Elektrisch beheizte Drehrohröfen

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Linn High Therm

2. Aachener Ofenbau- und Thermprozess- Kolloquium
11.10.2019

Vorteile von Drehrohröfen:

- hohe Produktivität durch kontinuierlichen Betrieb
- hohe Wärmeübertragungsraten
- homogenes Produkt
- Reaktionen lassen sich leicht kontrollieren
- konstanter Anfall von Reaktionsgasen und Abgasen
- hohe Energieeffizienz
- schnelles Aufheizen und Abkühlen

Anwendungen für Drehrohröfen:

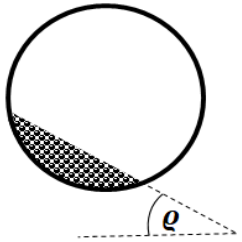
- Calzinierung,	(Keramik, Li- Batteriewerkstoffe)
- Reduktion	(Metalle, Nuklearbrennstoffe)
- Pyrolyse von organischen Stoffen	(Brenngaserzeugung, Reststoffverwertung
- Recycling	(Faserverbundstoffe, Aktivkohle)
- Herstellung von Kohlenstoffmodifikationen	(nano- tubes, Annodenwerkstoffe
- Herstellung hochreiner Substanzen	(Quarz, Kohlenstoff)
- „Einfrieren von Hochtemperaturstrukturen	(Kalziumphosphat)

$$L = n * d * \pi * \tan\alpha * \frac{d^2 * \pi}{4} * \varphi$$

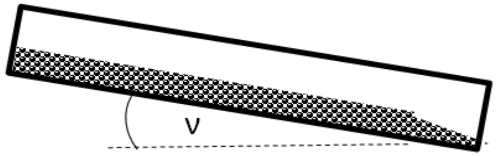
$$t_o = \frac{l}{n * \tan\alpha * d * \pi}$$

$$\tan\alpha = \frac{\sin\nu}{\sin\varrho}$$

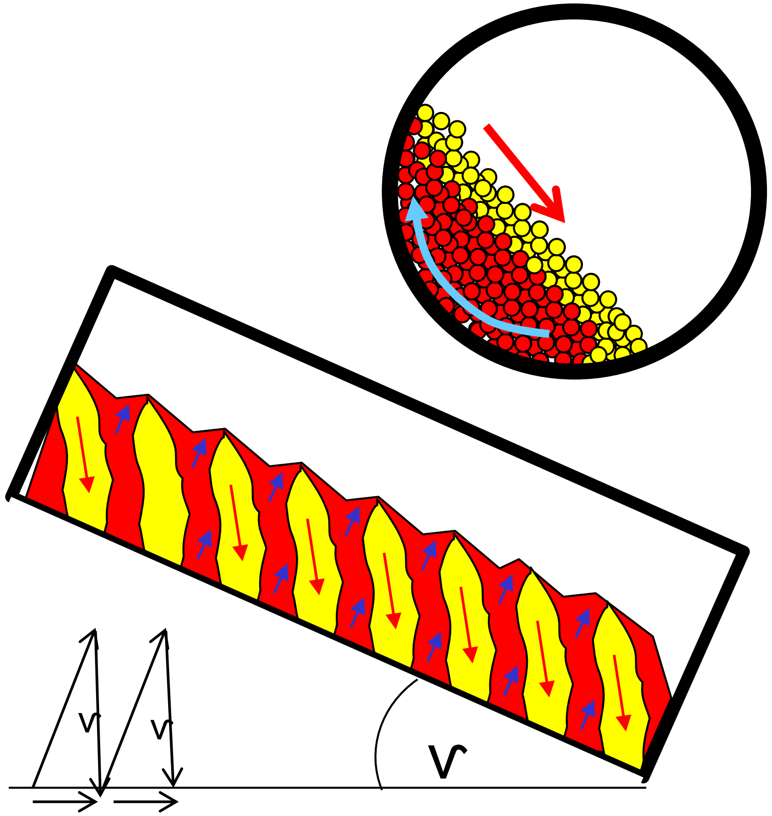
- L [m³/min]: Durchsatzleistung
- n [1/min] : Drehzahl
- ν : Kippwinkel
- ϱ : Gleitwinkel des Wärmegutes
- d [m] : Drehrohrdurchmesser
- φ : Füllgrad
- t_o [min] : Verweilzeit im Rohr

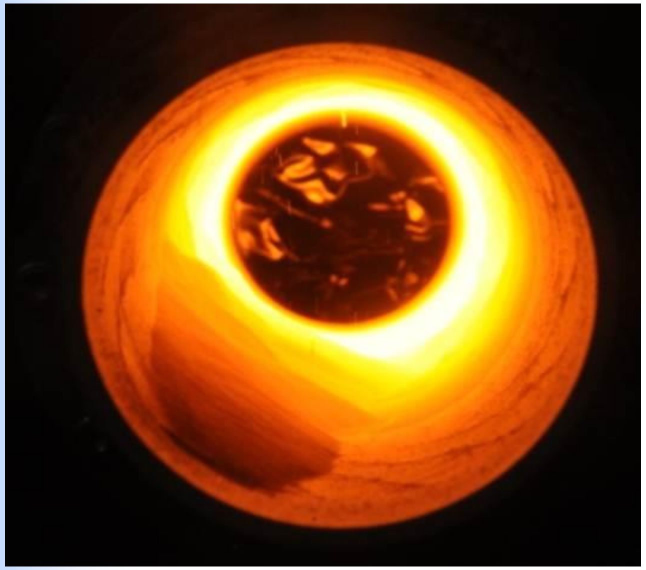


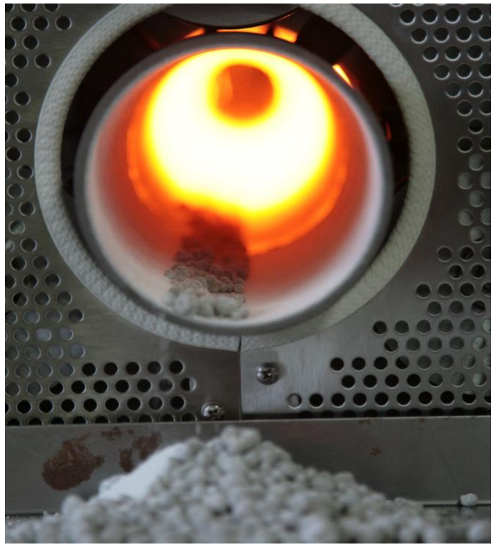
$$\nu = n * \tan\alpha * d * \pi$$

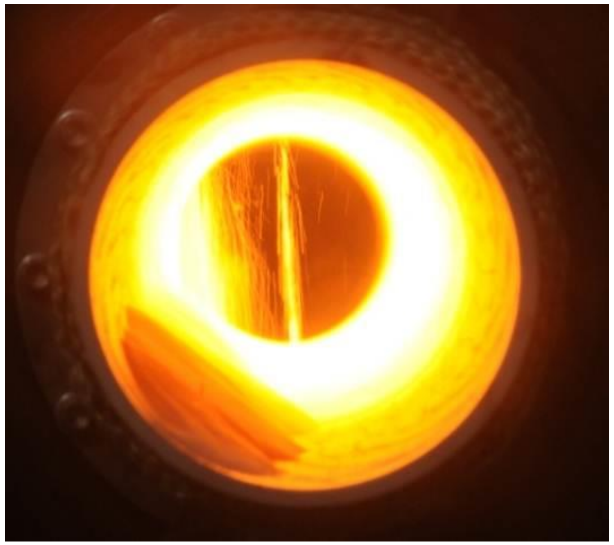


W.Heiligenstaedt Formel:



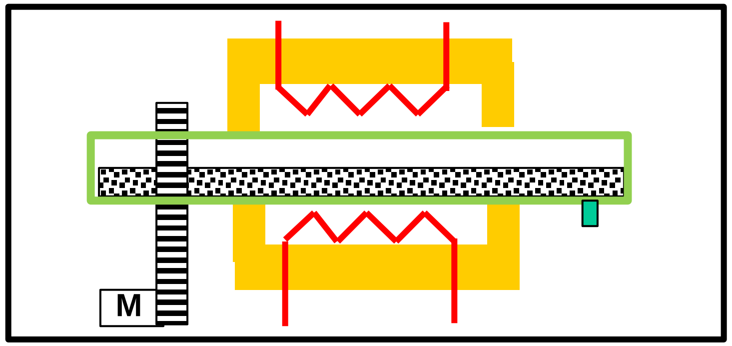






Möglichkeiten zur Beheizung von Drehrohrofen

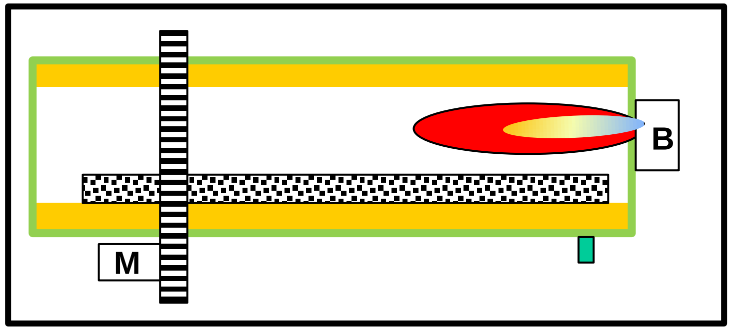
indirekt



Antrieb

Heizer
Widerstand, Gas, Öl

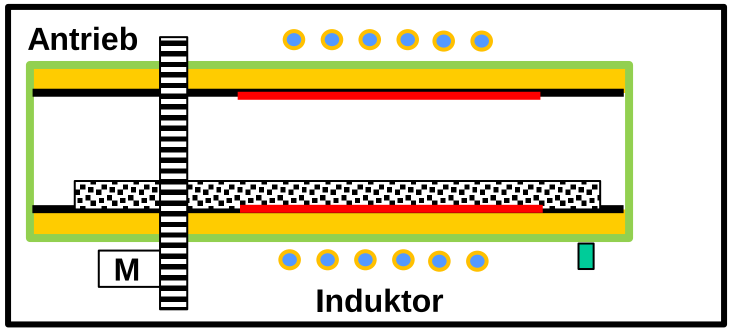
direkt



Heizer
(Gas, Öl
Mikrowelle)

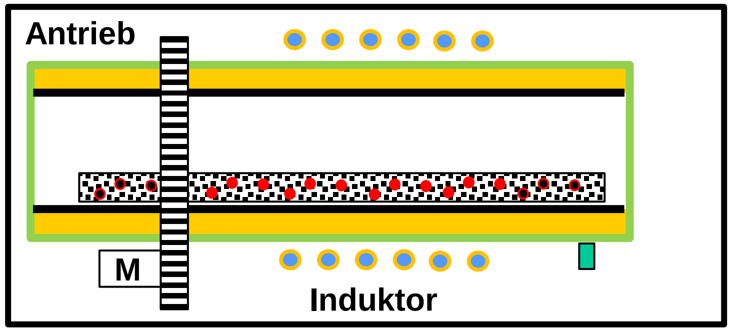
Antrieb

indirekt inductiv



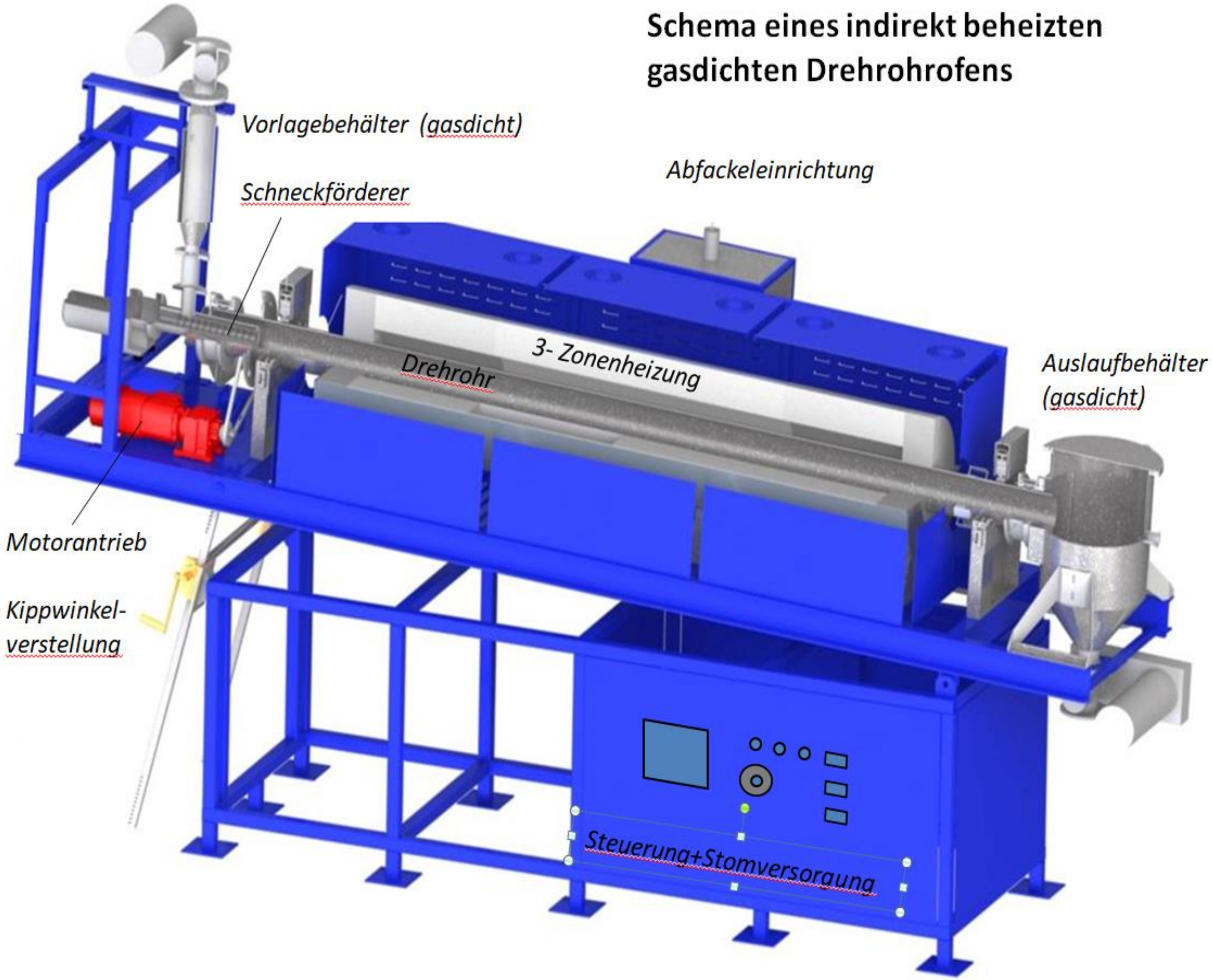
Heizer
Innenrohr
= Suszeptor

direkt inductiv



Heizer
Suszeptor - Teilchen
Im Schüttgut

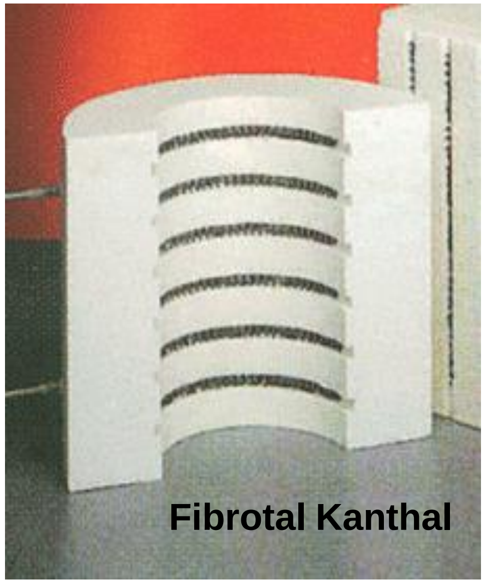
Schema eines indirekt beheizten gasdichten Drehrohrofens



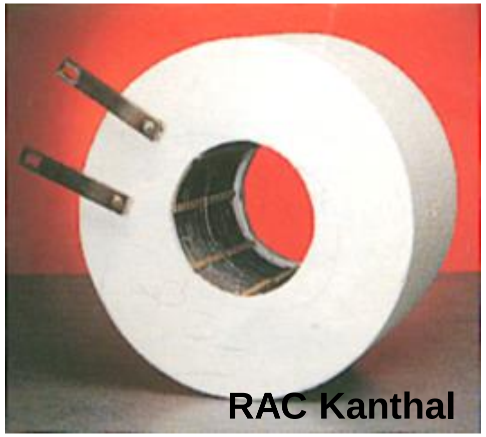
Heizermaterialien für Drehrohröfen

Heizer aus FeCrAl bis max 1400°C

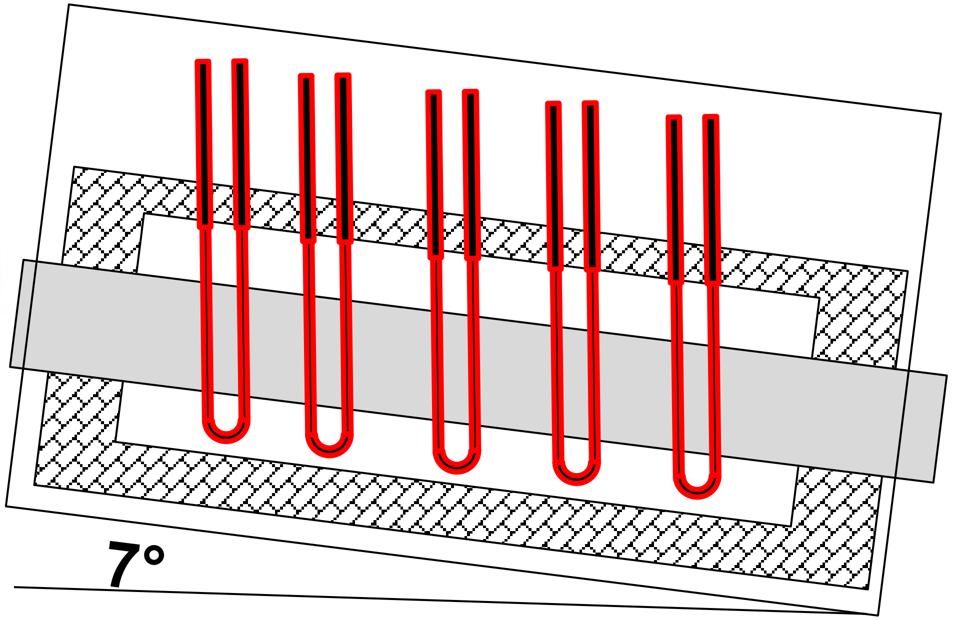
max 1150°C



max 1300°C

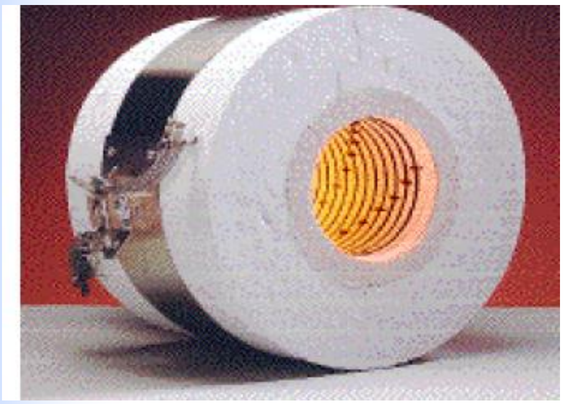


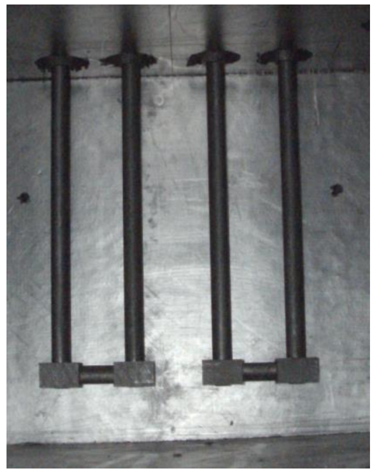
Heizer ausMoSi$_2$ bis max 1820°C



Graphit max 2600 °C (3000°C)

Modul-Heizer ausMoSi$_2$ bis max 1700°C



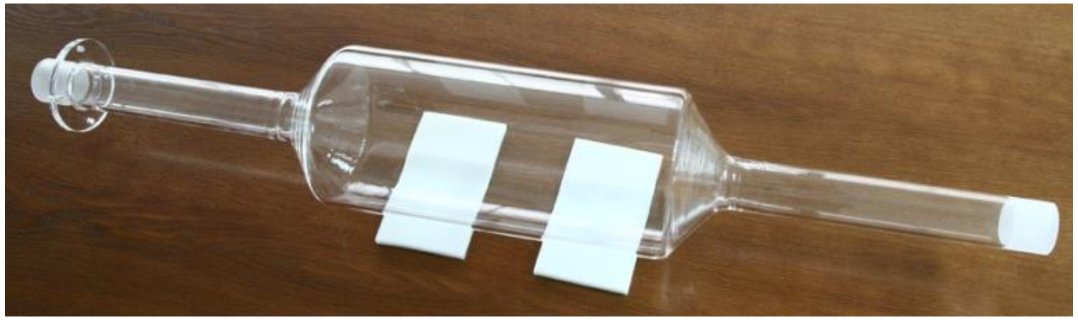


Metallic Tubes

with or without installed fittings
high heating and cooling rates.
Usual materials:
1.4828 to 950 °C
1.4841 to 1100 °C
Inconel to 1200 °C
APMT® up to 1300 °C
Possible dimensions:
Diameter: -2000 mm
Length: -15000 mm

Quartz Tubes up to 1050* °C

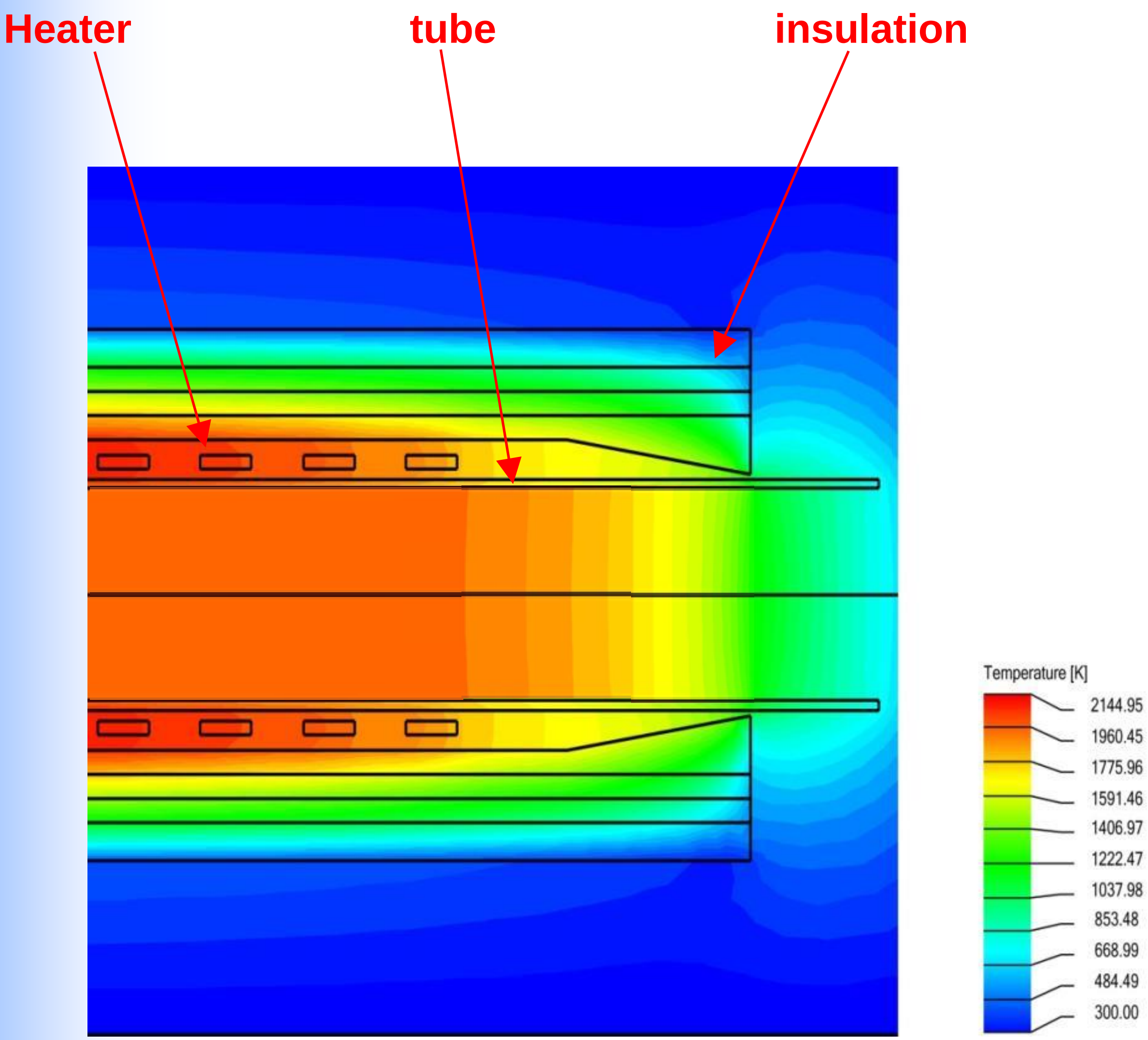
Possible dimensions:
Diameter: 500 mm
Length: 5000 mm



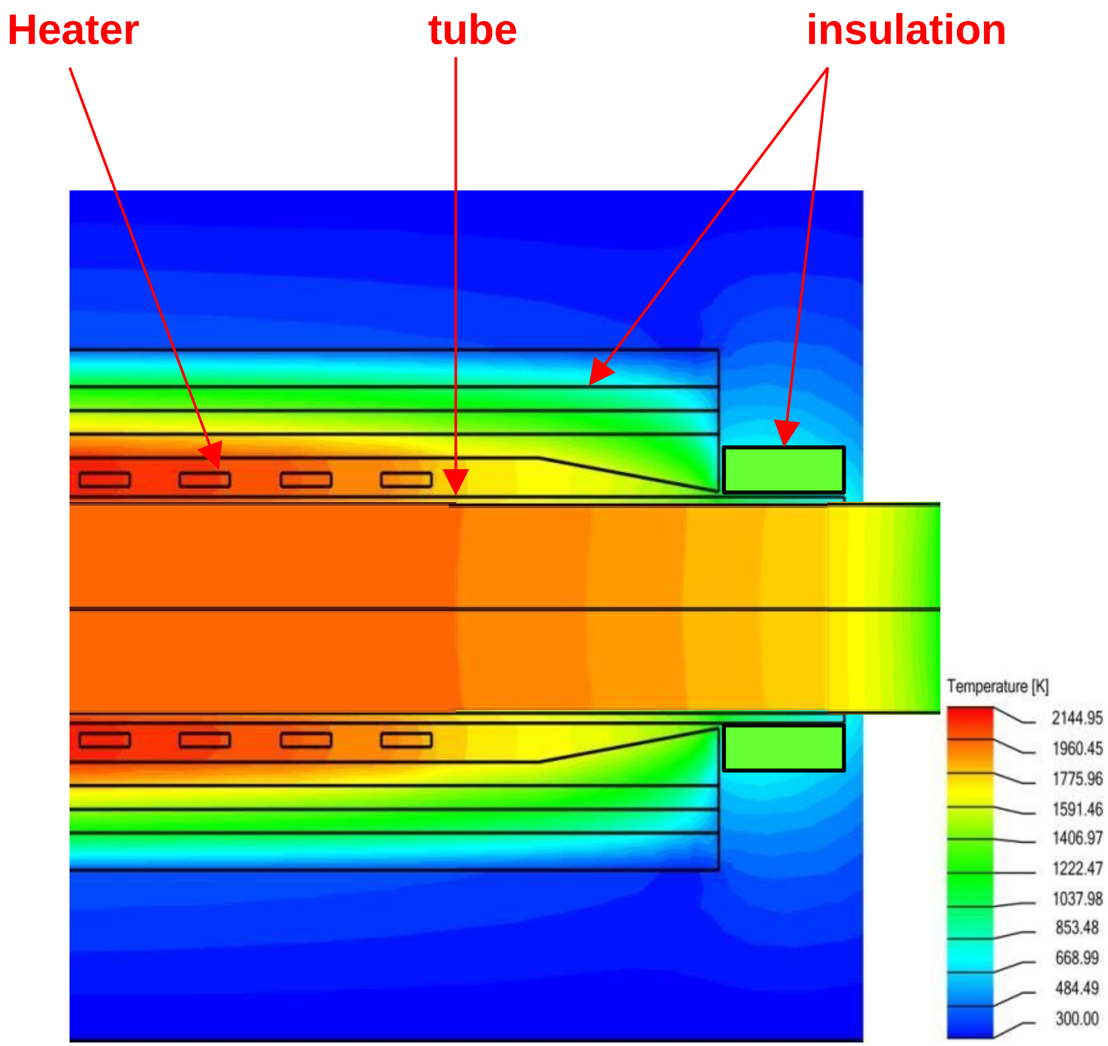
Ceramic Tubes (Al_2O_3, ZrO_2, SiO_2, sapphire)

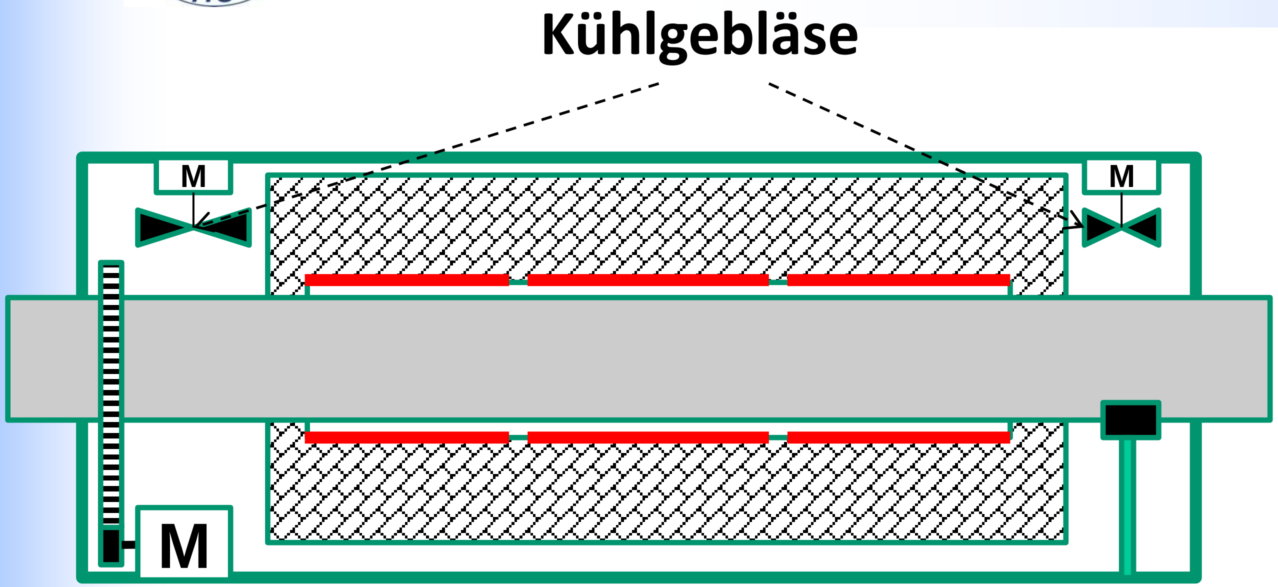
high abrasion resistance
up to 1700 ° C
Possible dimensions:
Diameter: ≈ 500 mm
Length: ≈ 5000 mm

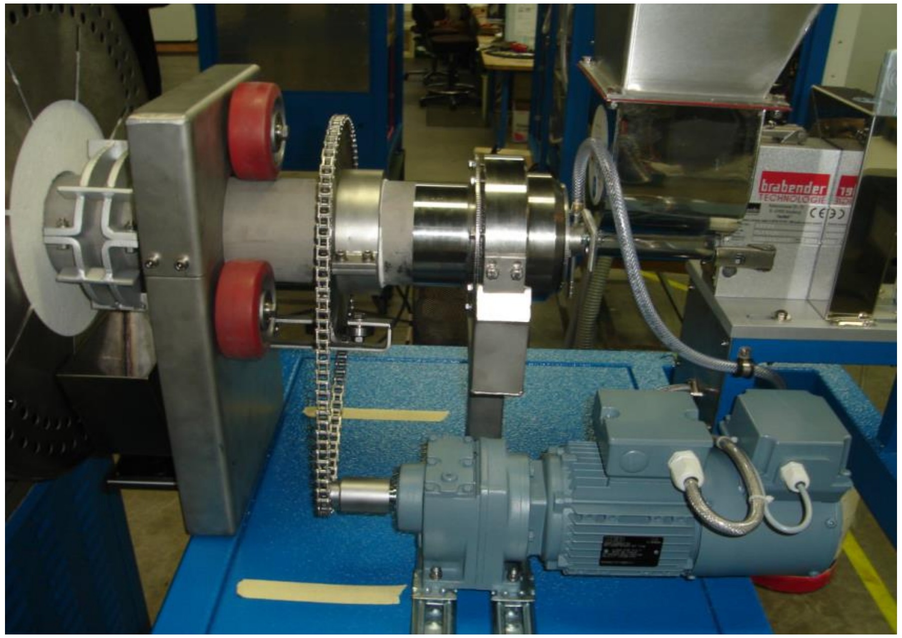
PC Simulation of Temperature distribution in a rotary tube furnace

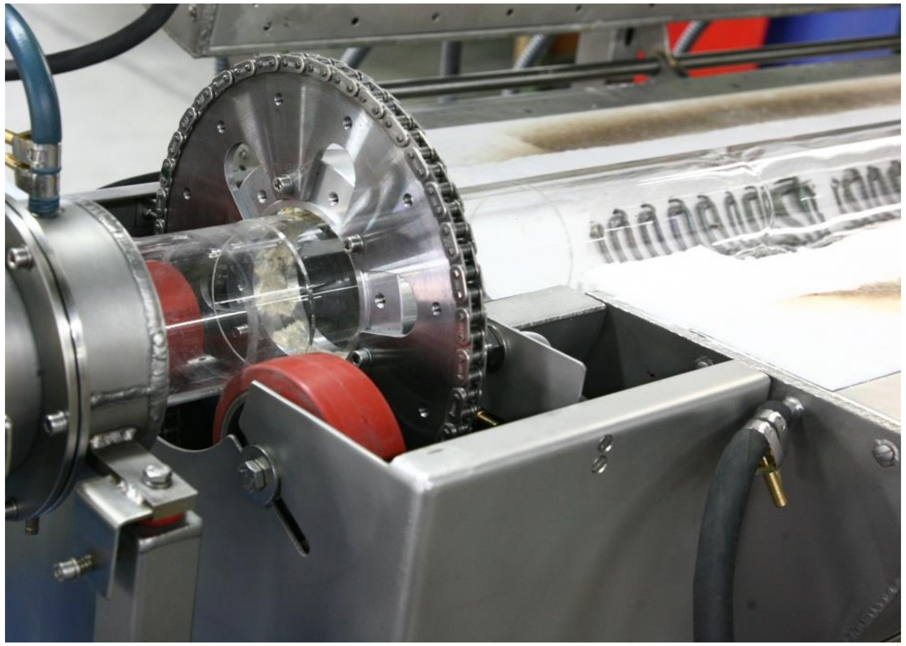


Improvement for ceramic tubes




Kühlgebläse
M
M
M


brabender



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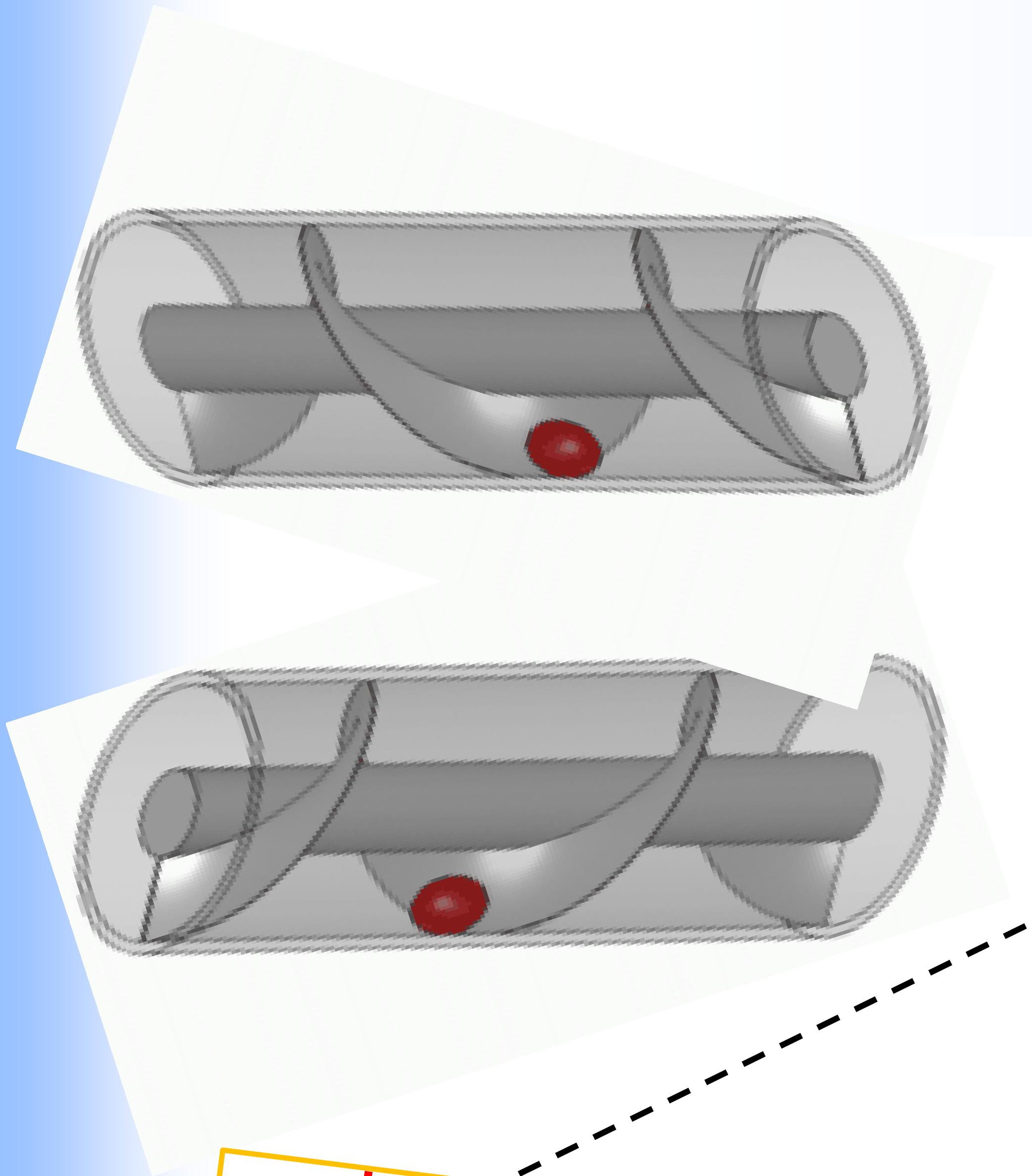
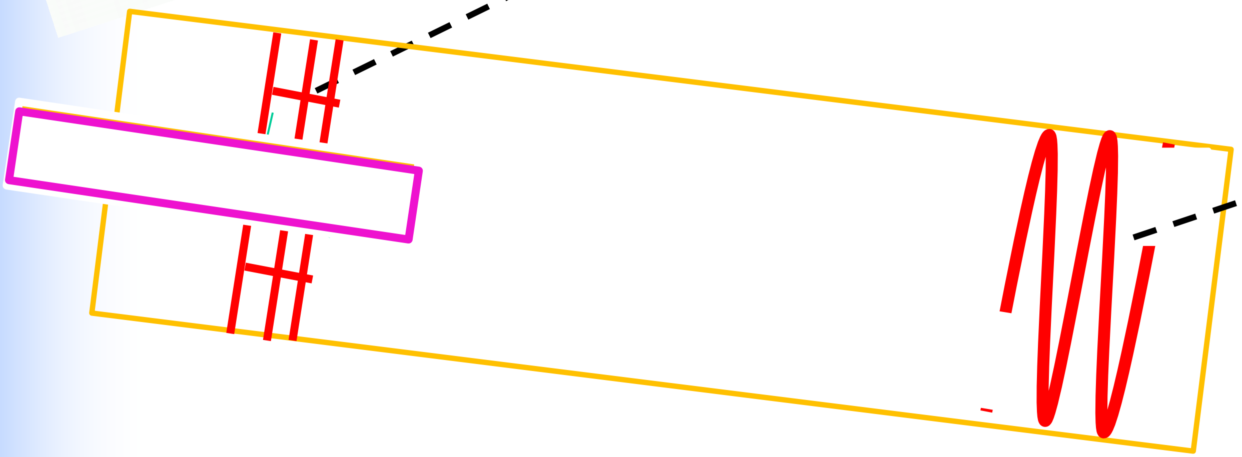
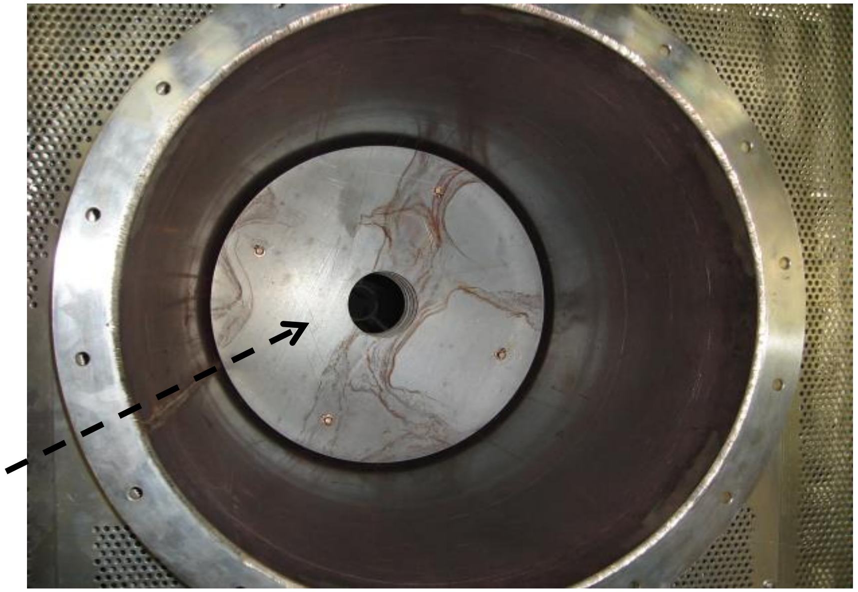




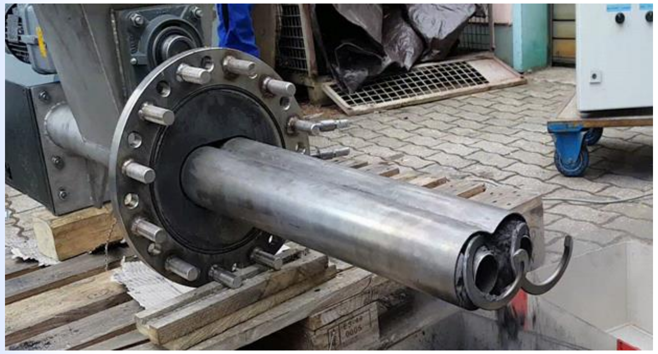


TÜV International Certification
TÜV THÜRINGEN
CERT
ISO 9001:2008
15 100 64236
TIC

Linn High Therm

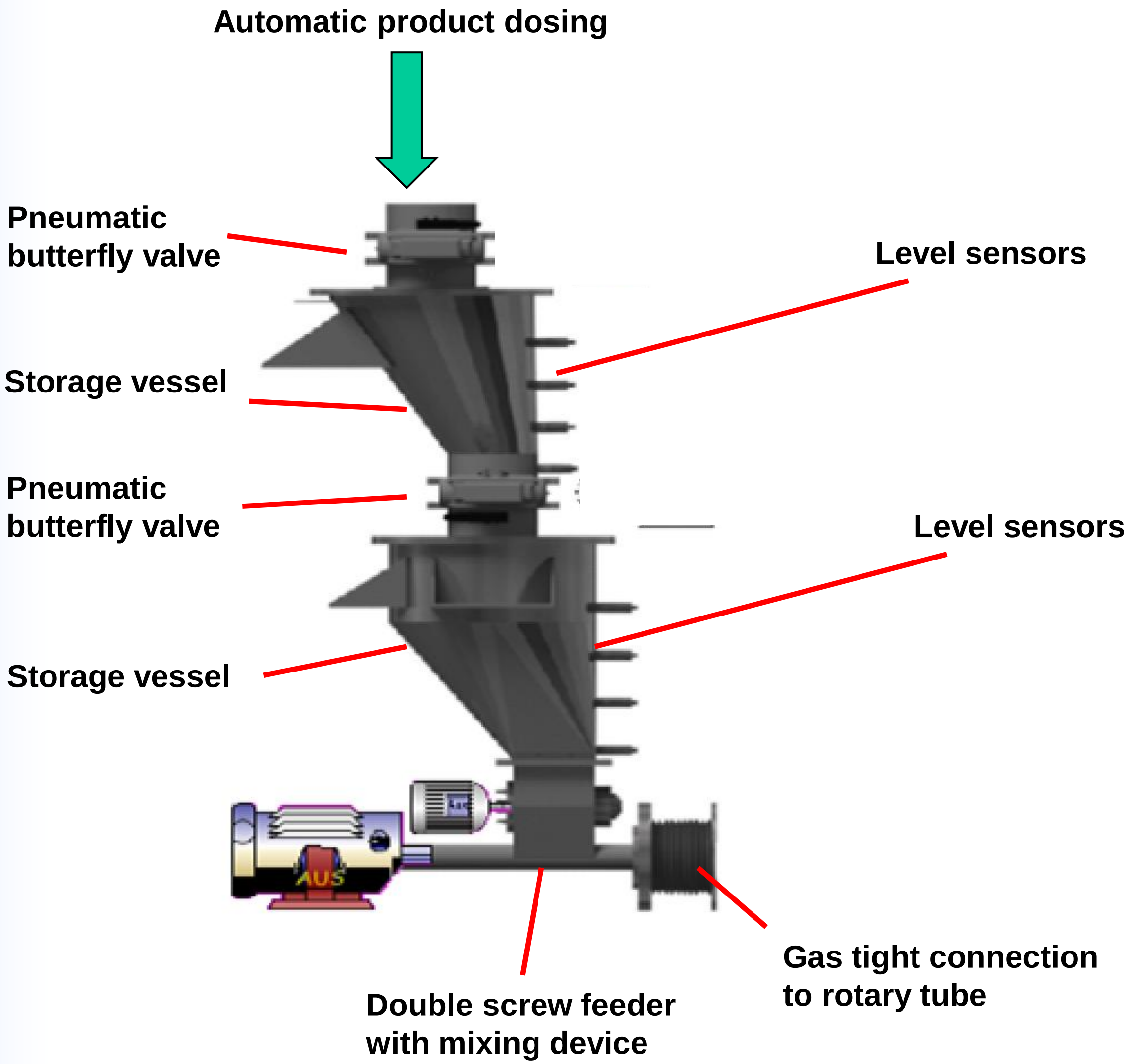
Beschickungseinrichtungen

Schneckenförderer
Doppelschneckenförderer
Vibrationsförderer
Zellradschleusen
Bandförderer
Doppelschleuse

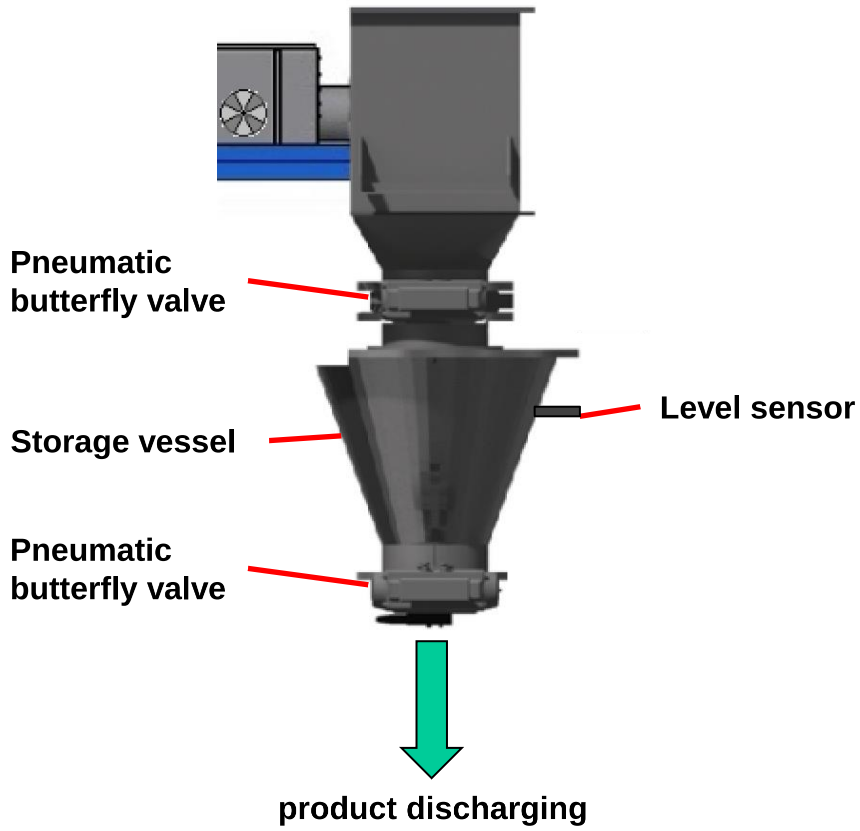


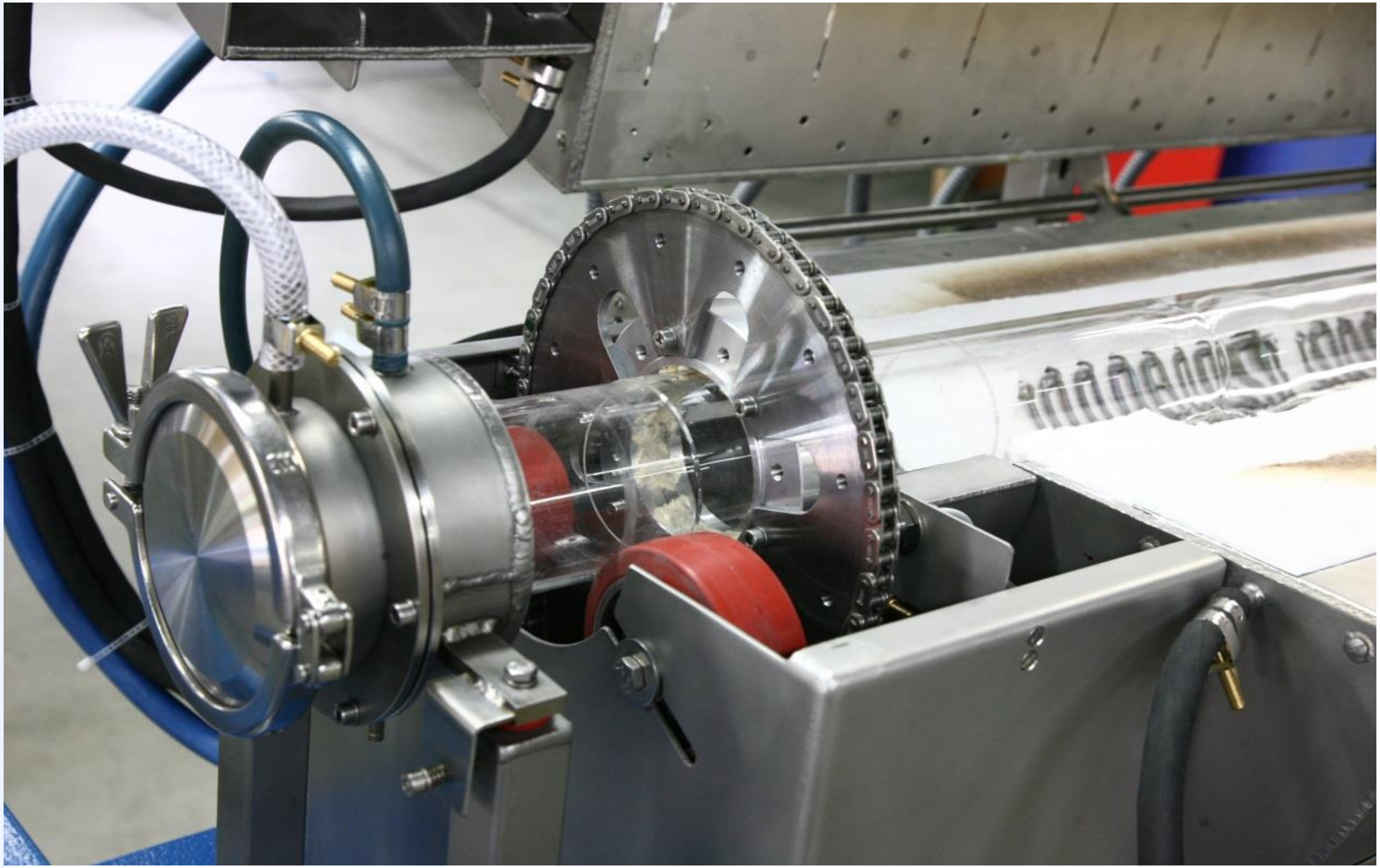
Integrated Automatic Product Feeding And Discharging

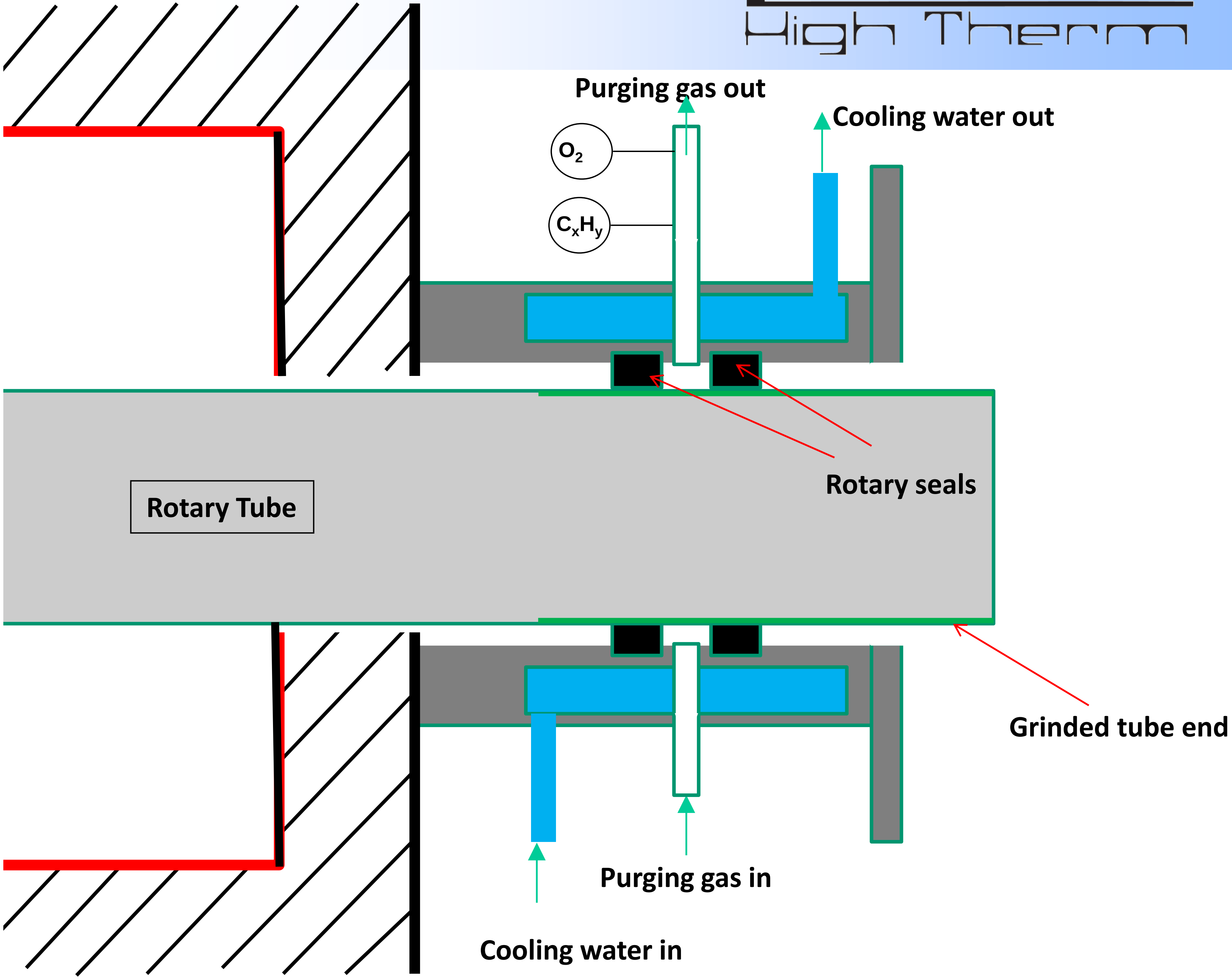
Automatic product feeding



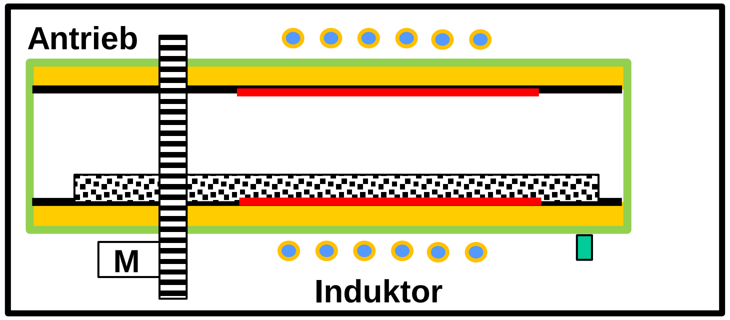
Automatic product discharging



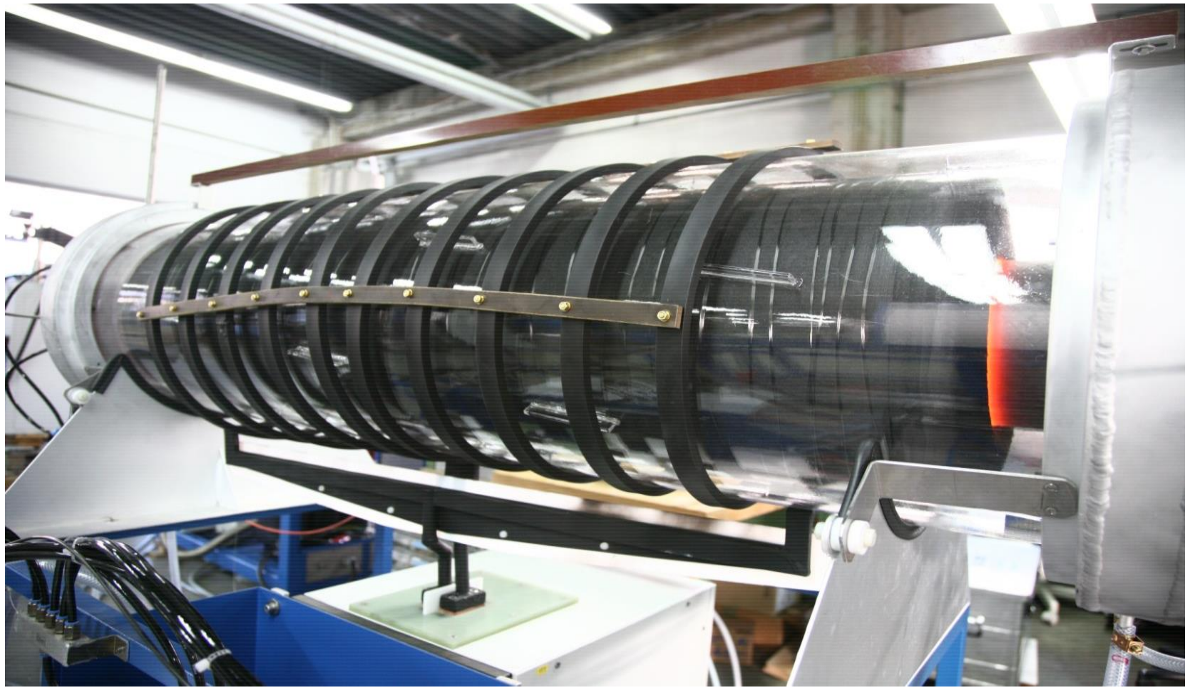



Purging gas out
Cooling water out
O_2
C_xH_y
Rotary Tube
Rotary seals
Grinded tube end
Purging gas in
Cooling water in

indirekt inductiv



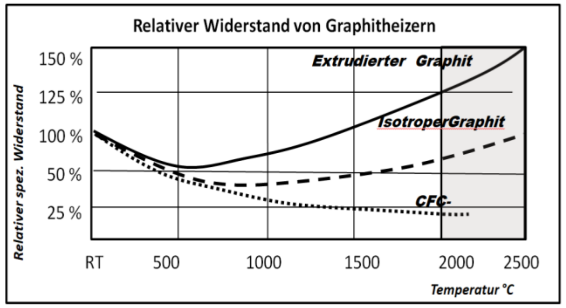
Heizer
Innenrohr
= Suszeptor

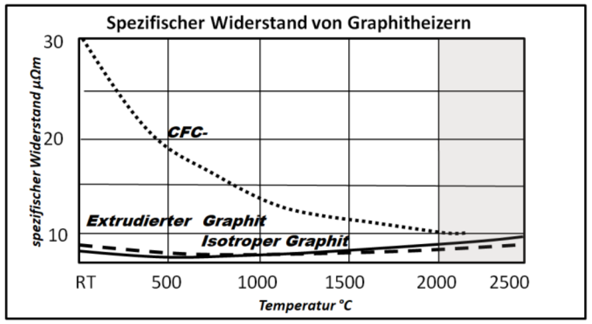


Wirkungsgrad bei Rundinduktoren
Näherungsformel nach Kretzmann

$$\eta_{th} = \frac{1}{1+\frac{D^2}{d^2}\left(1+6{,}25\,\frac{\delta^2}{d^2}\right)\sqrt{\frac{\varsigma 1}{\mu\varsigma 2}}}$$

D : Induktordurchmesser
d : Werkstückdurchmesser
ς_1 : spez.Widerstand Induktormaterial
ς_2 : spez.Widerstand Werkstück
μ : relative Permeabilität
δ : Eindringtiefe $\delta = \frac{1}{2\pi}\sqrt{\frac{\varrho}{f\mu}}$





Graphit Rohrsuszeptor:
$Di_{Spule\ Cu}$: 300 mm
$da_{Rohr\ C}$: 200 mm
ς_1 : 0,0175 Ωmm²/m ***(20°C)***
ς_2 : 8 Ωmm²/m ***(2000°C)***
μ : 1
f **: 9000 Hz**
η_{th} : 90%

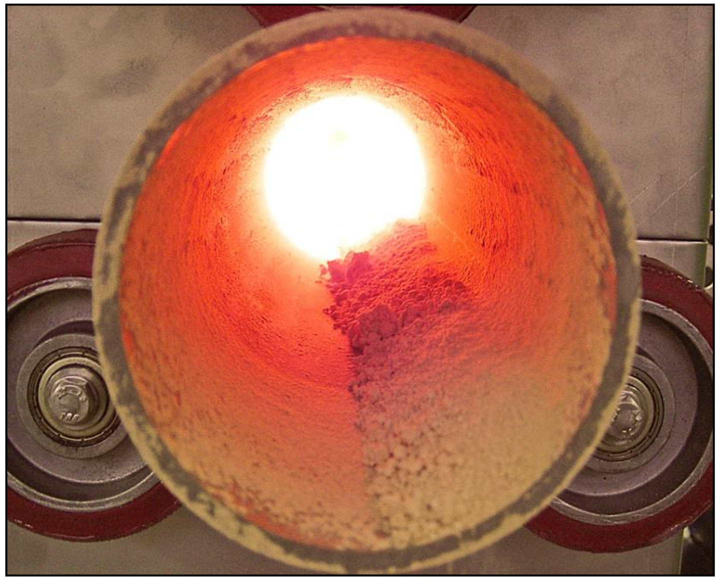
Verluste über Mantel
$da_{Rohr\ C}$: 200 mm
$L_{Rohr\ C}$: 1500 mm
Isolation $_{C\text{-}Weichfilz}$ 40 mm
Ca. 20 kW

Microwave rotary tube furnace

Hybrid-Drehretortenofen zum Behandeln von SiO_2

Drehrohrofen zum beschichten von C-Kurzfasern

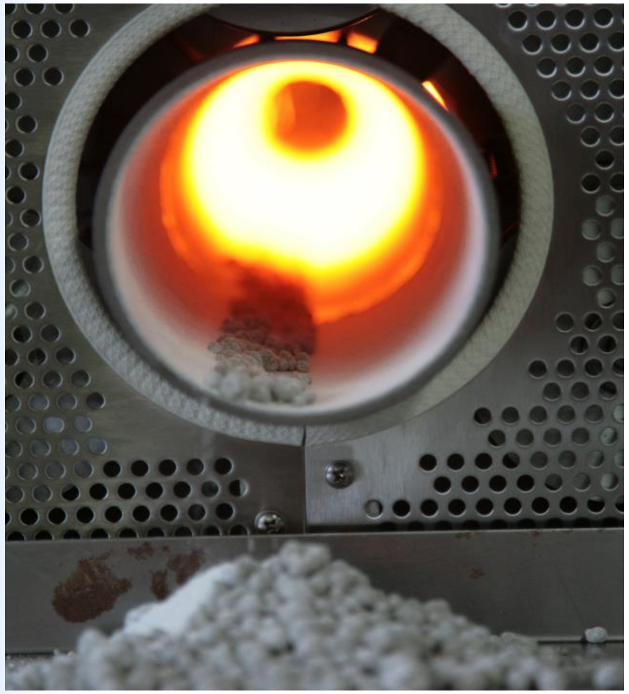


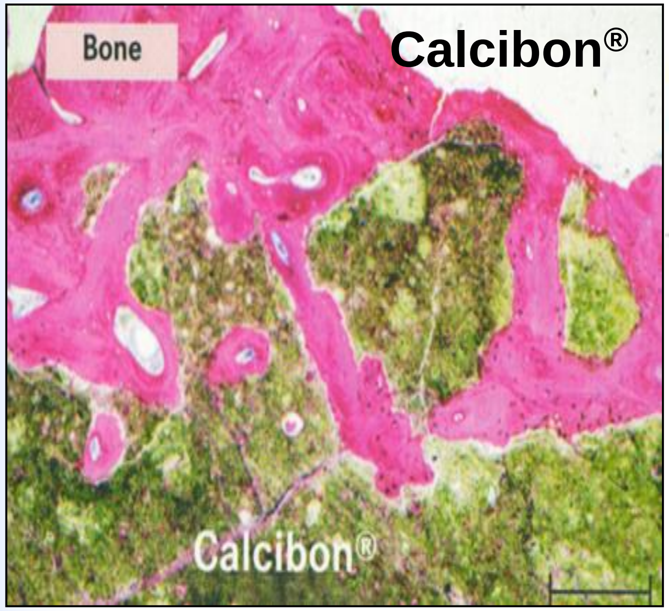



Color changing of natural granit for dekorative construction materials.
Rotary tube furnace (oxidising/reducing atmosphere), 1000°C

Drehrohrofen für Quarzsand Reinigung (pbb- Bereich)
Tmax 1700°C; Luft

Artificial bone material α-$Ca_3(Po_4)_2$





Rotary Tube Furnace FDHK 100/700/1600

Rare Earth Production Kasachstan

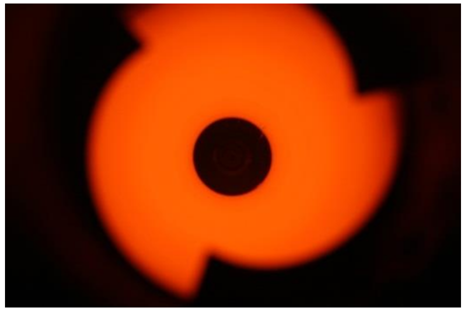
Process:	Drying	Sulphatisation / Digestion
Production rate:	2500 kg/h	1000 kg/h
Addition of H_2SO_4:	-----	600 – 1000 kg/h
Treatment time	6 h	4 h
Overall humidity:	40 wt.-%	-----
Bulk density at inlet:	1,3 – 1,8 g/cm³	1,45 g/cm³
Furnace atmosphere:	Air + H_2O + H_2SO_4	Air + H_2SO_4
Process temperature:	20 ° - 450 °C	450 °C - 550 °C
Tube diameter	1400 mm	1800 mm
Heated length	10800 mm	10800 mm
Heating power:	1500 kW	600 kW

To account for the highly corrosive environment containg sulphuric and phosphoric acid
, special corrosion resistant stainless steels,
like, eg. X1NiCrMoCu32-28-7, need to be applied

Rotary tube furnace with rotary tube cooler

Reduktion von Uranoxid
(*Kazachstan*).

$3UO_4 \cdot 2H_2O \rightarrow U_3O_8 + 6H_2O + 2O_2$



Type: FDHK-5-500/6000/1000

Heating power: 220 kW, 5 separately controlled heating zones;

Dimensions of the tube:
Ø500 x 6000 mm (heated length);

Material of the tube: heat resistant steel;

Max. working temperature: 1000 °C.

Carbonisation

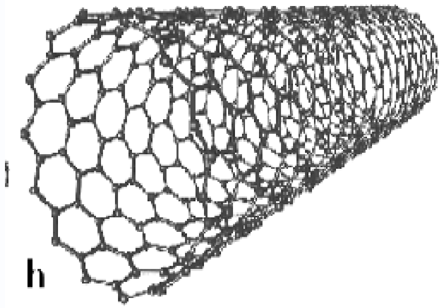
(= pyrolysis of natural fiber) and activation of wool (cellulose) from natural sources.

FDHK-3-300/3000/1000

Pyrolysis and partial oxidation of graphite for battery manufacturing.

Linn High Therm

Pyrolysis in rotary tube furnace with exhaust after treatment



Carbon nano tubes

950°C
H_2 + C_2H_4
800g/h Ni powder
18m³ Ethylen (C_2H_4)+ 1,8m³ H_2
Dewll time 10-20min

Laboratory mini Rotary Furnace FDHK-25/250/1000