CALIX CALCINED PRODUCTS
Calix has successfully used the CFC Reactor at Bacchus Marsh to calcine the following minerals:

- Magnesite
- Dolomite
- Limestone
- Bauxite
- Kaolin
- Gypsum

in its CFC Reactor. It has successfully trialed the CFC Reactor to both dry and gasify brown coal.

Calix believes that its CFC reactor design is leading the world in the development of 3rd generation calciners which are both energy efficient and which have minimal CO2 emissions.

ACTIVATED PRODUCTS
Calix has demonstrated that its CFC Reactor produces unique, highly activated products. In technical terms, this means that the particles have a very high surface area and are porous. Many applications of calcined products require such properties. Calix has found that its products are about 5-8 times more active, with surface areas in excess of 100 m2 per gram.

For Calix customers, these attributes add value to their industrial processes. The industries for building products, fertilizers and soil stabilization can benefit from these applications. Calix is working with its customers to optimize the products - a feature enabled by the flexibility for operating the CFC reactor. In the past, customers of calcined products had to adapt their process to meet the limited range of product specifications from conventional calciners. The CFC Reactor provides a product which maximizes the performance of our customers’ products.

Calix has found its own uses for such active materials, such as for CO2 sorption to decarbonize industrial process, such as power generation and Synthetic Natural Gas production from coal. In this particular application, Calix has embedded its CFC reactor into the Endex Reactor so that the CO2 sorbent, its active time, is regenerated for thousands of cycles.

IP PROTECTION
Calix has developed an extensive IP portfolio which is protected by patents. The patent covers the CFC Reactor, and its integration into its Endex Reactor, activated products and the applications of these activated products. Calix can provide its customers with the monopoly rights they require... at a price.

Footnotes
1 World Cement Conference, London, March, 2011
2 Hurley
4 “Turning Biomass into Adhesives and Plastics”, National Renewable Energy Laboratory (USA), Technology Brief, May, 1994
6 There is a large literature on these reactors, particularly Riser reactors, which are used for cracking petroleum. eg Theologos, K.N., I.D. Nikou, A.I. Lygeros, and N.C. Markatos, “Simulation and Design of Fluid Catalytic-Cracking Riser-Type Reactors,” AIChE Journal, 43(2):486-494 (1997).
7 www.torftech.com
The Maerz Double Shaft Kiln

**Calcination Background**
- Calcination is the process of transforming a mineral by the application of heat.
- The minerals processing industry calcines 1,500,000,000 tonnes per annum at temperature above 800°C, and even more when lower temperature mineral processes are considered.
- Industries include cement, lime, alumina, magnesite, chromium and titanium dioxide.

**Industrial Calcination**
- There are many types of traditional calciners – rotary kilns, shaft kilns, flash calciners.
- In the 1970-80s, kiln designs were optimized to minimize energy consumption.

**Future Cement and Calix**

**Calcination Flash Calcination**
Flash calciners use ground minerals as feedstock, instead of the rocks used in rotary and shaft kilns.
The particles are entrained by the transport gas with velocities in the range of 5-30 m s⁻¹, the calcination is completed in seconds, compared to hours in rotary and shaft kilns.
The Calytic Flash Calciner, patented and developed by Calix, is a flash calciner which separates the process of combustion and calcination through the transfer of heat across the walls of the calciner, rather than calcining the particles directly in the combustion heat. Steam is generally used for transport of the solids through the reactor.

**The Steam**
- Acts as a catalyst for many calcination reactions, by speeding up the calcination process.
- Promotes the fracturing of the particles, reducing the need for grinding.
- Transports the particles, and acts as an efficient heat transfer medium.
- Is readily condensed and recycled.

The benefits of the CFC process are:
- For carbonate minerals, the CO₂ produced by thermal decomposition of the mineral in the hot steam can be extracted by condensing the steam to give a pure CO₂ stream typically with >98% purity. This CO₂ can be sequestered, by geosequestration or biosequestration, or sold for industrial processes.
- The calcined product is not sullied by impurities from the combustion process.
- The steam promotes the production of very active products, which enhance the performance of the products in many applications of interest to Calix. Examples of this have been described in the application of the CFC for the production of building materials, as presented by Calix at the World Cement Conference.
- One CFC Reactor can be configured within hours to calcine different minerals.
- The reactors are compact, and can be readily demounted and installed at different sites, for example, at mine sites to minimize transport costs.
- The separation of combustion and calcination allows the combustion process to be optimized to produce minimal emissions of carbon monoxide (CO) and nitrous oxides (NOx). Conventional calciners struggle to keep these emissions below the regulatory standards, and often has to run at sub-optimal energy efficiency to meet regulations.
- Flexibility - Calix CFC Calciners can easily optimize the product properties to maximize the performance of our customers' products that use calcined materials.

The challenges for the CFC process arise from the requirement of transferring the heat across the steel boundary between the hot combustion gas and the flow of particles and steam. This has been made possible by the development of high temperature nickel chromium steels. To efficiently migrate the wall heat to the particles, Calix uses a Vortex Reactor design in which the tangential injection of the particles and steam into the reactor centrifuges the particles onto the steel walls.

The Vortex Reactor was first described by Hurley in 1931 and there is now a plethora of industrial applications. The Vortex Reactor was further developed by NREL (USA) for pyrolysis of biomass in 1991. The design principles of the Vortex reactor had been analysed by researchers at JPL Caltech. In developing the design, Calix also used knowhow from the design of Risér and Dønner reactors. The Torbed reactor uses the Vortex concept for pyrolysis and gasification.

**The CFC Reactor**
- The patented CFC Reactor design used by Calix is illustrated by the block flow schematic for calcining mineral carbonates such as magnesite, dolomite and limestone.
- The mineral feedstock, typically ground to less than 200 microns, is entrained in a superheated gas stream for injection into the Pre-heater, where it is heated to the calcination temperature through the steel walls of this stage by the flue gas from the combustion system. This injection is tangential so the particles are centrifuged onto the reactor walls by the vortex flow. The Pre-heater segment is designed so that the maximum energy is extracted from the combustion gas, so that the energy efficiency of the reactor is maximized.

The preheated particles and steam enter the Reactor segment injected tangentially into the CFC Reactor where the temperature of the walls is controlled for the desired mineral reaction by the main gas burners. The heat transfer in this stage is also optimized by the vortex flow of particles through both the riser and downer stages of the reaction. The reaction releases CO₂ from the particles as they calcine, and the particles are entrained in the CO₂ and steam mixture. Control of the gas flows minimizes the residence time of the particles in the reactor so that the particles suffer minimal sintering for maximum reactivity.

The hot particles are ejected from the Reactor into the Filler where cyclones and ceramic filters separate the hot product particles from the gas streams. The steam is condensed from the gas steam, to deliver a CO₂ gas stream which can be compressed for sale and sequestration. The water is treated and then superheated as it is used to cool the hot product (not shown), so that the product can be conveyed to silos for distribution to customers.

Calix has placed a strong emphasis on the design in maximizing the heat transfer efficiency within the calciner, and recuperating the heat from the product streams. Calix achieves best practice by extracting heat from the combustion gas exhaust to pre-heat the air for the combustors, and by using the steam cycle to recover heat from the solids and gas streams to generate the superheated steam.

In large plants, the energy efficiency can be maximized by using excess steam to generate electrical power for the plant using a steam turbine. In addition, the CO₂ in the combustion gas stream can be captured using Calix’ Endex Reactors, to give a true zero-emissions calcination process.
**FEATURE**

**FUTURE CEMENT AND CALIX**

**CALCINATION BACKGROUND**
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**INDUSTRIAL CALCINATION**
- There are many types of traditional calciners - rotary kilns, shaft kilns, flash calciners.
- In the 1970-80s, kiln designs were optimized to minimized energy consumption.
- Traditional calciners emit large volumes of carbon dioxide. With advent of taxes and regulations limiting CO₂ emissions, the costs of calcined products will rise.
- This will impact on most manufactured products, leading to increase in costs.
- There is a need for calciner designs that capture CO₂ to ameliorate global warming.
- CO₂ is emitted from the fabrication of carbonate minerals such as limestone and magnesite.
- CO₂ is emitted from the combustion of fossil fuels and biomass for all calcined products.
- Calix Catalytic Flash Calciner technology captures the CO₂ from the calcination of carbonate minerals, as described in this note.
- Calix Endex Reactor technology captures the CO₂ from the combustion of fossil fuels and biomass for any industrial process, including the fuels for calciners.

This will be considered in the Endex Reactor note.

**CATALYTIC FLASH CALCINATION**
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