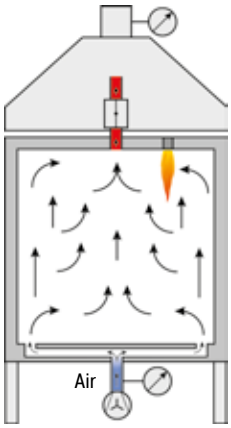
Safety Concept for other Processes where Organic Exhaust Gases Occur

I. BO Safety Concept for Processes with High Organic Vaporization Rates

The BO safety concept is recommended for processes with high vaporization dynamics that are difficult to control. Diluting the furnace atmosphere with air is not sufficient to guarantee non-ignitable mixtures in the furnace. Examples of this are processes with high binder amounts or rapid vaporization rates. This furnace concept is also suitable for processes in which the product is incinerated through ignition.

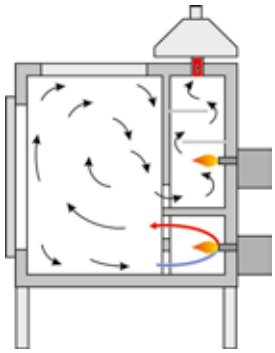


Air is continuously added to the furnace atmosphere to ensure a constant surplus of air. If, despite of this, an ignitable mixture forms in the atmosphere, this is ignited by a gas-fired ignition burner in the furnace. The system ensures that no considerable ignitable concentrations can form and ensures a safe incineration of the generated gases. The concept is recommended for products that are resistant against an uncontrolled temperature rising during the firing process. Debinding of organics can also be done at temperatures above 500 °C. Depending on the furnace model, the burn-off process can be followed by a subsequent process to max. 1400 °C.

Monitored devices and process states for safe operation:

- Temperature-controlled door lock
- Gas inlet pressure of burner system
- Flame of the ignition burner
- Flow rate of fresh air
- Exhaust gas flow
- The furnace controls respond differently depending on the specific malfunction and put the furnace into a safe condition

II. NB .. CL Safety Concept for Thermal Cleaning through Pyrolysis

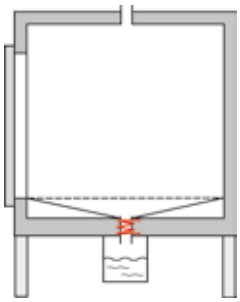


The NB .. CL safety concept is used for thermal cleaning of components through pyrolysis, i.e. in a low-oxygen atmosphere. Examples are thermal cleaning of coated steel surfaces or nozzles of plastic injection molding machines. The furnaces are gas fired and have an integrated thermal afterburning system, which is also gas fired. The preset reducing atmosphere in the furnace effectively prevents the charge from self ignition to avoid damage caused by flames and the resulting temperature increase. The exhaust gases are extracted from the furnace into the integrated thermal afterburning system, where they are incinerated. Residue-free conversion is possible, depending on the type of exhaust gas. The NBCL safety concept is not suitable for evaporating solvents or for products with a high water content.

Monitored devices and process states for safe operation:

- Gas inlet pressure of burner system
- Ensuring the thermal afterburning function: The furnace is equipped with a multi-stage safety monitoring system so that no untreated exhaust gases can escape. If the temperature in the thermal afterburning system rises above a set limit due to the generated volume of exhaust gases, the furnace gas heating switches from high to low load until the temperature in the thermal afterburner falls below the limit value again. If this is not sufficient because the volume of exhaust gases generated in the furnace is too high, the furnace heating is switched off and the process is interrupted.
- Pressure relief flap: in case of a pressure shock in the furnace, for example, due to incorrect charging or process control, a pressure relief flap is triggered to prevent the housing rupturing. The process is stopped.
- Extinguishing system: In case of unwanted self-ignition, fires can be extinguished with an ABC extinguisher through a special opening in the furnace
- Door lock: when the process starts, the door is electrically locked
- The furnace controls respond differently depending on the specific malfunction and put the furnace into a safe condition

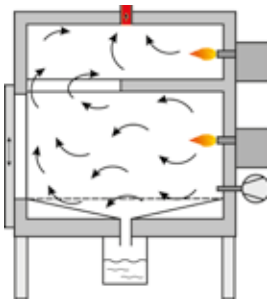
III. WAX Safety Concept for Electrically Heated Furnaces to Melt Out Wax below its Flashpoint



Furnaces of the WAX series with the corresponding safety concept are suitable for dewaxing parts, e.g. ceramic molds, below the wax flashpoint. The melted wax is collected in a container underneath the furnace. This collection container is positioned in an airtight drawer which can be removed for emptying. The wax runs through a grid into a funnel-shaped drain in the base of the furnace. The drainage channel is heated to stop the wax hardening. The furnace program is started only when the set temperature of the drain is reached. The customer has to choose the melting temperature and the melting time. When the melting process is complete, the furnace can be heated to 850 °C to sinter the molds.

Monitored safety functions for safe processes
- Temperature of the wax drain
- Two independent over-temperature limiters
  - First over-temperature limiter is set below the wax flashpoint. This prevents the wax from igniting during the melting process. The customer sets the duration of the dewaxing process. When this time has elapsed, the program deactivates the over-temperature limiter so that the furnace can continue the sintering process.
  - Second over-temperature limiter with manual reset as over-temperature protection for the furnace and the charge during sintering

IV. BOWAX Safety Concept to Melt Out/Burn Wax above its Flashpoint (Flashfire Dewaxing)



Gas-fired furnaces with the BOWAX safety concept are designed to melt out and burn- off wax above its flashpoint. Flashfire processes cause the wax to melt out suddenly. The hot furnace is charged i.e. at a temperature above 750 °C. This principle can also be used for large quantities of wax or if the flashpoint is unknown. The same applies to large quantities of residual wax that cannot be melted out using conventional methods.

Part of the wax melts and runs through a drain in the furnace bottom into a container filled with water. The second part of the wax vaporizes and forms an ignitable mixture in the furnace. This is ignited by a gas-fired ignition burner in the furnace. The furnace has an integrated thermal afterburning system that cleans the remaining exhaust gases and minimizes odors.

The ignition may cause uncontrolled temperature increases in the furnace. Therefore, the charge must be able to withstand temperature fluctuations and temperatures > 1000 °C.

Monitored safety functions for safe processes
- Gas pressure of the burners
- Flame monitoring of the burners
- Over-temperature limiter with manual reset as over-temperature protection for the furnace and charge
- Electromagnetic lift door lock, when the furnace has been charged
- Display when the permitted charging temperature is reached

Safety Concept for other Processes where Organic Exhaust Gases Occur

V. Safety Concept EN 1539 (NFPA 86) to Dry Liquid Solvents in Ovens

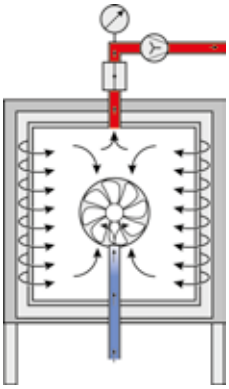
The safety technology of furnaces and dryers used for processes in which solvents or other flammable substances are released and vaporized relatively quickly is regulated throughout Europe in EN 1539 (or NFPA 86 in the USA)

Typical applications are drying of mold varnish, surface coatings, and impregnating resins. Users include the chemical industry as well as many other areas, such as the automotive, electric, plastic processing and metalworking industries.

EN 1539 distinguishes between safety concept types A and B.

1. Safety Concept EN 1539 Type A

The safety concept relates to preventing the formation of explosive mixtures through continuous air exchange in the entire vapor space.



Air

Implementation of the standard requirements

- An exhaust gas fan ensures continuous ventilation in the dryer or furnace. The fan functionis monitored for safe performance. The vapors occurring during heat treatment are extracted from the furnace chamber with the aid of the exhaust gas fan.
- The air exchange rate is ensured via a differential pressure system (differential pressure monitoring of the air circulation and the exhaust gas). If the system reports a fault, the furnace alarms malfunction and the heating is stopped.
- Underpressure ensures that the solvent safely exits the furnace
- The interior of the furnace is completely welded and prevents from solvent penetration and accumulation in the insulation

NABERTHERM specifies the amount of solvents that can be introduced in relation to the working temperature and furnace model. The amount of solvent is calculated in relation to the worst case scenario; in other words, rapid vaporization of solvent on the largest possible surface area.

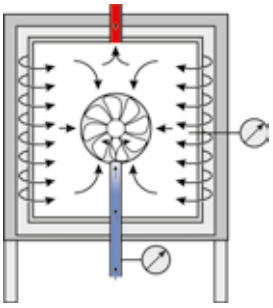
The standard also allows for exceptions where in the case of lower vaporization rates larger quantities of solvents per charge may be introduced to the dryer. Therefore, the customer has to assess the process to comply with the permitted solvent amounts.

When mold varnishes are being dried, the standard values can be increased by a factor of 10. If the customer's process involves drying of impregnating resin (e.g. for transformers, motor windings, etc.), the maximum quantities of flammable materials calculated for rapid vaporization can even be increased by a factor of 20. Depending on the process, customer must comply with the current valid standards.

The high rate of air exchange results in relatively high energy consumption. According to EN 1539, when the main vaporization time has expired, the minimum volumetric flow rate of the exhaust air may be reduced to 25 %. According to the norm, the main vaporization time is the time in which the main amounts of flammable substances are released. For dryers with safety technology, Nabertherm offers an additional control system to implement this energy saving option. Customers must set and acknowledge the end of the main vaporization time. When this time has elapsed, the system reduces the volumetric flow rate of the exhaust gas accordingly.

2. Safety Concept EN 1539 Type B

EN 1539-B describes an alternative safety concept based on dilution of the air in the furnace atmosphere. The safety concept specifies preventing the formation of explosive mixtures by limiting the oxygen concentration in every area of the vapor space.



Protective gas

Before the start of the process and after the debinding process the gas-tight container is flushed automatically with inert gas, which is monitored, to prevent flammable or explosive mixtures forming.
During the process, the flushing is safely monitored.

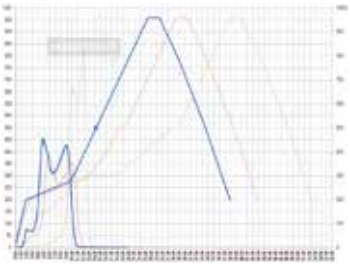
Implementation of the standard requirements

- Process control via failsafe PLC (F-PLC)
- Overpressure monitoring in the furnace
- Monitoring process gas inlet pressure and emergency flushing path
- Monitoring the door lock to prevent unauthorized opening of the furnace during operation
- In case of a malfunction, the furnace is flushed and the heating and air circulation are deactivated. The customer must provide for a failsafe protective gas supply.
- The oxygen concentration is monitored with oxygen sensors located in the exhaust gas stream.

Process Optimization by Nabertherm with Flame Ionization Detector (FID)

The binder removal often accounts for the largest part of the overall process time. Consequently, there is a lot of potential in this sequence to optimize the process curve times.

For process optimization, Nabertherm offers a production accompanying analysis of the debinding process by means of FID measurement. The aim of the measurement is to determine a possible reduction of the process time, an increase in throughput and an associated reduction of production costs. Based on the recommendations, the customer checks and validates the practical feasibility with respect to the material properties of his charge.



Process curves before and after optimization

- Process analysis including FID measurement and recommendations for potential process optimization
  - Recording of the current raw gas values using FID measurement
  - Evaluation and determination of periods with lower vaporization activity
  - Provision of the FID measurement device
  - Preparation of the evaluation and reports

- Process adjustment
  - Proposals for an optimized temperature profile
  - Implementation of the proposal, by performing one process cycle with accompanying measurement and evaluation after the customer has approved the proposal
  - Recommendations for the customer to carry out further optimization steps if feasible