PHOSPHORIC ACID EVAPORATOR BOTTLENECKS

CAUSES AND CURES

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Phosphoric acid evaporators which do not keep up with production requirements are a common occurrence. It happens so frequently that I thought it would be useful to compile a listing of reasons why it happens and discuss ways to either increase the capacity of existing evaporators or lighten their load. I'll also discuss some things to consider when adding new evaporators.

Sometimes a plant will have one major reason for an evaporator bottleneck, but in many instances the problem is an accumulation of a number of minor factors which, when viewed individually, may not seem significant.

WHY EVAPORATORS DON'T KEEP UP

Weak Feed Acid

Probably the most significant cause of reduced evaporator throughput is decreased feed concentration. To indicate the seriousness of such dilution, consider that a one percent reduction of filter product acid concentration from 28 to 27% P_2O_5 causes an 8% increase in the amount of water which must be removed to concentrate the acid to 53% P_2O_5. Low feed acid concentration can result from a number of problems, including:

1. Digestion and Filtration Requirements

   A generation ago, a typical dihydrate process produced 32% P_2O_5 acid using 68 to 70 BPL Central Florida rock. Now the rock concentration at most Central Florida phosphoric acid plants is down to 64 to 66 BPL, and the acid concentration is typically 28% P_2O_5. As impurity levels have increased, the acid concentration has been reduced to enable the digestion sections to produce gypsum crystals which are adequately filterable and reasonably free of hemihydrate.

2. Dilution from Wet Rock

   When using wet ground rock in a phosphoric acid plant, extra care must be taken to avoid additional water input. Problems such as difficulty in controlling the rock slurry moisture content or excessive slimes in the rock add extra water to the system. Little compensation can be accomplished by reducing filter wash water because of the expense of the

2. Dilution from Wet Rock (continued)

increased filtration losses. The net result of high water content in the rock slurry then becomes lower filtered acid concentration, thus causing an extra load on the evaporators.

3. Dilution during Filtration

Some minor dilution of the acid is inevitable during filtration, but this dilution can increase dramatically in the event of malfunctions in the cell dry or cloudy port section of the filter, misaligned water sprays on pan filters, backflow of recycle acid, poor draining of washed pans, or excessive seal water on the filter feed pump or No. 1 filtrate pump.

High Concentration of Impurities

It is interesting to compare current operating information with older data, such as the set of graphs for Florida phosphoric acid which Chemico issued in 1958. General lowering of rock quality in Central Florida has increased the impurity level in the phosphoric acid and caused marked increases in acid density, boiling temperatures, and viscosities. One result is a significant reduction in capacity of evaporators which were designed for purer acid. Another result is that the typical final product concentration has decreased from 54% to 53% P_2O_5 despite increased final evaporator temperatures.

Evaporator Condition

The capacity of an evaporator decreases significantly with time. The circulating pump flow rate drops with wear, particularly as the clearance around the periphery of the propeller increases. Heater capacity decreases as tubes fail and are plugged.

Proper cleaning and maintenance are essential to minimize the effects of scaling and lump formation.

Sludge Recirculation

The design of an evaporated acid clarification and storage area generally allows for return of sludge of higher concentration acid to the digestion or filtration area. Sometimes the feed rate of such a sludge will exceed the design rate, causing an increase in evaporator duty if the P_2O_5 concentration in the sludge liquid phase is higher than that of the filter product. A significant increase in evaporator duty will result if 40% acid sludge is routed directly to digestion instead of through the 28% clarifier.

Excessive Seal Water

Seal water to pumps in the evaporation and intermediate clarification sections which ends up in the acid adds a small extra evaporation load which is often ignored in the design of an evaporation section. Packed seals on the evaporator circulating pumps are the biggest source of seal water into the process, and the effect becomes quite significant when they are improperly maintained or if the seal water isn't carefully controlled.

Operating Considerations

If a typical three-stage set of evaporators operates at design capacity with design on-stream factor, it won't quite produce the design annual production. This is because during the 30 to 40% of the time that only two evaporators are on line, production will be significantly less than two thirds of design unless the evaporators are pushed to more than design capacity.

Another situation which reduces evaporator capacity is controlling to a certain intermediate concentration. This is frequently done to enhance intermediate clarification, which has been observed to perform best at a certain concentration of 41% or so, depending on the plant. When the evaporators are deprived of the flexibility to operate at whatever intermediate concentrations suit them best, a small but predictable reduction of capacity occurs.

Capacity Increases Elsewhere

The most favorable reason for lack of evaporation capacity occurs when the capacity of the remainder of the plant has been increased so much that evaporation can no longer keep pace, even if it runs at capacity or more. Digestion sections are freqently modified - or just plain pushed - to operate at well over design capacity. Filtration, clarification, and storage facilities are also often operated at rates which are much above the original design.

Evaporators, on the other hand, can only be pushed so far. Some pushing of capacity can be done, and some modifications can increase capacity a bit further. However, the capacity of an evaporator is ultimately limited by the size of its heater and vapor body. Replacing these items with larger ones is generally out of the questions. Thus, evaporators have a tendency to become the bottleneck of a phosphoric acid plant.

ADDING EVAPORATION CAPACITY

Any effort to increase the capacity of evaporation must consider a number of factors within the plant as well as the amount of increase which is required.

Correcting Specific Problems

Some increase in capacity may be possible by reviewing some of the factors which I discussed previously and making specific corrections as required.

Filter product should be carefully controlled at the concentration which is considered to be optimum for the particular plant.

Dilution of the acid by seal water or other sources should be minimized. Evaporator circulating pump seals are a prime culprit.

Heater tubes must be cleaned thoroughly. Sloppy cleaning techniques can raise havoc with evaporator capacity. The frequency of cleaning should be evaluated and tailored to the needs of the particular plant.

Maintenance should be carried out as required to maintain good performance, minimize downtime, and avoid excessive dilution with seal water. Clearance between the circulating pump propeller and casing should be checked periodically, because flow rate and efficiency decrease as this gap widens.

Proper maintenance, operation, and design are essential for minimizing breakage of graphite heater tubes. Heaters are usually pulled and overhauled when about ten percent of the tubes have been plugged. A heater will last several years or more before requiring an overhaul, under favorable conditions.

Increasing Circulation

A higher velocity through the heater tubes will increase the heat transfer coefficient, keep the tubes cleaner through scouring action, and slightly increase the mean temperature difference from steam to acid. Tube velocities of 8 to 9 feet per second can be achieved without incurring excessive abrasion problems.

Within limits, the circulation flow rate can be increased by increasing the circulating pump speed or by replacing the propeller. The latter is particuarly advisable where an old style three-bladed propeller can be replaced with a more efficient and durable four-bladed propeller. Some pump makers offer a variety of propeller pitches with different performance ranges. A sizeable increase in circulating rate usually requires a new motor for the circulating pump.

Major Modifications to Evaporators

It is not usually practical to obtain a major increase in capacity from an existing evaporator. One reason is because only a moderate increase in heater capacity can be obtained without replacing the heater, and this expense can rarely be justified. Another reason is that capacity is limited by the vapor body itself.

An exception to this rule occurred recently at Conserv. They had four small old LTV thermal siphoning type evaporators which were facing major heater overhaul costs, in addition to the usual LTV evaporator problem of low on-stream time. Bearden-Potter Coporation designed an arrangement whereby the evaporators were tied together in pairs, with each pair of vapor bodies sharing a single new heater and forced circulation pump. Each pair of vapor bodies was equiped with a single entrainment separator. Only minor modifications were required for the existing vapor bodies, condenser systems, structure, and utilities. The finished product looks awkward, but is running beautifully. A substantial increase in capacity was achieved through a combination of reduced downtime and increased instantaneous rates. The cost was a fraction of that for a new evaporator installation.

The Conserv example was a unique situation, but there may be other unique situations waiting to be discovered.

New Evaporators

The normal way to substantially increase evaporation capacity is to add one or more new evaporators. The new unit or units must be coordinated with the existing evaporators to operate in various sequences, depending on which evaporators are out of service.

To minimize spare parts, there should be considerable standardization of certain parts, particuarly when adding only one or two evaporators. Standardized parts usually include critical heater dimensions, circulating pumps, and some of the large piping. Within these limits, the design of the new evaporator may be quite different from the old ones, so the owner is free to incorporate a variety of improvements.

Layout of the new evaporator should allow good maintenance and operating access, and it should not block access to the existing evaporators. This can be a challenge in an area which was not originally designed for it.

Effects on Utilities

Addition of an evaporator places extra demand on all of the utilities which service it. Of particular concern are electric power, low pressure steam, and incoming and outgoing cooling pond water. Probably the most difficult

Effects on Utilities (continued)

of these systems to substantially increase in capacity in a typical phosphate complex is the cooling pond water. A major increase would typically involve an additional pond water feed pump and a pond water effluent pump. The increased flow rate would result in higher pumping pressure and increased power cost, or it would require either parallel or enlarged main pond water headers. Even a minor increase in pond water capacity would require modification of all pumps on the header which is involved, plus an increase in power cost.

Fortunately, there are ways of conserving pond water which can usually obviate the need for increased pond water through-put. Bearden-Potter Corporation has engineered two evaporator addition projects which required no increase in pond water. In each case it was done by pumping last stage (53% P_2O_5) evaporator hotwell water to an early stage evaporator condenser. Reusing hotwell water in this manner results in a substantial power saving, because it reduces both the incoming and effluent pond water flows, and the pressure required at the pump which reuses hotwell water is much less than that at the incoming pond water pumps.

Additional reductions in pond water usage can be achieved by tighter control of water flow rates to the evaporator and flash cooler condensers. Operators tend to use too much condenser water because a moderate excess causes them no problems, but a deficiency reduces the system's vacuum. For any given condition, a condenser requires a certain amount of cooling water to condense the vapors at the required vacuum. Any more water is surplus. Any reduction in this surplus not only alleviates any pond water capacity problem; it also saves about $15,000 per year in power cost for each 1,000 GPM decrease in flow rate.

FUTURE TRENDS

Acid Quality

The world's first phosphoric acid plant superintendent undoubtedly blamed a lot of his problems on the quality of the rock. It has always been that way and probably always will be. This claim is often valid with Central Florida rock, where rock quality has generally been steadily decreasing, as indicated by lower phosphate content and increased levels of troublesome impurities. Most of these impurities are dissolved when the rock is digested and are in the acid when it enters the evaporator.

Barring any major breakthroughs in rock processing technology, Central Florida phosphate rock will continue to decline in quality during the 1980's. The effect on evaporation will be a reduction of feed concentration, an increase in boiling temperatures, increased viscosities, and probably an increase in scale formation. All of these effects will reduce the capacity of any given evaporation system.

Materials of Construction

New materials of construction have increased the useful life of key evaporator components in recent years. Jessop 700 and Lewmet 55 alloys are recommended over the previous standard material, CD4MCu, for longer life of circulating pumps, especially for the propellers and casings.

Double layers of conventional three-ply rubber are recommended for areas of an evaporator which are subject to highly abrasive conditions. An FRP material and construction technique has been developed for vacuum service at temperatures well over 200°F. Bearden-Potter Corporation is supplying an evaporator which uses this FRP for the top dished head of the vapor body and for vapor piping.

Evaporator Design

The design of an evaporator should take into account the cost of structural steel, piping, pumps, platforms, and other factors which are outside of the evaporator package itself. Three evaporators which are currently being designed and installed by Bearden-Potter Corporation for W. R. Grace utilize this concept. These evaporators are substantially shorter than comparable earlier designs, and there are substantial savings in the total cost of the evaporation section. Two of these evaporators include special basket strainers in the circulating lines for more effective protection of the heaters and easier maintenance than with conventional conical lump screens.

There is a trend toward using water ring vacuum pumps instead of steam ejectors on evaporators. Steam ejectors are cheap but inefficient, and they were standard practice when energy costs were low and surplus steam was available in most phosphate complexes. Now energy is expensive, and process changes frequently reduce or eliminate the steam surpluses. In plants where surplus steam is available, it is often used for heating or power generation.

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SUMMARY

Phosphoric acid evaporators frequently limit the capacity of a plant. The causes of this situation may include:

1. Low feed acid concentration;
2. Increasing acid impurity levels;
3. Process changes in other sections, which add to the evaporation load;
4. Capacity increases in other sections;
5. Poor condition of the evaporators;
6. Extraneous water inputs.

Approaches to debottlenecking the evaporators may include:

1. Put the evaporators and related equipment in good condition;
2. Eliminate unnecessary water inputs to the acid;
3. Modify existing evaporators for a small increase in capacity;
4. Add one or more new evaporators for a major increase in capacity.

When adding one or more evaporators to an existing evaporation system, the new evaporators should be laid out for good maintenance and operating access and should be capable of operating in the required sequences with the other evaporators.

Utilities must be modified as required to service the new evaporators. Double use of cooling water can sometimes eliminate the need to expand the cooling water system.

When adding one or two new evaporators, standardization of circulating pumps, critical heater dimensions, and certain other items is generally preferred, to minimize spare parts. Other than that, the new evaporators may differ considerably, so improvements to design and layout can be incorporated.

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ABOUT THE AUTHOR

John H. Wing received a Bachelor of Chemical Engineering degree with honors from the University of Florida in 1961 and a Master of Engineering degree in Administration from the University of South Florida.

His experience includes 16 years in the phosphate industry, with positions in process design, project management, consulting, technical services, process development and production. A previous paper, which he presented at the 1970 Joint A.I.Ch.E. Meeting was entitled "Phosphoric Acid Plant Process Water Systems."

During the past six years with Bearden-Potter Corporation, he has been involved with design projects and consulting involving every section of a typical phosphate chemical complex. Five of these design projects have included the addition of phosphoric acid evaporators - the topic of this paper - to existing plants.

He is a registered professional engineer and a member of A.I.Ch.E.