Economic and efficient low-pressure carburizing in pit furnaces

Deep carburizing for massive parts

4.05.2022
Paweł Okińczyc

AGENDA

Typical equipment for LPC

Traditional technology

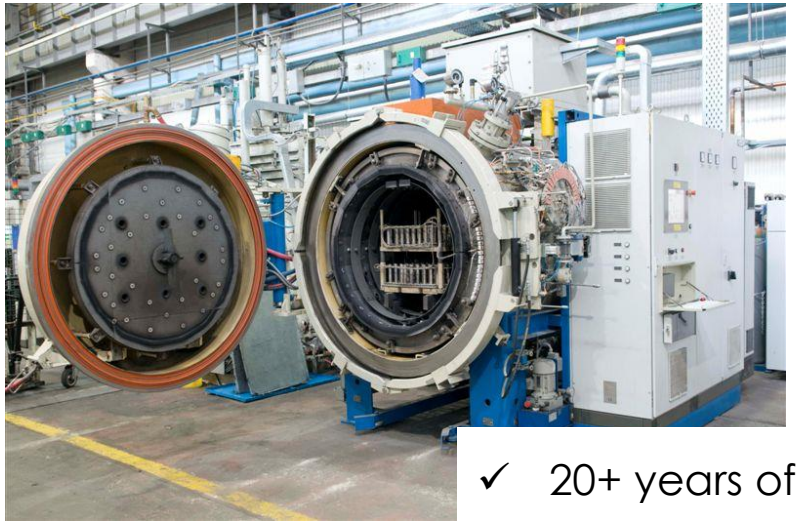
LPC technology - Fundamentals and benefits

Pit LPC system design

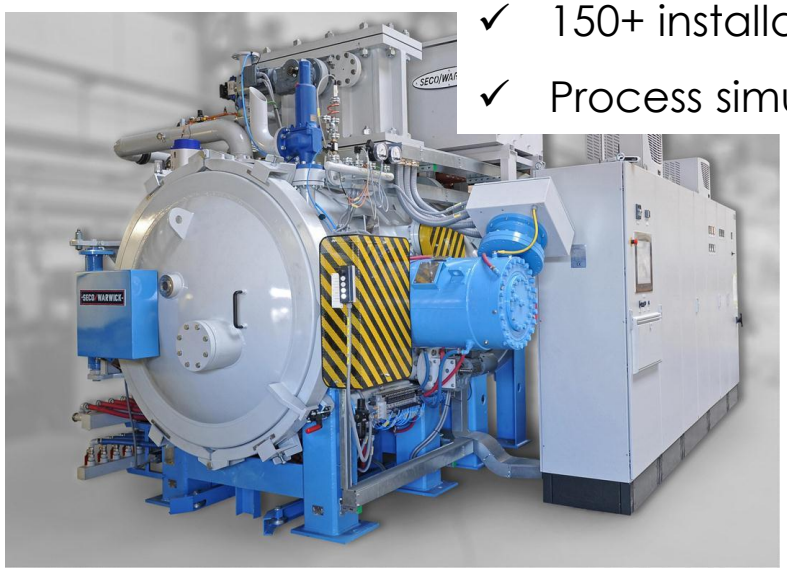
Economical Study of Carburizing: Atmospheric vs. Vacuum

Typical equipment for LPC

LOW PRESSURE CARBURIZING BY SECO/WARWICK



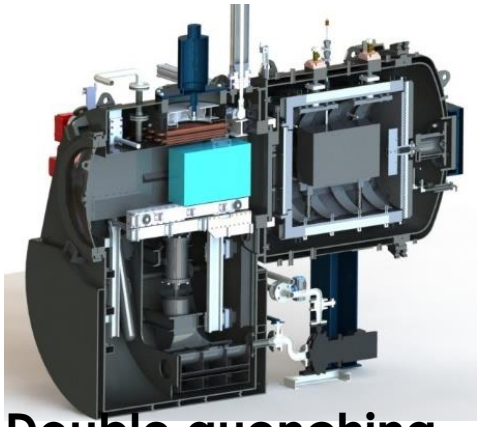
- ✓ 20+ years of experiences
- ✓ 150+ installations worldwide
- ✓ Process simulator SimVaC



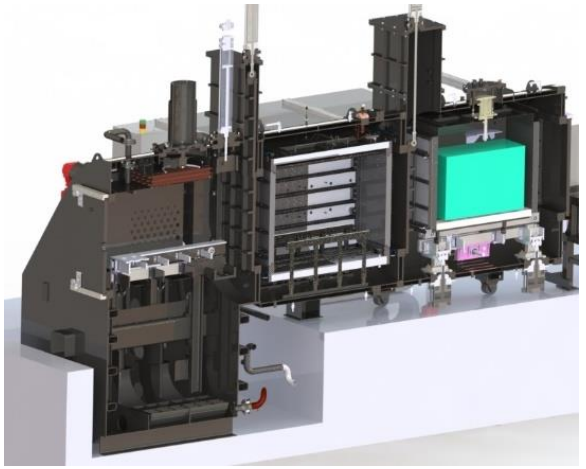
SECO/WARWICK INVENTION MEETS RELIABILITY

TYPICAL EQUIPMENT FOR LPC

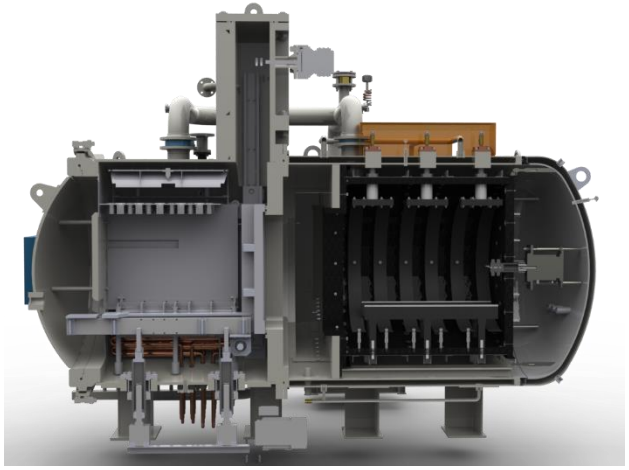
Single chamber
Gas Quenching
15 bar



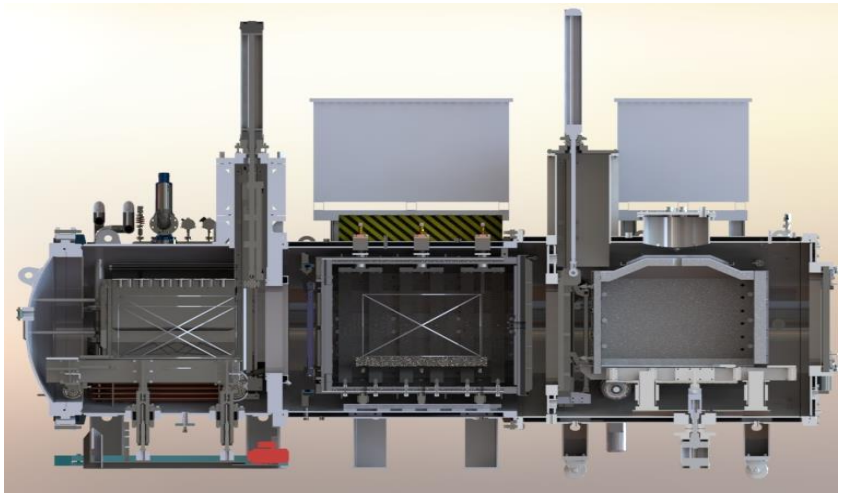
Double quenching
Oil hardening



Triple chamber
Oil hardening



Double chamber
Gas Quenching
25 bar



Triple chamber
Gas Quenching
25 bar

EQUIPMENT FOR OVERSIZED PARTS

Model 2.0VVPT-2OQ-82/67

Technical data:

- 850x1900x1700mm
- 5000kg

Technical data:

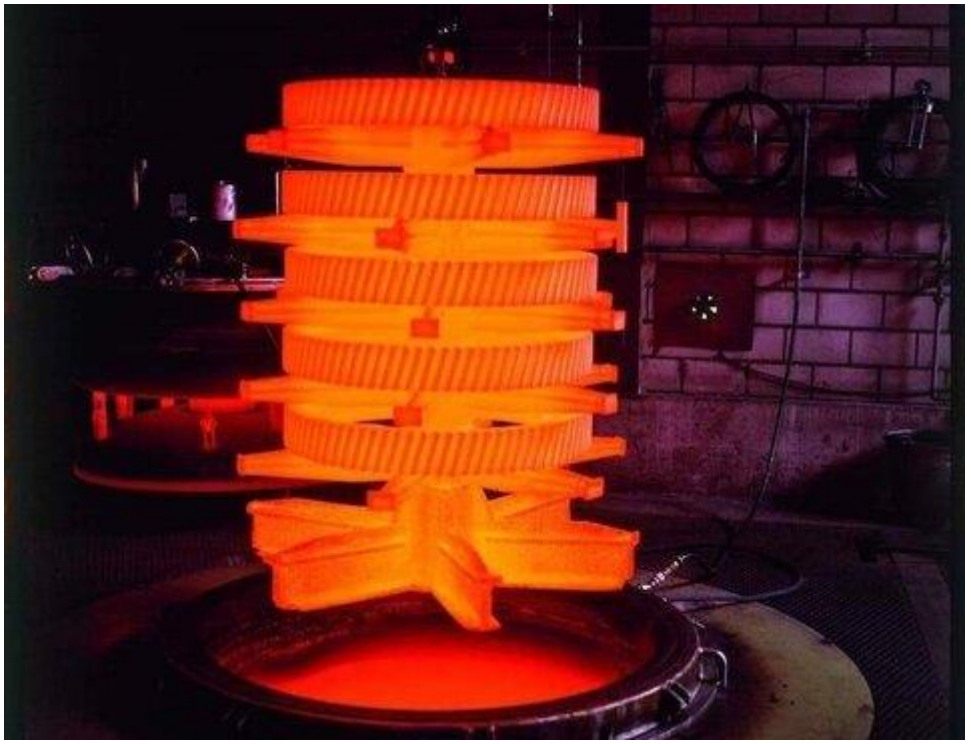
- 1500x1500x1500mm
- 2000kg

Model 2.0VVP-2OQ-70/84N

Traditional technology

TRADITIONAL PIT FURNACE APPLICATIONS

- ✓ Carburizing
- ✓ Heating for quenching
- ✓ Large components



Characteristic feature:

Opening to air

at process temperature

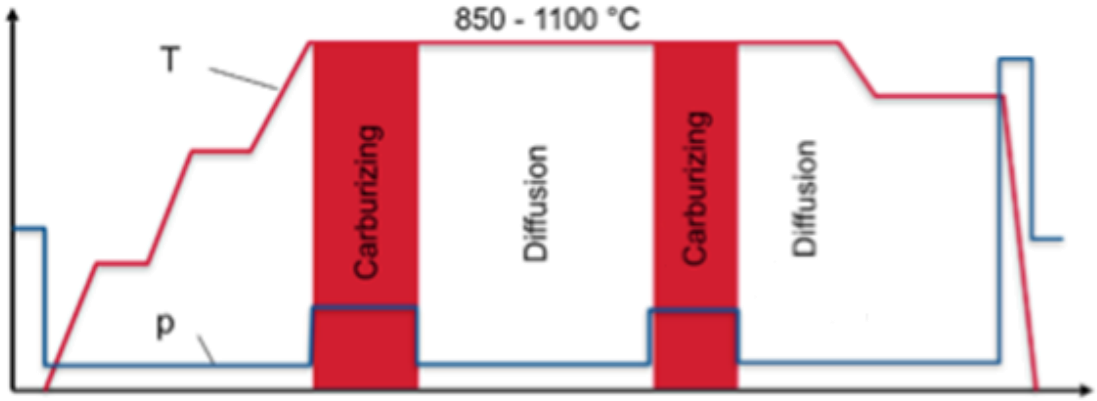
TRADITIONAL TECHNOLOGY DISADVANTAGES

- ✓ Long process time, temperature limit
- ✓ Typical carburizing temp. 920-940°C
- ✓ Limited lifespan of retorts and fans
- ✓ Presence of IGO
- ✓ Flammable atmosphere (CO + H_2)
- ✓ Emission of CO/CO_2
- ✓ Risk of fire and explosion
- ✓ Atmosphere conditioning time

LPC technology - Fundamentals and benefits

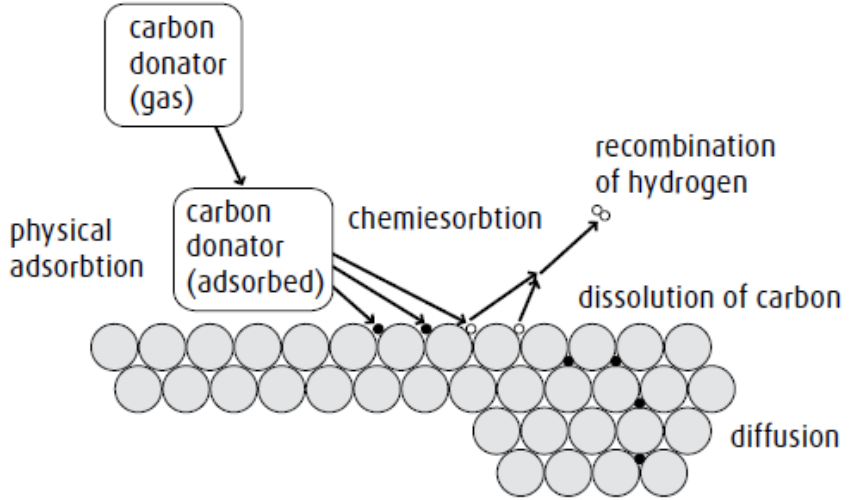
LOW PRESSURE CARBURIZING – FOUNDAMENTALS

- Process temperature – above **850°C**, typical **900-980°C** and up to even **1100°C**
- Process pressure **1-15 mbar** abs (5-7 mbar pressure fluctuations to improve the gas penetration through the densely packed charges)



Process phases:

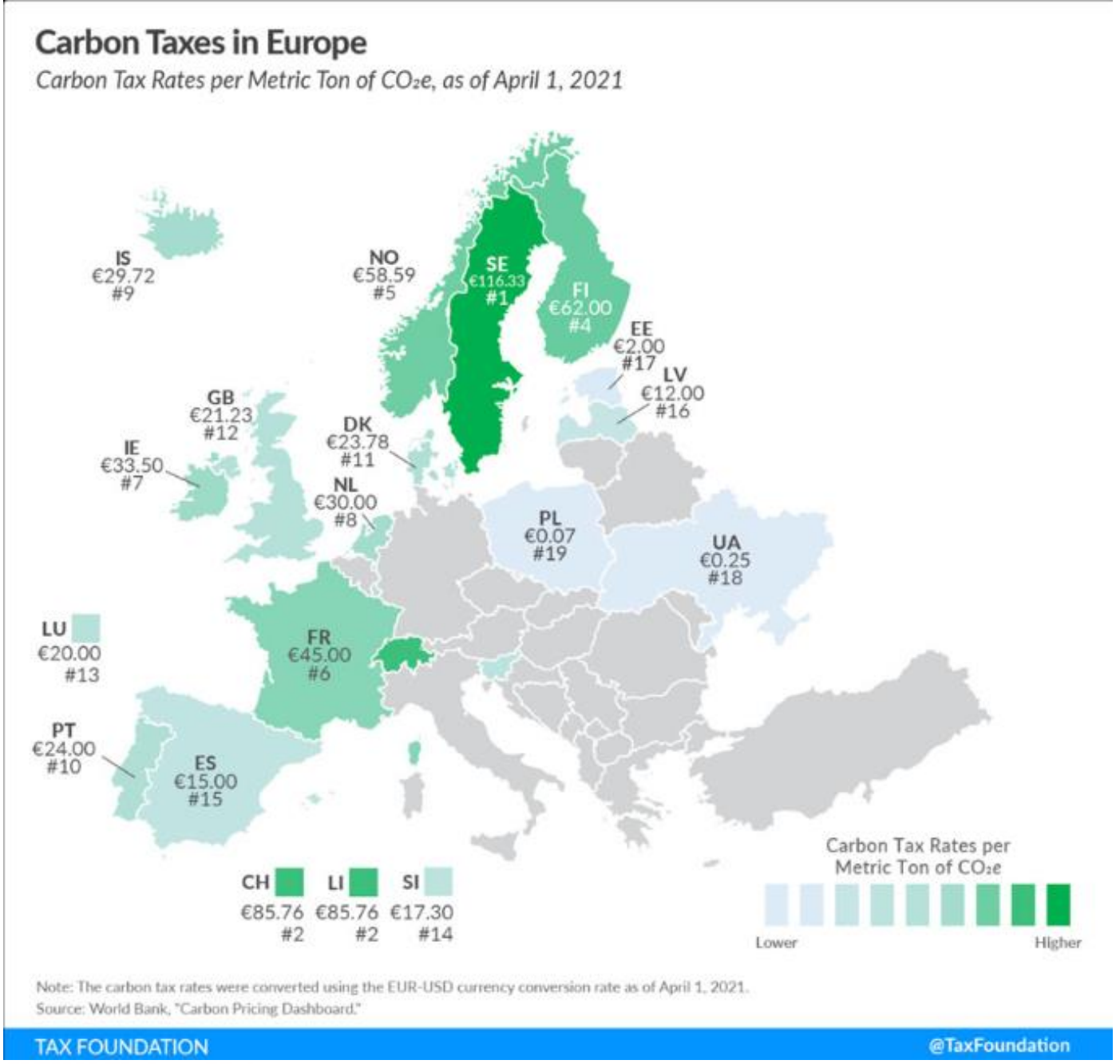
- **Carburizing**
  (gases transfer – carbon carriers (donator) – into the work zone)
- Dissociation
  (thermal or catalytical decomposition of process gases to obtain a high concentration of carbon in a relatively very short time)
- Absorption
  (i.e. the deposition of free atoms of saturated component at the border of solid phase as a film with a thickness similar to the diameter of an atom)
- **Diffusion**
  (diffusion of carbon into the depths of the material)



LOW PRESSURE CARBURIZING

- ✓ Effective and efficient carburizing
- ✓ Excellent process uniformity & quality
- ✓ Ideal surface quality
- ✓ **Fast, high temperature processes**
- ✓ No IGO
- ✓ Reduction of process consumables and costs
- ✓ Minimal consumption of process gases
- ✓ No time loss for atmosphere preparation and conditioning
- ✓ On-demand start-up and shut down
- ✓ Safe, no open flame, no risk of fire or explosion
- ✓ **Low heat and by-product emission (without CO & CO2)**
- ✓ Environmentally friendly

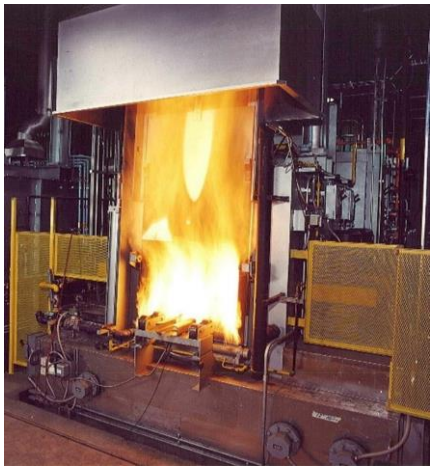
CO_2 TAX


Carbon Taxes in Europe
Carbon Tax Rates per Metric Ton of CO₂e, as of April 1, 2021
IS €29.72 #9
NO €58.59 #5
SE €116.33 #1
FI €62.00 #4
EE €2.00 #17
LV €12.00 #16
GB €21.23 #12
IE €33.50 #7
DK €23.78 #11
NL €30.00 #8
PL €0.07 #19
UA €0.25 #18
LU €20.00 #13
FR €45.00 #6
PT €24.00 #10
ES €15.00 #15
CH €85.76 #2
LI €85.76 #2
SI €17.30 #14
Carbon Tax Rates per Metric Ton of CO₂e
Lower
Higher
Note: The carbon tax rates were converted using the EUR-USD currency conversion rate as of April 1, 2021.
Source: World Bank, "Carbon Pricing Dashboard."
TAX FOUNDATION
@TaxFoundation

CO_2 EMISSION

Atmosphere Carburizing:

- Natural gas, Methane, LNG = **2,7 kg** CO_2/kg
- Propan, LPG = **3,0 kg** CO_2/kg
- Methanol = **1,4 kg** CO_2/kg
- **25 m³/h** ENDO atm = **10 kg/h** CO_2
  = **80 ton/y** CO_2



Vacuum carburizing, LPC:

- Acetylene = **0,0 kg** CO_2/kg

Electrical Energy:

- Coal = **0,8 kg** CO_2/kWh
- Oil = **0,6 kg** CO_2/kWh
- Gas = **0,2 kg** CO_2/kWh

EXAMPLE

Carburizing:

- Size 9912
- ECD - 1,1 mm
- Load - 800 kg net

Atmosphere Carburizing gas heated:

- Electrical Energy = 308 kWh
- Natural gas = 146 kg
- Propan = 5 kg
- Total CO_2 emission = **625 kg/proc**
- Unit CO_2 emission = **0,78 kg/kg load**

Vacuum Carburizing:

- Electrical Energy = 533 kWh
- Natural gas = 0
- Propan = 0
- Total CO_2 emission = **373 kg/proc**
- Unit CO_2 emission = **0,47 kg/kg load**

Less 40 % CO_2

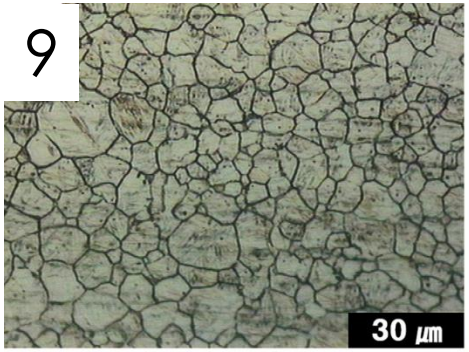
CARBURIZING TEMPERATURE EFFECT

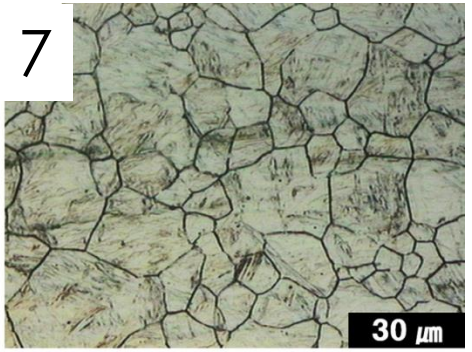
Effective Case Depth [mm]	Carburizing Time					
	925°C	950°C	980°C	1000°C	1020°C	**1040°C**
0.50	**1h 23m**	57min	39 min	30 min	24 min	**19 min**
1.00	**5h 30m**	3h 50m	2h 35m	2 hours	1h 35m	**1h 15m**
2.00	**22 hours**	15h10m	10h 20m	8 hours	6h 10m	**4h 50m**
Time relation	**100 %**	69 %	47 %	36 %	28 %	**22 %**

Tab.1. Carburizing time of 16MnCr5 for the given case depth with criterion of 0.35%C, at particular temp.

AUSTENITE GRAIN SIZE ASTM

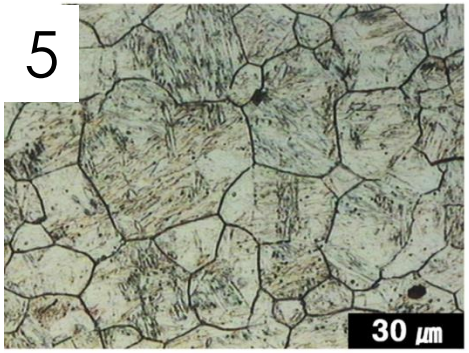
900°C

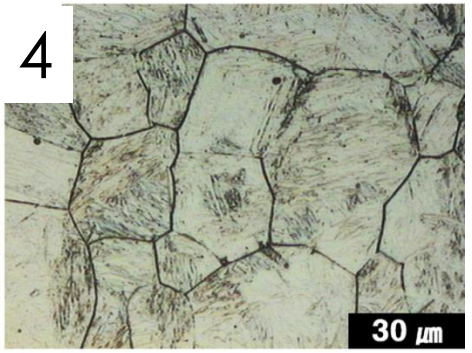




950°C

1000°C

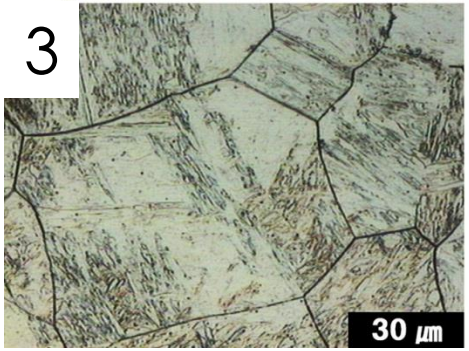


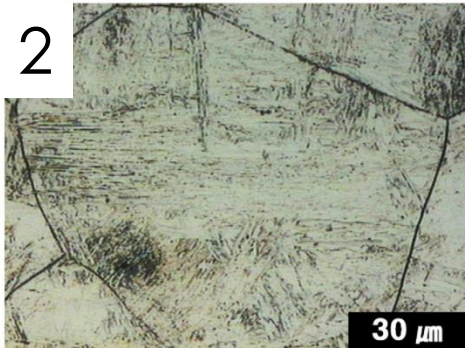


1050°C

Industrial Limit
ASTM 5

1100°C

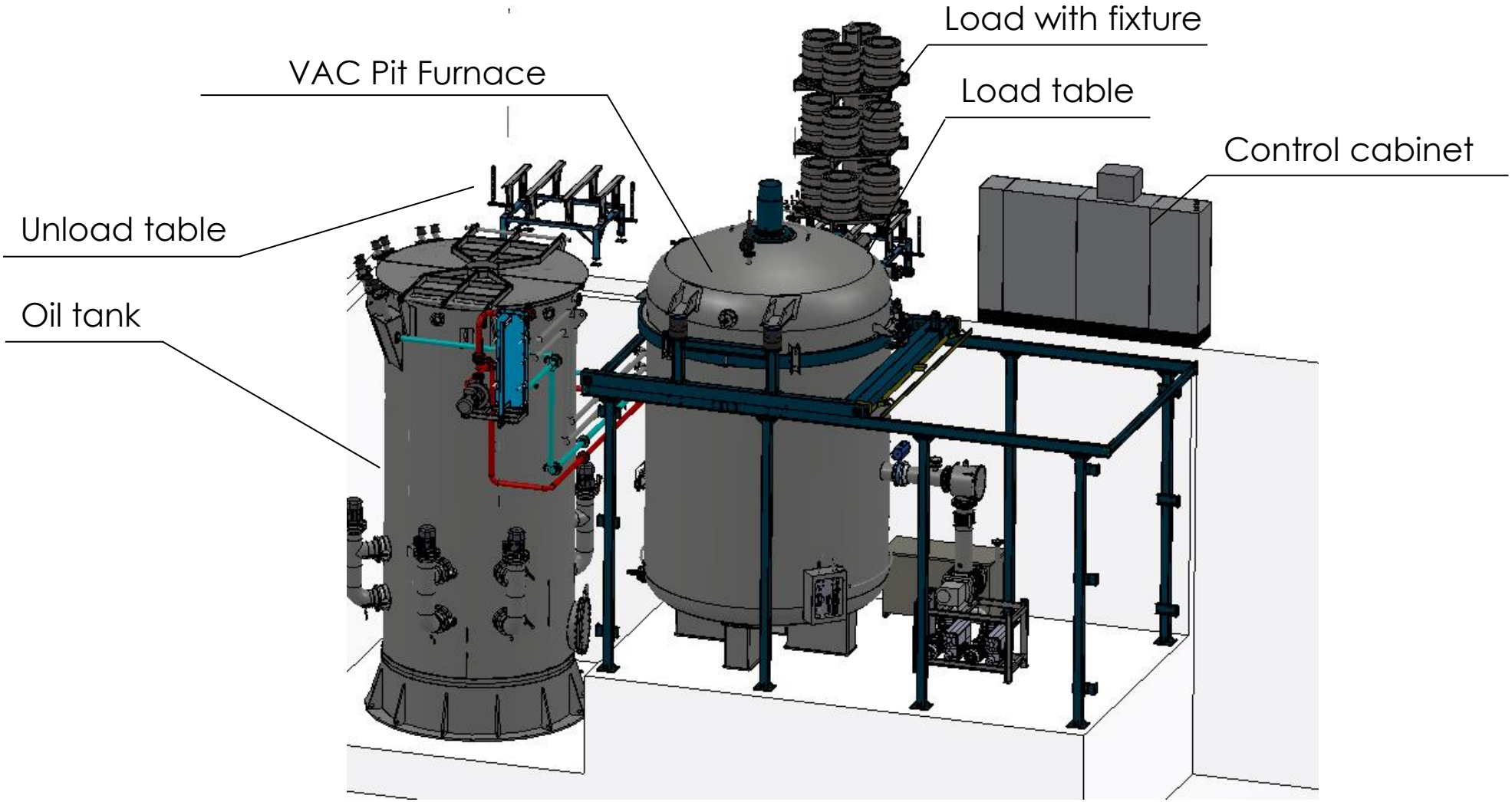




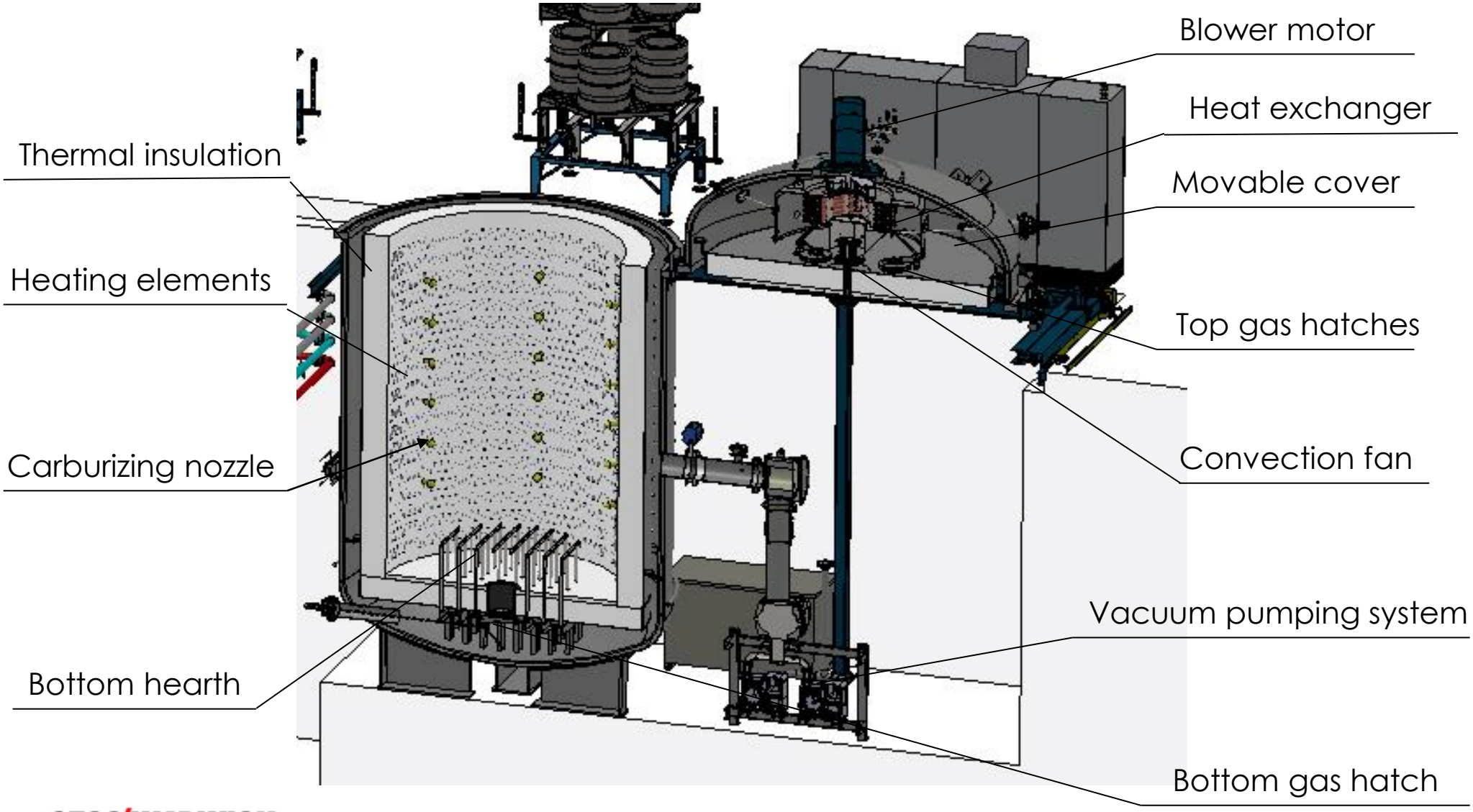
1150°C

Pit LPC SYSTEM DESIGN

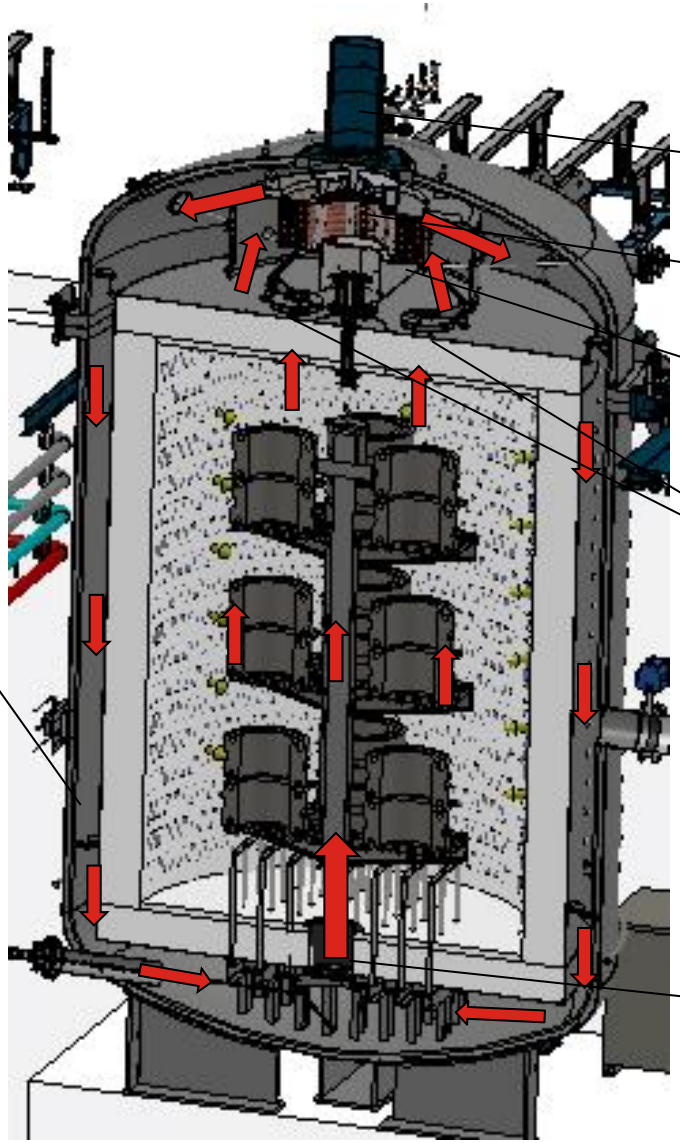
PIT LPC FURNACE – INSTALLATION



CROSS SECTION



GAS COOLING



Blower motor

Blower fan

Heat echanger

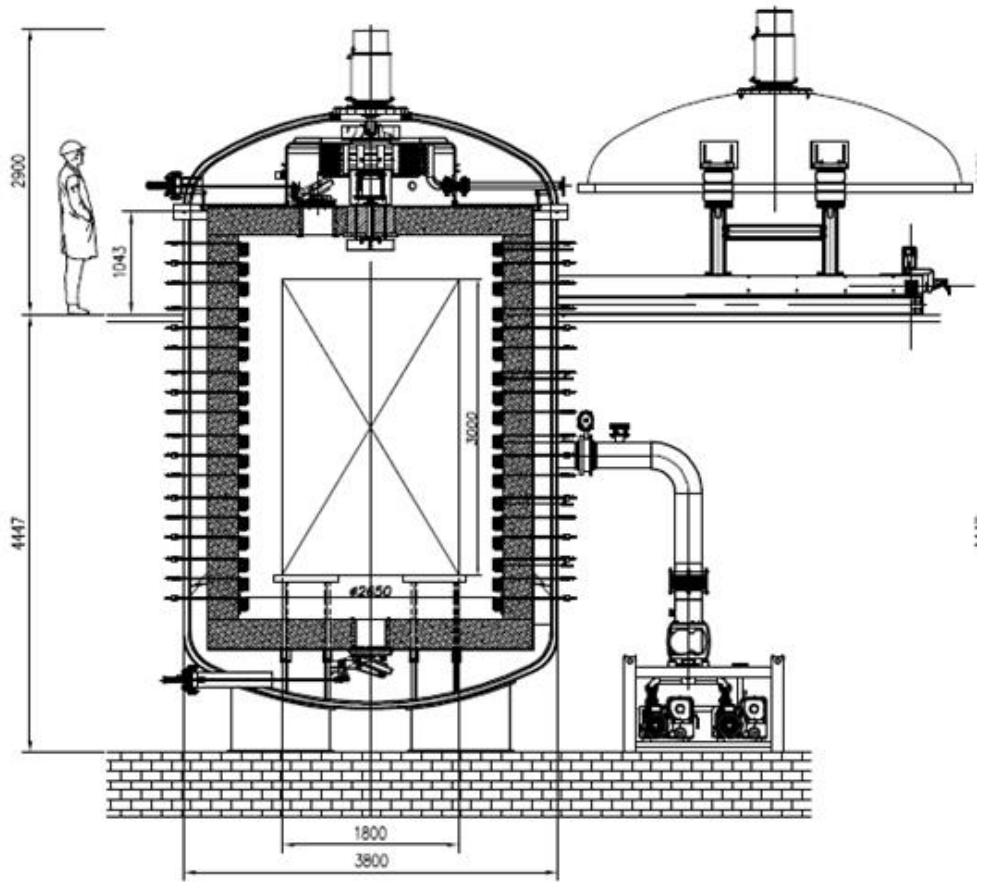
Double wall vessel

Top hatch

bottom hatch

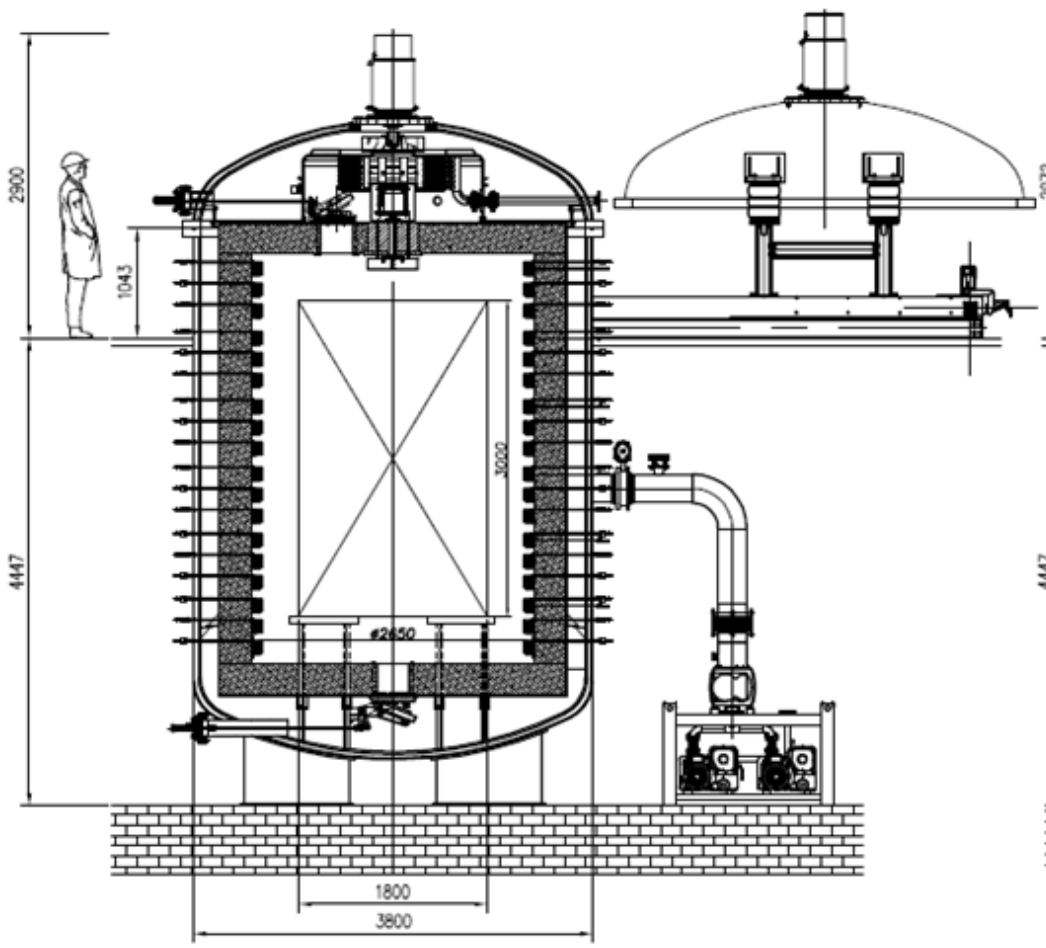
TECHNICAL SPEC. PIT LPC -1830

- ✓ Working zone dia.1800 x 3000 mm
- ✓ Load gross mass 8 000 kg
- ✓ Temperature 1050 °C
- ✓ Heating power 360 kW
- ✓ Vacuum range 10^{-2} mbar
- ✓ Carburizing gas acetylene
- ✓ LPC technology FineCarb
- ✓ Process simulator SimVaC
- ✓ Forced nitrogen cooling

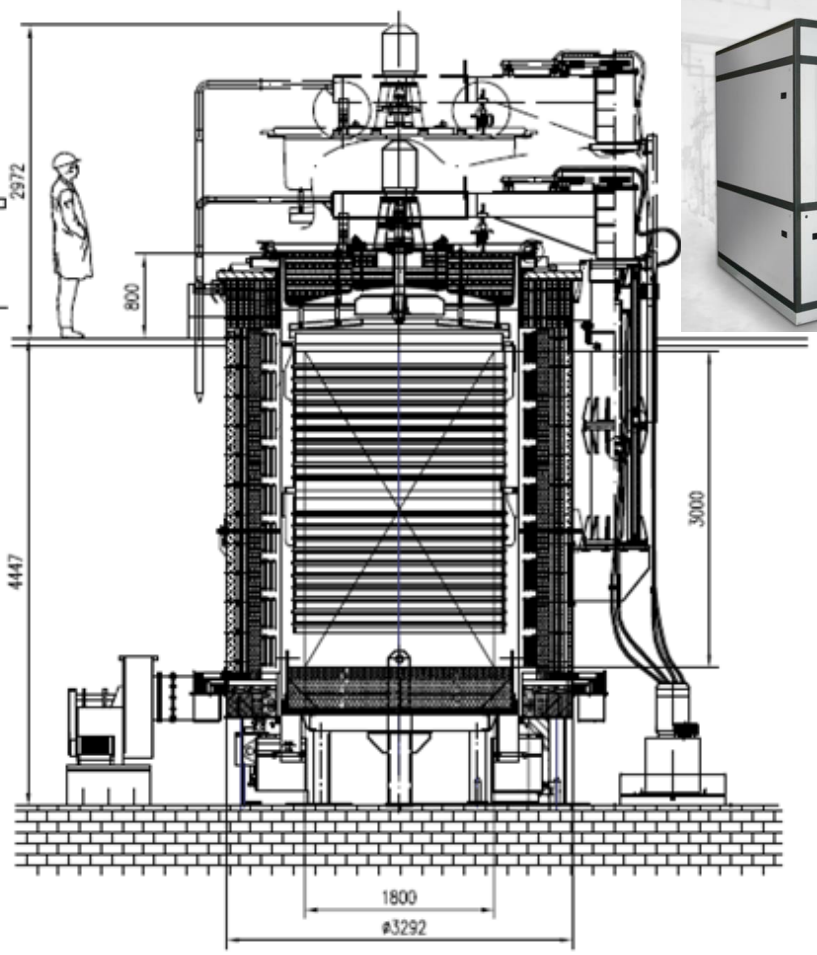


VAC AND ATM FURNACES

PIT LPC -1830



PIT ATM -1830



GEN

Economical Study of Carburizing Atmospheric vs. Vacuum

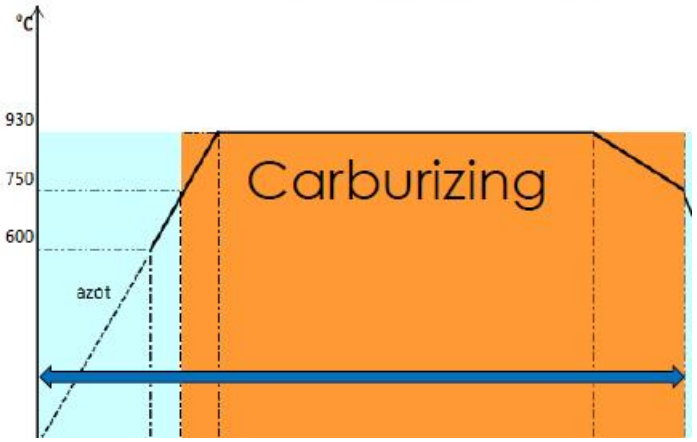
BASE PROCESS ASSUMPTION

Reference process taken from a pit retort carburizing furnace with endothermic atmosphere generated from propane, according to the following:

- ✓ Effective case depth **4,0 mm** (18CrNiMo7-6)
- ✓ Carburizing temp. **925 C**
- ✓ Batch gross mass **8 000 kg**
- ✓ Parts surface area **20 m2**

Process timing:

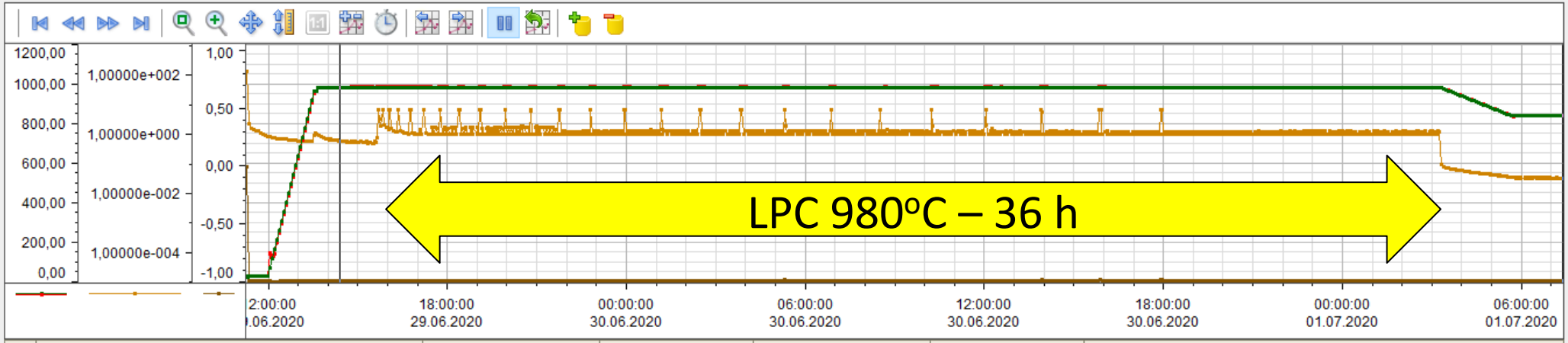
- ✓ Total process time **90 h** including:
  - ✓ Heating-up 5 h
  - ✓ Carburizing 82 h
  - ✓ Cooling to 840 C 3 h
- ✓ Direct quenching in oil



PROCESS TREND

RAPORTY - TRENDY

Nr procesu: 173 Czas startu: 6/29/2020 11:16:37 AM Czas końca: 7/1/2020 7:22:50 AM



	Label	Time stamp (LL)	Y value (LL)	Time stamp (UL)	Y value (UL)
1	WSP temperatura [°C]	29/06/2020 14:24:18	980,00	01/07/2020 07:22:50	843,00
2	Temp. kontrolna#1 [°C]	29/06/2020 14:24:18	980,40	01/07/2020 07:22:50	842,90
3	Ciśnienie pieca [bar]	29/06/2020 14:23:57 [i.]	-0,99 [i.]	01/07/2020 07:22:38	-0,99
4	Próżnia robocza [mbar]	29/06/2020 14:25:01	6,08071e-001	01/07/2020 07:22:50	3,27905e-002
5					

UTILITIES CONSUMPTION ATM VS. VAC 1800X3000 MM

Parameter	Unit	ATM PIT	VAC PIT		
Carburizing temperature	°C	925	925	980	1040
Process duration	h	**90** **100 %**	**90** **100 %**	**50** **55 %**	**31** **34 %**
Electrical energy	kWh	**8100** **100 %**	**6400** **79 %**	**4400** **55 %**	**3600** **44 %**
Nitrogen	Nm^3	140	310	200	170
Acetylene	kg	-	16	16	16
Propane	kg	200	-	-	-
Cooling water	m^3	390	390	210	130

UTILITIES COSTS COMPARISON PER PROCESS

Parameter	Unit	ATM PIT	VAC PIT		
Carburizing temperature	°C	925	925	980	1040
Process duration	h	**90** **100 %**	**90** **100 %**	**50** **55 %**	**31** **34 %**
Electrical energy	EUR [0,15 eur/kWh]	1220	965	666	538
Nitrogen	EUR [0,30 eur/Nm3]	42	93	60	51
Acetylene	EUR [4 eur/kg]	-	64	64	64
Propane	EUR [0,5 eur/kg]	100	-	-	-
Cooling water	EUR	-	-	-	-
Total :	EUR	**1362** **100 %**	**1122** **82 %**	**790** **58 %**	**653** **48 %**

PROCESS ECONOMICS

Parameter	Unit	ATM PIT	VAC PIT		
Temperature	°C	925	925	980	1040
Number of processes	No./year 7000 h	77 **100 %**	77 **100 %**	139 **180 %**	219 **285 %**
Price per process	EUR 2 EUR/kg	9 000	9 000	9 000	9 000
Revenue [R]	EUR/y	692 308	692 266	1 247 182	1 970 152
Unit process costs	EUR	1362	1122	790	653
Yearly Processes costs [Pc]	EUR/y	104 777	86 279	109 473	142 858
R – Pc	EUR/y	587 531	605 986	1 137 709	1 827 294
Process costs SAVINGS of VAC Pit	EUR/y	**0**	**18 456**	**550 179**	**1 239 764**

CONCLUSION OF ECONOMIC COMPARISON

✓ Installation of a **vacuum** pit furnace with **low pressure carburizing** results in saving costs, reduction of process time and increases throughput.

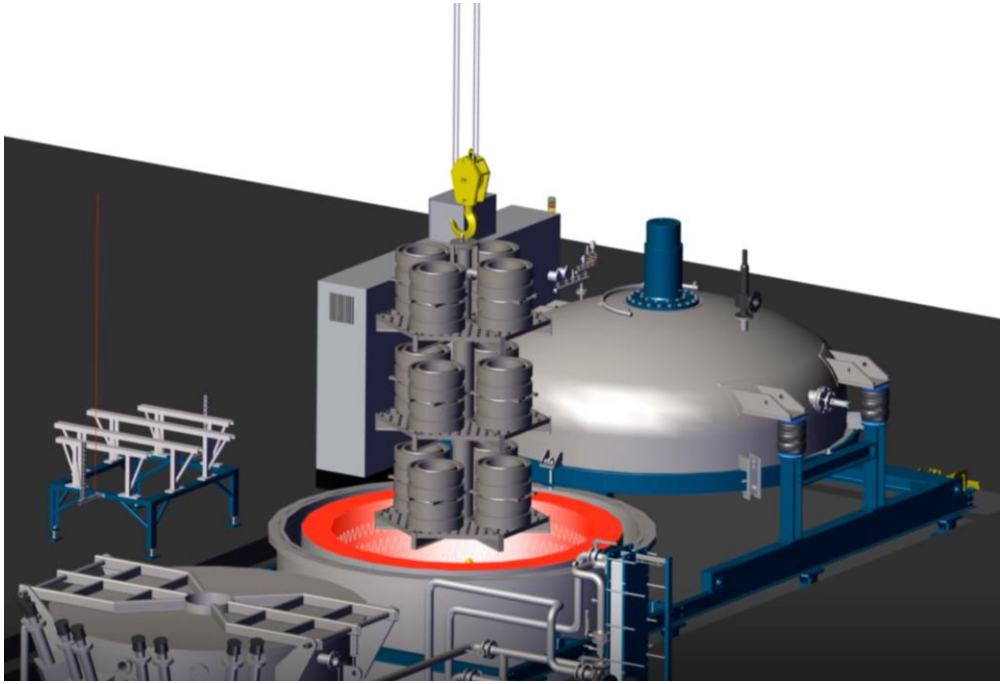
✓Process time can be reduced **2 times at 980 C** and almost **3 times at 1040 C** and the throughput increases accordingly.

✓Process costs can be reduced of **half at 980 C and 1040 C**.

✓Total cost savings can reach **0,5 million Euro per year** for processes in 980 C and **1,2 million Euro in 1040 C**(for estimated unit costs, market price and the same costs of: labor, maintenance, depreciation, etc.).

✓Austenite grains grow at high temperature therefore, processes over 1000 C may require additional actions for making grains finer what was not considered in this study

BENEFITS OF PIT LPC OVER ATMOSPHERE FURNACE



- ✓ Less process costs
- ✓ Multiple throughput
- ✓Less utility consumption
- ✓ Fit into existing space
- ✓ Elimination of an atmosphere generator
- ✓ Less emission
- ✓ … plus all LPC benefits and over 20 years of experiences

POTENTIAL CUSTOMERS

- ✓ Wind turbines
- ✓ Heavy machines
- ✓ Shipbuilding
- ✓ Railway
- ✓ Mining, oil & gas

Rys. 2. Nowoczesne pędniki azymutalne z zabudowanymi silnikami elektrycznymi o mocy 14 MW [2]

SECO/WARWICK

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Paweł Okińczyc

Vacuum Heat Treatment