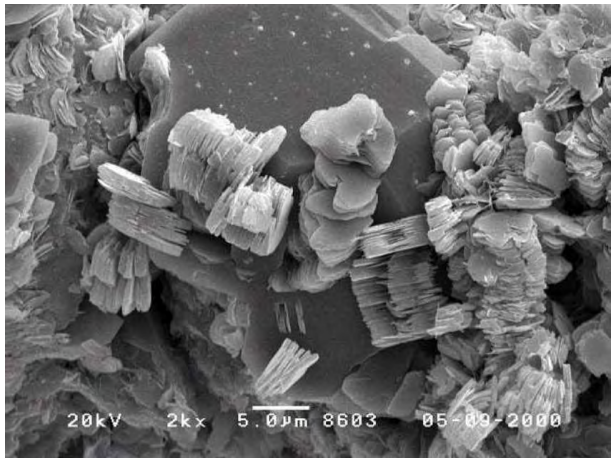
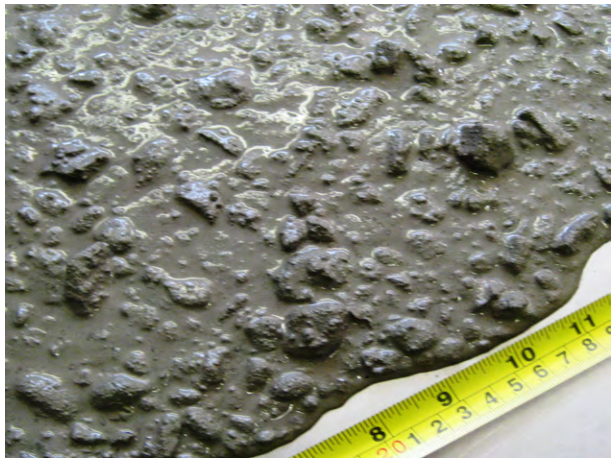
METAKAOLIN





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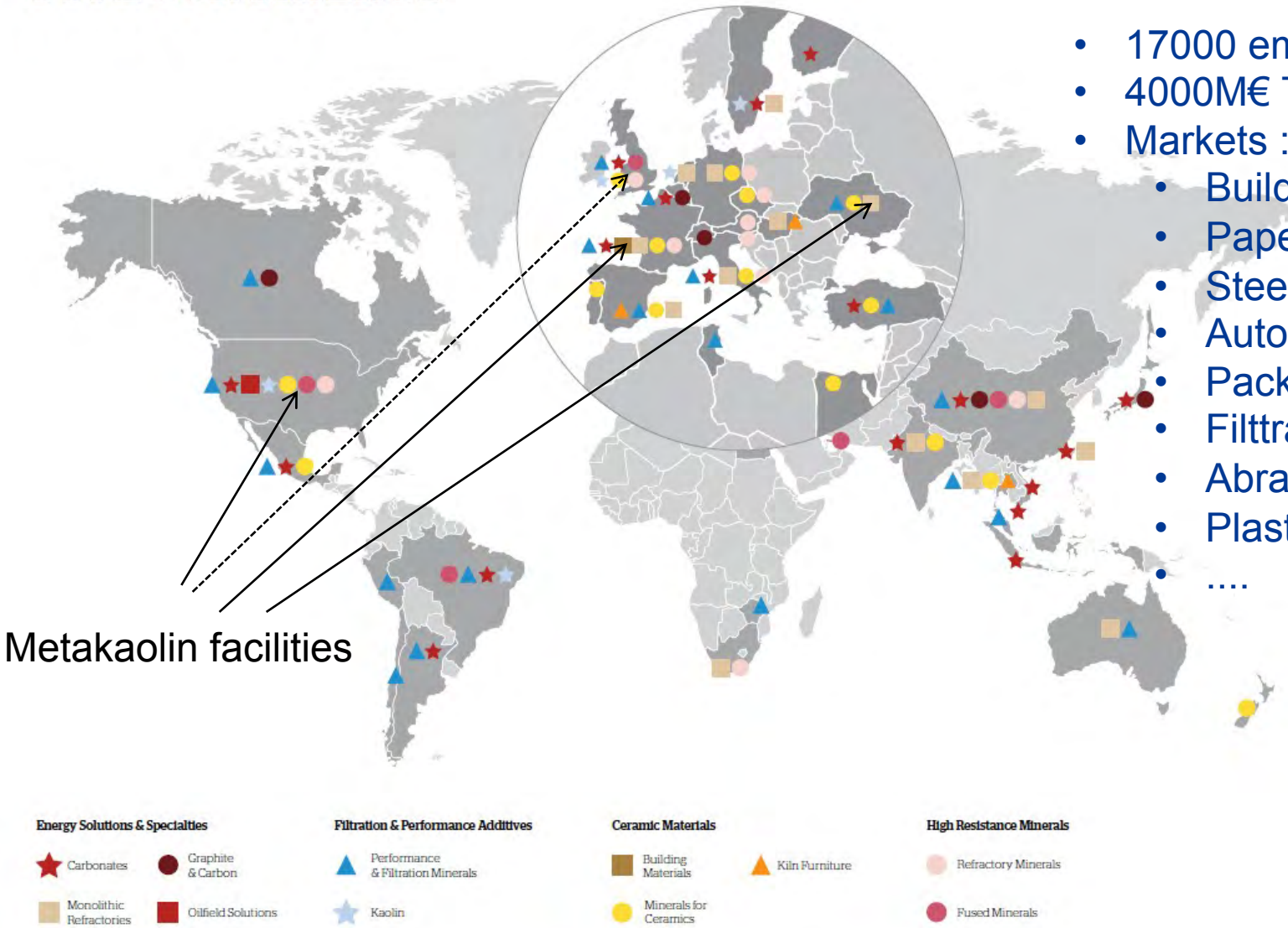
Imerys in a Nutshell



- 17000 employees
- 4000M€ Turnover
- Markets :
  - Building
  - Paper
  - Steel work
  - Automotive
  - Packaging
  - Filttration
  - Abrasive
  - Plastic
  - ....

Presence in 47 Countries with more than 250 Industrial Facilities

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What is a METAKAOLIN? Usage in cementitious material.

- METAKAOLIN is an Amorphous state of Kaolin or Kaolinic clay obtained by firing the mineral at a temperature between 700 and 950°C.
- Due to this Amorphous state, Metakaolin is able to react with lime in presence of water.
- Metakaolin react with lime released by cement during its hydratation. Lime could also be Natural lime, quick lime …used in some mortars or renders.
- It's a Pozzolanic material.
  - The Pozzolanic reaction = The reaction with lime (in presence of water)

- Consumption of free lime following :

Ordinary Portland Cement + H2O → CSH + CH

CH + AS2metakaolin → C2ASH8 + CSH

Binder

CH like free lime is responsible for degradation with time

C2ASH8 : additional phase due to Metakaolin. Dense phase.

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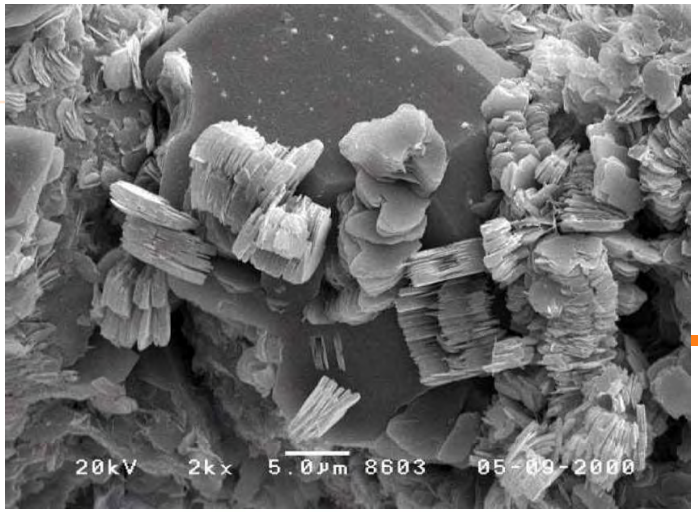
What is Metakaolin?



Thermal transformation of Kaolin / Kaolinite

Kaolinite : $2SiO_2\ Al_2O_3,\ 2H_2O$

Water — **Deshydroxylation** — 500-550°C

Métakaolinite $2SiO_2\ Al_2O_3$ — 750-950°

960-980°C

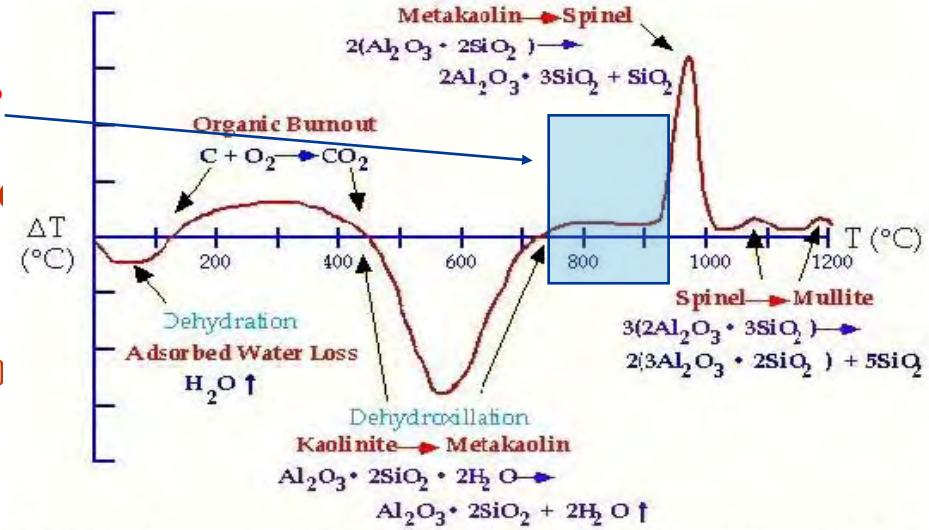
Si-Al Spinelle $Si_3Al_4O_{12}$

1100-1150

Mullite $3Al_2O_3\ 2SiO_2$

Chamotte

Over-heating = densification and loss of pozzolanicity



2.4. DTA thermogram of kaolin [DTA and TGA of Ball Clay and Kaolin, 1998]

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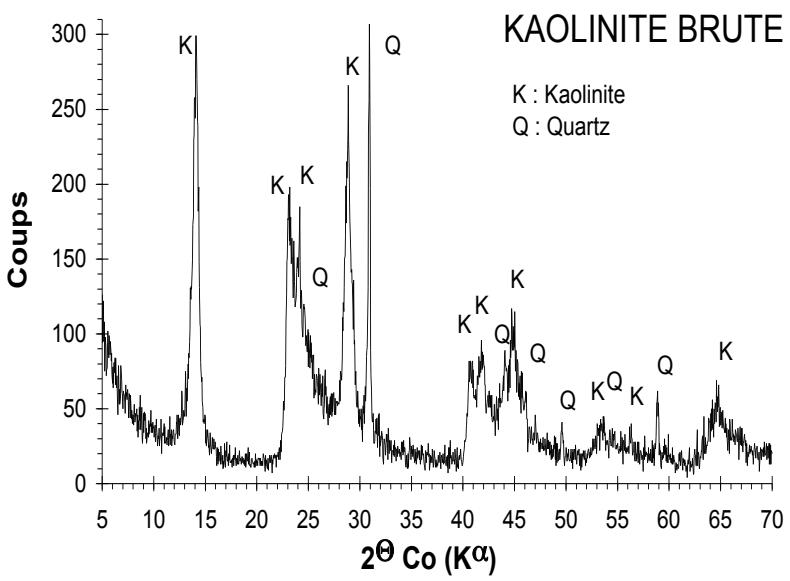
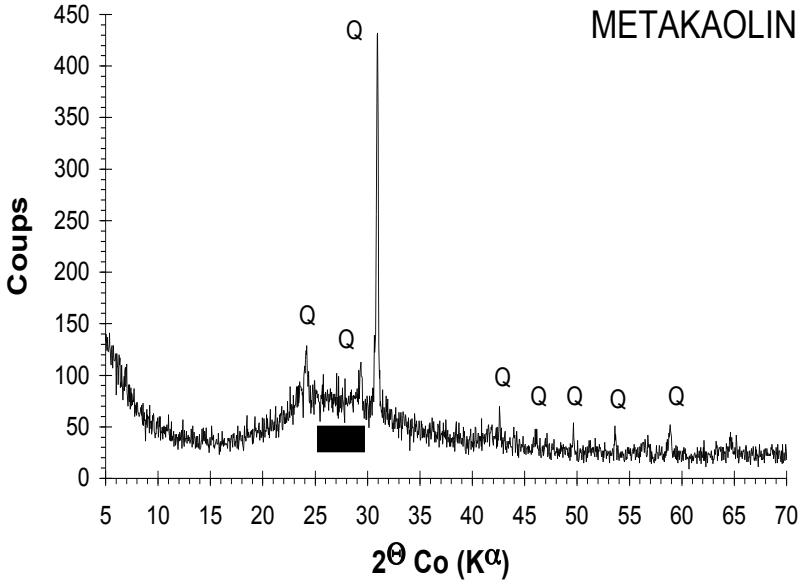
What is Metakaolin?

XRF show us the transformtion of clay/kaolin in amorphous material
Amorphous state is the one of interest for Geopolymer





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Calcination process

- As a basis for the calcination method, we must underlined that
  - Metakaolin quality is directly link to the source of Raw material so to the quarry it comes from
  - Ratio of kaolinite, so the global chemistry is a main parameter for the reactivity of the product
  - The way to prepare the kaolin is also a important parameter for the final result :
    - Pellets for rotary kiln
    - Milling - sieving for fine powder entering to flesh Kiln
  - Strict control of calcination is needed (Temperature, time)
  - Control of final product : reactivity, quality of the calcination, reliability, reproductibility

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Calcination process

Several kind of way to calcine a clay/kaolin but we can talk about two mains :

- Roraty kiln / circulation kiln :
  - « plate » kiln (type Herreshoff) (Imerys US)
  - Rotary Kiln : Imerys France (IRMC), Ukraine (VKV), US (CE Mineral)
- Flash kiln :
  - Torbed calciner (Imerys UK)
  - Flash kiln FCB type (IRMC, CLERAC)

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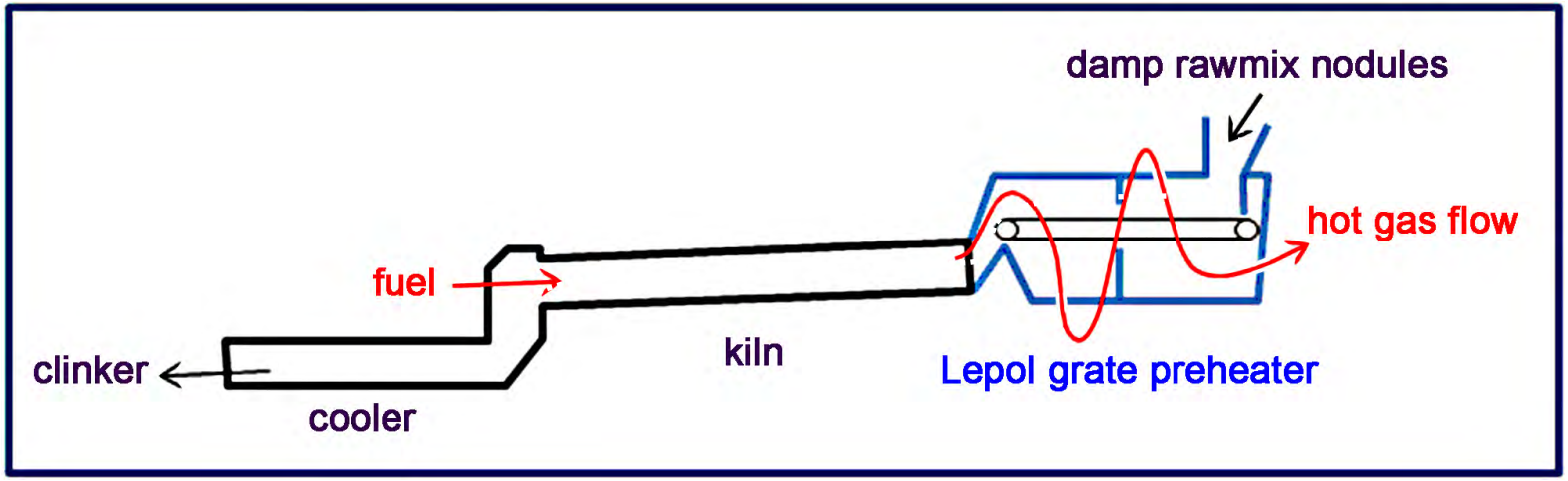
Rotary Kiln : IRMC (France), VKV (Ukraine)



Clérac France Kiln N°3 (L= 34 m, ø 2,5 m)
Production 10 T/heure
Fuel + Biogas + Saw dust

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Rotary Kiln : IRMC (France), VKV (Ukraine)

- *Avantages:*
  - Technology is reliable and robust (similar as cement plant)
  - Energy consumption is efficient (800-1200 KWh/t)
  - Good outlet rate for production (10-12 tons/h)

- *Drawbacks :*
  - Dehydroxylation control after heating : means to have a good knowledge of the process
  - Using pellets as inlet material means also that a temperature gradient exist in the product.
  - Product have to be milled after calcination so means harder material to mill so fineness is « limited »
  - Kiln have to be run continuously so need certain volume or combination with other materials.

Product available : ARGICAL M1000 (France), MK40 (Ukraine)

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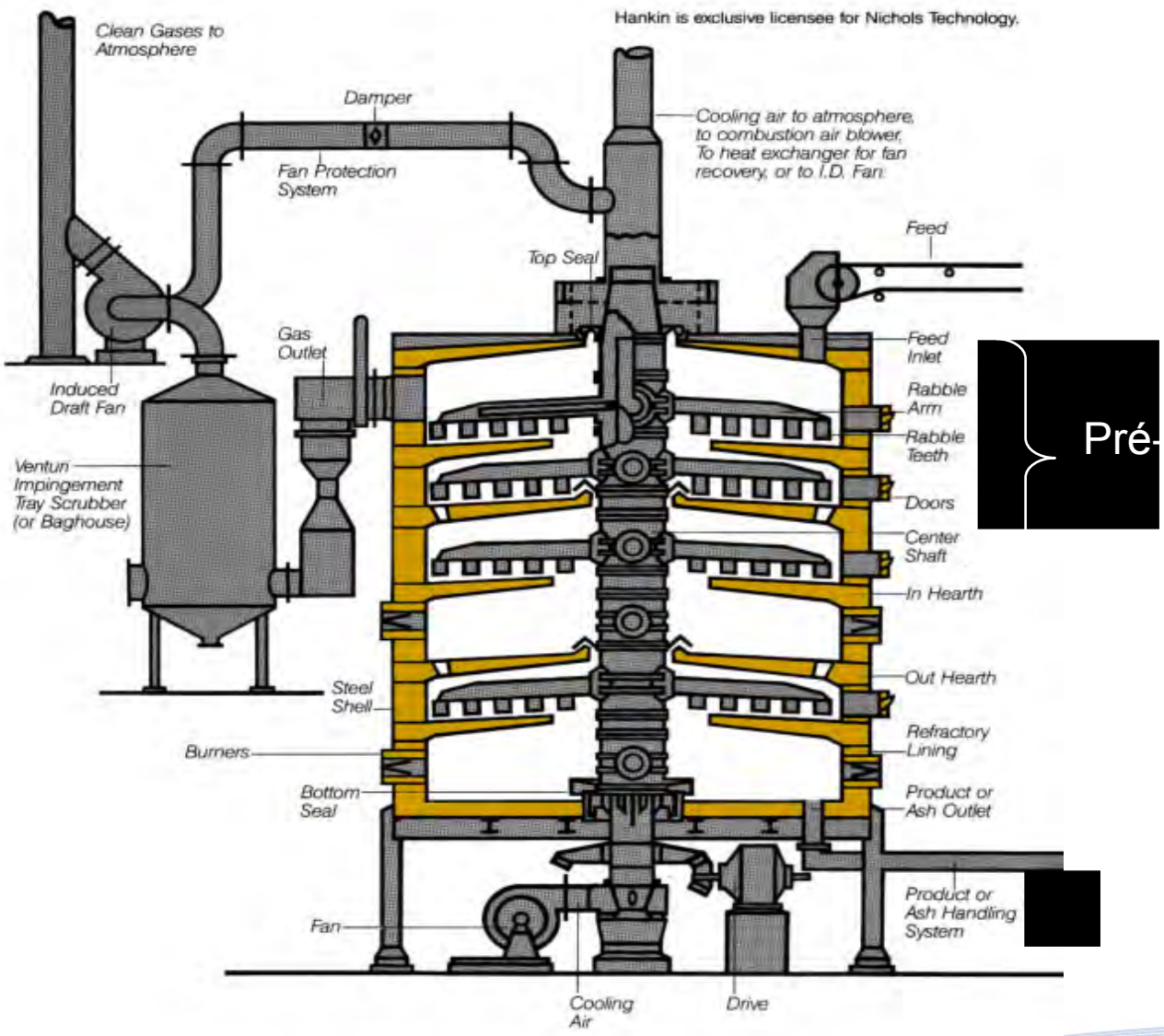
Herreshoff kiln : Imerys USA



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Herreshoff kiln : Imerys USA

- *Avantages:*

  - Technology is reliable and robust (similar as rotary kiln)
  - Energy consumption is efficient (600-1200 KWh/t)
  - Good control of temeprature of calcination

- *Drawbacks :*

  - Dehydroxylation control after heating : means to have a good knowledge of the process
  - Thermal inertie of the kiln
  - Cost of such kiln ; 1,5-2 times more compare to rotary kiln

Product available : METASTAR 501

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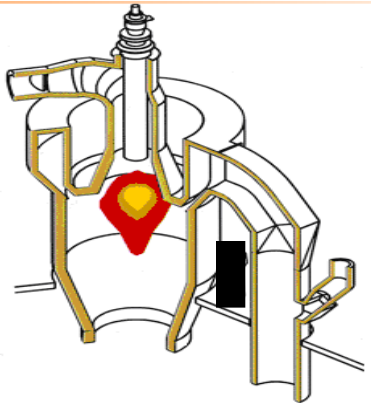
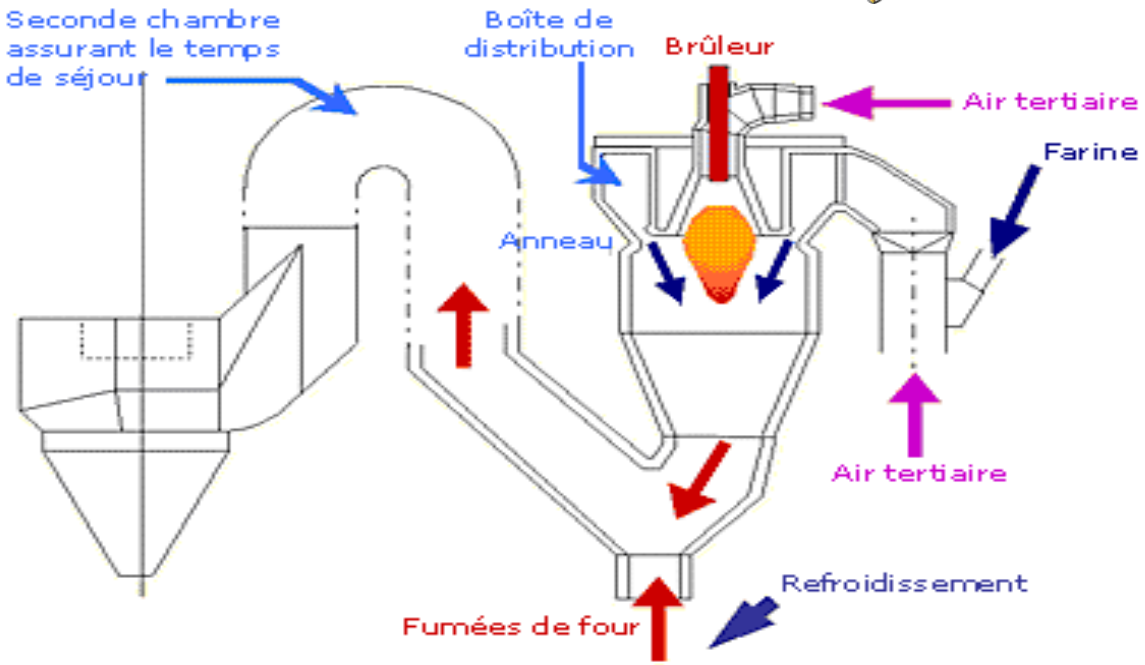
Flash Kiln : IRMC (France)

-



Very short calcination time (second)



Powder inlet

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Flash Kiln : IRMC (France)

- *Avantages:*
  - Really flexible : Temperature is reached quickly
  - Control of dehydroxylation of the Kaolin
  - Good control of Temperature
  - Energy consumption is limited : 400 to 800 KWh/t
  - Capacity of kiln adapted by initial design (1tonne/h for IRMC)
  - Can produce very fine metakaolin (pre milling).

- *Drawbacks :*
  - Complex operational system
  - Investment cost not negligeable
  - Milled raw material in inlet is needed.

Product available : ARGICAL M1200S

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Important parameters for the Metakaolin

- Origin of the raw material :
  - **Primary Kaolin :** coming from the Granitic stone by processing it. Low in impurities (Ti, Fe), « low » in surface specfic value).
  - **Secondary Kaolin :** Clay deposit, erosion of granite stone. Contain more of impurities (Ti, Fe..). Specific surface is generally higher vs Primary Kaolin (15m²/g and more).
- Chemistry of the Kaolin
  - The more the Alumine the better is for the reactivity. Alumina content closer to pure Kaolinite increase the amorphous rate of the Metakaolin.
- PSD and calcination :
  - Reactivity is link to the fineness of the material
  - BUT the calcination process and the nature of the raw material can modify the reactivity.
  - A poor Metakaolin (low reactivity) will not bring much more reactivity only by milling. The raw material influence is high.

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Important parameters for Metakaolin for Geopolymer

Which is the best Metakaolin for a Geopolymer!

For Geopolymer technology, the subject is still today under investigation within Imerys!

We can anyway point out couple of point :

- Alumina content is of importance as it brings us the Al/Si ratio and good combination with Silicate.

- The more the kaolinite... the more the metakaolinite you will get. Amorphous ratio is important for reactivity

- influence/control of calcination process

- PSD is also a parameter that can influence the reactivity

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Important parameters for Metakaolin for Geopolymer

All metakaolin can be use in geopolymer system as reactants!

It will give/bring a certain :

- Setting time
- Rheology
- Resistance
- ...

But the mains points are your parameters. **What you are looking to do!**

So please don't ask me a Metakaolin for Geopolymer!

Better explain what you are looking to do!

And neither forget that Metakaolin is only on part of the Binding system!

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Range of product summarize

Name	Calc. Type	Reactivity (Chapelle test)	Colour	BET (m^2/g)	Fineness	Cost Index
Metastar 501 (US) d50 = 1µm	Hereshoff	1400	+++	14	Finer	5
Argical M1200S (F) d50 = 1,5µm	Flash	1370	++	23		2
MK 36 (I) d50 = 6µm	Rotary	1200	++	19		1,5
Argical M1000 (F) d50 = 10µm	Rotary	1150	++	19		1
MK 40 (Ukr) d50 = 20µm	Rotary	1100	+	15		1

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Thank you for your attention

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