

S^{OLAR} CRATCES

Carbonator: From Modeling to Development

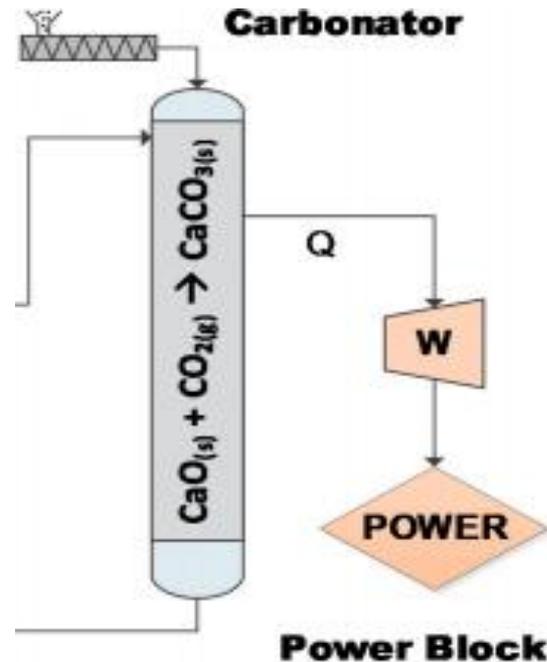
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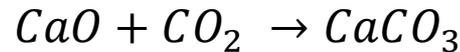


Carbonator: a brief description

- Initially, CaO solids are introduced to the reactor via a screw feeder.
- Preheated CO₂ is entering from the top.
- A heat exchanger composed of a set of helical coils encircles the reactor in order to transfer the energy released by the exothermic reaction ($\text{CaO} + \text{CO}_2 \rightarrow \text{CaCO}_3$)



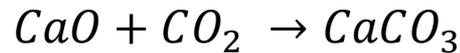
Mathematical Model



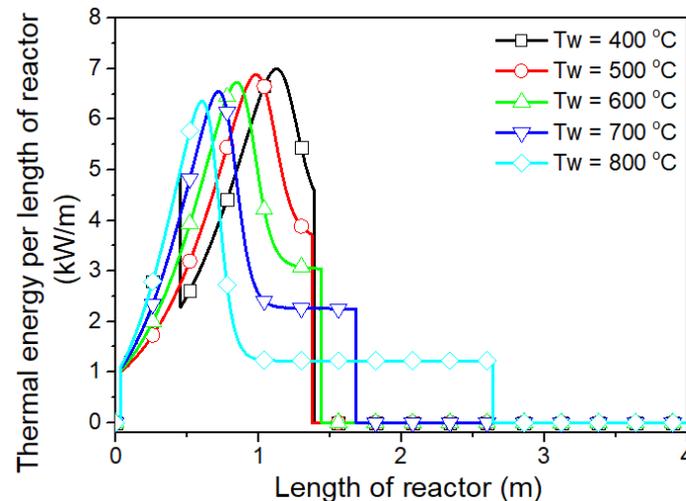
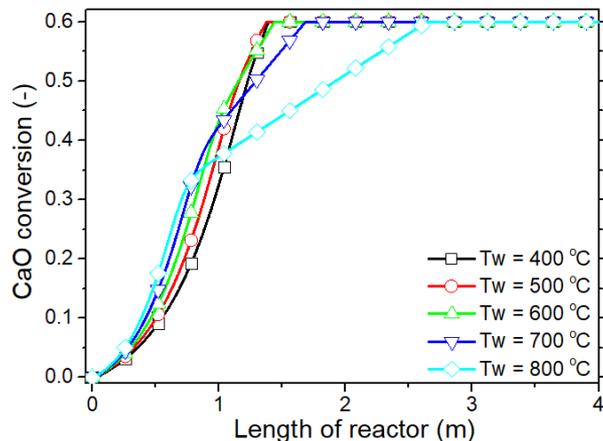
- A one-dimensional (1D), steady-state carbonation model was developed to describe the physical and chemical phenomena taking place in a downflow carbonator reactor.
- The model was developed in a generic form and it was used in accordance with the SOCRATCES project design criteria e.g. 10Kw thermal power.
- The affect of various parameters on the performance of the reactor was studied.
 - Wall temperature
 - Mass Flows CO₂, CaO
 - Pressure

The simulation has shown that carbonation up to 60% can be achieved in drop tube reactor with downflow gravity direction. Additionally, by monitoring parameters such as wall temperature, mass flow, etc. safety and efficiency of the process can be improved.

Mathematical Model



- After a preliminary study, we concluded to create a reactor of 4 meters length to assure that CaO conversion will reach up to 60% for feeding rates up to 80kg/hr and also thermal energy will be transferred efficiently through the working gas to Stirling engine.
- Estimated Thermal Power distribution along the reactor's length.



Reactor Design

➤ A two parts Reactor Design

Since we need ~ 4 meters to ensure that the reaction will have the time to take place and the maximum conversion will be reached we had to tackle three main issues:

1. The CO₂ preheating process
2. To achieve the maximum heat exchange between the reactor's wall and the medium (air)
3. The overall handling of the reactor e.g. the assembly on the general construction, the nesting inside the furnaces, the thermal elongation, etc.

Reactor Design

- High temperature operation
 - Super Alloys in both Reactor and Coil Tubes



- Heat exchanger design
 - 10 Tubes 1/2"
 - Collector 1 1/2" that assures that gas speed will not cause any problems e.g. vibrations.

Reactor Design

- Upper part -> CO₂ preheating
- Lower part -> Air heat exchanger



- Easier construction
- Easier handling during assembly

Carbonator Pre-Heating

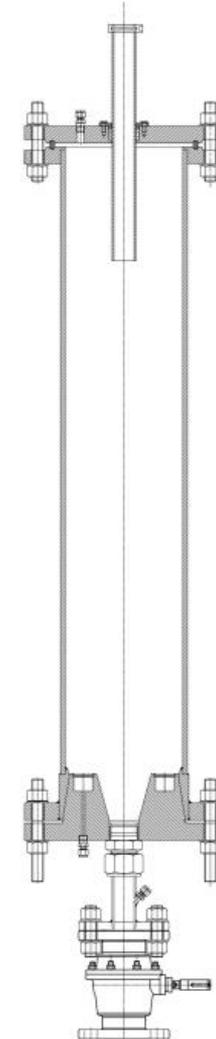
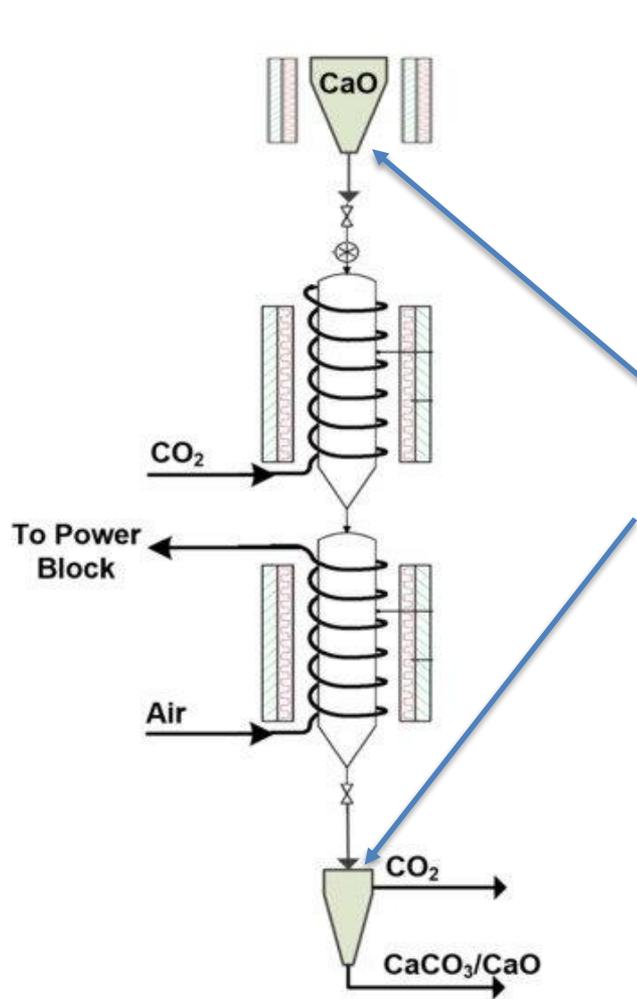
- ✓ Two Furnaces of 44.4 kW each are employed to reach temperatures at Reactors wall up to 850oC
- ✓ Thermocouple elements are used to monitor both Furnaces operation and Reactor's wall temperature
- ✓ The control of the furnaces operation temperature is done via PID controllers from the Programmable Logic Controller (PLC) of the unit



Swappable Vessels

Requirements

- Easy attachment to the unit
- Moveable
- Handle high temp ~650oC
- Handle reactor's
- Handle the stick material that is (



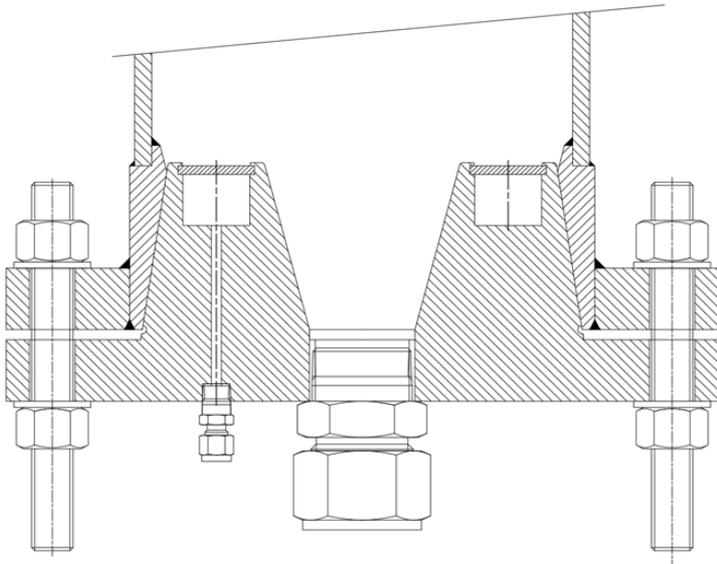
Swappable Vessels

- ✓ Simplified solution for attaching and detaching the vessel without tools
- ✓ Special design to absorb the elongation of the reactor inside the vessel and to avoid gas leakages by employing gasket seal cord
- ✓ Super alloys for the body of the vessel along with 316 stainless steel parts to ensure operation in high temperatures



Swappable Vessels

- ✓ Special design for the bottom of the vessel
 - ✓ Slope to ensure that material flows
 - ✓ Fluidization ring
 - ✓ Able to remove the flange after operating in high temperatures.



- ✓ Designed to stand on a trolley easy to move by one person.



Swappable Vessels

Is it a Vessel or is it a Reactor?

- ✓ With the way the vessel is designed it is very easy to operate as an in situ calcination reactor.
- ✓ We performed such experiments in CERTH facilities with success.

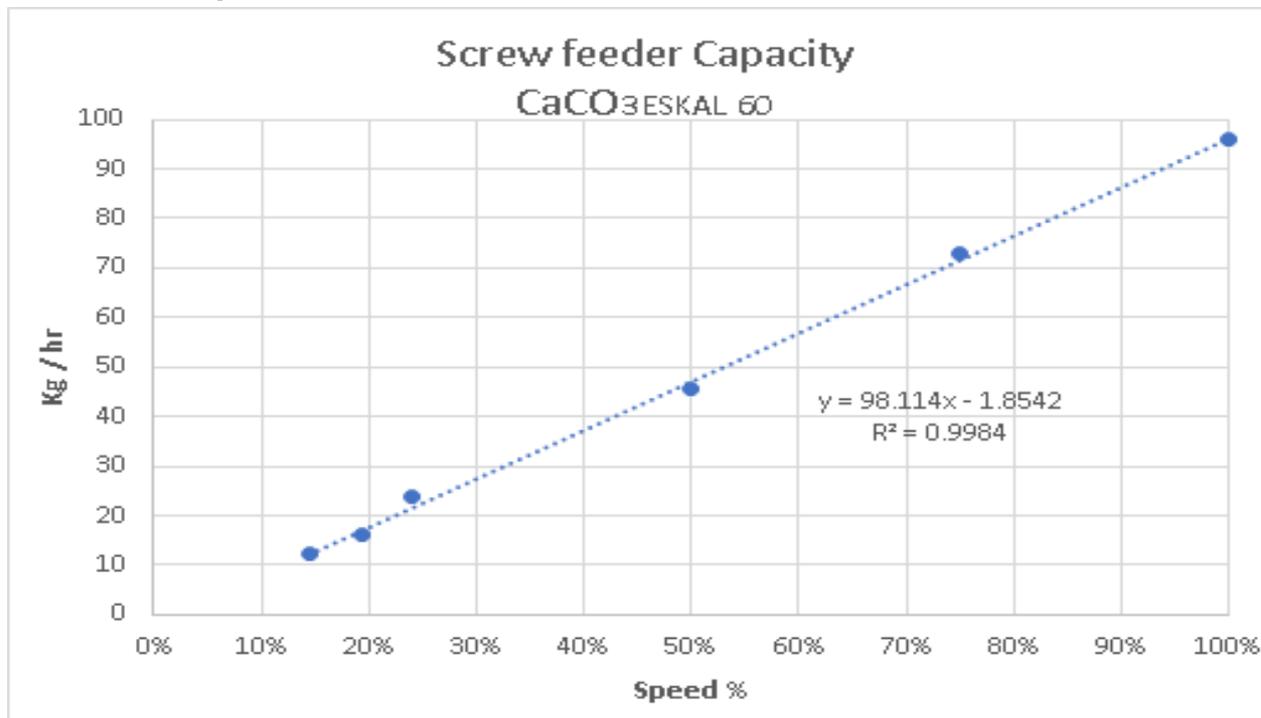
#	Sample position	Weight Loss (%)	Estimated CaO content (%)
1	Sample from the top of the vessel	14.59%	66.8%
2	Sample from the bottom of the vessel	11.34%	74.2%

- We estimate that we achieved a conversion rate of 70%.

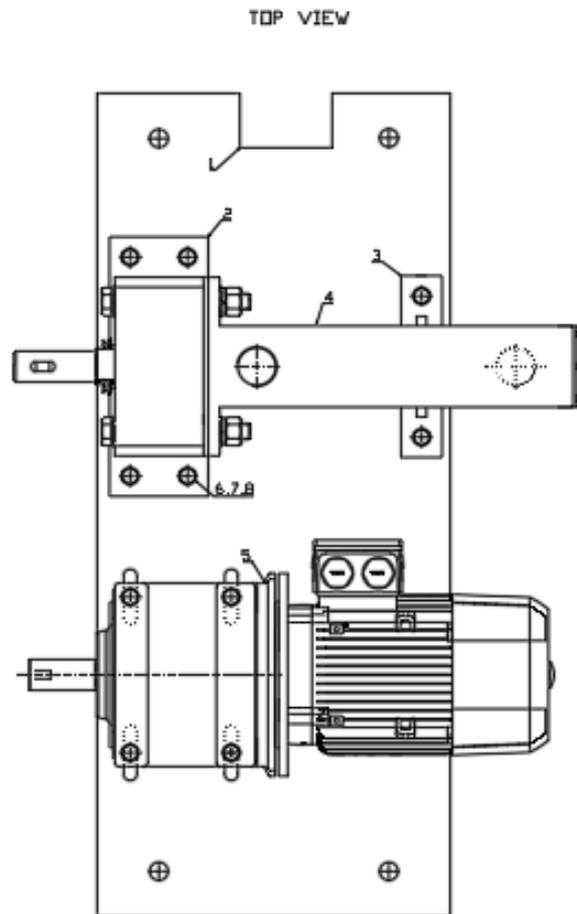


Feeding

- Variable feeding capacity from 20Kg – 80Kg per hour
- Hardened screw and shaft walls
- Design that allows operation with material up to 300°C



Feeding



Swappable Vessel , Valve & Screw Feeder group

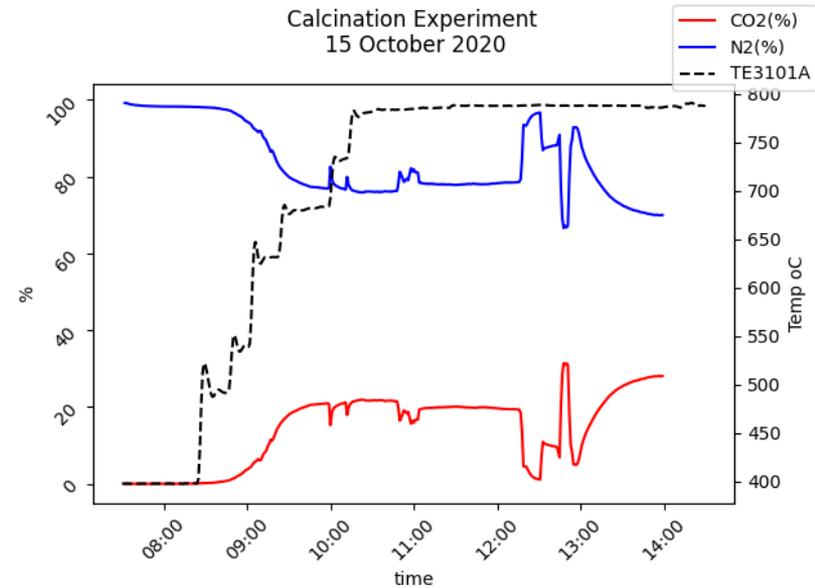


Experiments Conducted in CERTH facilities

Calcination Experiment

Materials / Conditions

- ESKAL 60 (30 Kgs)
- Vacuum (~0.15 bar)
- 800°C
- N₂ Presence
- 3 Days
- Portable CO₂ gas analyzer



Results

Estimated CaO content (%) ~ 70% (Three samples)

Experiments Conducted in CERTH facilities

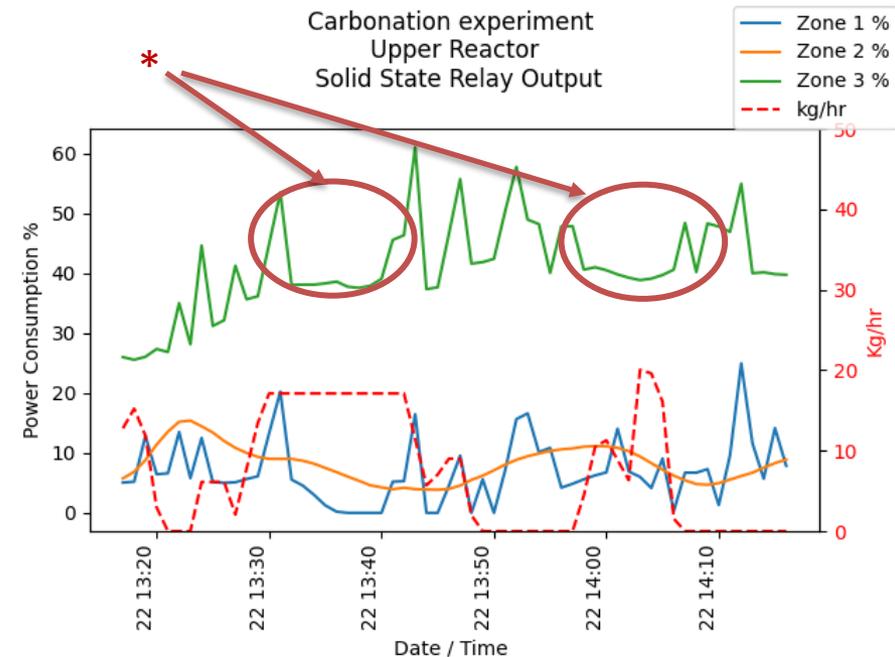
Carbonation Experiment

Materials / Conditions

- Calcined ESKAL 60
- 800 °C
- CO₂
- Air

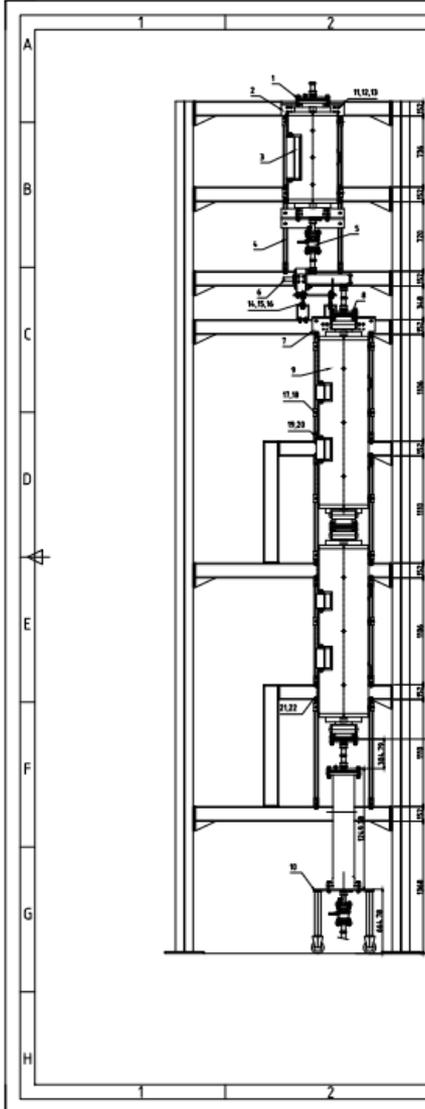
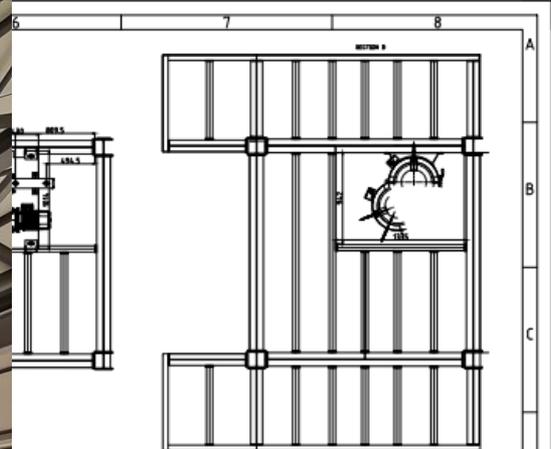
Results

- Estimated CaO content (%) ~ 33.3% (Two samples)
- Estimated Conversion CaO → CaCO₃ ~66%



* power consumption is significantly lower when reaction takes place.

STATUS OF CARBONATOR DEVELOPMENT

22	6	Single Angle Fittings	Unistrut	P1026			
21	20	Channel Nuts M12	Unistrut	PNL12ZP			
20	30	Screws M12 x 35					
19	10	Double Angle Fittings	Unistrut	P1346			
18	16	Channel Nuts M10	Unistrut	PNL10ZP			
17	16	Screws M10 x 35					
16	16	Washer M20					
15	16	Nuts M20					
14	4	Threaded rod M20x250mm					
13	30	Washer B12					
12	60	Nuts M12					
11	30	Screws M12 x 45					
10	1	Vessel trolley		Socr-100.20.1xx			
9	2	Furnace xx kW (ATS ltd)		Socr-100.20.111			
8	2	Reactor		Socr-100.20.112			
7	3	Reactor supports	304	Socr-100.20.104			
6	1	Screw Feeder Group		Socr-100.20.1xx			
5	2	Ball Valve	Metso	00084610AA-01			
4	11	Single channel P1000	Unistrut				
3	1	Furnace xx kW (ATS ltd)		Socr-100.20.110			
2	2	Feeding vessel supports	304	Socr-100.20.107			
1	2	Feeding vessel		Socr-100.20.101			
POS		items	name - dimensions	mtr	standard	dwg no	weight
FILE NAME		general assembly rev. 5 bul.dwg		SHEET		SCALE	
SIZE		A2				1:30	
DRAWN		04/22/2020 ggrav					
CHECK		P. Vouretakis					
APPR.		P. Vouretakis					
ISSUED							
REV							
DWTG NO							
UNIT						Socratces Unit Assembly	
						Socr - 100.20.100	

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Thanks for your attention

PP(s): CERTH

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EKETA
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ΕΡΕΥΝΑΣ & ΤΕΧΝΟΛΟΓΙΚΗΣ
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This Project has received funding from European Commission by means of Horizon 2020, the EU Framework Programme for Research & Innovation, under Grant Agreement no.727348.