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Calcining and producing plaster with One Step

In this paper the Energy Saving Equipment Company (ESEC) discusses the merits of its unique drying-cooling-calcining-sieving ('One Step') kiln design for the processing of phosphogypsum into a product capable of use in construction applications.

Phosphogypsum is a type of powdered gypsum of high water content that is produced during the manufacture of phosphate fertiliser. The grain size of phosphogypsum is typically <80μm mesh and the pH value is normally 3–4, with a $CaSO_4$ content greater than 70–80%. The main impurites in phosphogypsum are SiO_2, Al_2O_3, Fe_2O_3, alkali metal oxides, phosphorus, fluoride and residual acids.

Table 1: Characteristics of local phosphogypsum types in China

Capability	Company (Province)		
	Jinshan (Sichuan)	Hengtai (Shandong)	Puyang (Henan)
$CaSO_4$ quality	78%	70%	75%
Attached water	14%	11%	12%
Constitution water	16.4%	14%	15.7%
Standard consistency	65%	60%	66%
Initial setting time	7min	6min	5min
Final setting time	12min	11min	8min
2h breakage resistance	3.5MPa	2.8MPa	2.5MPa
Fineness	<120μm mesh	<120μm mesh	<120μm mesh
Viscosity w/out binder	Good	Good	Excellent
Standard coal consumption	48kg/t	47kg/t	47.5kg/t
Power consumption	10.5kWh/t	12kWh/t	–
Production scale	100kt/y	50kt/t	60kt/y

Normally 3–5t of phosphogypsum are produced when manufacturing 1t of phosphate fertiliser in China. This equates to about 20–30Mt of phosphogypsum produced annually. As a result, China has over many years accumulated huge stock piles of phosphogypsum.

The main component of phosphogypsum is $CaSO_4 \cdot 2H_2O$, and as such its physical and chemical properties are the same as naturally-occuring gypsum. After calcining and modification, phosphogypsum powder forms products that are almost identical with those derived from natural gypsum. This is true for the hydrated capacity, condensability and other physical properties. However, where it differs from natural gypsum is the level and nature of impurities. Phosphogypsum has some charateristics of reclaimed gypsum.

In China there is a shortage and an uneven distribution of high grade natural gypsum. Modified waste phosphogypsum is therefore an attractive starting material for the manufacture of building materials. As a result, the time is right for phosphogypsum to attract experts, engineers and factories to capitalise on this significant business opportunity.

Phosphogypsum history in China

Investigations into phosphogypsum technology began in the 1990s, and since then ESEC has accumulated a large amount of data. Today, ESEC manufactures the single stage process of cooling-separate-calcine kiln, which deals with drying, cooling, calcining, sieving (removing impurities) and at the same time completely modifying a kiln (refer to Chart 1). This production line has 16 patents associated with it, and is able to make high grade plaster and other gypsum products requiring low invest ment and low consumption of coal and power (see Figure 1 and Table 1).

Heating process

The water attached to phosphogypsum constitutes 10–15% by mass. The energy consumed when drying and calcining phosphogypsum is more than natural gypsum. The use of gas to power this heating process is one of the more efficient methods, but gas quality and kiln efficiency must also be considered. The GXDF type boiling furnace used by ESEC is protected by nine patents, and it has the following advantages:

- Burn-out efficiency is 99%;
- Thermal efficiency is ≥96%;
- Desulphurisation in the furnace is 80%;
- Carbon residue in the ash dust is ≤2%;
- Purifing gas temperature is 400–900°C, a level that ensures gypsum quality and makes no difference to the product brightness.

Capability	Guangzhou power plant
$CaSO_4$ quality	78%
Attached water	14%
Constitution water	16.4%
Standard consistency	65%
Initial setting time	7min
Final setting time	12min
2h breakage resistance	3.5MPa
Drying breakage resistance	<120μm mesh
2h pressure resistance	Good
Drying breakage resistance	48kg/t
Standard coal consumption	10.5kWh/t
Viscosity w/out binder	100kt/y

Table 2: Capability of plaster powder produced by desulphurised gypsum

Process of drying-cooling-calcining-sieving

Before phosphogypsum is produced, phosphorite is ground to a powder of less than 80μm mesh. By treating the powder with a displacement reaction, phosphogypsum is formed. However, the newly-formed phosphogypsum still contains impurities, and in addition, stacking in open air may cause some blocks to fuse, resulting in agglomeration. This raises some issues: 1) Before drying, impurities entrained within the wet phosphogypsum are difficult to sieve separately; 2) Gypsum quality is adversely affected by the presence of these impurities; 3) Coking phosphogypsum is not able to ensure calcination homogeneity.

The solution to these problems is achieved via ESEC's Drying-Cooling-Calcining-Sieving kiln design. The four-stage process starts by drying, followed by the use of a so-called Soft Shivering Device that works by 'shivering,' i.e. cooling, lumps of phosphogypsum plaster. After calcining, qualified plaster is sent to the next process. All impurities are then discharged out of the kiln for treatment. The special kiln can therefore accomplish four important process steps from drying, cooling, calcining and sieving.

Figure 1: A and **B)** A 100kt/y gypsum line producing phosphogypsum for Jinshan Dawei Co, Sichaun Province; **C)** Kiln used by ESEC

When the calcination process is accomplished in high temperature and high humidity conditions, the resulting β-gypsum is found to contain α-gypsum entrained within it. This results in strength increases of the plaster, characterised by a breakage resitance of 4.8MPa when $CaSO_4$ content is more than 80%.

Modification process

Calcined phosphogypsum is normally contaminated with clay on its surface. As a result, most calcined phosphogypsum samples have poor viscosity and are dark in appearance, making treatment of it necessary. With this in mind, ESEC has designed the JNGXM series modification mill. The JNGXM can process 7t/h, 14t/h and 28t/h of plaster, has a low internal volume, runs smoothly and draws only a low amount of power for its operation. For example, grinding 1t of plaster powder consumes only 0.9–1.8kWh/t.

After modification, the plaster has the following advantages:

- No binder is necessary to adhere paper or cloth;
- It has increased strength of 0.4–0.8MPa;
- Enhanced brightness;
- Increased specific surface area of 1000cm^2/g;
- Initial and final setting times are stable.

The JNGXM series modification mill contains no screws, belt or link plate. Furthermore, the overall system works on the basis of negative pressure. These design features means the kiln consumes a relatively small amount of power, has a low failure rate and leaks no dust, the latter point being advantageous to operators' health.

This system also can be used to process desulphurised gypsum. Compared to phosphogypsum, desulphurised gypsum is of higher purity, higher quality, contains fewer impurities and lower granularity, removing the need for pre-treatment during production, and the system tends to run on a more stable basis. ESEC has purchased 20t of desulphurised gypsum with a 92% $CaSO_4$ by mass content from Guangzhou Power Plant for testing in ESEC's novel kiln system. The results of this project are shown in Table 2.

According to the data, this system could produce high-quality plaster. As a result, ESEC has signed a contract for 50,000t of desulphurisd gypsum powder produced by the Zhuzhou Huayin power plant in Hunan Province. This system has also been used successfully to treat natural gypsum calcination, with minor adjustments, in collaboration with the Shenmei Group in Liangning Province and Juyuan Gypsum Develop Co in Shandong Province.