh air required for the debinding process. The furnace is operated with overpressure during the debinding process. Exhaust air and exhaust gas are blown out via an outlet equipped with a motor driven flap into an exhaust hood with exhaust interruption. This is the interface to the customer's exhaust air system.

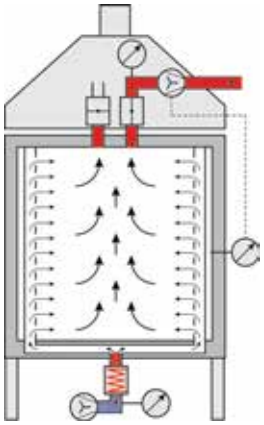


Monitored devices and process states for safe operation:

- Electromagnetic door lock
- Redundant fresh air volumetric flow rate
- Position of the fresh-air flap
- Position of the exhaust air flap
- Temperature gradient
- Power loss (emergency program after power has returned)
- Fresh air fan
- Thermocouple break
- The furnace controls respond differently depending on the specific malfunction and put the furnace into a safe condition.

DB200 Debinding Package for Production Furnaces with Air Circulation or Radiation Heating

The DB200 debinding package is the professional solution for the variable ceramics production because it can be used flexibly for different debinding processes and also for frequently changing debinding processes. Like with the DB100 debinding package, the fresh air required for the process is preheated. The air is introduced via perforated ceramic tubes that blow the preheated air into the furnace chamber horizontally. This ensures very good heat transfer and improves the temperature uniformity.



As opposed to the DB100 debinding package, exhaust air and exhaust gas are extracted via separate outlets, each equipped with a motor driven flap. The furnace is equipped with a fresh air fan and an exhaust gas fan. Both devices are reconciled so that the volume of air required for the debinding process is blown in and, at the same time, negative pressure is controlled in the furnace chamber. The exhaust gases during the debinding phase are extracted through the exhaust gas outlet, which is connected directly to the local exhaust gas piping. Due to the direct connection, the exhaust gas volumes are reduced and subsequent exhaust gas treatment systems can be dimensioned smaller. For cooling, the exhaust air blown out into the exhaust hood with exhaust interruption, which is the interface to the customer's exhaust air system.

Monitored devices and process states for safe operation:

- Electromagnetic door lock
- Redundant fresh air and exhaust gas volumetric flow rate
- Position of the fresh-air flap
- Position of the exhaust gas flap
- Position of the exhaust air flap
- Temperature gradient
- Power loss (emergency program after power has returned)
- Fresh air fan
- Malfunction of exhaust gas fan
- Underpressure in the furnace chamber
- Thermocouple break
- The furnace controls respond differently depending on the specific malfunction and put the furnace into a safe condition

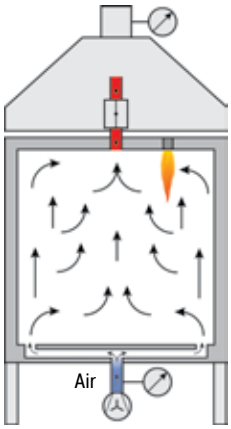
Safety Concept for Debinding

The main differences and/or advantages between the DB100 and DB200 debinding packages are:

- Automatic control of the exhaust gas fan in relation to the selected volume of fresh air. This is beneficial for temperature management (uniform temperature) and an adaptable extraction of the exhaust gas volumes. Reduced odors and condensation in the exhaust gas piping.
- Perforated tubes in the furnace chamber for even distribution of preheated fresh air throughout the horizontal charging levels
- Exhaust gas system can be dimensioned smaller, since no cold air is added via an exhaust interruption system (energy efficiency).

1.2. Active Safety Concept

Alternatively, the passive safety concept can be upgraded into an active safety system with additional equipment so that safety is monitored actively. The current limit concentrations in the furnace are monitored by flame thermal analysis (FTA). Accordingly, the fresh air and exhaust gas fans, as well as the furnace heating, are controlled automatically. For example, if the furnace is in an unsafe condition, due to overloading, too rapid heating gradients or too little fresh air, the necessary emergency program is initiated depending on the process step.



2. BO Safety Concept in Electrically Heated Furnaces for Processes with High Vaporization Rates

The BO safety concept that burns off ignitable gas mixtures by means of an additional gas-fired ignition burner can be used to burn off organic residues. The concept is recommended for products that are resistant against an uncontrolled temperature rising during the firing process. Please see page 10 for a detailed description of this safety concept.

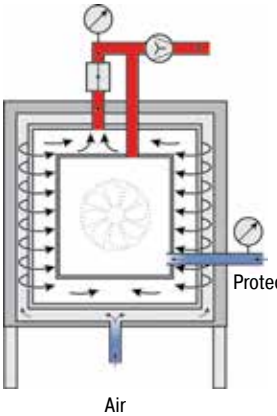
3. Debinding in Direct Gas-Fired Furnaces

Compared to electrically heated furnaces, gas fired furnaces have the advantage that large quantities of released hydrocarbons are incinerated directly in the furnace during the process. In this respect, gas-fired furnaces are especially suitable if the vaporization process is difficult to manage, for example, due to high vaporization dynamics. Complex process controls or long process times are avoided even for dynamic processes with a high degree of released hydrocarbons. Gas-fired furnaces are especially suitable for debinding when precise temperature management or optimum temperature uniformity during debinding are not top priority.

II. Debinding or Pyrolysis under Non-Flammable or Flammable Protective or Reaction Gases

IDB Safety Concept for Debinding in Protective Gas Boxes under Non-Flammable Protective Gases with Low Residual Oxygen

The IDB safety concept with an inert atmosphere in protective gas boxes is ideal for debinding processes under protective gas where a small amount of residual oxygen for the materials is permitted. The furnace technology in combination with a protective gas box made from heat-resistant stainless steel has a very good price performance ratio.

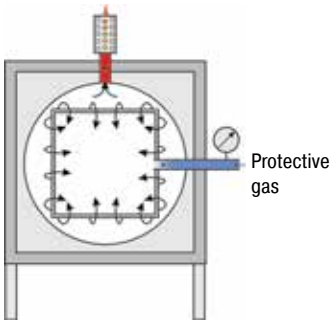


A monitored inert gas pre-flushing and conservation flushing during the process ensure that a residual oxygen concentration of 3 % is not exceeded in the protective gas box. The customer must check this limit value with regular measurements.

- Monitored inert gas pre-flushing and conservation flushing in the protective gas box
- Monitor of inert gas inlet pressure
- Monitored flushing of the furnace chamber with fresh air to dilute the furnace atmosphere in case of any leakages of the protective gas box

IDB Safety Concept in Retort Furnaces for Debinding under Non-Flammable Protective Gases or for Pyrolysis Processes

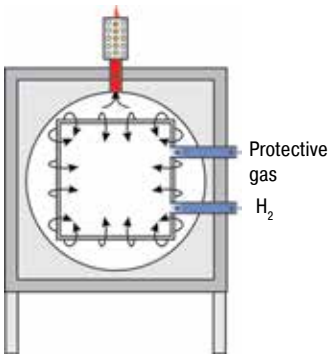
The retort furnaces in the NR(A) and SR(A) series are ideal for debinding under non-flammable protective gases or for pyrolysis processes. With the IDB option, the furnace chamber is flushed with protective gases. Exhaust gases are incinerated in an exhaust gas torch. The flushing and the torch function are monitored to ensure safe operation.



- Process management under monitored overpressure of 35 mbar relative
- Failsafe Siemens PLC and graphic touch panel to enter data
- Monitored process gas inlet pressure
- Bypass for safe flushing of the furnace chamber with inert gas
- Torch for thermal incineration of the exhaust gases

Safety Concept for Heat Treatment under Flammable Process Gases

If flammable process gases, such as hydrogen, are used, the retort furnace is also equipped and delivered with the required safety technology. Only components with the corresponding certification are used as safety-relevant sensors. The furnace is controlled by a failsafe PLC control system (S7300/safety control).



- Inlet of flammable process gas with controlled overpressure
- Certified safety concept
- Process control H3700 with PLC control and graphic touch panel to enter data
- Redundant gas inlet valves for hydrogen
- Monitored inlet pressures of all process gases
- Bypass for safe flushing of the furnace chamber with inert gas
- Torch (electric or gas) for thermal afterburning of flammable process gas
- Emergency flood container for purging the furnace with protective gas in case of malfunction

CDB Safety Package for Catalytic Debinding with Nitric Acid

- The safety concept prevents explosive gas mixture forming when the furnace is operated with nitric acid. For this purpose, the gastight retort is automatically flushed with a controlled flow of nitrogen which displaces the atmospheric oxygen before nitric acid is introduced. During debinding, the monitored mixing ratio between the nitrogen and acid prevents an excess acid dosis and, or consequently, the formation of an explosive atmosphere.
- Monitoring the pumping rate of the acid pump
- Nitrogen volumetric flow with redundant flow sensors
- Failsafe Siemens PLC
- Over-temperature limit controller to monitor excess and low temperatures
- Emergency flood container for purging the furnace with protection gas in case of malfunction
- Torch for thermal incineration of the exhaust gases