HEMI OR HEMI-DI?

ARCADIAN CONVERTS PHOS ACID FROM DIHYDRATE TO HEMI

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SUMMARY

The Arcadian phosphoric acid plant was converted from a 540 STPD dihydrate plant to a 720 STPD Hemi plant. Feedstocks are BuCraa phosphate rock and 99% H_2SO_4. The product is made into superphosphoric acid and food grade phosphoric acid. The process is the Hydro Hemi Process. It was engineered by HiTech Solutions, Inc. - North American licensee for Hydro Hemi and Hemi-Di conversions.

The plant started up quickly and runs very well - easily exceeding all guaranteed performance criteria. Benefits include greatly reduced evaporator steam consumption, increased capacity, easier operation than dihydrate, and purer product. Elimination of evaporation and cooling water limitations allows increased evaporator product concentration and subsequent capacity increase and cost reductions in the superphosphoric acid plant.

BACKGROUND

The Arcadian plant is on the Mississippi River at Geismar, LA. It receives BuCraa phosphate rock by ship from north Africa. Most sulfuric acid is produced from sulfur on site as 99% H_2SO_4, and a small amount is received from outside. Before the Hemi conversion phosphoric acid capacity was about 540 STPD P_2O_5, and it was all made into superphosphoric acid and liquid fertilizers. Production rate had been limited by capacity of the evaporators and the recirculated cooling water system.

A capacity increase to 720 STPD P_2O_5 was needed, and some of the phosphoric acid would be fed to a new wet acid purification plant. The acid purification plant consumes steam and would returns dilute raffinate to the phosphoric acid plant.

Expansion of capacity by three routes was considered:

<1> <u>DIHYDRATE</u> — Produce 26% P2O5 filter product by expansion of the existing process.

<2> <u>HEMI</u> — Produce 40% P2O5 filter product by a straight Hemihydrate process.

<3> <u>HEMI-DI</u> — Produce 40% P2O5 filter product. Re-digest the Hemi filter cake to obtain very high recovery.

PROCESSES CONSIDERED

DIHYDRATE PROCESS

The Dihydrate route is conventional and predictable. The Arcadian plant is one of dozens of Prayon dihydrate phosphoric acid plants in the United States which have been operating for many years. This process wastes much energy, because weak filter product acid requires so much evaporator steam to raise its concentration. There is a trend to convert such plants to Hemi or Hemi-Di.

Acid concentration is limited, because a small increase in concentration puts the reaction in the transition range between making calcium sulfate as dihydrate or hemi hydrate, as shown in the attached graph. In this transition range the crystals are small, filter very slowly, and can cause serious scaling.

HEMI PROCESS

The Hemi process is by Hydro (formerly Fisons but now part of the Norsk Hydro Group), and its track record includes over ten plants which have been built or converted from dihydrate during the past 20 years.

Hemi plants operate further from the hemi/di transition range than dihydrate plants (shown in the attached graph), which enhances stability and minimizes scaling. A hemi plant can produce acid between 40% to 50% P_2O_5. A combination of high temperature and high concentration is avoided to keep out of the hemi/anhydrite transition range. Where energy cost is low or there is no requirement for higher concentration, hemi plants frequently make 42% P2O5 filter product.

The most recent previous Hydro Hemi conversion in North America was at Belledune, NB, Canada. We designed the conversion of this plant from a Prayon dihydrate plant, which is similar to the Arcadian plant and many Florida and Louisiana plants. It was started up in September, 1986, and within 19 days it was consistently exceeding guaranteed performance criteria, using Central Florida phosphate rock. It continues to be reliable, is easy to operate, averages 95% recovery on Florida rock (2% above the guarantee), and readily exceeds the 500 mt/d design capacity.

A Hydro Hemi conversion for Royster in 1985 had initial difficulties due to use of the wrong anti-scalant and an ineffective defoamer, but not due to the process per se. Once these problems were corrected the plant ran reliably at capacity. Eventually the Royster plant was converted to a dihydrate plant of increased capacity. Reasons for selecting the dihydrate route for expansion rather than Hemi included ease of conversion (for example, an existing old second filter was OK for dihydrate, but it had not been converted for proper Hemi operation). Economic justification for Hemi was hurt by a low price for exported electricity, and by a requirement for a large quantity of weak acid.

HEMI-DI PROCESS

Advantages of Hemi-Di are 3-4% less filter loss than either Hemi or Dihydrate, purer gypsum, and reduced P2O5 content of pond water. There are several Hemi-Di plants in the eastern hemisphere, but none in the Americas. During the past 17 years, Hydro has licensed several such plants, including grass roots plant and conversions of existing plants. The latest Hydro Hemi-Di conversion is designed for 68 BPL Central Florida rock in a former Prayon dihydrate plant in Chinhae, South Korea, making 46% P2O5 filter product.

HEMI VS. DIHYDRATE COMPARISON

Conversion of the Arcadian phosphoric acid plant from a Dihydrate process to Hemi was considered for the existing 540 TPD P2O5 production rate, and for expansion to 720 TPD. At the existing rate the Hemi conversion was shown to be a good investment. Expansion to 720 TPD via Hemi conversion was exceptionally attractive.

Hemi advantages over Dihydrate include elimination of most steam consumption by the evaporators (even at increased capacity), improved recovery, elimination of evaporator and cooling water system bottlenecks, and reduction of superphosphoric acid production cost via higher feed concentration. Hemi advantages outweighed the advantages of a Dihydrate expansion, which included more experience with the process, less corrosion, and less reagent consumption. Total operating cost with the Hemi conversion would be much less than for a Dihydrate expansion.

A Hemi-Di conversion would offer the same advantages as Hemi, plus another 3% increase in recovery. However, the added capital for transformation tanks and a second filter system made it less attractive at this time.

STEAM SAVINGS

The Hemi process is very energy-efficient, because higher filter product concentration reduces the evaporator steam load per ton of P2O5 to under one third that of a dihydrate plant - for equal product concentration. Evaporator steam consumption is approximately proportional to the amount of vapor removed in concentrating the acid. The following table illustrates that high feed acid concentration dramatically reduces evaporator load:

TONS VAPOR REMOVED PER TON OF P_2O_5:

	EVAPORATOR PRODUCT CONC., %P_2O_5:					
	40	45	50	52	54	56
EVAPORATOR FEED, %P_2O_5:						
DIHYDRATE PLANT:						
25%	1.5	1.78	2.0	2.08	2.15	2.21
26%	1.35	1.62	1.85	1.92	1.99	2.06
27%	1.20	1.48	1.70	1.78	1.85	1.92
28%	1.07	1.35	1.57	1.65	1.72	1.79
HEMI PLANT:						
40%	0	0.27	0.50	0.58	0.65	0.71
42%	*	0.16	0.38	0.46	0.53	0.59
44%	*	0.05	0.27	0.35	0.42	0.49
46%	*	*	0.17	0.25	0.32	0.39
48%	*	*	0.08	0.16	0.23	0.30

* Feed is stronger than required product.

The Arcadian Hemi plant can make 33% more acid at a higher concentration, yet it uses half as much steam. The saving in low pressure steam provides steam for the new acid purification plant and for co-generation of power in an existing generation facility.

EVAPORATION AND COOLING WATER LOAD

Major disadvantages of expanding Arcadian's existing Dihydrate process included requirements for a new evaporator and expansion of the cooling water system. These two items alone would have involved a multi-million dollar investment. Steam production and distribution facilities would have to meet the increased evaporator capacity as well as acid purification demands.

Both the Hemi and the Hemi-Di options overcome the evaporator bottleneck, because the higher filter product concentration would cut evaporation duty drastically. Consequently, cooling water and steam requirements would also be reduced.

ARCADIAN'S SELECTION

Preliminary information had indicated that the BuCraa rock would perform well in a hemi reactor. Pilot plant testing confirmed the expectations, and provided quantitative data for sizing equipment. Once the feasibility of using BuCraa rock in a Hemi reaction was confirmed, the choice was between Hemi and Hemi-Di. Expansion of the existing dihydrate process was easily ruled out, because it lacked the operating cost savings, and would have required millions of dollars worth of evaporation, cooling, and steam system expansion, in addition to reactor and filter work.

Both Hemi and Hemi-Di were attractive finacially. A straight Hemi conversion provided very rapid payout, and an option to extend to Hemi-Di later, with little waste of equipment. Hemi-Di requires considerably more capital for the second filtration and reaction, but the very high recovery provides good incentive. Arcadian chose to install a straight Hemi process, which can efficiently be converted to Hemi-Di in the future.

ARCADIAN CONVERSION AND OPERATION

Modifications included dividing the existing reactor into two zones with controlled recirculation, filtration improvements and slight enlargement, and a system to transform filter cake from hemi to dihydrate.

The plant started quickly and reached 100% rate after 40 hours. After some modification to equipment and operating parameters, the plant can easily sustain full capacity, achieves nearly 96% filter recovery, has no serious problems, and is easier to operate than the dihydrate plant had been.

REACTION

Attack tank walls were modified to provide two reaction zones, as shown in the attached sketch. Cooling load is much less, even at higher capacity, so one of two existing flash coolers was abandoned. One of the existing flash cooler pumps was re-located as the recirculation pump.

The agitator impellers in the acid addition compartment were replaced with a special impeller specified by Hydro. Several badly worn impellers in other compartments were replaced with Prochem Maxflo T impellers - hydrofoil impellers which provide high efficiency, resistance to stalling with gas, and long life due to lack of eddy currents.

Sulfuric acid and recycle acid were routed to a special mixing cone. A second fume pre-scrubber was added, but the existing tail-gas scrubber and fan required little change.

The existing carbon brick lined walls were badly deteriorated, and they required much overhauling in addition to modifications. The old concrete top was so deteriorated before the conversion, that we re-mounted all agitators on steel beams. These beams are supported by the walls, but not by the roof, because the concrete roof could not be trusted to handle the agitator stress.

On-stream factor is better than it had been with dihydrate, and the attack tank stays cleaner than with dihydrate. There is no scaling in the flash cooler system.

There is no problem with scaling or setting up of slurry in the attack tank, even when temperature and concentration drop below the hemi/di transition range. The Belledune plant offers even more dramatic proof of the stability of the Hemi process. Belledune schedules only five days operation per week, due to limited H_2SO_4 supply. The hemi reactor is attended only by the guard for two days, and starts smoothly every Monday. Belledune also shuts down every summer, and they once had to start up acid with only 24% P_2O_5, rather than the preferred 40%. The weak acid meant that the reactor was making dihydrate at first, and then went thru the transition range to hemi. This "pushing thru" technique required two days, but there was no problem with scaling or setting up anywhere in the system.

FILTRATION

A set of Bird's new design fast drain pans were installed on the existing Bird 24C tilting pan filter - the first complete set of this type. Active filter area increased about 10% to 96 m2, and filtrate removal from the pans is faster. A third wash was added, and recycle acid was changed from gravity flow to pumping and metering. Competitive filter pans of the Chamberlain and Pleus Brothers designs had been seriously considered.

The filter had recently been converted to a "low level" design - without seal tank, and filtrate pumps close to the central valve. The two existing filtrate pumps were used for #3 and #4 filtrate, and new product and recycle acid pumps were added. The new pumps are ANSI pumps, located considerably lower than the existing filtrate pumps. The lower location avoids previous problems of surging flow and cavitation. The existing pumps were lowered later to the same level. The central valve was modified to add the third wash, to improve filtrate division, and to add some proprietary innovations.

A combination of several improvements enable the filter cloths, pans, central valve, pumps, and piping to stay cleaner than a dihydrate filter. Hemi solids which sit for many hours in places like the acid wash boxes eventually harden, but this is a minor problem. The filter pans once sat full of hemi cake for hours after a broken hose knocked down a wash box. After the filter was re-started, the cake flushed cleanly from the cloths in two trips thru the cloth spray section. Similar situations at Belledune caused no scaling or plugging problems. This demonstrates that although hemi solids will eventually harden, only a rare incident or gross negligence causes hemi to plug equipment in a well-designed hemi plant. Good design is a key factor.

A system was installed to wash the entire filter system and filter feed line with recirculating hot condensate. This is an easy way to do a thorough cleaning.

RECOVERY

Recovery has averaged 95.6% - based on filter cake analyses. This exceeds the guaranteed recovery of 95.5%.

MONTH:	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	AVERAGE
P_2O_5 LOSSES:								
Water Soluble	1.3	0.9	1.0	0.9	0.9	1.4	1.6	1.12
Water Insol.	3.4	3.4	3.6	3.4	3.1	3.1	2.9	3.27
	---	---	---	---	---	---	---	----
Total Loss	4.6	4.2	4.6	4.3	4.0	4.5	4.5	4.39
RECOVERY:	95.4	95.8	95.4	95.7	96.0	95.5	95.5	95.61%

The attached filter recoveries sheet for March illustrates the consistency of recovery. Daily standard deviation was only 0.47%. Further small recovery improvements result from the reduced load on evaporation and superphosphoric acid sections.

A major indirect improvement in recovery occurs because the dicalcium phosphate which co-precipitates with hemi crystals is redissolved and eventually partly recovered from the pond water. The mechanism is as follows: Hemihydrate crystals dissolve in contact with pond water and re-crystallize as dihydrate. Co-precipitated dicalcium phosphate (which was counted as citrate-soluble filter cake losses) dissolves into the pond water, and most of it remains in solution. Some of the pond water remains in the gypsum stack, but most of this P2O5 is recovered in cake wash water. This bonus recovery is obtained with any Hemi plant which recirculates water from the gypsum stack.

Sulfuric acid consumption is reduced because of the improved recovery and a lower free sulfate level in the product.

CAPACITY AND RELIABILITY

The plant easily achieves its design capacity of 720 STPD P2O5, and it normally runs at that rate. Until about March, 1991 there was little need to exceed design rate, because the adjacent food-grade acid plant which receives some of the product has started up only recently and was not up to full rate. There has been some operation at 800 TPD, but sometimes the plant won't hold that rate.

The plant is reliable and has no major problems. Both this plant and the Belledune Hemi conversion of 1986 demonstrate that the latest Hemi technology plus good engineering implementation provide successful operation and solid reliability in converted dihydrate plants. Each successive Hemi conversion has brought numerous refinements to improve performance. Belledune's general foreman calls their plant "one sweet plant to run." The Arcadian plant runs better as a Hemi plant than it ever did as a Dihydrate plant.

CORROSION

Acid from BuCraa phosphate is more corrosive than Florida acid, so higher alloy metals are required than for Florida acid. The higher temperature of the Hemi process also increases corrosion rates, so a Hemi plant requires higher alloys than a dihydrate plant. The Arcadian plant has the double impact of very corrosive acid plus high temperatures. Most new metal equipment in contact with the hottest slurry and acid is either Hastelloy G-30 or Alloy 904L. Existing equipment made of Jessop 700, Ferralium 255, or 904L was left in place. By comparison, the Belledune Hemi plant, which we designed for Florida acid, is doing very well with 317L and 904L.

After seven months of operation, there has been no problem with corrosion of new or existing alloy equipment in contact with the hot Hemi slurry.

CLAY ADDITION

The first pilot plant test of BuCraa rock produced highly corrosive acid, and the hemi crystal were shaped somewhat like match sticks, but filtered satisfactorily. Further evaluation revealed that addition of a small amount of clay reduced corrosivity to manageable levels, and produced short hemi crystals. Clay is added in the plant, and performance has proven that corrosion rate is acceptable, filtration rate is more than adequate, and washing efficiency is excellent.

Arcadian had been adding clay to the dihydrate plant also, so this is not an added expense.

REAGENTS

Neither the Hemi process nor the Dihydrate process requires any defoamer with BuCraa phosphate rock. The Hemi process uses a proprietary anti-scalant reagent.

TRANSFORMATION AND GYPSUM HANDLING

Filter cake is converted from hemihydrate to dihydrate by stirring as a slurry. Then it is pumped 2.7 miles thru existing pumps and single line to an existing stacking area.

The gypsum slurry from transformation behaves like normal gypsum slurry. Usually only one of two pumps in series is required, despite the increased capacity. The long gypsum line operates reliably and does not scale or plug. Gypsum continues to stack like normal gypsum.

BENEFITS TO SUPERPHOSPHORIC ACID PLANT

The reduction in evaporator duty allows Arcadian's existing evaporators to be lightly loaded. This results in the capability for the existing last stage evaporator to concentrate the acid to about 62% P2O5, versus previous average of about 55%. The load on the superphosphoric acid plant is reduced accordingly, resulting in major savings of fuel, maintenance, and operating cost.

PROCESS COMPUTER

A Foxboro I/A Distributed Control System was installed in the plant, handling all instrument measurements and control, except for local instruments. It became fully operational along with the Hemi startup.

CONSIDERATIONS FOR OTHER HEMI PLANTS

ENERGY SAVINGS

How much is the saved evaporator steam worth? This is the key question when considering a Hemi conversion. A typical situation involves power generation from surplus steam. Most of this power would either be sold or used by the owner's nearby mine, because many existing phosphate plant co-generation facilities already produce enough power for the chemical plant. A 1,000 STPD phos acid plant will save about 550,000 T/yr of evaporator steam - enough to generate about 9 megawatts of power. Another 2 megawatts of power would be saved in rock grinding, evaporation, etc., for a total of 11 megawatts.

Value of exported power from a single typical plant is a multi-million dollar per year asset, but the actual figure must be determined for each individual case. The improving political situation makes it more likely that co-generators will receive a fair price for exported power.

In a broader sense any such production of electricity from waste heat benefits two ways. First, it conserves the limited supply of fossil fuels and reduces oil import. Second, it is one of the few ways to make electricity with no environmental harm.

ROCK GRINDING

The Hydro Hemi Process can handle rock which is quite coarse - 100% thru 10 mesh BSS (1.68 mm). This eliminates the need for grinding of flotation concentrate. Florida pebble requires some low-energy grinding. Damp pebble can be ground as-is, without drying. Chain, hammer, or cage mills with hardened materials appear to be suited to this service. Fine grinding in a ball mill is unnecessary, and wet ball milling would leave too much water.

Mill power savings with the Hemi process are summarized below, in terms of Mill HP/TPH Rock:

	DIHYDRATE PROCESS		HEMI PROCESS	POWER SAVED WITH HEMI
	WET BALL MILL		DAMP PEBBLE FEED	(HP/TPH)
	OPEN CIRCUIT	CLOSED CIRCUIT	CHAIN, HAMMER or CAGE CLOSED CIRCUIT	
FLA. PEBBLE	15	12	3-7	5-12
FLA. CONCENTRATE	15	12	NEEDS NO GRINDING	12-15

The BuCraa rock which Arcadian uses requires no grinding. Belledune uses an existing dry ball mill on a blend of Central Florida concentrate and pebble.

ACID FOR DAP PRODUCTION

A major advantage for DAP producers is that hemi filter product acid is much purer than dihydrate acid that is evaporated to the same 40% P2O5. This benefit was clearly demonstrated at Belledune, where the first Hemi acid (from Central Florida rock) into the DAP plant produced DAP which was too pure - 18.2-47.5-0. They quickly learned to leave calcium sulfate diluent in the phos acid by simply using coarse filter cloths and no clarification. Royster also reported that hemi acid made it "easier to make DAP grade". Most plants which produce DAP from Florida dihydrate phos acid have difficulty meeting the 18-46-0 specification, and they incur major expense removing impurities from dihydrate acid. The high purity of Hemi acid eliminates this DAP quality problem.

If the DAP feed acid is all Hemi acid, we recommend that the feed acid all be one concentration (39-40% P2O5), rather than two (e.g.: 26% & 54%). This maximizes the high concentration benefits of the Hemi process. Typical single-strength DAP production can make an unacceptable visible plume of sub-micron ammonium fluoride particles. The lower fluoride concentration in hemi acid will tend to counteract this tendency. However, we recommend that the DAP plant also have "Double Mol" acid scrubbing, which reduces fluoride emissions. Double Mol conversion quickly pays for itself in improved ammonia recovery, in the three conversions that we designed.

If a DAP plant is fed from both Hemi and Dihydrate plants, the Dihydrate plant would provide weak acid for scrubbing, while the Hemi plant would provide acid for further concentration to strong acid feed.

Hemi saves sulfuric acid by requiring a lower free sulfate in the 40% P2O5 product. However, if sulfuric acid must be added in the DAP plant for grade control, this sulfuric acid saving is eliminated.

THE HEMI-DI OPTION

THE PROCESS

The Hemi-Di Process is an extension of the Hemi Process which cuts total filter cake loss to 1 to 1.5%. The front end is like a Hemi plant, with the two-zone reactor and hemi filter. The sluiced hemi (calcium sulfate hemihydrate) filter cake is then treated with sulfuric acid in agitated conversion tanks. The hemi crystals dissolve in transformation and re-form as dihydrate crystals. The dihydrate crystals are then filtered and washed on a dihydrate filter.

HIGH RECOVERY

The justification for the conversion and second filtration is a 3-4% increase in P2O5 recovery, and corresponding reduction in sulfuric acid requirement. Most of this recovery improvement comes from recovering the dicalcium phosphate, which had co-precipitated with the hemi crystals in the hemi reactor, and would be counted as citrate soluble P2O5 loss. When the hemi crystals dissolve and re-form as dihydrate in the transformation reactor, the dicalcium phosphate also dissolves. Nearly all of the dical remains soluble in the acidic solution and is recovered when it is recycled back to the hemi reactor.

Undigested rock gets a second chance to react in the transformation reactor, so citrate insoluble loss is near zero. Water soluble loss is kept low by efficient washing on the dihydrate filter. Filter washing efficiency benefits from the low concentration of acid in the dihydrate filter feed.

The EPA is considering requiring partial neutralization of phos acid plant pond water and gypsum slurry. This would mean that losses would incur added expense of neutralization, so there would be extra incentive to maximize recovery.

CLEAN GYPSUM

Since gypsum from a hemi-di plant has had most of the dicalcium phosphate and undigested rock removed from it, it is purer than gypsum from a dihydrate or straight hemi plant. This is beneficial to most gypsum utilization processes, including those which recover sulfur and produce calcium-containing by-products.

HEMI-DI EXPERIENCE

There are six Hydro Hemi-Di plants in successful operation. The latest is the Chinhae plant in South Korea, which started up in December, 1990 and makes 46% P2O5 from 68 BPL Central Florida rock. The Supra Hemi-Di plant in Sweden (1986) was designed to handle Florida, Morocco, or Jordan rock. A contract has been awarded for a Hydro Hemi-Di plant due to start up in China in 1993.

BENEFITS OF HEMI CONVERSION

1. SAVES MOST EVAPORATOR STEAM

   Make 54% acid with one third as much steam.

2. ELIMINATE EVAPORATOR AND COOLING WATER BOTTLENECKS

   Make 54% acid with half as many evaporators.
   Eliminates 40% evaporator condensers, and about half of flash cooler condenser water.

3. CUT EVAPORATOR & FLASH COOLER OPERATING COST & LOSSES

   Lighter load in evaporation allows reduced operation and/or more capacity or concentration with the same evaporators. At Arcadian one of two existing flash coolers was shut down - even though the capacity increased. Evaporator and flash cooler entrainment and operating losses are reduced.

4. ELIMINATES OR REDUCES GRINDING

   Most concentrate requires no grinding.
   Pebble can be damp-ground by chain, hammer or cage mill.

5. LESS SCALING

   Reactors and flash coolers run cleaner.
   Filter system scaling (which used to cause problems in hemi plants) has been solved.

6. SOLVES DAP GRADE PROBLEM

   Unclarified Florida phosphoric acid can easily meet the 18-46-0 DAP grade requirements - as demonstrated at Belledune - because hemi product acid is much purer than dihydrate 40% acid. With dihydrate phos acid, even clarified acid has difficulty meeting DAP grade.

7. RECOVER DICAL LOSSES

   Much of the citrate soluble filter "loss" is eventually recovered if the filter cake is washed with pond water.

8. SPECIAL BENEFITS

   Every plant's situation is unique, and additional benefits can be found in most cases.
   For example, Arcadian greatly reduced superphosphoric acid fuel and production cost and increased capacity, because the feed acid concentration could be increased from 55 to 62%.
   Belledune shut down two large oil-fired boilers when they abandoned their evaporator section, and they use only one small boiler for building heat and startup steam.

BENEFITS OF HEMI-DI CONVERSION

1. MAXIMUM P_2O_5 RECOVERY

   98.5-99% Recovery - based on filter cake

2. MINIMUM POND WATER P_2O_5 CONTENT

   Especially important if EPA should require partial neutralization of pond water

3. PURER GYPSUM

   With much less dicalcium phosphate and undigested rock than gypsum from a dihydrate or straight hemi plant

4. ALL OF THE HEMI BENEFITS

   #1 thru 8 on the preceding page

ABOUT THE AUTHORS

S.V. HOUGHTALING - President of HiTech Solutions - is a chemical engineer with over 30 years experience in phosphate chemicals. He was responsible for process design of ten large phosphoric acid plant and was project manager for the world's largest single-train DAP plant and the world's largest dual-train NPK plant.

He pioneered wet grinding of phosphate rock and holds patents for wet rock grinding and a low-level flash cooler. He received the 1974 Vaaler Award in Energy Conservation for Wet Rock Grinding, and the 1982 Vaaler Award for the Grace DAP plant recycle system.

He consults internationally regarding wet rock grinding, phosphoric acid, and phosphate fertilizer production, and has presented many technical papers on phosphate technology. He is a Fellow of AIChE, Engineer of the Year in 1980, and a past chairman of the Central Florida Section.

JOHN WING - Vice President of HiTech Solutions - is a chemical engineer whose 27 years in the phosphate industry includes process design, project management, consulting, technical service, process development, and production supervision. He designed modifications and expansions of several phosphoric acid, DAP, and GTSP plants. He did the process design of Conserv's fluosilicic acid recovery system, and performed equipment design for five phosphoric acid evaporators and over twenty scrubbers.

He did the process design for the Belledune and Arcadian Hemi conversions, and was project manager for the Arcadian Hemi project. He is a registered Professional Engineer, Fellow of AIChE, and past chairman of the Central Florida Section.

ahemi 4/11/91

EFFECT OF REACTION CONDITIONS ON CALCIUM SULPHATE CRYSTALLISATION

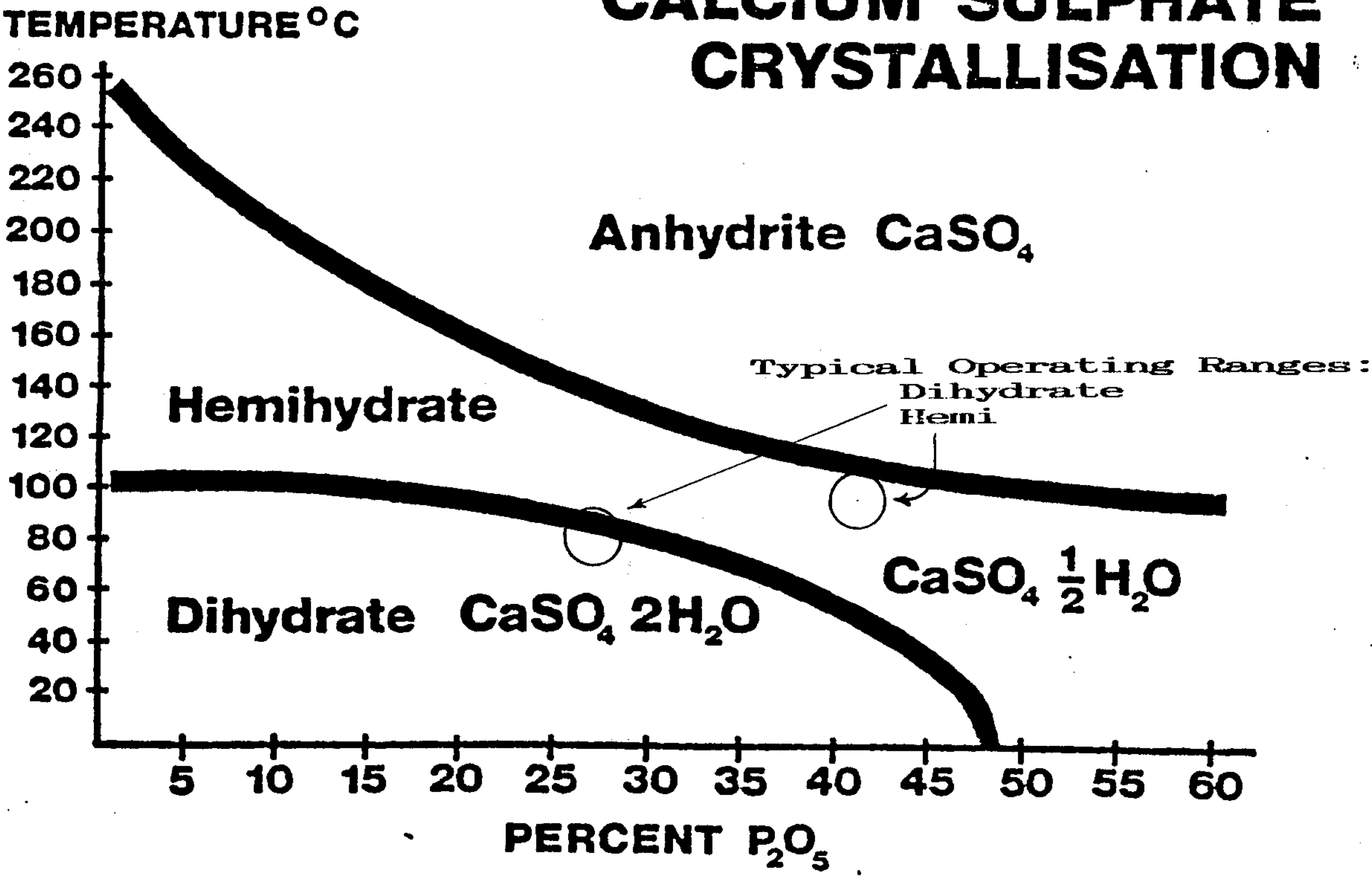


FIGURE 1 ORIGINAL PRAYON REACTION SYSTEM

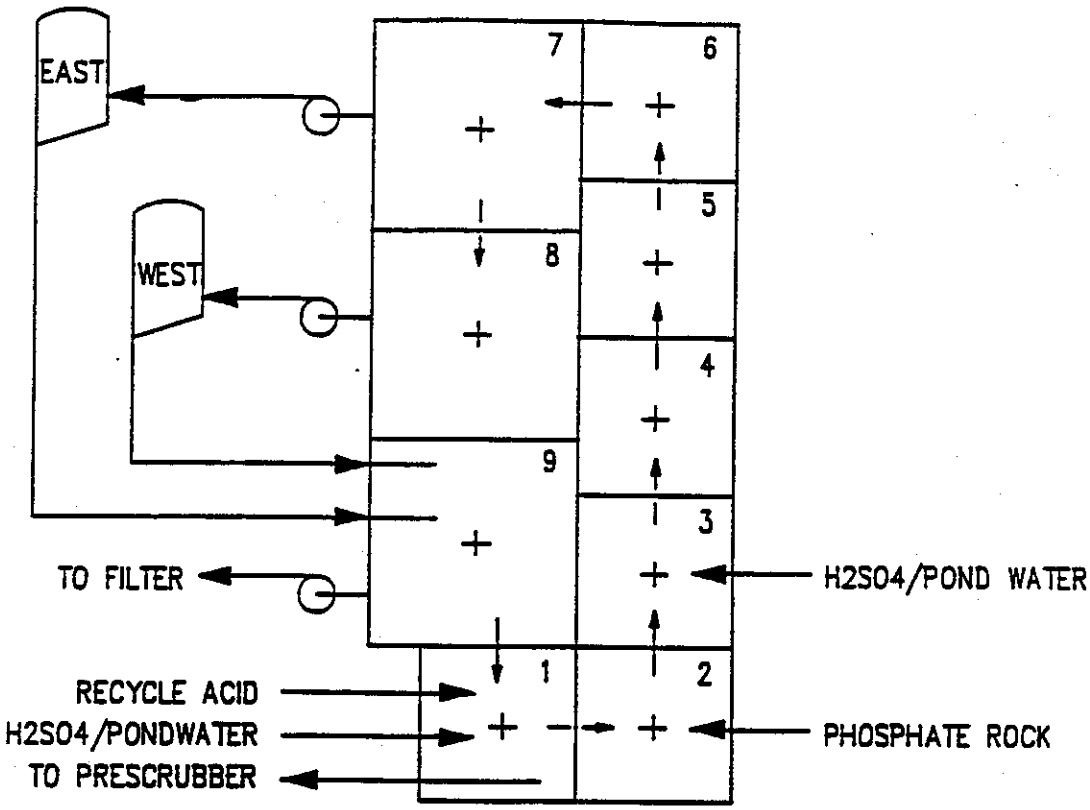
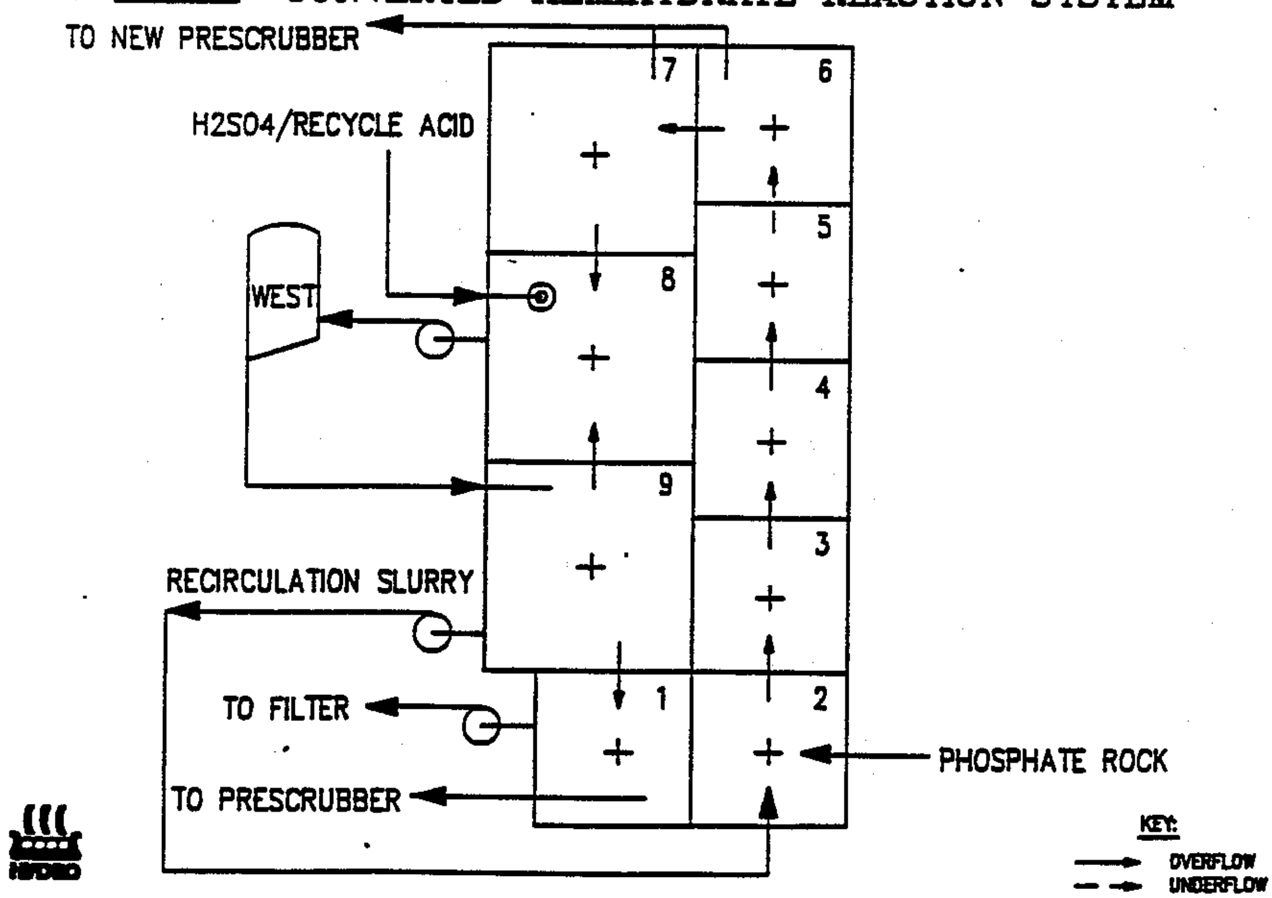


FIGURE 2 CONVERTED HEMIHYDRATE REACTION SYSTEM



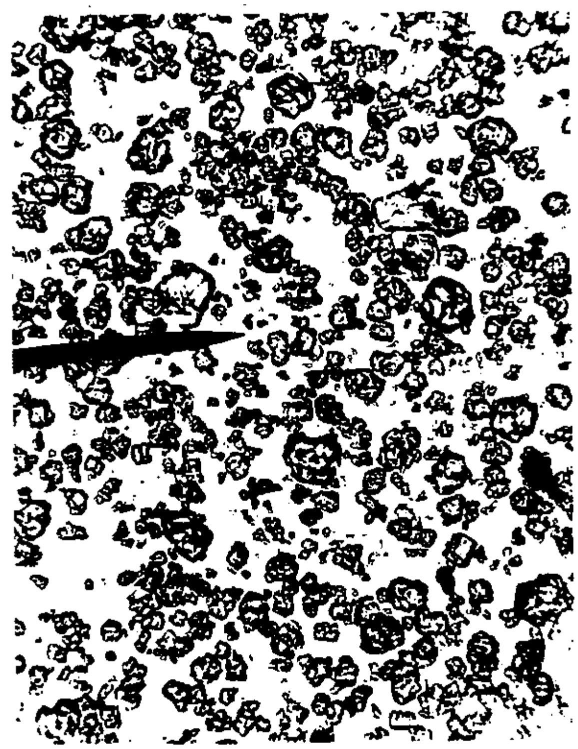
ARCADIAN CORPORATION
GEISMAR PLANT
PRAYON FILTER RECOVERIES
MONTH OF MARCH 1991

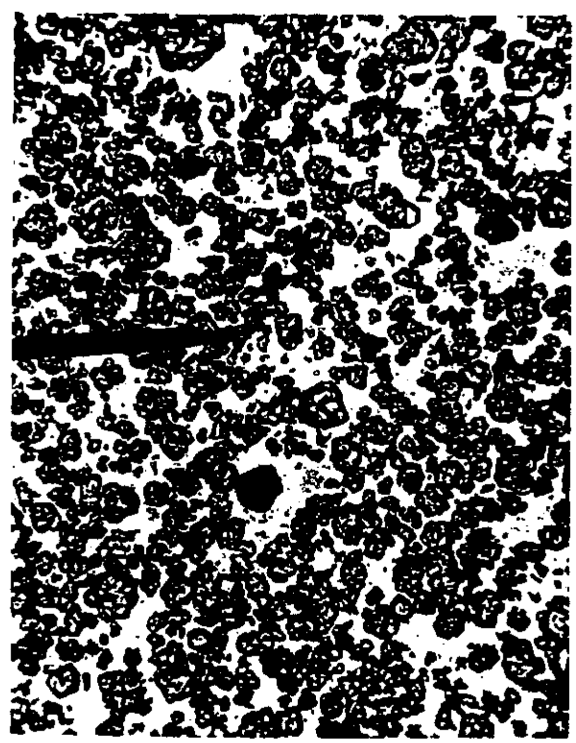
DATE	CAKE ANALYSIS % TPA	% WSPA	% WIPA	% H20	%TPA WASH	CORR WSPA	P205 RECOVERY % WSPA	% WIPA	% TOTAL
1	1.68	0.70	0.98	19.7	2.25	0.26	99.04	96.33	95.37
2	1.61	0.80	0.81	22.1	2.13	0.33	98.77	96.97	95.74
3	1.46	0.67	0.79	19.4	2.17	0.25	99.07	97.05	96.11
4	1.65	0.93	0.72	19.5	2.11	0.52	98.06	97.31	95.37
5	1.47	0.62	0.85	17.7	2.20	0.23	99.14	96.82	95.96
6	1.64	0.80	0.84	20.3	2.12	0.37	98.62	96.86	95.48
7	1.51	0.74	0.77	20.0	2.25	0.29	98.92	97.12	96.04
8	1.78	1.01	0.77	21.9	2.40	0.48	98.19	97.12	95.31
9	1.72	1.11	0.61	23.7	2.58	0.50	98.14	97.72	95.85
10	1.52	0.82	0.70	17.3	2.49	0.39	98.54	97.38	95.93
11	1.51	0.72	0.79	21.0	2.55	0.18	99.31	97.05	96.36
12	1.70	0.96	0.74	20.8	2.44	0.45	98.31	97.23	95.54
13	1.65	0.82	0.83	19.4	2.50	0.34	98.75	96.90	95.64
14	1.92	1.22	0.70	21.4	2.46	0.69	97.41	97.38	94.79
15	1.70	0.85	0.85	23.9	2.45	0.26	99.01	96.82	95.83
16	1.86	1.00	0.86	23.6	2.47	0.42	98.44	96.78	95.22
17	1.75	0.98	0.77	23.2	2.41	0.42	98.43	97.12	95.55
18	1.91	0.98	0.93	25.6	2.32	0.39	98.56	96.52	95.08
19	2.00	1.32	0.68	27.7	2.45	0.64	97.60	97.46	95.06
20	N	O -	S	A	M	P	L	E	S
21	1.66	0.89	0.77	26.0	2.30	0.29	98.91	97.12	96.03
22	1.92	0.97	0.95	24.0	2.47	0.38	98.59	96.45	95.04
23	1.90	1.18	0.72	20.9	2.72	0.61	97.71	97.31	95.02
24	2.00	1.32	0.68	21.4	2.77	0.73	97.28	97.46	94.74
25	1.59	0.74	0.85	18.6	2.79	0.22	99.17	96.82	95.99
26	1.73	0.83	0.90	20.7	2.91	0.23	99.15	96.63	95.78
27	1.94	1.26	0.68	20.8	3.01	0.63	97.63	97.46	95.09
28	1.94	1.05	0.89	23.5	3.10	0.32	98.80	96.67	95.47
29	1.65	1.14	0.51	20.2	3.15	0.50	98.12	98.09	96.21
30	2.06	1.31	0.75	21.8	3.25	0.60	97.75	97.20	94.95
31	2.22	1.39	0.83	25.1	3.12	0.61	97.73	96.90	94.63
AVERAGE	1.76	0.97	0.78	21.7	2.54	0.42	98.43	97.07	95.50
COUNT	30	30	30	30	30	30	30	30	30
STD	0.19	0.21	0.10	2.45	0.33	0.15	0.58	0.38	0.47
MAX	2.22	1.39	0.98	27.70	3.25	0.73	99.31	98.09	96.36
MIN	1.46	0.62	0.51	17.30	2.11	0.18	97.28	96.33	94.63

TYPICAL HEMI CRYSTALS

ARCADIAN CORP.

Nov. 17,18,19; 1990





HEMI COMPARISON
BELLEDUNE & ARCADIAN

	BELLEDUNE	ARCADIAN
DESIGN CAPACITY, STPD P2O5	550	720
ACTUAL CAPACITY	600-700	730-800
CAPACITY BEFORE CONVERSION	500	540
ROCK	CENT. FLORIDA	BuCraa
BPL	66-68	79
Form	Dry	Filter cake
Grinding	Ball mill	None
H2SO4, Avg. conc.	89%	99%
RECOVERY: ACTUAL	95%	95.6%
GUARANTEED	93%	95.5%
FILTER (24C) m2 \ STPD/m2	88 \ 6.25	96 \ 7.50
STPD/ft2	0.58	0.70
PRODUCT FROM:		
FILTER	39-42% P2O5	41% P2O5
PHOS ACID PLANT	39-42% P2O5 Unclarified	54% P2O5 & 62% P2O5
FINAL PRODUCT	DAP	Food Grade Acid & Superphosphoric Acid
HEMI CAKE DISPOSAL	Pump 0.6 mi. to bay	Transform to gyp. Then pump 2.7 mi.
OWNER	Brunswick Mining & Smelting Co.	Arcadian Corp.
LOCATION	Belledune, NB, Canada	Geismar, La., USA
STARTUP	Sept., 1986	Sept., 1990

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