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PROCESS AND EQUIPMENT DEVELOPED TO MEET THE CHALLENGE TO PUT TO THE PHOSPHATE INDUSTRY BY HIGH ENERGY COST AND VARYING QUALITY OF THE RAW MATERIALS

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I. INTRODUCTION

In the recent years, the following events have occurred:

- cost increase of raw materials including phosphate rock.
- significant cost increase of energy.
- marketing of additional quantities of lower grade phosphate rock.
- stagnation of fertilizer prices caused by lower than expected consumption, as a result of currency fluctuations causing local cost hikes

Inevitably, the needs will continue to grow as world population increases: current UNIDO projections for the year 2000 show an annual consumption of 75.000.000 tons P_2O_5.

Production capacity forecasts for that same year 2000 are estimated at about 90 million tons P_2O_5.

II. TRENDS IN THE PHOSPHATE INDUSTRY

In view of this, 2 main approaches have been taken in the recent years in concepting phosphoric acid plants. PRAYON techniques are well adapted to both these approaches.

1. In the rock producing countries

Very high capacity units are being set up with many advantages:

a) Wet grinding of phosphate rock allowing to spare energy, not only in the grinding operation itself but also by avoiding the rock drying operations.

b) The new attack system must be able to gulp the most difficult phosphate rocks that must be transformed on their production site as they are too poor and/or contain too many impurities to be earmarked for exportation.

c) Possibility of using settling ponds: land is usually available in mining areas to create settling ponds allowing recovery of P_2O_5 that would otherwise be lost with effluent waters.

The aim of these big units is to produce fertilizer grade P_2O_5 at a very low cost for the whole chain of production, i.e. from the mine to the finished fertilizers, and to use grades of phosphate rock that would be very difficult to commercialize. This is performed by big capacity units able to run with a high operating factor and delivering a limited number of products.

As will be shown later on, the Prayon process is well adapted to that goal thanks to its great flexibility.

2. In industrialized countries having no raw materials

To manufacture their fertilizers, these countries can, of course, import merchant grade phosphoric acid.

This however has two disadvantages:

1. the acid qualities do not always meet their requirements;
2. these countries usually produce sulphuric acid that would then remain unused.

Moreover highly efficient production sites do exist in certain countries of long standing industrialization which bear the economical comparison with production complexes integrated to the mines.

It seems then more interesting to proceed as follows:

- Import phosphate rock of a well defined quality;
- If necessary, use a blend of several qualities of phosphate rock in order to produce a phosphoric acid matching the real needs (i.e. finding the best compromise price/quality);
- Achieve high P_2O_5 yields;
- Upgrade the by-products such as calcium sulphate, fluosilicic acid, etc...

The Central-Prayon process perfectly meets these goals and has now reached full maturity. We intend to present its up-to-date features at another occasion.

III. PROCESS DESCRIPTION

Today, we will present you in more details the process that is particularly suited to the needs and objectives of rock producing countries, the Prayon Mark IV design which has been applied for the first time at the IMC New Wales Florida factory. The plant was started at the end of 1981 and has given convincing results.

Let us review the main features of this Prayon Mark IV design:

1. Wet rock grinding

Phosphate rock coming out of the beneficiation plant usually contains 8 to 12 percent moisture.

As no transportation problems are involved when the phosphoric acid plant is close to the mine, it is more economical to by-pass the drying operation and to grind the wet rock. This also allows to minimize the handling facilities.

The advantages of that procedure are:

- Sparing of fuel normally needed for drying the rock;

  (It is interesting to note that, in some cases, it is even economical to grind a wet phosphate rock that was received dry; in that case, however, there is of course no saving of fuel at the drying operation).

- Sparing of energy as grinding as wet rock requires less horse power than grinding a dry rock;

- Lower investment cost as the whole air classification and dust collecting equipment is avoided;

- No dust pollution;

- No handling losses of a dusty product;

- Better dispersion of rock into the attack tank slurry.

a) As the mixing of two slurries is easier than the dispersion of a solid into a slurry;

b) As the rock slurry can be easily split and injected at various points in the attack tank by means of several inlet pipes. (This is more difficult and costly to perform with a dry and dusty product).

It should be pointed out that the wet rock grinding technique somewhat limits the amount of water available on the filter for gypsum cake wash.

Therefore, the filtration operation will need to be performed with equipment allowing a high filtration efficiency in order to obtain a suitable overall P_2O_5 recovery.

The Bird-Prayon filter is particularly well suited for that operation.

Even so, we must realize that processes which produce a high P_2O_5 concentration straight from the filter cannot use the wet rock grinding technique as the water balance of such processes would not leave enough cake wash water for an efficient exhausting of the P_2O_5 contained in the filtration cake.

2. Attack section

It consists of a multi-compartment concrete monoblock with carbon bricklining and connected to a vacuum flash cooler.

The objectives

The attack system design was done keeping in mind the prime objectives of reacting phosphate rock with sulphuric acid:

a) To leave in the gypsum the lowest possible amount of unreacted and co-crystallized P_2O_5. This means a progressive and thorough reaction providing a high P_2O_5 yield.

b) To control the slurry temperature; indeed, as the reaction is exothermic the resulting slurry needs to be cooled down, but in doing so, too great temperature gradients should be avoided as they would jeopardize the three objectives hereabove.

c) To produce a gypsum with good filtration rate. This means good size and homogeneous size crystals avoiding as much as possible the formation of tiny crystals.

d) To produce at the outlet of the attack tank a stabilized medium that does not create build-up problems.

And of course, these objectives must be reached in an economical way.

The means used

Let us see how this is achieved by the Prayon Mark IV design:

- A high flow, low manometric head axial flow pump is installed on the barometric leg of the low level flash cooler and creates a very high rate of slurry circulation across the flash cooler itself as well as throughout the attack tank.

- This very high slurry flow allows a temperature drop across the flash cooler of only 3° F. The supersaturation is hence minimal and practically no scaling can be noticed in the whole flash cooler circuit.

- This tremendous flow of slurry circulates throughout the various attack tank compartments through vertical openings provided on the whole tank height in the middle of the walls. In each of these compartments, Lightnin-Prayon agitators ensure a complete homogenization. These agitators generate high mixing flows by means of two sets of helical blades as well as a great dispersion of reagents at the interface thanks to a set of defoaming paddles.

- Depending on its characteristics, the phosphate rock can be fed (under dry or wet form) in one or in several points. This applies also to the sulphuric acid and the recycle acid that are mixed before their injection above the slurry level. The dispersion of phosphate rock, sulphuric acid and recycle acid is effected by the defoaming paddles located on the upper part of the Lightnin-Prayon agitators.

  These paddles not only mix these reagents but also kill the foams appearing when the phosphate rock contains CO_2 and organic matters: the paddles, located at the slurry level, create above the liquid level a spray of slurry droplets which knock down these foams.

- On top of the abovementioned features, the Prayon Mark IV design incorporates an automatic and continuous sulphate analyser developed by Albright & Wilson (UK) and commercialized by Prayon.

  The objectives we set up earlier can be summarized in three concepts:

  - $\underline{P_2O_5}$ yield.
  - Gypsum size.
  - Stabilized medium.

  The means used by the Prayon Mark IV design to achieve these objectives are:

  - Slurry circulation flow in the attack system;
  - Specific feed points of reagents;
  - Efficient temperature control throughout the system;
  - Low temperature drop across flash coolers;
  - Close control of sulphate level;
  - Digestion tanks economical to build and to operate.

  Note:

  As a side effect, the Prayon vacuum cooling system also provides a good degazification of the slurry under vacuum with minimal gaseous effluents properly scrubbed before discharge to the atmosphere.

  Unlike vacuum cooling, cooling by air injection gives rise to very important gas effluents (thousands of CFM to be scrubbed before discharge to the atmosphere).

  If we now look at the figures, we notice that energy consumptions in attack tank for the Prayon Mark IV design are very significantly reduced compared to those of the former design.

  To summarize:

  - Agitation of the attack tank and digestion tanks consumes 1.7 times less energy.

- Slurry cooling and circulating require 2.2 times less energy.

3. Filtration section

The calcium sulphate and phosphoric acid slurry produced in the attack section has to be filtered to separate the solid phase from the liquid phase.

The tool

To achieve this operation, the Prayon Mark IV plant is equipped with a tool as performing as those described hereabove: the Bird-Prayon filter.

It is not necessary to present you this filter: in the last 25 years, it has been a traditional piece of equipment in phosphoric acid plants.

Recently, its use has been extended to other fields of application such as:

- Filtration of very fine solids, with low filtration rates, in the hydrometallurgical industry;

- Filtration of incrustating slurries, such as hemihydrate calcium sulphate in two-stage crystallization phosphoric acid processes.

These new applications have led to important improvements in the design and construction of Bird-Prayon filters:

- Sophisticated automatic systems for washing the filter pans in the inside as well as on the outside;

- A special device for keeping the pans individually in a horizontal position (this device allows the filtration of very thin cakes);

- The inside design of the pans has been improved from the hydraulics point of view.

These improvements as well as many other details make the Bird-Prayon filter even more reliable and efficient than before.

Process requirements/design features

The most important objectives to aim at for high performance filtration are:

1. Uniform distribution of the slurry on the filter surface. This criterion is best achieved by the Bird-Prayon filter as the slurry is fed into a closed pan having a flat horizontal bottom made of a perforated plate which supports the filter cloth.

   Moreover, when the slurry is being fed to the pan, this pan is not yet under vacuum.

   The advantages resulting from these features are:

   - The slurry spreads uniformly on a flat and closed surface;

   - The slurry is well distributed over the whole surface of the pan before vacuum is applied to that pan.

   The horizontality and rigidity of the pan bottom

   a) Allow to work with very thin filtration cakes when necessary due to low filtration rates.

   b) Eliminate formation of cracks in filter cake, specially during dewatering of cake.

2. Prevent the mixing of the various liquors:

   Using individual pans instead of one filtration area for the whole filter makes it easier to avoid mixing of the various wash liquors, specially when filtration conditions are difficult.

3. Use the quantities of wash liquors available for efficient liquid displacement by piston effect:

   Here again, a filter divided into numerous pans can best achieve this effect as each pan is individually flooded with wash liquor that passes through the cake and displaces the weak acid impregnating the cake thanks to the piston effect.

4. Keep the filter cloths as clean as possible after each cake discharge:

   The Bird-Prayon filter achieves this very well. The cake is discharged after the pan has been inverted and air is blown (at low pressure) under the filter cloth to help the complete discharge of the cake. The filter cloth is thereafter washed with a minimum amount of wash water and the pan is drained after resuming normal horizontal position; it then starts a new filtration cycle.

   These are, briefly reviewed, the main advantages of the Bird-Prayon filter. Many other features are offered such as:

   - Cloudy port section avoiding dilution of mother liquor with cloth wash water;
   - Pans inner wash system for filtering highly incrustating slurries such as hemihydrate.

IV. EQUIPMENT DESCRIPTION

In this chapter we shall describe in more details two pieces of equipment, the proper design and sound operation of which are critical for the reliability and satisfactory performance of a Prayon phosphoric acid plant: the attack and digestion tanks agitators, on the one hand, the filter on the other hand. These equipments are presented by LIGHTNIN MIXERS and BIRD MACHINE respectively.

1. Lightnin-Prayon Agitation System

1.1. History of the Lightnin-Prayon agitator development

By the mid 1970's, the challenges put to the phosphate industry of high energy cost and varying quality of raw materials had indicated a need to develop an improved agitation system.

At that time a variety of combinations of axial and radial flow impellers were used with no detailed regard to agitation fundamentals. Some smaller plants were utilizing a Prayon developed impeller, the so-called Prayon Helicoidal Turbine 4-PHT but again, whilst this impeller showed improvement, there was an absence of the application of mixing technology. Examples of problems occurring were localised reactions and loss of volume due to settled solids, both caused by inadequate mixing.

Lightnin are recognized worldwide as the leaders in the development and application of fluid mixing technology and Prayon and Lightnin embarked on a mutual development programme to optimize the agitation system in the light of Prayon's phosphoric acid knowledge.

A critical item in this development was the application of laser technology. A basic problem in mixing research is the speedy and accurate measurement of flow magnitude and direction at all parts of a mixing vessel, without mechanical interference to flow. In simple terms the laser has the capability to measure two components of the velocity vector at a point by splitting and recombining the laser beam at a point in the vessel to produce an interference pattern. Velocity and direction can then be measured by noting particle movement across the interference pattern.

Mechanical strain on the agitator shaft is measured using bonded straingauges. Shaft mounted amplifiers are used to amplify the straingauge bridge signal before passing through the slip rings giving excellent signal to noise ratio.

The heart of the system is a mini computer which operates the experiments records data and performs fundamental data analysis.

Testwork in the laser laboratory indicated the suitability of the 4-PHT when applied in accordance with Lightnin experience with regard to such design considerations as impeller speed and diameter combinations, off-bottom, spacing, etc...

Attention was then turned to the surface agitation requirements. The basic reaction is exothermic and the agitator must contribute to the cooling of the reaction vessel contents. Good feed distribution is required in combination with a flow pattern which defoams. Widely varying raw materials have had widely varying gas quantities and the agitation system is required to ensure adequate degassing of the liquor and reduction in foam.

The addition of the GTA impeller (vertical paddles) resulted in the current Lightnin-Prayon Generation IV impeller-shaft system.

This impeller-shaft system gives up to 200% flow at only 50/60% of power levels when compared with earlier wetted parts designs, which means an improvement in process result for a reduction in power usage.

1.2. Mechanical aspects

Reference has already been made to measurement of mechanical strain by the laser laboratory. The agitator duty in the phosphoric acid process is extremely arduous. Significant quantities of coarse solids are added to a reactor which is itself degassing. There are significant side-flows caused by the circulation through the reactor compartments.

The Lightnin-Prayon agitator design incorporates the Lightning gearbox specifically designed for mixing duties with long overhung shafts and features an independent bearing design referred to as "Hollow Quill". The gearbox output shaft is hollow and supported in its own bearings. The mixer shaft passes through the output shaft and is itself supported in its own bearings. Connection is via a steelflex coupling. Shock loads are thus isolated from the gearing, a major part of the mixer investment.

In conclusion, the Lightnin-Prayon agitation system represents the very best combination of mixing and phosphoric acid technology. Both process and mechanical performance have been optimised by application of the most sophisticated mixing research facilities available, and the impeller-shaft system has been combined with a gearbox designed for agitator service and featuring an independent bearing support system to maximize mechanical reliability.

2. Recent improvements to the Bird-Prayon filter

It is impossible to describe in this short presentation all process and mechanical improvements brought to the Bird-Prayon filter, which undergoes constant adaptation to new requirements.

We will then show you several pictures illustrating more particularly some features discussed earlier in this paper.

2.1. Filter cell design

The first slide shows a certain number of cloths supports used over the years in the cells of the Bird-Prayon filter. The latest design is shown by slide N° 2.

Slide N° 3 shows how the shape of the filter cell was modified step by step in the past until it reached the current design illustrated by slide N° 4.

To complete your information on the filter cell design, slide N° 5 shows the design of the inner wash system of the filter pan.

2.2. Central valve design

The new filter cell design was aimed at improving the process hydraulics of the filtration operation.

It was also the concept adopted for the new design of the central valve. This new design also ensures easier separation of the air from the liquid.

Slide N° 6 shows both the old and the new design. The latter allows to reduce the height of the filter building by about 2 meters.

2.3. Example of new application

There are presently a certain number of phosphate ore deposits around the world that have a sufficient P_2O_5 content but that have not been exploited for phosphoric acid production due to their high chloride content which poses a severe corrosion problem. A few years ago, Bird was consulted to investigate possibilities of reducing the chlorine content of phosphate ores in view of their commercialization.

The ore to be treated contains a significant amount of clay that has to be eliminated before or during the dechlorination operation.

As this clay contains very little phosphate, its elimination enriches the P_2O_5 concentration of the remaining product.

The process needs a solid/liquid separation operation. This operation could be efficiently carried out on a Bird-Prayon filter. However, the filtration rates were low due to the presence of a thin layer of clay on the filter cake: an adaptation of the Bird-Prayon filter needed to be found to overcome this problem.

The solution adopted took advantage of a main characteristic of the filter: the splitting of the filtration area into individual pans. The procedure finally developed was the following (slide N° 7):

- The slurry to be filtered is first fed into the pan; vacuum is not applied immediately in order to allow for the natural settling of the biggest particles contained in the slurry.

- The inner wash system of the pan is then used to wash the filter cake from the inside of the pan.

- Through this operation, the fines (mainly clay) are partially removed from the filter cake surface.

- The filter pan is then slightly tilted so as to discharge part of the supernatant liquid; this eliminates most of the fines from the pan.

- The pan is brought back to its normal horizontal position.

- Only then is vacuum applied to the pan.

Slide N° 8 shows the filter pan specially adapted for this application.

The whole procedure is achieved without modifying the filter cake formed after feeding of the slurry to the pan. It has allowed to increase the resulting porosity of the filter cake to such an extent that the filtration capacity has been significantly increased, even taking into account the filtration area devoted to that procedure.

The desliming effect of this procedure can be appreciated when looking at the particle size distribution of the product before and after the operation described hereabove.

Particle size (mesh Tyler)	Percentage	
	Feed slurry	Product
+ 60 mesh	29.2%	40.0%
60 to 150 mesh	30.3%	46.3%
150 to 200 mesh	8.2%	9.8%
200 to 325 mesh	26.1%	3.6%
- 325 mesh	6.2%	0.3%

This technique was made possible by the existence of the recent features of the Bird-Prayon filter. It was developed in the phosphate field but can be extended to more difficult applications thanks to process and mechanical devices giving the Bird-Prayon filter more flexibility than ever.

TA/82/16 Process and equipment developed to meet the challenge put to the phosphate industry by high energy cost and varying quality of the raw materials, by A. DAVISTER & M. PEETERBROECK, Société Chimique Prayon-Rupel, Belgium, H. GRAY & K. MOLINEUX, Lightnin Mixers Limited, Belgium, G. GRANVILLE, Bird Machine International, Belgium

DISCUSSION : (Rapporteur : Mr. N. SIMOGLOU, PFI, Greece)

Q - Mr. P. ORPHANIDES, PFI, Greece

In one of your slides you have shown a weak solution tank below the filter where I think phosphate rock and water are added. Could you please give more details about the tank?

A - After it receives countercurrent washing liquors, this collecting tank will help to achieve a first dechlorination with the slurry introduced in the vessel; it means that, in that tank, we receive phosphate rock, which has to be dechlorinated and deslimed, the make-up water and recycled weak acid.

This system is used to remove the fines which form an impermeable layer on top of the cake and which affect the porosity of the cake. This is a desliming and not a reactor.

Q - Mr. P. BECKER, COFAZ SA, France

What amount of antifoam agents do you save with your foam breaking devices? (compared with the previous reactor type).

A - 1. For current phosphates containing 3-4% CO_2, the use of new agitators and of the low level flash cooler enables to avoid the use of antifoaming agents, except for exceptional corrections of possible disorders. In addition these new systems make it possible to process low grade phosphate rocks high in CO_2 and organic matter with a limited usage of antifoaming agents. As a result phosphates containing more than 10% CO_2 have been processed using only a maximum of 2 lb/t P_2O_5 antifoaming agent. But the adjustments are being made to improve the results in accordance with industrial experience.

2. Foam breaker paddles used in the previous agitator design (Mark III) are the same as in the new Mark IV design. If we compare performance of these plants with that of the plants that do not have foam breaker paddles in their agitators (Mark I and Mark II), the defoamer consumption has been reduced from 6-8 lb/t P_2O_5 to 2-3 lb/t P_2O_5. This applies to 66/68 BPL Central Florida rock containing 3-4% CO_2. With a typical defoamer cost of $ 0.15/lb, this reduction in defoamer consumption equates to a saving of $ 200,000/year for a 300,000 tpy P_2O_5 plant.