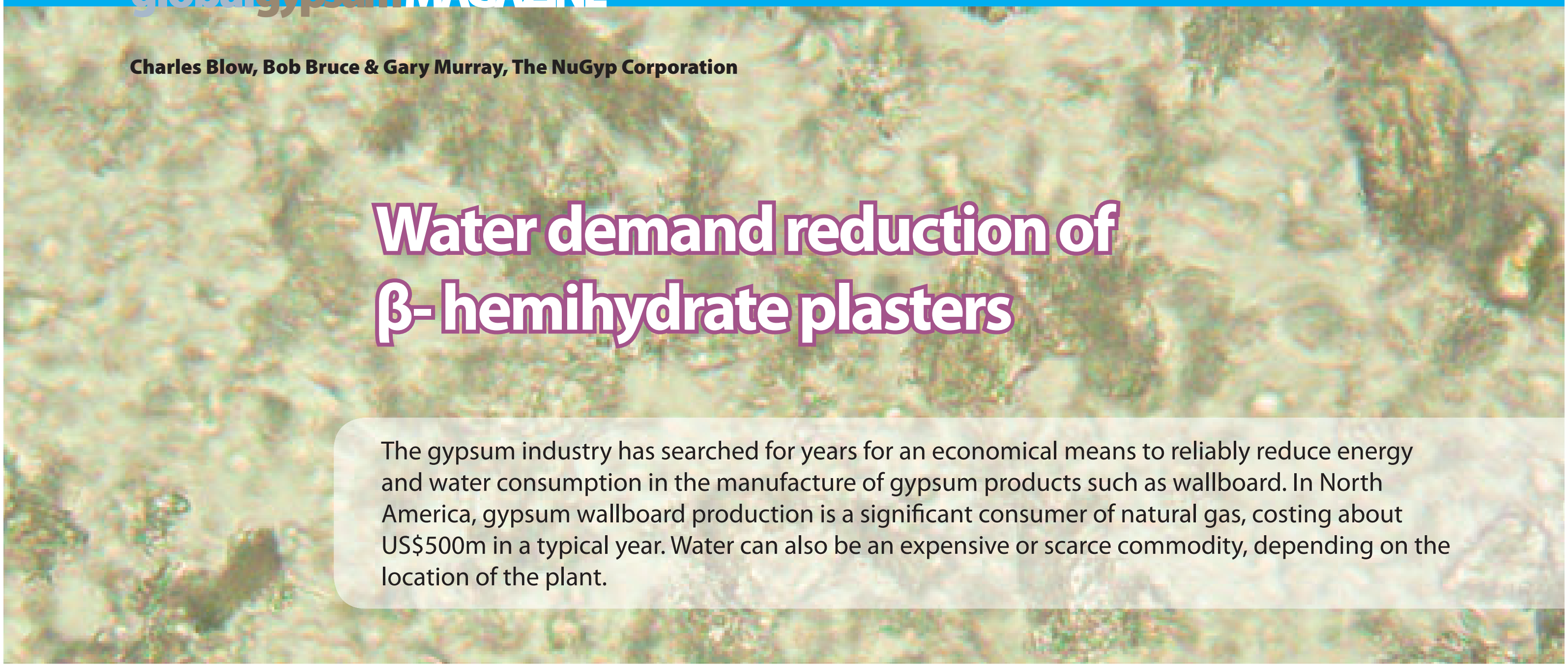


Charles Blow, Bob Bruce & Gary Murray, The NuGyp Corporation

Water demand reduction of β- hemihydrate plasters

The gypsum industry has searched for years for an economical means to reliably reduce energy and water consumption in the manufacture of gypsum products such as wallboard. In North America, gypsum wallboard production is a significant consumer of natural gas, costing about US$500m in a typical year. Water can also be an expensive or scarce commodity, depending on the location of the plant.

Above: Enlarged photomicrograph of disintegrated NuGyp plaster in water. (Taken from Figure 4).

Right/Watermark: Greek letter nu, which has been assigned to NuGyp's new type of plaster.

The current techniques available to reduce energy and water consumption in the gypsum industry can be expensive, can reduce quality and may be unreliable. A solution to these longstanding problems has now been found using the NuGyp LoCal(™) process.

The NuGyp LoCal process is a low capital and operating cost process that reduces the water demand of beta hemihydrate from any calciner in a reliable and predictable manner, whilst maintaining the beneficial properties of good strength and fast setting times. In addition, the treated plaster has some of the attributes of aridised plaster and alpha/beta mixes, extending its use into industrial plaster products.

Low water demand plaster made by the NuGyp LoCal process is now a commercial reality. In its first full production scale installation, it works as predicted by laboratory and pilot plant trials. A full range of board products has been produced, meeting all quality specifications and production standards. Optimisation of the process continues, but the impact on energy and water use in a plasterboard plant is now proven full-scale.

Water demand

The chemistry of making plaster and its rehydration to gypsum is well known.

$$\underset{\text{(Gypsum)}}{CaSO_4{\cdot}2H_2O} \underset{\text{Rehydration}}{\overset{\text{Calcination}}{\rightleftarrows}} \underset{\text{(Plaster, Stucco)}}{CaSO_4{\cdot}\tfrac{1}{2}H_2O + 1\tfrac{1}{2}H_2O}$$

During the calcination process, some of the hemihydrate may be further calcined to anhydrous calcium sulphate (anhydrite) that can exist in two forms; soluble anhydrite that has a reactive crystal structure and insoluble anhydrite which has a very stable and un-reactive crystal structure.

$$\underset{\text{(Plaster, Stucco)}}{CaSO_4{\cdot}\tfrac{1}{2}H_2O} \rightleftarrows \underset{\text{(Anhydrite)}}{CaSO_4 + \tfrac{1}{2}H_2O}$$

Rehydration of 100g pure hemihydrate to gypsum requires 18.62ml of water, and so plaster has a theoretical water demand of 100/18.62. For anhydrite, the theoretical water demands are 100/6.62 for rehydration to hemihydrate and 100/26.47 to dihydrate. At these ratios, however, the mixture would be an inhomogeneous paste of damp powder that would be difficult to use in conventional applications. To make a 'pourable' slurry, excess water must be added so that the mixture quickly and accurately takes up the shape of the mould into which it is poured. The ratio of hemihydrate to total water used to make the 'pourable' slurry is referred to as the pourable water demand.

In plasterboard manufacture, the mould is in the form of two cardboard liners and the typical water demand figure for a beta hemihydrate slurry to fill this mould is 100/80. Excess water then has to be dried out from the board. In a typical board plant, therefore, pourable water demand exceeds theoretical water demand by a factor of 4.5. The fluidity of plaster slurry is also important in other applications, for example self-levelling floorscreeds and ceramics plasters. In these applications, low water demand beta plaster can be used in place of expensive alpha/beta plaster mixes.

Typically, alpha plaster has a water demand between 100/28 and 100/45 and beta plaster has a water demand between 100/70 and 100/95.

Factors affecting water demand

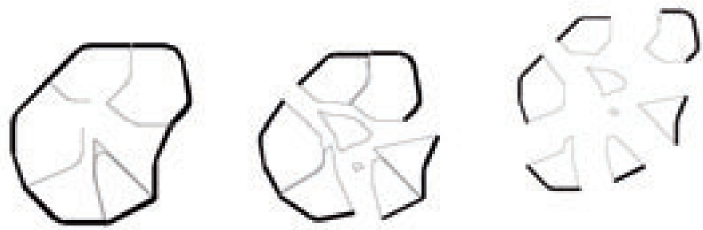
The main factors that affect the water demand of plaster are; phase analysis, particle shape, particle size distribution, disintegration and surface energy.

Phase analysis

Soluble anhydrite is present in over-calcined plaster and it has a marked affinity for water. Soluble anhydrite-containing plaster has a greater water demand than pure hemihydrate because some of the water is used in the re-hydration to hemihydrate. However, since this water is used in hydration it does not need to be evaporated in the dryer.

Modern flash calcination techniques can result in variable soluble anhydrite levels which will rehydrate to hemihydrate when exposed to typical ambient humidity in the plant conveying and storage systems. In these circumstances, the rehydration is uncontrollable and causes variability in feed properties to the mixer.

The NuGyp LoCal process exposes all of the plaster to steam under controlled conditions that convert a proportion of the soluble anhydrite back to hemihydrate. The level of conversion depends on the level of treatment. Under some conditions, such as low initial anhydrite concentration or high-level treatment, it can reach 100%. Production of insoluble anhydrite must be avoided because it will not rehydrate to gypsum and thus cannot contribute to strength development in the final product.



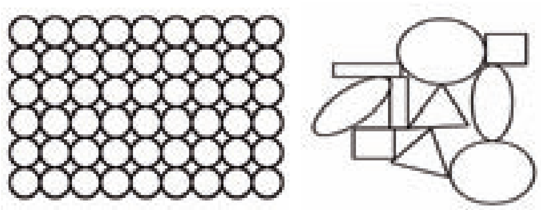
Right - Figure 3: Particles may disintegrate on wetting, increasing surface area and water demand.

It can be seen that overcalcination to anhydrite of either form gives a variable material that is more difficult to use in a finely tuned and efficient wallboard plant.

In laboratory and pilot plant trials the residual gypsum content of the NuGyp plaster has always decreased slightly or remained the same, improving the overall phase analysis of the plaster.

Particle shape and size distribution

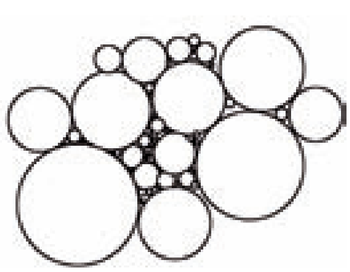
Particle shape and size distribution affect the fluidity of plaster slurry because the water added to the powder acts as a lubricant between the particles making the particles flow.



Right - Figure 1: Particle shape distribution can affect water demand.

If the particles are spherical they need minimal lubrication to make them flow. For obvious reasons, more lubricant is needed if the particles have an irregular shape, (Figure 1).

If the particles have both regular shapes and a good distribution of sizes, the gaps between the particles are smaller and less lubricant is needed to make them flow,



Right - Figure 2: Spherical particles with a broad size distribution will have a low water demand.

thus they have a lower water demand, (Figure 2).

The NuGyp process has no effect on particle size, shape or size distribution of the treated plaster.

Disintegration

During the calcination of gypsum, water molecules are driven from the crystal structure, leaving cracks and fissures in the particles, which cause them to be fragile. In addition, the thermal shock of calcination induces additional stress fractures into the crystal structure.

As a result the hemihydrate particles can shatter when they are mixed with water. This increases the specific surface area of the powder. Shear forces caused by mixing will accelerate the disintegration process. The degree of disintegration depends on both these factors. Alpha hemihydrate, for example, does not disintegrate at all, even with high shear, whereas beta plaster can disintegrate to some degree even with hand mixing. If there is an increase in surface area of the powder, more water is needed to lubricate the particles and the water demand of the plaster is increased, Figure 3.

To produce a flowable mix, excess water is required. The range of water demands for alpha plaster is 100/28 to 100/45. The range for beta plaster is between 100/70 and 100/95. NuGyp LoCal plasters water demand range is between 100/50 and 100/95

The disintegration properties of plaster may be measured by mixing in water with set retarder for increasing periods of time and analysing the surface area or particle size distribution of the particles that result. This analysis has shown that NuGyp plaster exhibits similar disintegration to untreated plaster with some minor differences. For example, the Blaine surface area of disintegrated NuGyp plaster is typically less than beta plaster but the corresponding particle size analysis data is equivalent.

In summary, the plaster treated by the NuGyp LoCal process still exhibits the disintegration properties typical of beta plaster, while taking on the water demand properties of alpha plaster. For this reason we use the name NuGyp plaster (referencing the Greek letter 'nu' or 'ν') to refer to this unique material.

Surface energy

The surface energy of any material reflects the environment from which it was derived. When the material is a collection of fine particles the surface energy can have a large impact on how the material behaves. Hemihydrate plaster is a good example of this because the powder particles are submitted to both the energy of fine grinding and the heat associated with calcination. The high energy surface created impacts both its flow properties as a dry powder and its suspension in water.

Dispersing agents are surface active agents that are specifically designed to influence how particles interact with one another in water, either by adsorption and/or through steric interference, (i.e. colliding with the surface active agents). Being highly surface active themselves, the dispersants can be subject to interference from other surface active materials often associated with hemihydrate.

Exposure to steam for only a few seconds using the NuGyp process is enough to remove the charges on the surface of the hemihydrate crystals. When compared with untreated beta-hemihydrate, NuGyp hemihydrate particles show decreased interactions between particles when suspended in water.

The photomicrographs (Figure 4) show hemihydrate samples mixed by blender in water. Agglomeration of disintegrated particles occurs with the untreated hemihydrate sample while the dispersant naphthalene sulphonate abolishes this agglomeration, allowing free suspension in water. NuGyp plaster is similarly freely suspended in the absence of dispersant.

Dispersing agents can still be used in combination with the NuGyp process, their efficiency dependent on the degree of treatment and particle characteristics.

Important aspects of NuGyp plaster

The most important aspect of NuGyp plaster is that its water demand is adjustable over a wide range. Figure 5 (below) shows the typical results obtained for treating fresh hemihydrate plasters.

Note that a 15% improvement in the water demand of the plaster will yield an energy saving of more than 15% on the board-line because some of the water that is added to fluidise the mix is used to convert the hemihydrate to gypsum. For example, a 20% improvement in water demand for plaster of 90% purity will reduce the evaporative load on a board dryer by 26%. It is expected that a board plant implementing the NuGyp LoCal process will typically start with a target of 20% reduction in evaporation as illustrated by the red area in Figure 5.

Additionally, if the water demand of the untreated plaster should change for some reason, for example a change in gypsum supply, then the treatment process can be adjusted to compensate and the desired water demand regained.

Having discussed the changes that the NuGyp LoCal process makes to plaster, it is important to note the following. 1. Compressive strength at the same water ratio is unchanged at equivalent set times. 2. The response of treated plaster to added accelerators, retarders and other chemicals is unchanged. 3. To match the setting time of untreated plaster, a small increase in accelerator use may be needed.

The properties of alpha, beta and NuGyp plaster are summarised below.

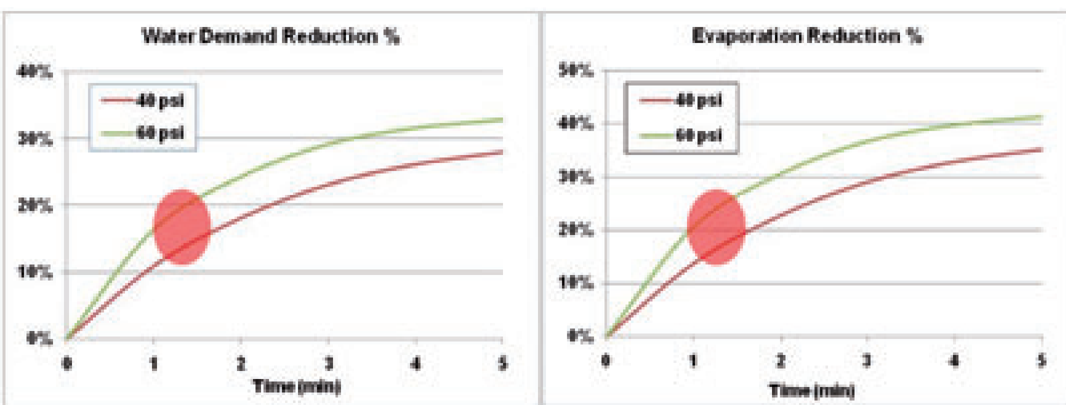
Below - Figure 4: Photomicrographs of disintegrated plaster in water. Untreated (left), treated with dispersant (centre) and NuGyp plaster (right).

	α	β	ν
Production cost	High	Low	Low
Production rate	Slow	Fast	Fast
Water demand	Low	High	Tunable
Setting properties	Limited	Wide range	Wide range
Compressive strength	High	Low	No Loss

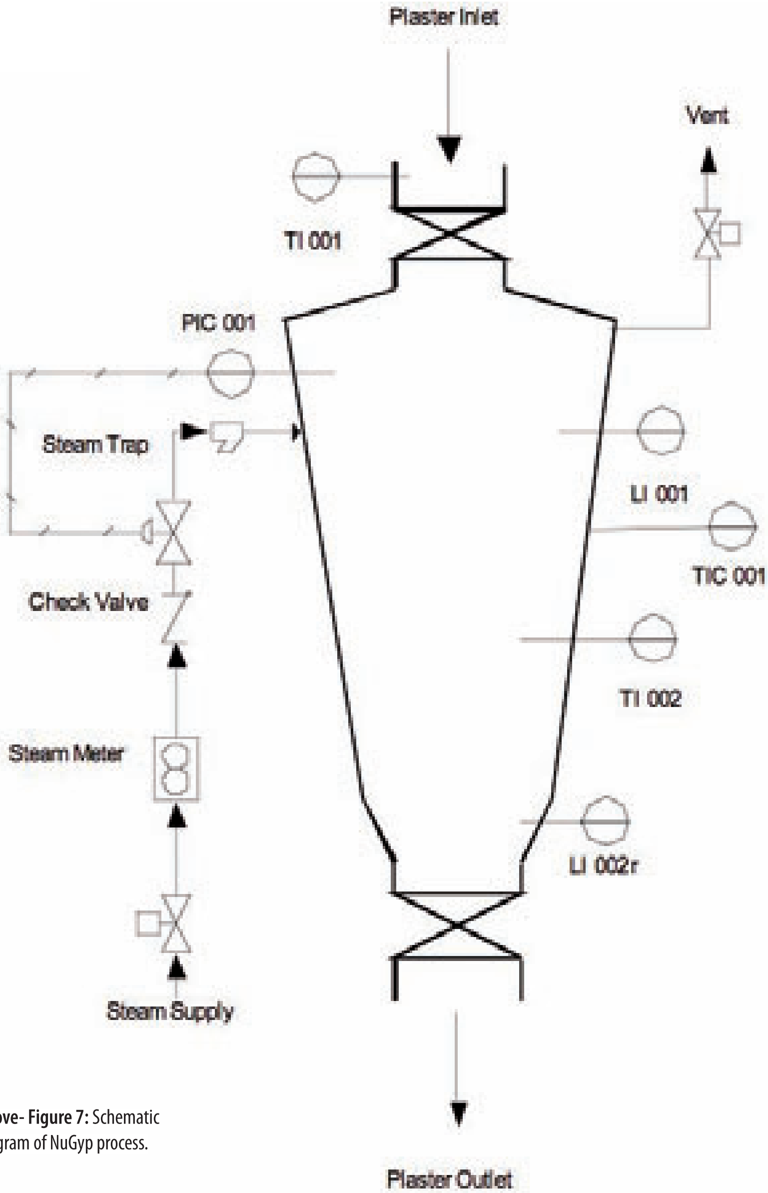
Left - Figure 6: Comparison of the characteristics of alpha, beta and NuGyp plasters.

The NuGyp LoCal process and equipment

The NuGyp LoCal process exposes the freshly calcined plaster to steam at above atmospheric pressure for specified times. A measured volume of freshly calcined plaster is fed into the treatment chamber which is then sealed and live steam injected. The time of exposure and the pressure used dictate the level of water reduction achieved. At the end of the treatment time, the steam supply is closed, the pressure in the chamber is vented



Left - Figure 5: Effect of NuGyp LoCal process on water demand and evaporation reduction.



Above- Figure 7: Schematic diagram of NuGyp process.

and the treated plaster discharged (Figure 7).

Typically, steam pressures of 40 psig to 80 psig and treatment times from 30 seconds to 3 minutes are used, depending on the reduction in water demand desired.

The temperature of the chamber walls is monitored and if necessary, heat can be applied to avoid condensation of the steam on the chamber surfaces. The relative temperatures of the plaster and steam are controlled to achieve the optimum treatment conditions. The present design of pressure chamber has a maximum working pressure of 100 psig and a volume of approximately 1.25m^3. Pressure chambers are installed between the calciner and the plaster storage. Their number depends on the capacity of the calcination plant and the maximum treatment time.

A steam raising plant is also needed. Its size depends on the capacity of the chambers and the quantity of soluble anhydrite (if any) which will be rehydrated during the process.

Figure 8 shows the possible locations of the NuGyp LoCal treatment process in the mill. Note that the plaster is stable after treatment and thus can be stored and used when needed.

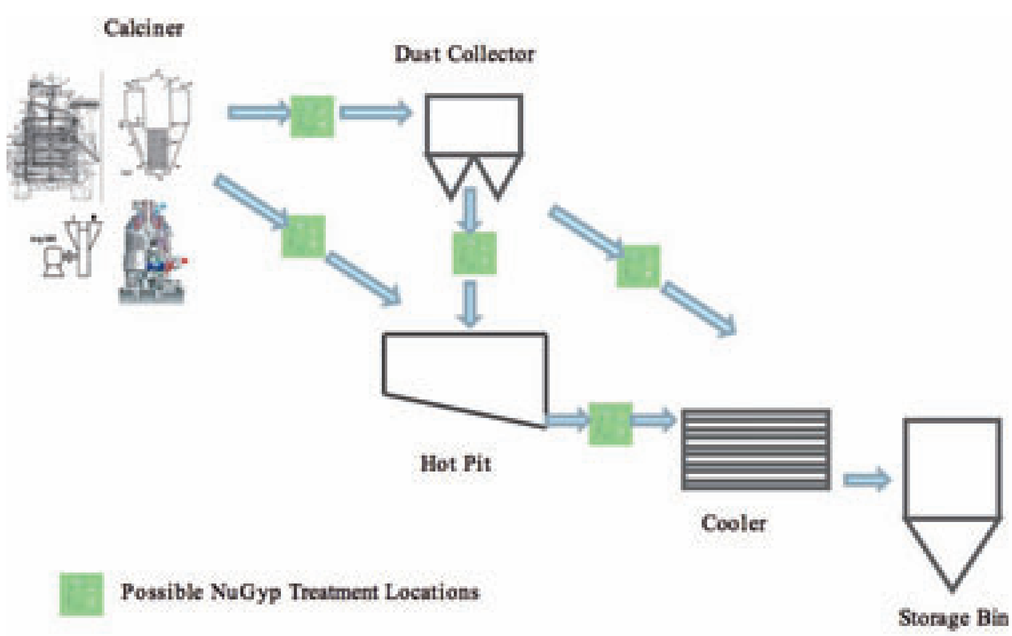
The location of the treatment chambers is flexible and will depend on the layout of the plant. The temperature of the plaster fed to the chambers should be in excess of 120°C.

The pilot chamber is used to test the process with the mineral and calcining process in use at the customer's site.

Intellectual property

A full patent application (US-2008-0148998-A1) was submitted in December 2007 and proceedings are underway to obtain patents in 71 countries.

The NuGyp Corp has three owner-directors,



Right - Figure 8: Possible locations for the NuGyp LoCal process.

Left - Figure 9: 'Estucco Ecologico' - The first full scale installation at Panel Rey, Mexico.

Bob Bruce of Innogyps Inc, Charlie Blow of Caso-Four Ltd and Gary Murray of Gypsum Technologies Inc (Gyptech).

The directors bring many years of experience to the company in the areas of operations, wallboard and calcination technology, chemistry, chemical engineering, mechanical engineering, business development and the supply of equipment for gypsum wallboard.

The equipment capital cost is relatively low. The cost of installing the process in an existing plant will depend on the materials handling system required. In a new plant, the equipment can be built into the materials handling stream.

The operating costs are also low compared with other methods of water demand reduction. Steam costs are approximately US$0.10/msf (2010 prices), and electricity costs are negligible. No extra staff-time is needed and maintenance costs are low.

The process is controllable and the level of water demand reduction is 'tunable' up to 40% reduction. The process reduces soluble anhydrite and residual gypsum levels. The process evens out variations in stucco quality. Dispersant usage may be reduced or eliminated and/or water usage decreased. Evaporation is decreased by up to 30% if water usage is decreased. Line speeds are increased in plants which are dryer constrained. Savings of between US$2.50 and US$8.00/msf of wallboard can be expected (2010 prices).There is also the opportunity to manufacture new, low water demand products such as self-levelling floor-screeds. The process can also be used to make low water demand special plasters without the use of alpha plaster.

The first full-scale plant

The first commercial-scale installation was commissioned in Monterrey, Mexico, during November 2009 and was in full production as of 1 December 2009 for Panel Rey SA who have designated the project 'Estucco Ecologico.'

Thus the process has been tranformed into a full-scale operation and it performs as predicted. The quality of plasterboard made from NuGyp plaster is the same as the previous method and Panel Rey is making a full range of product types and board thicknesses without problems.

Panel Rey has also seen major cost savings, with low operating costs for the process itself. In addition, the process can be turned on, up, down or off without affecting normal calcining mill operation, downtimes or availabilities. To date, water demand reductions of 18% have been obtained under normal plant operation, with more to be gained as the process is optimised.

These results in the board plant could not have been accomplished without the outstanding support shown by Panel Rey president Nicolas Alverde and plant manager Marco Patino as well as the diligent and outstanding efforts by the plant operating and engineering staff at Monterrey. They should be commended for helping to bring this new energy- saving process from pilot scale possibility to full scale reality.

Left - Figure 10: The 2m pilot chamber used to configure the NuGyp LoCal process at production plants.