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## Latest technology in the design of high-temperature furnaces

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### Summary:

Rapid heating laboratory furnaces and high-temperature furnaces by Linn High Therm are the result of many years of experience in the high temperature sector. Linn was the first company in Europe to market laboratory furnaces with full fibre insulation. Continuous development work has steadily improved the technology. The outcome is a modular furnace concept with short heating and cooling times, the possibility of operating under reducing/oxidising atmospheres or vacuum, a minimum temperature gradient in the furnace chamber and, last but not least, a low energy requirement. They represent innovative, state-of-the-art products.

The extreme demands of atmosphere, pressure and temperature which arise during the heat treatment of corundum, the production of larger HTSL parts or lithospheric research are a challenge to the furnace builder. The Corundum-Star range of furnaces allow work to be carried out at up to 1800 °C under oxygen mixtures at pressures up to 25 bar or even in pure oxygen at pressures up to 6 bar. With the ZrO<sub>2</sub>-heated VHT models operating under atmospheres containing oxygen up to temperatures of 2100 °C, Linn High Therm are able to provide suitable solutions in all areas.

HT furnaces for inert gas or vacuum operation by Linn High Therm are designed in various standard sizes with capacities of 4, 12, 26 and 52 litres. Special designs up to 0.1 m<sup>3</sup> for various maximum temperatures are available. The standard range for operation in the presence of air up to 1760°C (1800°C) ranges from inexpensive small furnaces with 0.3 dm<sup>3</sup> for laboratory, research and development to the 1 m elevator furnace type for production. New molybdenum disilicide ( MoSi<sub>2</sub> ) heating elements permit the highest heating and cooling rates as a result of their higher thermal shock resistance.

Up to 1400°C Kanthal-Super-1 700 elements are used. For use to 1750 °C Kanthal-Super-1800 are fitted and for up to 1820 °C Kanthal-Super-1900 heating elements are used. Since molybdenum disilicide has a

restricted life under inert gas atmospheres, heating conductors of APM (1400 °C ), molybdenum and tungsten are possible options.

Graphite-heated and graphite fibre insulated HT furnaces can be used under inert gas up to 2000°C and more. These are primarily used for the graphitizing and sintering of non-organic ceramic as well as of hard metals.

For high vacuum ( < 10<sup>-3</sup> mbar ) and low dew point (-40 °C), HT furnaces of cold wall construction are designed with molybdenum or tungsten. With both variants special designs up to 2800 °C are also possible.

Following recent developments the HT furnace series has been extended in the high and low working volume range. Thus, for Achema 1997, the mini high temperature furnace EVA with a working volume of 0.80 litres and a constant temperature of 1700°C was added to the programme.

When this furnace has a working sapphire tube of 34mm internal diameter it becomes the mini pipe furnace ADAM with a heated length of 80 mm.

Another economical HT series completes the production range with 60, 120 and 180 liter volume, 1600 and 1700°C.

High temperature elevator furnaces up to 1 m<sup>3</sup> working volume for the manufacture of ceramic cutting materials, substrates, electrical component ceramics, special ceramics and raw materials - e.g. Y<sub>2</sub>O<sub>3</sub> - are now available for work up to 1750°C. Charging is carried out either by means of a built-in scisso-lift platform or lift truck with optional interchangeable bottom plate and special cup inserts.

With the standard gassing and vacuum module the following operating conditions can be accommodated:

Oxidising atmospheres,

Reducing atmospheres including all combustible gases,

Vacuum up to 10<sup>-2</sup> mbar,

Combination vacuum / inert gas at elevated pressure.

Additionally a safety package with gas warning system can be provided for safe use of burnable protective gases.

Homogeneous temperature distribution and short heating and cooling times are achieved through the interaction of good insulation, low stored heat and high radiant factors. The heating time to 1600°C is about 60 minutes or less with an empty furnace. The temperature distribution is about ±10°C with optimum batch distribution.

Modular design technology provides unbeatably easy servicing.

Tests have shown that savings of up to 45 % of energy costs can be achieved with fibre-lined furnaces.

The low thermal conductivity of the fibres produces a high insulation value and together with the low

thermal capacity of the lining enables the "small" HT furnaces to be operated with just a 230/240 V mains supply.

The insulation of the furnace chamber consists of several layers of fibre panel of various qualities and classification temperatures. Experience has shown that the latest materials, despite the general shrinkage, require a certain expansion provision for use under conditions of frequent temperature changes and prolonged soaking order to reduce the tendency to failure by cracking. As a consequence, for stabilising the side walls and floors,  $\text{Al}_2\text{O}_3$  or sapphire tubes are installed (Patent No. DE 3606988 "Insulation for a high temperature heating device and the use of the same").

The complete insulation structure is accommodated in a separate internal housing made of stainless steel. As a result it is possible to design this internal housing as an inert gas/vacuum/ pressure chamber, with all the thermally stressed functional elements, such as the door seal, sight glass, thermocouple and power lines water cooled. This double housing construction and an additional cooling air system (between both the housings) results in the temperature on the external housing being less than 30°C above room temperature at every point. Of course this is a slightly more expensive design than a simple box but it soon pays for itself.

Since the dimensions of the door opening are equivalent to the size of the working area, simple loading and unloading of the furnace chamber is ensured, without laborious "round-the-corner" manoeuvres. To avoid excessive heat losses with complicated opening and closing of the door routines, a spring-loaded quick closure is used which simultaneously serves as an excess pressure safety device.

Due to the change of the resistance of the heating elements as a function of the temperature, thyristor controllers with phase control and simultaneous power limitation are used for constant load control. This prevents load peaks in the heating elements and considerably increases their service life.

The temperature control is provided by easily programmable, self-optimising, microprocessor controlled digital PID controllers with programmer. The process is also optimised by the microprocessor control. A further advantage is that the storage of all programs is continued even during a power failure and the interrupted program can continue to operate from the same point when power is restored.

Where extreme demands are made on the accuracy of temperature control, the furnaces can also be set up in a multizone manner.

Upon request, the furnaces can also be provided with a mobile undercarriage, permitting a single person to move or reposition them.

Possible applications of these HT laboratory furnaces as result of the features detailed above:

In the ceramics industry for the manufacture of electronic components.

HT furnaces provide advantages for the production of piezoceramics, capacitor ceramics, ceramic carriers for IC's and thick-film technology where high accuracy of temperature control and temperature gradient are required.

For other special ceramic materials requiring special furnace atmospheres:

Sintering of MIM and CIM parts, e.g. nozzles, electric motors, magnets, interference suppressers, etc.).

Microwave ceramics , sparkplug insulators or materials from the high temperature refractory industry.

Pure oxygen sintering of high frequency ferrites.

Vacuum inert gas brazing of ferrites for video technology.

Improving the colour and increasing the value of corundum material.

Tempering of laser crystals

Development of processes for the recycling of residual materials in the paper industry. Development and production of special lenses for sensors or for telecommunications.

Development and production of new types of highly coercive magnetic materials.

The efficiency of the HT furnaces is fundamental for the development and production of new high temperature super conductors. For the further development of super conducting materials, higher process temperatures or atmospheres are essential for these furnaces. In the nuclear sector, these furnaces are employed in a modified manner in production and research for the sintering of atomic fuels and the incineration or vitrification of radioactive waste. These processes require the use of totally water-cooled and glove box versions of the HT range.