

HEMIHYDRATE PHOSPHORIC ACID PLANT RETROFITS

AT GEISMAR AND CHINHAE

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INTRODUCTION

As the operating margins of existing phosphate fertilizer plants become increasingly more difficult to maintain, many producers are looking for ways of increasing throughput, improving recovery efficiencies and reducing raw material and utility consumptions by retrofits or plant modifications.

This paper describes two examples of retrofits of existing phosphoric acid plants, utilising the Norsk Hydro Licensing hemihydrate processes. (See Appendix I for process details).

The first, Arcadian Corporation of Geismar, Louisiana currently operate a 490 mtpd dihydrate process Prayon plant, built in 1966. They produce around 26% P₂O₅ ex-filter from Bu Craa rock. This acid is evaporated in two stages to 42% P₂O₅ and then 58-61% P₂O₅ for use in liquid fertilizers. Steam is raised from a 1455 mtpd H₂SO₄ plant.

The phosphoric acid plant is being converted to the Norsk Hydro Licensing hemihydrate process. HiTech Solutions Inc., are doing the detail and engineering whilst the Engineering Department of Arcadian Corporation are handling electrical and off-site details.

The second, Chinhae Chemical Company of Chinhae, South Korea, currently operate a 200 mtpd dihydrate process Prayon plant, also built in 1966. They produce around 32% P₂O₅ ex-filter from 68 BPL Florida rock. This is evaporated to 42% P₂O₅ and used to produce DAP. Some acid is concentrated to 48% P₂O₅, defluorinated and used to produce animal feed ammonium phosphates. Steam is raised from a 550 mtpd H₂SO₄ plant.

This plant is being converted to the Norsk Hydro Licensing hemidihydrate process. Lurgi GmbH (Frankfurt) are carrying out the basic engineering design whilst Sunkyong Engineering and Construction Ltd., Seoul, S. Korea are handling the detailed engineering.

As background, Appendices I and II describe the basic hemihydrate processes and the principles of conversion to the hemihydrate route.

Details of referenced plant conversions are given in Appendix III.

1. HEMIHYDRATE PLANT CONVERSION - ARCADIAN CORPORATION, GEISMAR

a) Background

Arcadian Corporation have a 490 mtpd P_2O_5 dihydrate process phosphoric acid plant, producing approximately 26% P_2O_5 acid from the filter. This is then evaporated in stages (42%, 55%, 58+% P_2O_5) to produce superphosphoric acid (SPA) at around 70% P_2O_5 . This highly concentrated and pure product is used to manufacture liquid fertilizers.

Conversion to the hemihydrate (HH) process will increase the ex-filter acid concentration to 40% P_2O_5 and at the same time increase plant capacity to 655 mtpd P_2O_5 . Thus the combined effect will dramatically reduce the evaporator loading together with a significant saving in steam consumption. As evaporator loadings are reduced, the present cooling tower water supply will cease to be a bottleneck.

The high concentration acid feed to the SPA plant will also lead to a significant saving on SPA vapour load per ton of product. Thus another bottleneck will be eliminated. Some of the hemi acid (concentrated to 54% P_2O_5) will be put through a new Wet Acid Purification Plant (WAP). Various side streams and scrubber liquors from the SPA and WAP plants will be recycled back to the phosphoric acid attack tank.

The phosphoric acid plant modifications will be carried out in parallel with normal production to minimise the shutdown and tie-in period, which is scheduled for approximately four weeks.

The hemihydrate process is due to start-up at Geismar in August 1990.

b) Project Details

The original dihydrate process Prayon attack tank is illustrated in Figure 1. It consisted of a rectangular concrete structure, divided into 9 compartments.

Phosphate rock was washed on a belt filter and discharged into compartment 2. Sulphuric acid, diluted with pond water, was fed to compartments 1 and 3. Slurry was pumped from compartments 7 and 8 to the two flash coolers to control temperature and returned to compartment 9.

The Prayon filter was supplied with slurry from compartment 9 and the calcium sulphate dihydrate (gypsum) separated from the product phosphoric acid (26% P_2O_5).

The dihydrate reactor will be converted to the hemihydrate process, as illustrated in Figure 2, as follows:-

- Reaction zone 1 consists of compartments C2 to C7.
- Reaction zone 2 consists of compartments C8 and C9.
- Compartment C1 is the filter feed tank.

The attack tank will be modified slightly such that reaction volume, circulation and extraction profiles are optimised.

The basic construction of the reaction system, however will be unchanged and the existing materials of construction are expected to be resistant to the hemihydrate process conditions.

FIGURE 1 ORIGINAL PRAYON REACTION SYSTEM

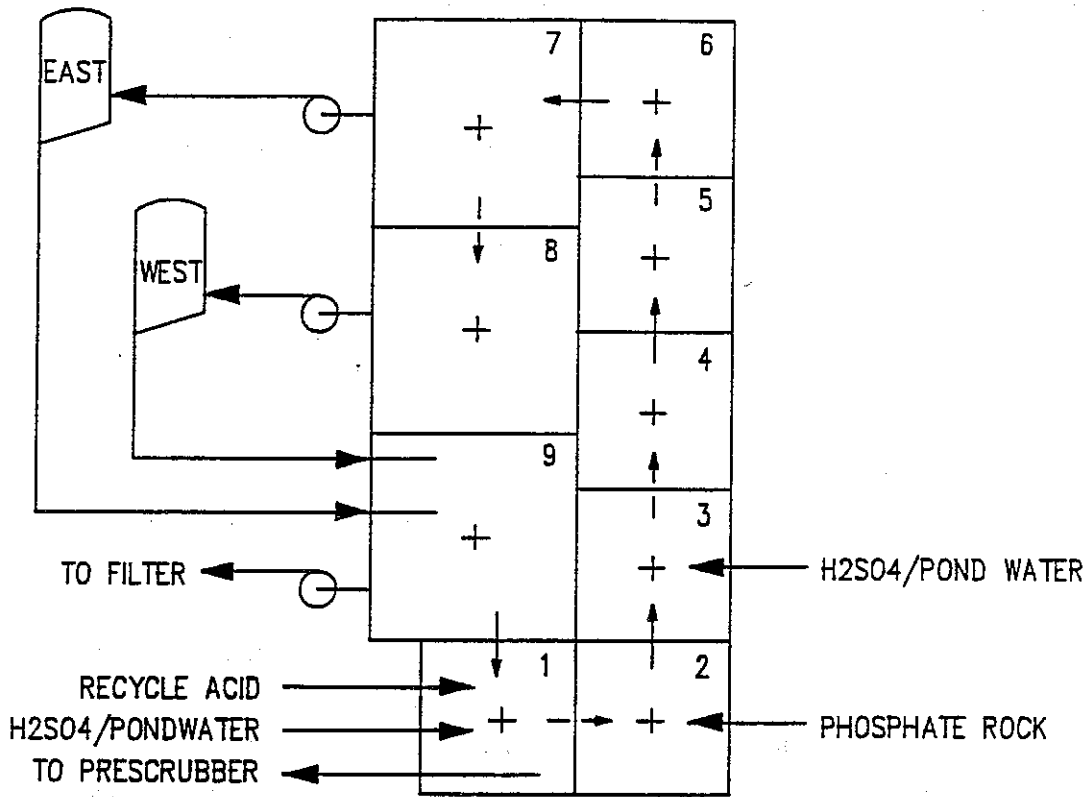
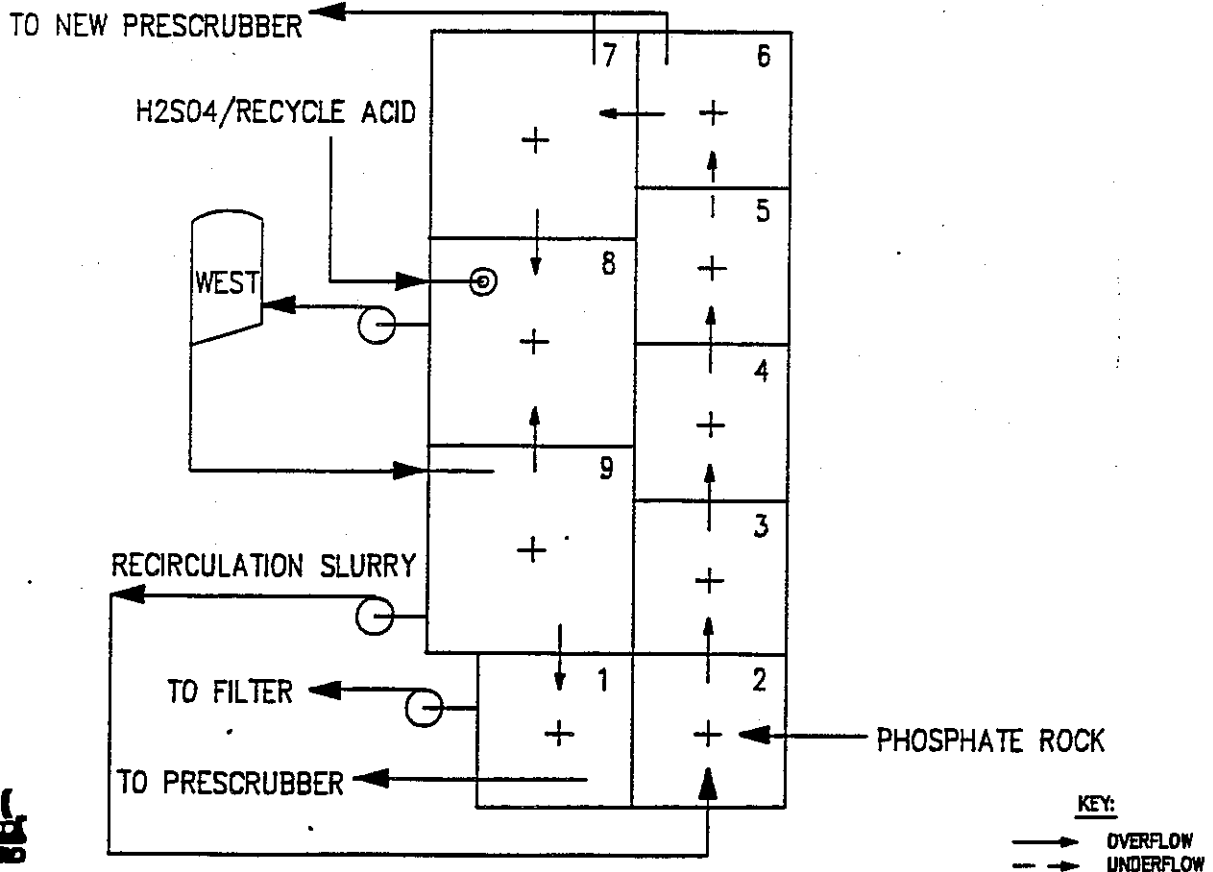


FIGURE 2 CONVERTED HEMIHYDRATE REACTION SYSTEM



Several new nozzles will be added whilst others will be modified or removed:-

- New nozzle for Recirculation Pump Suction in C9.
- New nozzle for filter feed pump suction in C1.

The agitators were checked and it was decided to renew the agitator in the most critical compartment, C8.

The compartment 8 agitator will be replaced by a new single 45° pitched turbine to ensure adequate mixing of Reactor 1 slurry with sulphuric and recycle acids.

The existing agitators in other compartments are a mixture of Maxflo T's and twin sets Radial/Maxflo T turbines. These agitators will gradually be replaced, as they become un-serviceable, with dual Maxflo T turbines, as Arcadian had already planned.

99% sulphuric acid and 37% P₂O₅ recycle acid streams will be introduced to compartment 8 through a new conical mixer, designed to efficiently mix the two acids before they contact the slurry.

At the higher concentration and temperature of the hemi process, more silico fluoride fumes are emitted from the attack tank, than in the DH process. Therefore it is necessary to increase scrubbing capacity to maintain acceptable emission levels. The main Teller scrubber will be revamped, and supplemented by a new pre-scrubber.

The filter is a Bird Prayon 24C, being modified to 1037 ft² (96 m²) effective area. The pans are especially fabricated for fast drainage and constructed in 904L stainless steel.

The central valve, also in 904L, is being extensively modified and changed from a two-wash to three-wash system. Filter cut sizes will be optimised and flexible dividers installed between cuts.

The filter hood will be extended, to cope with extra fuming of filtrates, and a proprietary anti-scalant system will be installed to prevent scale formation in the filter circuits.

The Arcadian philosophy of "no seal tanks" is being retained for the hemi conversion. The two filtrate pumps are horizontal vortex impeller pumps and operate directly off the central valve. The recycle acid and product acid pump will also feed directly off the central valve.

All 40% P_2O_5 acid will be fed directly to a day settler tank. The recycle acid fed to the acid mixer will be supplemented by a stream of product acid from the day settler tank, using an existing sludge pump. The concentration and total flow of recycle acid returned to the attack system is controlled by adjusting the flow of this supplementary product acid.

The filter cake will be washed with warm pond water, obtained from the flash cooler scrubber.

Upon discharge from the filter, the hemihydrate cake will be sluiced into the gypsum tank with water from the flash cooler scrubber.

As hemihydrate produced from Bu Craa phosphate is relatively reactive, it readily transforms to the dihydrate gypsum form. To prevent any such transformation and subsequent scaling in the discharge line, a transformation section is being installed. The hemihydrate will be transformed to the dihydrate form prior to pumping the slurry to the gypsum stack.

2. HEMIDIHYDRATE PLANT CONVERSION - CHINHAЕ CHEMICAL COMPANY, KOREA

a) Background

Chinhae Chemical Company currently operate a 200 mtpd P_2O_5 dihydrate process phosphoric acid plant, producing approximately 30-32% P_2O_5 acid from the filter.

This acid is held in store and then concentrated to 42% P_2O_5 and used to formulate ammonium phosphate fertilizer. Some acid is defluorinated and concentrated to 48% P_2O_5 to manufacture animal feed quality ammonium phosphate.

68 BPL Florida rock is currently processed by reaction with 80% H_2SO_4 diluted from 93% H_2SO_4 .

Conversion to the hemidihydrate (HDH) process will boost plant capacity to 250 mtpd P_2O_5 and increase product concentration to 46% P_2O_5 ex-filter thus dramatically reducing the steam requirements. The HDH process will also result in a much improved reaction efficiency of 99%. Sulphuric acid dilution will not be required; 93% acid will be fed to the attack system.

Installation of fluorine recovery units in the flash cooler circuit will allow a valuable by product, fluosilicic acid, to be recovered from the waste gases. It is also intended to utilise the pure gypsum by-product for the manufacture of gypsum board and cement retarder.

Again the hemihydrate process modifications will be carried out alongside normal production to minimise the shut-down and tie in period, scheduled for approximately three weeks.

The Chinhae retrofit is scheduled to start-up in the hemidihydrate mode in November 1990.

b) Project Details

The original dihydrate process Prayon attack system is illustrated in Figure 3. Again, it is a concrete compartmented reactor comprising 9 compartments.

Ground phosphate rock was pneumatically conveyed from the Ball Mill to the ground rock bin and Hardy Scale Unit, prior to entering compartment 1 of the attack tank. Dilute sulphuric acid, recycle acid and water were also added to compartment 1.

Temperature control of the DH process was achieved by pumping slurry from C8 through the flash cooler and into C9. Slurry from C9 was fed to the Prayon tilting pan filter, where up to 32% P₂O₅ acid was obtained.

The dihydrate reaction system will be converted to the hemidihydrate process, as illustrated in Figure 4, as follows:-

- Reaction zone 1 consists of compartments C1 to C6.
- Reaction zone 2 consists of compartments C7 to C9.
- There is no filter feed volume, as such, although compartments 7 and 8 will operate at a reduced level to accommodate surge capacity.

The above reactor zones will be engineered by minor modifications to the existing attack tank. Again, the existing reaction tank materials of construction are expected to be suitable for the hemihydrate process conditions.

FIGURE 3 ORIGINAL PRAYON REACTION SYSTEM

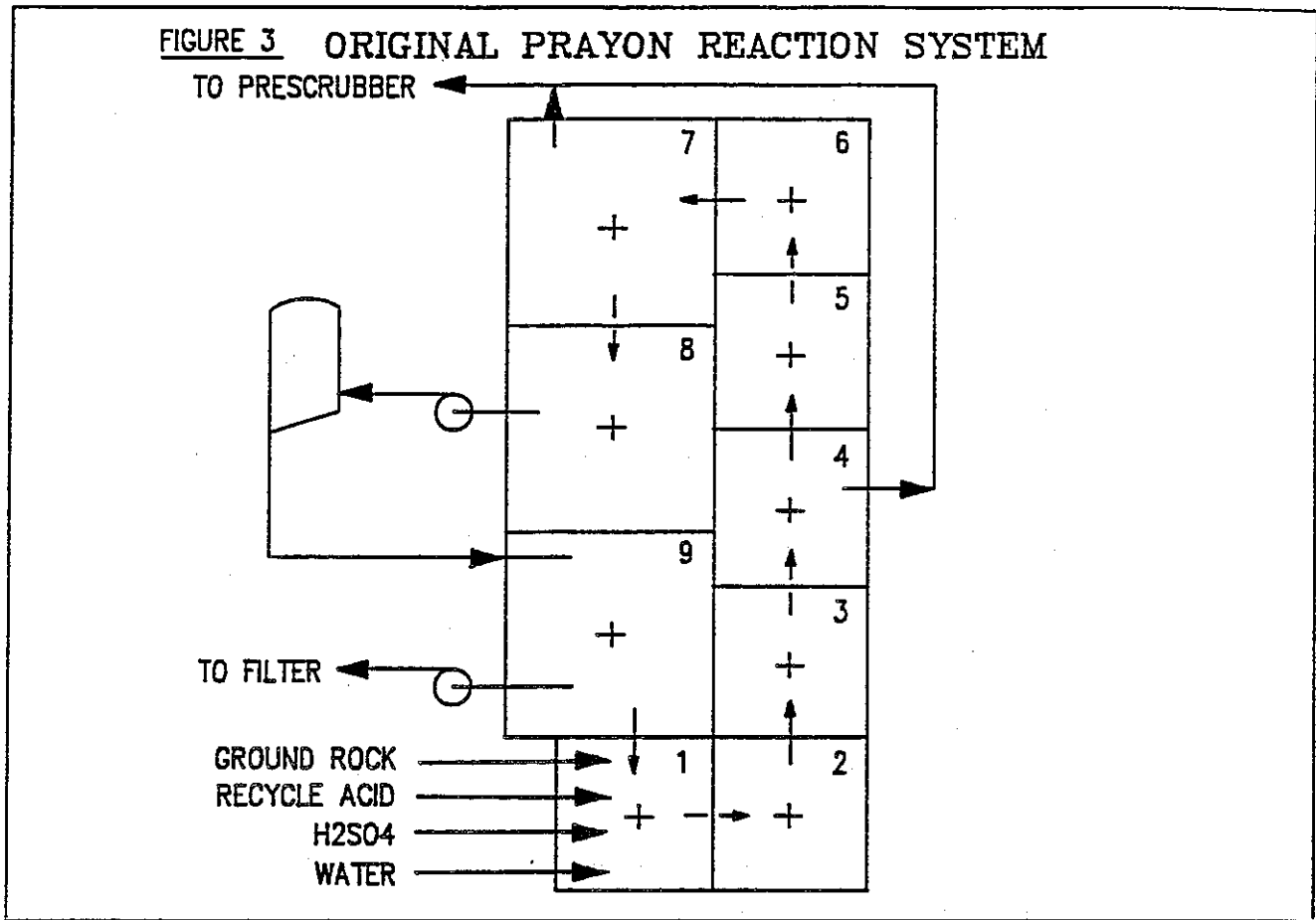
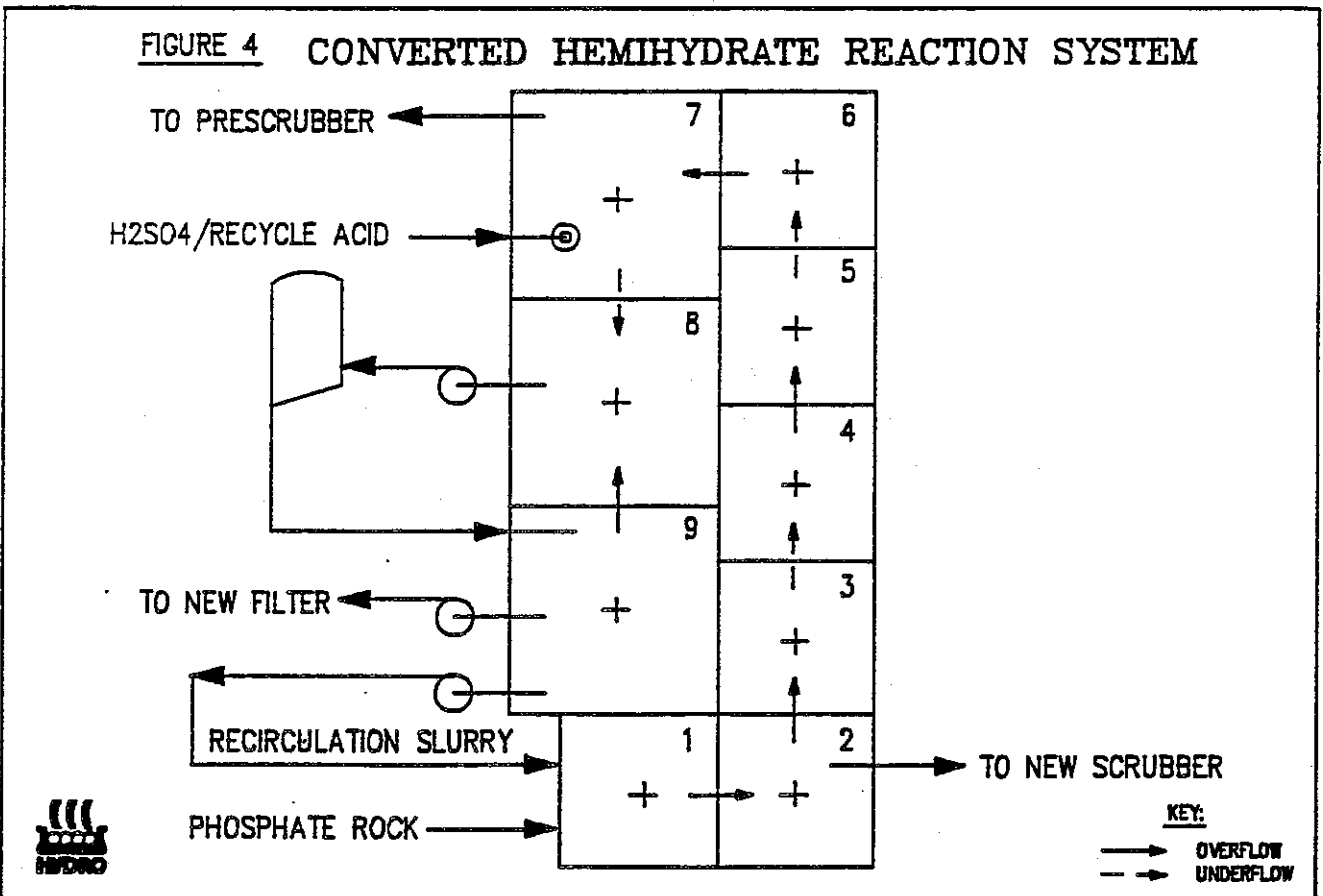


FIGURE 4 CONVERTED HEMIHYDRATE REACTION SYSTEM



Other modifications include:-

- New vertical submerged filter feed pump in C9.
- New vertical submerged recirculation pump in C9.

93% Sulphuric acid will be mixed with 41% P₂O₅ recycle acid in a conical mixer, located in the roof of compartment 7.

The gas scrubbing system is being substantially modified and up-graded. The existing reactor pre-scrubber and Teller scrubber will be retained and an additional new scrubber system will be provided.

The reactor off gas duct from C4 to the prescrubber becomes redundant, but the duct from C7 will be retained and equipped with irrigation sprays. Reactor off-gases pass into the prescrubber and after removal of excessive silica, the partially cleansed gases pass to the existing Teller scrubber, where they will be joined by gases from the new hemi filter, transformation tanks and filtrate tanks. The scrubbing medium will be pond water, on a once-through basis.

The reactor extraction will be enhanced by installation of a new scrubber system, consisting of two void towers extracting from compartment 2. The off-gas duct will be irrigated and the scrubbing medium will be pond water.

The use of two separate gas scrubber systems will enable the allowable fluorine emissions to be met and also give flexibility during inspection and cleaning periods.

An important by-product of the process, fluosilicic acid, is recovered as a 20% w/w solution. New equipment is being installed between the flash cooler and flash cooler condenser, consisting of two void towers, seal tanks and an entrainment separator. Fresh water will be used as make-up to the second tower and the resulting weak fluosilicic acid will be cascaded to the first tower, from which a product suitable for manufacture of cryolite and fluosilicates is pumped.

A new Eimco belt filter (50 m²) is being installed for the hemihydrate filtration stage, producing 46% P₂O₅ acid directly. New filtrate seal tanks, pumps and ancillaries will also be installed, together with a new variable speed filter feed pump.

The transformation section consists of two agitated tanks situated below the discharge of the hemi filter.

A new variable speed pump is being installed to supply the old 21B Bird Prayon filter directly with dihydrate slurry; the splitter box will not be required. Other modifications to the 446 ft² (41.4 m²) filter will include changing from a three-wash to a two-wash system, new feed and wash boxes and adjustment of the filter valve and wash box positions.

The existing flat bottomed filter pans will be progressively replaced with new sloped bottom pans, during operation, in the next 1 or 2 years.

The dihydrate gypsum filter cake will be washed with warm pond water and the discharged cake slurried and pumped to the existing stack system.

3. COMPARISON OF THE TWO RETROFITS

a) Phosphate Rock

Although the two retrofits are both Prayon DH process conversions to NHL hemihydrate and hemidihydrate processes, it is clear there are other major differences, apart from the process route.

The main difference is that of phosphate rock source. The Arcadian plant will process high grade (80 BPL) Bu Craa phosphate whilst the Korean plant will process 68 BPL Florida phosphate.

The Bu Craa rock is already of suitable size analysis (100% - 2mm) for the hemihydrate processes, therefore can be fed without grinding. The Florida rock (pebble) will require scalping and grinding of the oversize (+ 2.0 mm) prior to feeding to the attack tank in dry form.

The Bu Craa rock arrives from Morocco with a high chloride content (≈ 3000 ppm) due to it having been beneficiated and washed with sea water. The chloride level is reduced to 100 ppm by slurring in water and further washing on a belt filter. Hence the washed rock is discharged to the attack tank system as a wet solid containing approximately 17% w/w free moisture.

b) Acid quality and its impact on Materials of construction.

The expected analyses of the product acids are given in Table 2

Although the Bu Craa acid contains a lower level of impurities, (particularly chloride) than the Florida acid, it is much more corrosive.

The fluorine content of Bu Craa rock is high, which, together with a high pond water (cake wash) fluorine level, leads to an increased level of fluorine in the product acid. Furthermore, the relatively low iron content in the Bu Craa acid makes for a very aggressive acid.

The Florida acid, on the other hand, contains more chloride resulting from contamination of pond water used as cake wash, due to the coastal location of the Chinhae plant. The recovery of fluosilicic acid from the process will lower pond water fluorine levels at Chinhae and therefore produce an acid of more moderate fluorine level. However the corrosivity of the chloride and fluoride is reduced by a relatively high iron level in the reaction acid.

The above differences in acid composition are reflected in the utilisation of different materials of construction for relevant equipment.

For the corrosive Bu Craa acid the materials of construction of many of the pumps will be Neoprene rubber lined and equipped with Hastelloy G-30 wetted parts. Reactor agitators will be renewed in Hastelloy G-30.

However with Florida acid at Chinhae, 904L and 317L steels will be used for these duties in spite of the higher reaction acid concentration.

c) Some process characteristics of the modified plants

The specific details of the two plants and their associated process characteristics are compared in Table 1 overleaf.

It can be seen that for Arcadian, the HH process, despite utilising wet rock, is able to produce acid of 40% P₂O₅ concentration. The HDH process at Chinhai, processing dry rock, produces an acid in excess of 46% P₂O₅ even when using 93% H₂SO₄.

The performances expected from the two retrofits are compared in Table 2. These reflect the main differences between the HH and HDH process routes.

The HH process P₂O₅ recovery efficiency of 95.5% compares well with that obtained from the DH process. The expected recovery is significantly increased to 99% by transformation of hemihydrate to dihydrate in the HDH process. As the hemihydrate is transformed to dihydrate, co-crystalline P₂O₅ is released from the crystal lattice into the liquid phase, enabling the P₂O₅ to be recovered via the DH filtration stage.

The HH process consumes less H₂SO₄ than the DH process, mainly due to a lower concentration of SO₄ in the reaction acid. The HDH process consumes even less, mainly due to the improved HDH reaction efficiency.

Fluosilicic acid (FSA) can equally be recovered from the HH process as well as the HDH process. At Geismar, however, FSA was not required by Arcadian and therefore all the scrubber fluorine effluents are retained in the pond water system.

The acid analysis given in Table 2 shows the good acid quality from the HH and HDH processes. The low levels of sulphate and aluminum of hemihydrate acids contribute to reduced sludge handling requirements and the quality of downstream products is enhanced.

TABLE 1: SOME PROJECT DETAILS

PLANT LOCATION	GEISMAR, USA	CHINHAE, KOREA
Process	HH	HDH
Rock	17% H ₂ O 80 Bu Craa Unground and Washed	Dry 68 Florida Scalped and Ground
Product	40% P ₂ O ₅	46% P ₂ O ₅
H ₂ SO ₄	99%	93%
By-product	None	20% FSA
Capacity	655 mtpd	250 mtpd
Materials of Construction	Neoprene Hastelloy G-30 904L	904L 317L

TABLE 2: EXPECTED PERFORMANCE

PLANT LOCATION	GEISMAR, USA	CHINHAE, KOREA
Capacity (mtpd)	655	250
P ₂ O ₅ (%)	40	46
Solids (%)	1.5	1.0
SO ₄ (%)	1.6-2.0	1.6-2.0
Recovery (%)	95.5	99.0
H ₂ SO ₄ (t/t P ₂ O ₅)	2.62	2.48

Acid analysis

% w/w

P ₂ O ₅	40	46
SO ₄	1.6-2.0	1.6-2.0
Al ₂ O ₃	0.1	1.3
Fe ₂ O ₃	0.34	1.5
F	2.15	1.3
MgO	0.07	0.7
Cl	0.01	0.02

4. REASONS FOR RETROFIT

Conversion of the two dihydrate process plants to the hemihydrate processes will be yet another example of phosphate producers looking to the future and making decisions to substantially increase their operating margins.

The main reasons and benefits for retrofitting the Geismar and Chinhae plants are as follows:-

a) Rock Grinding

Substantial savings will be realised at Chinhae from the reduced rock grinding requirement; the introduction of screens and other modifications to the rock handling section will allow in-specification rock particles to by-pass the ball mill, whilst only those outside specification will be ground.

b) Capacity

In both retrofits, a boost in production capacity will be obtained without increasing the number of HH reaction vessels. The Chinhae plant production will increase by 25% and the Geismar plant by 33%.

c) Cooling

Another beneficial result of retrofitting the two plants to hemihydrate processes will be a reduction in the plant cooling requirements. The lower heat of reaction and greater natural losses due to operating at a higher temperature are the main factors which contribute to a reduced load on the flash cooler system and in the case

of Arcadian, allows for the complete abandonment of one of the two flash cooler circuits. This in turn leads to a lower cooling water consumption.

d) Filter acid strength

Considerably higher acid strength will be produced directly from the filter, offering substantial savings in steam and cooling water consumptions.

At Arcadian the current 26% P_2O_5 acid will be increased to a product strength of 40% P_2O_5 . At Chinhae, the product acid strength will increase from approximately 31% P_2O_5 to 46% P_2O_5 .

Economies are made by eliminating the requirement for evaporating weak acid (26 to 32% P_2O_5) up to intermediate 40-45% P_2O_5 . The cooling water normally used on the evaporator condensers during this concentration process will no longer be required.

In the case of the Geismar Plant, cooling water and SPA plant bottlenecks will be removed.

There will be considerable savings in steam consumption in the evaporators. In the Chinhae plant, there will be no need at all to evaporate filter acid prior to use in downstream products. At Geismar, 40% P_2O_5 acid will be the starting point for the concentration process, realising substantial steam savings.

The reduced evaporator loadings will also result in lower maintenance costs for the evaporator units.

e) Product quality

The two plants will benefit from retrofitting due to the superior acid quality produced in hemihydrate process plants. Levels of both sulphate and aluminium, in particular, will substantially reduce sludge handling requirements, and also lead to improved quality of downstream products.

The production of high strength acids will also simplify the acid storage system, eliminating the requirement to store weak acids.

On an earlier plant retrofit at Belledune, Canada the hemihydrate acid produced from 68 Florida rock was of such purity that clarification was not required.

Acid produced from the hemihydrate or hemidihydrate processes can be expected to cure the frequent problem of low P_2O_5 levels in DAP produced from DH process Florida acids. After conversion to the hemihydrate process at Belledune, over formulation of DAP was a common problem, even when the cloudy port acid was allowed to combine with the product acid.

f) Plant Operation

Retrofitting to the HH process at Geismar will simplify operation of the evaporator and acid purification systems. Control of the HH process will also be simplified with only one H_2SO_4 addition and control point. Experience with previous retrofits shows that savings can also be made by reducing the number and work load of plant operators.

After nearly four years of hemihydrate operation at Belledune, the plant habitually runs at or above design rate with minimal effort from the plant operators.

5. CONCLUSION

This paper has given the project details of retrofitting two dihydrate process plants to the Norsk Hydro Licensing hemihydrate processes.

Both plants are due to start-up this year and we hope to be back with news of start-up and performance of these retrofits next year.

We believe they will endorse the relevance of hemihydrate technology to the cost saving aspirations of the phosphate producer.

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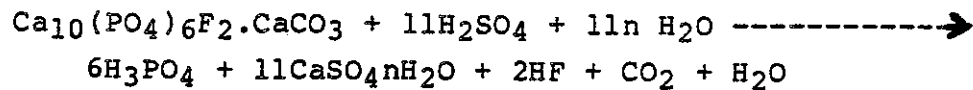
APPENDIX I

PROCESS DESCRIPTION

The following descriptions of the hemihydrate processes are written for conventional new plants but the principle is still relevant to converted plants.

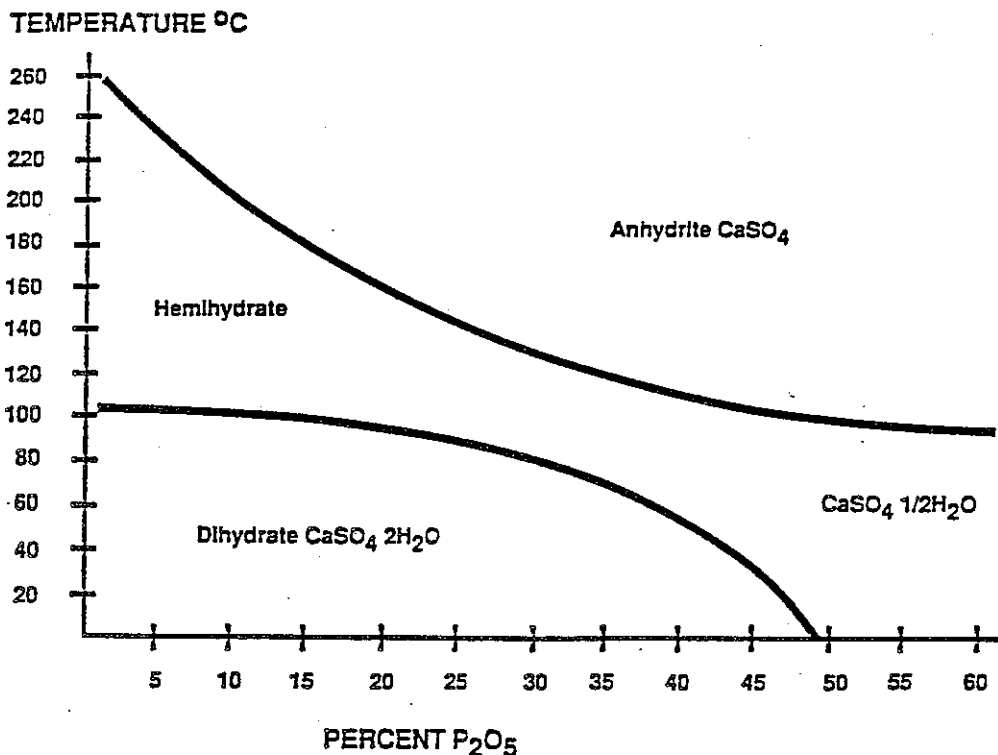
They may be of assistance for those people not already familiar with the hemihydrate processes.

The chemical reaction involved in phosphoric acid production can be expressed:



the degree of hydration, n, being 0, $\frac{1}{2}$ or 2 depending on whether the calcium sulphate is in the form of anhydrite, hemihydrate or dihydrate. This, in turn, is determined in accordance with the phase diagram shown in Figure 5.

Figure 5

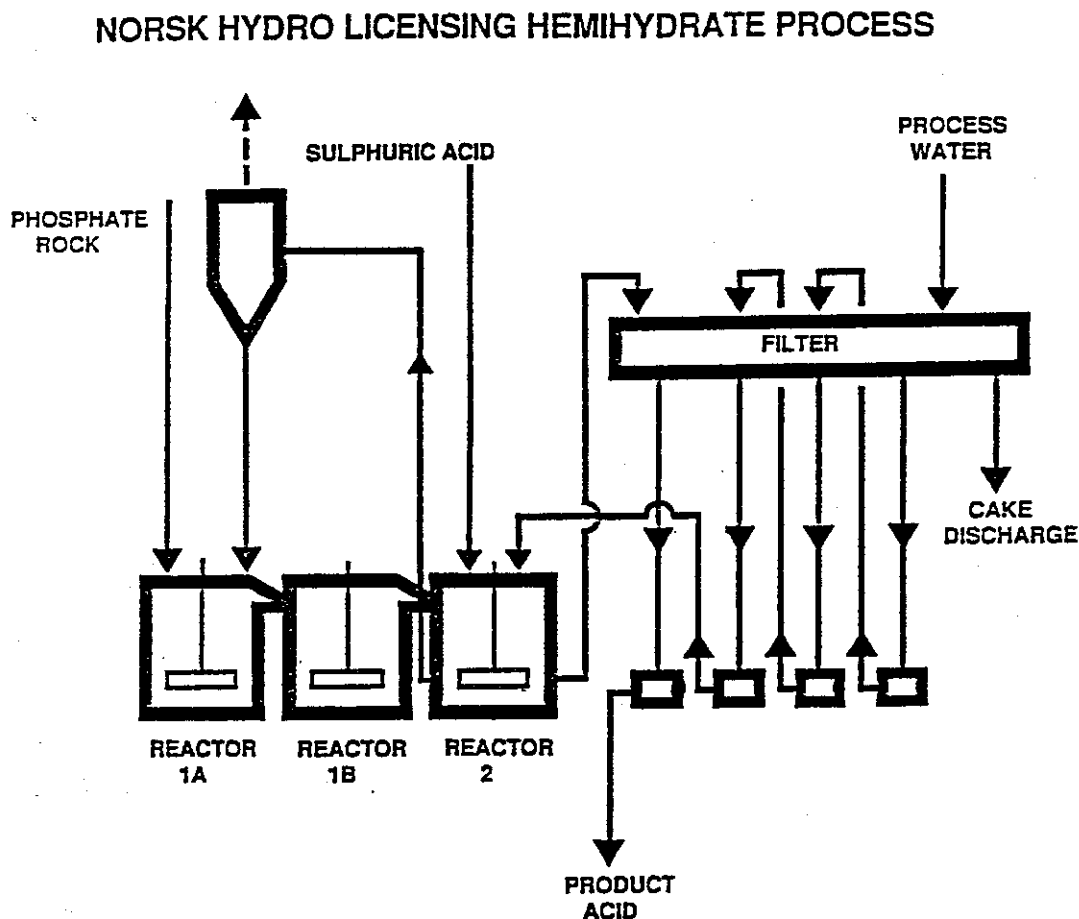


It can be seen that, to produce calcium sulphate in the dihydrate form, conventional processes operate typically at 80°C and 30% P₂O₅. Hemihydrate processes are controlled at 100°C and 40-50% P₂O₅, so that no separate concentration stage is required and significant reduction in energy consumption is achieved. Further, a number of unit operations necessary for a dihydrate process (e.g. intermediate acid storage, concentration, clarification) are avoided with the hemihydrate route.

Hemihydrate (HH) Process

The major operations involved in the HH process are shown in Figure 6. Reaction and filtration are the key process steps. The hemihydrate reaction proceeds in two distinct zones. It is therefore necessary to have at least two vessels or compartments. The preferred volumetric ratio is 2:1.

Figure 6



Phosphate rock is fed to reaction zone 1, sulphuric acid and dilute phosphoric acid ("return acid" from the filter) are fed to reaction zone 2. Slurry from reaction zone 2 is recycled to reaction zone 1, thus exposing the phosphate rock to sulphate ions under controlled chemical conditions. Heat is removed by air or vacuum cooling to maintain the reaction slurry temperature at 98-100°C.

Acid can be produced at between 40-52% P₂O₅ depending on downstream requirements.

The product acid and hemihydrate are separated by a horizontal vacuum filter with counter current wash stages. The product acid from the filter passes directly to storage. It does not require clarification or solids removal.

The HH process is simple with few unit operations. It is especially suited to mine site operations where phosphate rock is readily available at a relatively low cost.

Hemidihydrate (HDH) Process

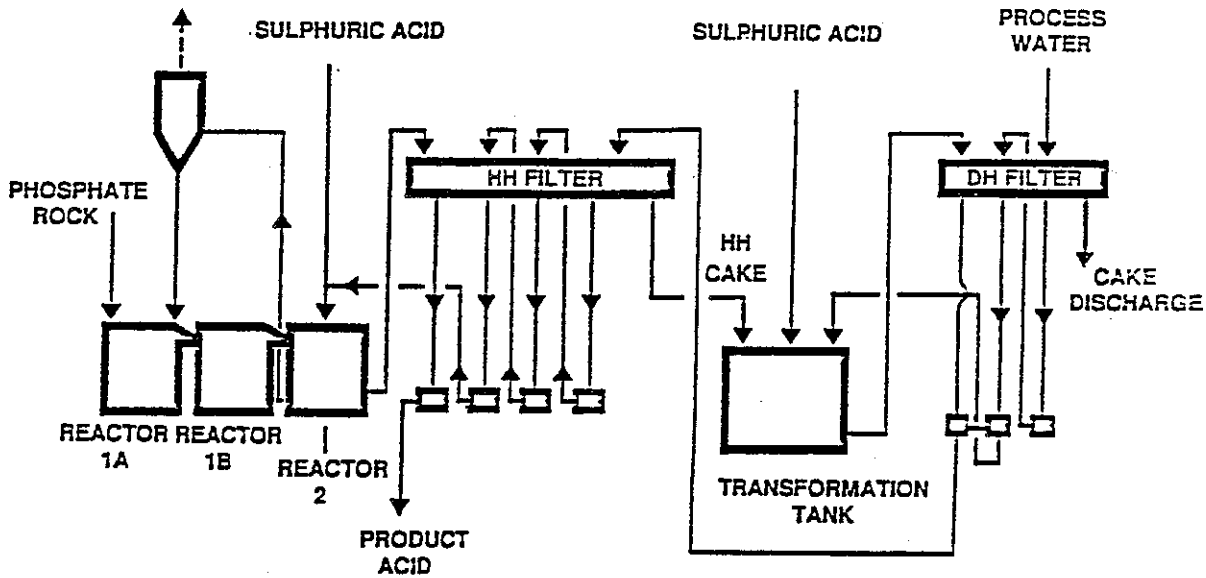
The HDH process is a development of the HH route whereby the P₂O₅ recovery efficiency is increased to around 98.5%.

In the HH process, as in the dihydrate process, the P₂O₅ recovery efficiency is affected by co-crystallisation of phosphate in the calcium sulphate crystal lattice. When phosphate rock costs are increased for example by the cost of transportation and handling, the lattice P₂O₅ loss from the phosphoric acid process can be reduced by using the HDH route. The addition of a transformation stage to the HH process, allows hemihydrate to be re-crystallised to dihydrate thus releasing lattice P₂O₅ into solution from which it can be recovered. This makes the HDH process particularly attractive for manufacturing locations remote from the source of phosphate rock.

A simplified flow diagram of the HDH process is shown in Figure 7 over page.

Figure 7

NORSK HYDRO LICENSING HEMIDIHYDRATE PROCESS



The first stage of the process is almost identical to the HH process already described.

In the transformation stage the hemihydrate cake is discharged from the first stage filter into an agitated vessel. The operating conditions are controlled to ensure complete transformation of hemihydrate to dihydrate and to allow sufficient time for the dihydrate crystals to grow. The rate of transformation is increased by the addition of a small feed of sulphuric acid. Nearly all the lattice P O co-precipitated with the hemihydrate

APPENDIX II

PRINCIPLES OF PLANT CONVERSION TO THE HEMIHYDRATE PROCESSES

This section covers the fundamental aspects of a plant conversion to the hemihydrate (HH) or hemidihydrate (HDH) processes. It is a general guide to the basic principles of converting an existing plant to the hemihydrate processes.

Any conversion of an existing dihydrate plant to a hemihydrate process starts with a review of the process design and operating parameters of the hemihydrate technology with respect to the dihydrate equipment available. The objective is to achieve compatibility between the two. The main unit operations to be considered are as follows:-

Phosphate Rock Feed

Because the hemihydrate processes can normally accept a coarser particle size analysis of phosphate rock than the dihydrate process, a plant converted to hemihydrate technology can utilise the existing rock feed and preparation system with minimal modifications. Providing the rock passes a 2mm seive, grinding will not be necessary. However, if the existing grinding system cannot be bypassed then a finer grind is quite acceptable for both processes.

Reaction

Although hemihydrate operation requires two reaction zones, these can take place in a number of reactors or compartments. Phosphate rock and recycle slurry is fed to the first compartment and the reaction system can be arranged such that a hemihydrate process can be operated.

The exact details of the attack system will require studying to fully optimise the reactor configuration.

Agitation

Following developments in agitator and reactor design, the agitator power requirement in the hemihydrate stage of the process is not significantly different from that of the dihydrate process.

However, because of the higher P_2O_5 in the liquid phase, the hemihydrate reaction slurry normally has a higher viscosity and higher specific gravity than dihydrate slurry. The effect can be easily compensated for, if necessary, by reducing the speed of rotation or diameter of the agitators to the level where the absorbed power matches the installed power of the gearbox.

Cooling

Norsk Hydro Licensing normally designs hemihydrate plants to utilise a flash cooling system, however air cooling can be used and is easily adapted to the hemihydrate system.

The heat of reaction when producing calcium sulphate hemihydrate is approximately 20% lower than when producing the dihydrate form. Furthermore the hemihydrate reaction slurry is cooled to $100^{\circ}C$ whereas the dihydrate slurry is cooled to $80^{\circ}C$ requiring extra cooling capacity. As a result the reaction cooling load in the hemihydrate process is lower than in the dihydrate process. The acceptable temperature differential across a flash cooler in a hemihydrate system is larger than in a dihydrate plant and therefore the cooling capacity of an existing flash cooler can be increased. Scaling of flash cooler and slurry piping does not occur under the conditions of the hemihydrate processes.

Gas Scrubbing

Because the operation of a hemihydrate process is at a higher temperature than a dihydrate plant it results in increased fluorine evolution mainly as SiF_4 , in the exhaust system. The degree of fluorine evolution is dependent on the level of

impurities in the phosphate rock being processed. It is therefore necessary to examine an existing gas scrubber system to assess whether it can cope with the increased fluorine levels in the reaction exhaust gases. A pre-scrubber is normally used so that fluorine and silica quantities can be reduced prior to the gases entering the main scrubber.

Filtration

Although the filtration rate of hemihydrate slurry can be lower than that of dihydrate slurry, because of hemihydrate permeability and acid viscosity, with many widely used phosphates there is little if any penalty on filtration when producing acid below 45% P₂O₅.

Commercial hemihydrate plants have used belt, table and tilting pan filters, each of which has been satisfactory. Therefore the use of an existing filter of these types is not expected to present a problem.

Transformation

The rate of transformation of hemihydrate to dihydrate can vary with different phosphate rocks. Normally it is sufficient to provide a residence time of 3-4 hours and a small flow of sulphuric acid.

Agitation in the transformation stage, though important, is not critical and a simple mixing system will suffice.

APPENDIX III

EXPERIENCE WITH CONVERSIONS

This section provides details of the growing number of retrofits already licensed by Norsk Hydro Licensing.

1. Hydro Agri Rotterdam (Windmill)

Location : Vlaardingen, near Rotterdam, Holland
Date of Conversion : 1983
Capacity as
Dihydrate Plant : 320 mtpd
New Capacity : 330 mtpd
Significant New
Equipment : Reaction gas scrubbing facilities

2. The Royster Company

Location : Mulberry, Florida, USA
Date of Conversion : 1985
Capacity as
Dihydrate Plant : 585 mtpd
New Capacity : 585 mtpd
Significant New
Equipment : Fluorine scrubbing

3. Brunswick Mining and Smelting

Location : Belledune, New Brunswick, Canada
Date of Conversion : 1986
Capacity as
Dihydrate Plant : 500 stpd
New Capacity : 500 mtpd
Significant New
Equipment : Additional fluorine scrubber

4. Hydro Supra AB

Location	:	Landskrona, Sweden
Date of Conversion	:	1986
Capacity as		
Dihydrate Plant	:	240 mtpd
New Capacity	:	360 mtpd
Significant New		
Equipment	:	New hemihydrate reaction and filtration equipment