# PRODUCTION OF WET PROCESS PHOSPHORIC ACID

# USING

# THE SWENSON ISOTHERMAL REACTOR


***Gulf Design Division***

Badger America, Inc.

Tampa, Florida

A Raytheon Company

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Recognizing that the most important aspect of efficiently producing wet-process phosphoric acid lies in the proper formation of gypsum crystals, The Swenson Corporation set out in the early 1960's to develop a phosphoric acid process based on its years of experience in crystallizer design. The end result of this effort was the development of the highly-successful Isothermal Phosphoric Acid Reactor for which Badger acquired the exclusive license. This presentation will deal with the process itself and the mechanical and operational aspects of the Reactor--including operating data from currently operating commercial Isothermal units.

Since the 1920's, many continuous processes have been developed and most modified numerous times in order to achieve maximum yields. Producers learned that uniformity of temperature and free sulfate levels, along with positive control of these parameters, were of utmost importance in promoting complete reaction and producing filterable gypsum--thereby minimizing $P_2O_5$ losses. Numerous laboratory studies and actual reactor compartment samples proved that retention time required for reaction and crystal formation could be drastically reduced if temperature and sulfate levels could be closely controlled throughout the mass of reacting slurry. Based on these findings, it was concluded that an ideal reactor would maintain a uniform mixture of reactants and products at an optimum operating point.

Following-up on this concept, Swenson began development work for modifying their standard crystallizer design for the production of phosphoric acid. The patented Isothermal Phosphoric Acid Reactor which evolved was a single-vessel vacuum crystallizer with a draft-tube agitation system.

The Reactor System is shown here in Figure 1. The Reactor vessel is a rubber and carbon-brick-lined carbon steel vessel with a cone and

dished head, top and bottom. The top dish is removable to allow setting and/or removal of the Reactor internals.

The Reactor is equipped with a top-entering, high efficiency turbine-type agitator/circulator that operates at close tolerances within a baffled draft tube. The shaft is sealed at the top of the Reactor with a simple water-flushed stuffing box packing gland. The overhung end of the shaft normally is held by a water-flushed rubber steady bearing. However the Reactor may be fitted with a stiff shaft agitator that does not require a steady bearing. The first full size commercial unit built for Farmland Industries was fitted with a rubber-lined carbon steel draft tube, however, problems with rubber failures dictated the need for alloy internals. The units currently in operation are fitted with Hastelloy-G impellers and draft tubes.

Concentrated sulfuric acid is metered and fed into the Reactor in the highly agitated area above the impeller near the center of the draft tube for maximum acid dispersion. Rock slurry is introduced in the highly turbulant area near the bottom of the draft tube to allow dispersion before entering the acid addition area. Recycle acid is brought back to the Reactor and introduced into the annular space just above the liquid level. The Reactor operates with a constant level established by the fixed overflow to the agitated filter feed tank.

Vacuum is maintained in the Reactor by condensing of water vapor in the barometric condenser and removing of noncondensable gases with a steam jet or vacuum pump system. Heat of reaction is removed by flash cooling which occurs at the liquid surface. Carryover of acid droplets or foam in the vapors released is prevented by the low vapor velocity

designed into the freeboard section above the liquid surface. Gases leaving the Reactor pass through a centrifugal separator "catchall" for final demisting before going to the barometric condenser. The catchall drains and is sealed in the filter feed tank.

The first Isothermal Unit was installed in 1966 for the American Fertilizer Corporation in Bakersfield, California, processing Western and Florida rocks. This 25 TPD $P_2O_5$ unit, along with the 600 TPD unit installed for Farmland Industries and the 255 TPD unit installed for Valley Nitrogen Producers, Inc., have proven the Isothermal Reactor to be a most successful process. They have also demonstrated the many definite advantages to be realized by utilization of a highly-agitated single vessel reactor for phosphoric acid production. These advantages include:

(1) Reduced Capital Cost as a result of utilizing a simple single vessel reactor with less than four hours total slurry retention time.

(2) Reduced Utilities Consumption as a result of the use of a single highly efficient agitator/circulator. Also, operators of the units report power saving in the rock grinding area because the Isothermal Units operate more efficiently on coarsely ground rock.

(3) Reduced Maintenance Costs as a result of drastically reducing the number of pieces of equipment in the Unit.

(4) Environmental Advantages afforded by the fact that all of the Reactor gases are scrubbed in the barometric condenser.

(5) Excellent Sulfate Control as a result of the high level of uniform circulation within the Reactor.

(6) Excellent Temperature Control with negligible temperature gradients resulting from high circulation and automatic control of the vacuum in the vessel.

(7) High Operating Factor resulting from the relatively few pieces of equipment utilized and from the ease of draining and cleaning the Reactor.

(8) High Operating Efficiency with improved $P_2O_5$ recovery realized as a result of the fact that the Reactor has a very high onstream factor and the reaction takes place under ideal conditions a high percentage of operating hours.

With these claims in mind, let us look at the records of the commercial units which are currently operating.

FARMLAND INDUSTRIES.--The Farmland unit was started up in December of 1971, and was designed to produce 600 TPD $P_2O_5$ with Florida Rock feed. The vessel is 35 feet in diameter and utilizes one 200 HP agitator for circulation. This Unit has been operating for over six years at above-design rates, and has been fed numerous types and grades of Florida rock of varying particle size, both unground and ground, using cage mills or ball mills. The Unit currently operates on rock feed ground in a dry, open circuit ball mill and mixed with fresh water or pond water in a small mix/pump tank. The rock is ground to approximately 50% passing a 200 mesh Tyler screen as Farmland has found this to be the optimum grind specification.

Farmland feels that they have never pushed the reaction system because the plant is filter limited. They are currently considering the installation of additional filter capacity which they believe will bring the unit capacity to near 900 TPD $P_2O_5$. They have operated the unit at rates exceeding 800 TPD for short periods of time.

Operating Capacity and Efficiency.--Farmland analytical data collected over the past three years indicates the following average operating results:

| Production: | | At Design Rate | 750 TPD $P_2O_5$ |
|---|---|---|---|
| Losses: | Water Soluble: | .90% | 1.24% |
| | Citrate Insoluble: | .28% | 1.23% |
| | Citrate Soluble: | 2.50% | 2.50% |
| | Total Measured Losses: | 3.68% | 4.97% |

$P_2O_5$ Recovery at Farmland, based on losses in gypsum, therefore, averages in excess of 95%--even when operating at above design rates.

Operating Factor.---.Farmland log sheets for the period of March 1975 to March 1978 indicate the following onstream factors were achieved:

| Plant Down Due To | Downtime % Total Time | Operating Factor % |
|---|---|---|
| Reactor | 1.4% | 98.6% |
| Filter | 2.1% | 97.9% |
| Other | 2.4% | 97.6% |
| Total | 5.9% | 94.1% |

Farmland reports that the extremely high operating factor of the Isothermal Reactor Unit is primarily the result of two things:

(1) The annual turnaround of the plant takes only five days, as opposed to the normal 14-day requirement of a multicompartment reaction system.

(2) The agitator steady bearing which was normally checked every 16 weeks, has been found to consistently have a serviceable life of well over six months.

Utility Consumption.--Power consumption for the Reactor circulator which provides for both agitation and slurry cooling is approximately 185 horsepower.

Steam consumption for the vacuum system at capacities up to 800 TPD with up to 4% $CO_2$ in the rock feed is 30,000 lbs. per hour.

Defoamer Usage.--Farmland has operated both of their phosphoric acid plants (the Isothermal Reactor and the conventional multi-compartment reactor system) on the same rock feed a number of times. Defoamer usage was studied and it was determined that the actual defoamer requirement of the Iosthermal Unit is 40 to 50% less than that of the multi-compartment unit.

Maintenance Costs.--The serviceable life of an agitator impeller before having to be rebuilt has proven to be in excess of three years. The agitator shaft steady bearing requires replacement less than twice each year. In general, the maintenance cost for Farmland's Isothermal Unit is far less than that of their conventional multi-compartment unit.

VALLEY NITROGEN PRODUCERS, INC.--The Valley Nitrogen Unit was started up in July of 1977, using a vessel 26 feet in diameter with a 100 HP agitator. The plant was designed to produce 255 TPD $P_2O_5$ from ground, calcined western USA phosphate rock which when processed characteristically forms gypsum that has a low filtration rate of about .35 daily tons of $P_2O_5$ per spare foot of filter area. This Unit achieved the design capacity during the first week of operation, with recoveries that often exceeded 97%. The Unit has been operated at above design capacity and filtration rates in excess of 0.6 tons $P_2O_5/ft.^2$ per day have been achieved on the 24B Bird dry gypsum discharge filter.

Operating Capacity and Efficiency.--Typical results of current operation show the following:

| | | |
|---|---|---|
| Production: | 255 TPD $P_2O_5$ | |
| Losses: | Water Soluble: | 1.28% |
| | Citrate Insoluble: | .65% |
| | Citrate Soluble: | 2.97% |
| | Total Measured Losses: | 4.90% |

Average $P_2O_5$ recoveries for the unit during the first months, therefore, exceeded 95% and Valley Nitrogen Producers, Inc. reports that recoveries are increasingly steadily as operating personnel gain epxerience in phosphoric acid production.

Utility Consumption.--Power consumption for the Reactor circulator is approximately 80 horsepower. Steam consumption for the vacuum system at design capacity is 3500 lbs. per hour. Valley Nitrogen has also found that the Isothermal Reactor operates more efficiently on coarse ground rock feed and therefore power savings are realized. The current grind specification is approximately 30% passing a 200 mesh screen.

Defoamer Usage.--The Valley Nitrogen unit requires no addition of defoamer.

Environmental.--The plant has exceeded all of the environmental requirements of the State of California which are among the most stringent in the USA.

ISOTHERMAL REACTORS CURRENTLY BEING DESIGNED.--A third Isothermal Reactor System is presently in the design state for a client in Brasil. The design capacity of this plant is 600 MTPD $P_2O_5$ based on rock feed from Florida, Moroccan, and Brasilian sources. Gulf Design anticipates two additional Isothermal plants in Brasil following the start up of this plant in 1979.

## WET ROCK FEED TO THE ISOTHERMAL REACTOR

Wet grinding of phosphate rock and the feed of wet rock to phosphoric units has been practiced since the 1920's. Phosphoric acid producers have, in the past, however, avoided the use of wet rock feed because of rock metering problems and contamination of the acid produced with elements contained in the phosphatic clays that can be removed in the rock drying operation. However, environmental and cost related factors have reversed this trend toward the use of wet rock feed in recent years.

The very nature of the Isothermal Process, which utilizes concentrated sulfuric acid and rock mixed with fresh water outside of the Reactor, makes it readily adaptable to either ground or unground wet rock feed. Systems utilizing wet rock feed to the Isothermal Process have been offered by Gulf Design since 1972. The high degree of circulation and excellent sulfate control of the Isothermal Process allow better Reactor control than other processes under the condition of erratic rock feed which is inherent in even the most successful wet rock metering and transfer systems.

When the foregoing factors of improved process control, superior inherent control of fluorine emissions, improved operating efficiency, and simplicity of adapting to wet rock feed are coupled with reduced capital and operating costs, investors in phosphoric acid production facilities are finding the advantages of the Isothermal Process to be of supreme interest.

# ISOTHERMAL PHOSPHORIC ACID REACTOR

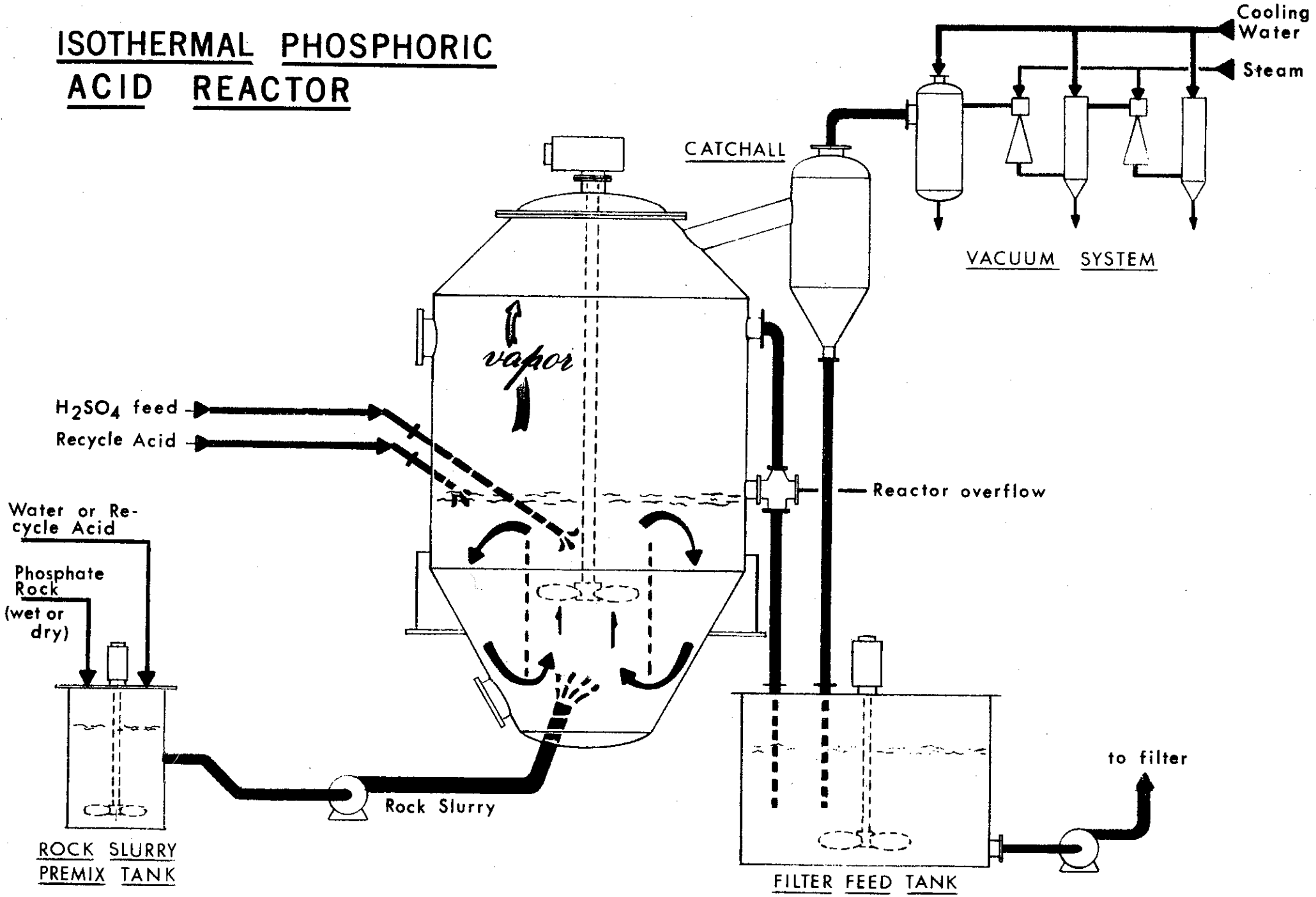


figure 1.