Davy McKee

The DAVY/PRAYON High Strength Phosphoric Acid Process: "Cogenerations Ideal Partner"

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Davy McKee and Prayon are pleased to present, at the 1985 Sand Key meeting, a significant phosphoric acid technology improvement. This new phosphoric acid process is fully compatible with wet rock grinding, and permits production of high strength acid while maintaining high yields. Furthermore these conditions are achieved while operating in a stable dihydrate mode.

To fully explain this new technology it is necessary to examine the historical background that provides the basis for it. For about 25 years, both Prayon and Davy McKee have been successful in the development of new technology for the phosphate fertilizer industry as the following figures show:

120 Prayon plants worldwide
37 Davy/Prayon plants in North America
28 Davy/Prayon plants in Florida

As engineers we must always be sensitive to change in the socio-economic environment and the impetus this provides to development of improved technology.

In the early 60's, the phosphate industry was looking for new technology that would provide larger, more reliable plants with reduced downtime for maintenance and cleaning. The rapid acceptance of the Prayon process, 20 plants in North America in about 5 years, evidenced the establishment of a new industry standard.

In the early 70's, general growth of the fertilizer industry produced a need for large, single-train plants, capable of operating with low-grade captive mine product. Once again, within a few years, the technology was extended such that an additional 8500 tons per day of P_2O_5 capacity was added at six sites.

Part of this latter development occurred in parallel to the OPEC oil shock that sent oil prices soaring and prompted a search for energy conservation methods. Our response was the development, testing and successful implementation of wet rock grinding, also now an industry standard.

This history of technology development, for the U.S. industry, started with plants designed for 300 tons per day P_2O_5 using high grade dry rock, and currently reaches to an operating unit capable of 2000 tons per day in a single train, fed by wet rock and achieving approximately 97% P_2O_5 recovery. We believe this latest plant, which we refer to as the Mark IV design, is the best dihydrate technology demonstrated to date.

However, in the last few years once again economic forces have dictated change and improvement in phosphoric acid plant design and operation. With the present depressed market, the impetus is not so much for increased capacity but rather, lowering of overall operating costs. For a change, government has assisted the industry by promulgation of the PURPA rules and helped establish cogeneration as a viable economic technology. In response we have re-examined the various established processing routes to see how they can best be modified to suit current and future needs.

The background provided by having over 30 operating plants, using a wide variety of Florida phosphate, and in sizes from 120 to 2000 tons per day P_2O_5 is extremely useful in studying new developments. One must also consider the fundamentals as developed by detailed study of the crystallization of calcium sulfate and the factors affecting it. To meet this need, both Prayon and Davy McKee maintain well equipped testing laboratories to explore the potential of new deposits and new processing methods. Ultimately, it was the world's largest single train plant operating at 97% recovery (the mark IV process), which provided the insights for the development of the new Davy/Prayon High-Strength (DPHS) process.

The Davy/Prayon Mark IV design is noted for several significant features:

- .. High internal reactor circulation
- .. Uniform high-flow agitation
- .. Low flash cooler temperature drop (3°F)
- .. Multi-compartment flexibility

Long-term operation of this process has demonstrated a high degree of process stability. Pilot plant research, based on the Mark IV design, has shown that the previously accepted limits of dihydrate technology can be pushed much farther than currently believed by conventional wisdom. Stable operation of a dihydrate process with acid strengths greater than 38% P_2O_5 have been achieved while producing good filtering gypsum.

This work on improved dihydrate technology enables us to match a high-strength process, suited for a cogeneration based complex, with a feed of wet rock slurry since the dihydrate cake will remove about 19% more water from the process than the equivalent hemihydrate cake.

As part of our development work on high-strength acid technology we also tested various methods of dewatering ground rock slurry. While we feel it possible to build a workable system, it will generally require a substantial investment in processing equipment.

Process Description

Our laboratory investigations and subsequent pilot-plant work were based on the concept of using known "building blocks"; process steps which have been individually proven in commercial operation. Prayon's considerable experience in purification and recrystallization of calcium sulfate, (a valuable byproduct of their phos-acid operation for more than 15 years) also provided valuable insight. The result of this combination of experience and research is the DPHS process.

Essentially the front-end of the DPHS process is operated in what we refer to as a Mark IV mode, i.e., with high slurry circulation using the low-level flash cooler concept and incorporating high-flow agitators. This technique permits a reduction in reactor retention volume. The primary reactor section operates at about 167°F with a liquid phase containing 38% P_2O_5 and a low sulfate level. These lower than normal temperature and sulfate levels are important to maintaining stable dihydrate conditions at high acid strength.

The primary reactor slurry passes to digestion tanks which allow sufficient retention to stabilize the slurry before primary filtration. The slurry is pumped by flow-controlled variable speed pumps to a belt filter to separate the mother-liquor which is then divided into product acid and a portion for primary recycle acid. This filter also has a short cake wash section to reduce its P_2O_5 content as low as possible. The wash used is the strong filtrate from the final filtration step described below. The strong filtrate plus the acid displaced from the cake is combined with the excess product acid and recycled to the primary attack system where it is mixed with the incoming strong sulfuric acid. A belt filter is well suited to this filtration operation since it requires a short cycle time comprising only mother liquor separation and a single wash.

The washed cake is sluiced to a recrystallization system using the second filtrate from the final filtration step. The recrystallization is assisted by addition of a small amount of the incoming sulfuric acid. Conditions in this recrystallization section, low P_2O_5 level, high excess sulfuric and carefully controlled temperature, enable the production of good filtering, low P_2O_5 content gypsum, using a short retention time.

The slurry from recrystallization is then fed to a Bird-Prayon tilting pan filter which can provide clean separation and maximum wash capability. The washes are recycled as described above and the gypsum cake discharged in the normal manner by sluicing with pond water. Test results on typical Florida rock show overall P_2O_5 efficiencies up to 96.5%, based on cake losses, while producing 38% P_2O_5 product acid. 38% P_2O_5 acid was chosen because it can be used directly for DAP manufacture and also provide significant amounts of extra steam available for power generation. The overall flowsheet is shown on Figure 1.

Comparison with Other Process Options

Until now the only option available for direct production of high-strength acid was some version of hemihydrate technology, either straight hemihydrate (HEMI) with one-step filtration, or a hemi-dihydrate process (HEMI-DI) with two filtration steps and intermediate recrystallization. Accordingly we have prepared some comparison data (Table 1) based on published information and our own test results with the Davy/Prayon High Strength Process (DPHS) using 67-69 BPL Florida rock.

TABLE 1 - PROCESS COMPARISON

	HEMI (Dry Rock)	HEMI-DI (Dry Rock)	DPHS (Wet Slurry)
Primary attack volume (m^3/MTPD P_2O_5)	2.0-3.0	2.0	1.3
Recrystallization volume (m^3/MTPD P_2O_5)	-	3.0	0.4
Total slurry volume (m^3/MTPD P_2O_5)	2.0-3.0	5.0	1.7
Product acid filter (MTPD P_2O_5/m^2)	6-7	4.0	10-12
Gypsum filter (MTPD P_2O_5/m^2)	-	8.0	6-8
P_2O_5 recovery, %	93-94.5	97-98.5	95.5-96.5
Product strength, % P_2O_5	38-40	38-48	36-38

The comparison of these parameters leads us to believe that the DPHS process has the inherent character to be built in large single-train units which are the basis of world-scale plants today.

A further comparison of processing cost was made, again based on published data, to see where the DPHS process would rank if applied to a large plant (1000-1500 MTPD P_2O_5) based in Florida. This analysis is shown in Table 2 below:

TABLE 2 - COST OPERATING COMPARISON (\$/ton P_2O_5)

	HEMI	HEMI-DI	DPHS
Dry rock at \$20/ton (dry basis)	68.80	65.20	66.90
Sulfuric acid at \$50/ton	135.00	134.00	135.00
Steam at \$8/ton	0.80	2.64	0.80
Power at 5¢/kWh	8.40	6.95	4.36
Defoamer at \$0.4/lb	1.32	0.96	0.4
TOTAL	214.32	209.75	207.46

A comparison such as shown in Table 2 is necessarily generalized since the exact specifics of the published cost data are not detailed. For example Davy/Prayon would use self-pumping barometric condensers whereas the data on other processes may be based on the use of steam-jet ejectors. A true comparison can only be made using site-specific data with care taken to ensure that all alternatives are on the same basis. This is especially true for a revamp project where the actual guarantees on capacity and efficiency may be the major factor in process selection. Nevertheless, the data tabulated above does indicate that the DPHS process is a viable alternative to presently available hemihydrate technology. Furthermore, there are some serious problems to be overcome in the application of current hemihydrate technology to the present generation of plants based on Florida phosphate, for example:

... Wet ground ground slurry may require dewatering
... Hot, high-strength acid may be incompatible with existing alloys in use for pumps, agitators and filters
... Existing filter installations may not suit the scaling tendencies of hemihydrate
... Potential capacity reduction unless substantial reactor capacity is added
... Hot water may be required for hemihydrate cake filter wash
... Fluorine emission levels may require scrubber modification

Of course all of these problems are capable of technical solution but inevitably lead to increased capital cost or start-up problems in a revamp situation.

Unfortunately all high strength processes also have some degree of incompatibility with presently commercialized uranium recovery technology. Complexes committed to production of uranium could have to modify their solvent system or settle for significantly reduced recoveries.

Practical Revamp to DPHS Process

Any process improvement can appear interesting until you consider the implications of plant revisions arising from a detailed study of a particular plant. We have studied the modifications required to convert an existing large-capacity Davy/Prayon plant built in the 70's, a so-called Mark III design, to the DPHS process. The layout of the plant is shown on Figure 2 and Figure 3. Basic parameters for this study were as follows:

... Wet rock slurry feed at 68-70% solids
... Approximate design capacity 1150 MTPD presently operating at 1500 MTPD
... Current dihydrate operation at 28% P_2O_5 with 95% recovery
... Maintain 1500 MTPD capacity but increase product strength to 38% P_2O_5 at 96% recovery

In this revamp study we emphasized the concept of practical solutions to the process modifications required, since we felt it important to design a system which could maintain a high on-stream factor and ease of operation.

The Mark III system studied consisted of an eight-compartment primary attack system with heat removal by two parallel flash-coolers. Slurry circulation was provided by internal low-head circulating pumps. The product slurry was aged by series flow through three mildly agitated digester tanks prior to discharge on the 30-D Bird/Prayon Filter.

The upgrade to Mark IV conditions requires improvement to agitation by installation of high-flow agitators. This would require replacement of shaft and turbines only since the hydraulic horsepower would be decreased. A single large low-level flash cooler would be installed to provide heat removal in the primary circuit. This in itself will save 200-300 HP over the earlier design and also provide a system that has demonstrated scale free operation over many years of operation. The primary circuit will consist of only six compartments.

Slurry from the primary attack system would then flow to the digestion tanks (the former 6 and 7 compartments plus one of the original digestion units), prior to being fed under flow-control to the belt filter system.

For a plant of this size (1500 MTPD), we foresee two new 60 square meter belt filters operating in parallel with a common seal tank. The filters separate the 38% strong product acid and provide a single cake wash prior to discharge of the gypsum to the recrystallization system. The belt filter cake is sluiced to the recrystallization system using the second filtrate recycled from the final filter.

The two remaining digester tanks are used as the recrystallization system for the re-pulped gypsum cake. Since part of the incoming sulfuric is added at this point heat removal is required to provide steady temperature control of the operation. For this purpose we would plan to use just one of the existing flash cooler systems, however, the low heat load will mean a minimum slurry temperature drop and consequently minimal scaling.

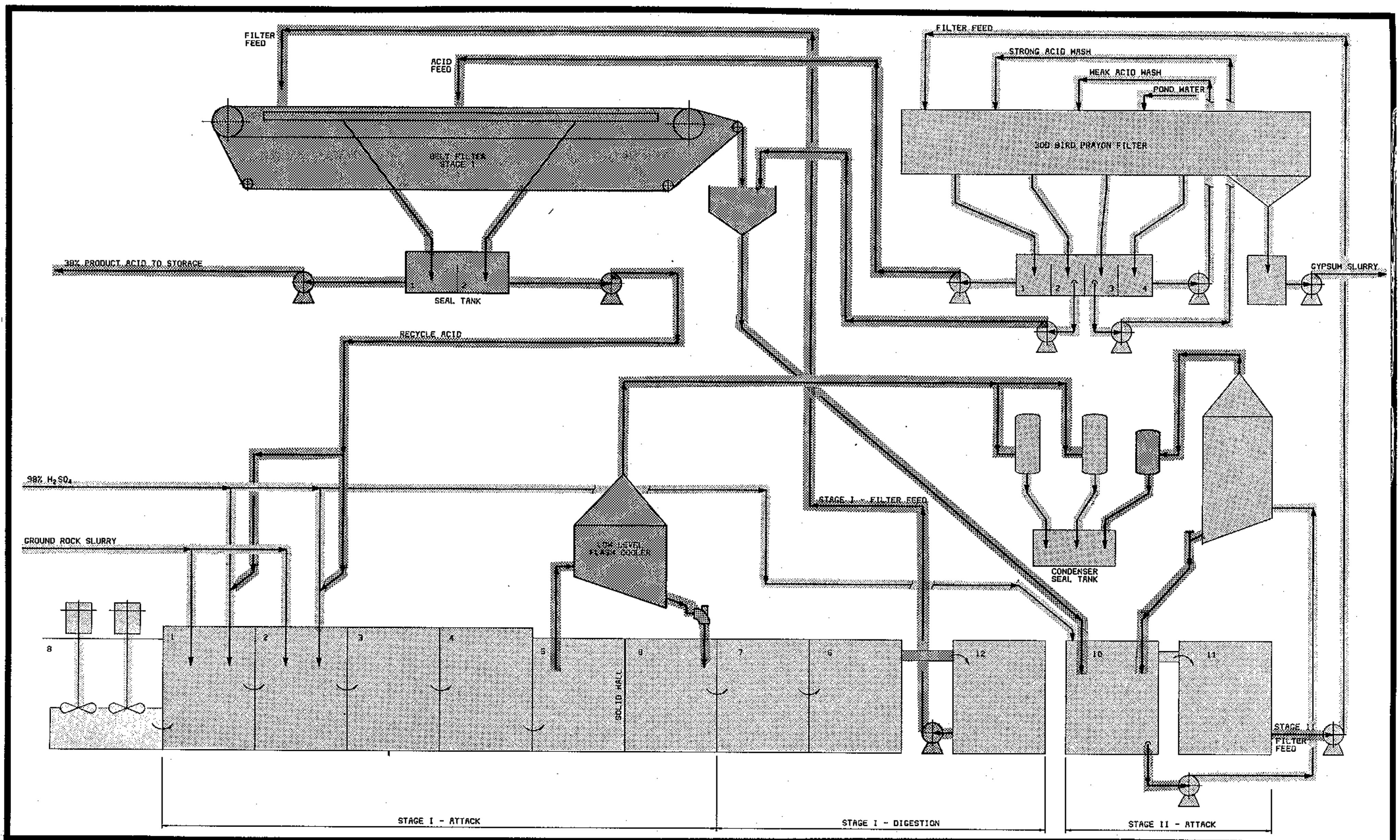
The recrystallized gypsum with its accompanying sulfo-phosphoric mother liquor is pumped in the normal fashion to the existing Bird/Prayon filter where the P_2O_5 and H_2SO_4 values are reclaimed and recycled, and the dihydrate cake is discharged to the pond. As mentioned previously, the second filtrate is used to repulp the first filter cake, the strong filtrate being used to wash the belt filter cake thus becoming part of the acid recycle to the primary attack.

As might be expected, this kind of extensive revamp carries a significant capital cost. In the case of the 1500 MTPD P_2O_5 plant described above we estimate approximately $7,000,000. However there will be substantial benefits resulting from improved recovery and steam savings in the evaporation section. The value of steam savings are very hard to quantify in a general fashion since it depends on whether a cogeneration system exists or can be expanded and, most importantly, just how your local friendly utility system will let you value the power. Analysis of the electric power realisable from the steam saved by the DPHS process in the 1500 MTPD plant studied, indicates a potential of about 9 MW. A power value of 5 cents per KWH for internal use, would generate savings of about $3.5 million dollars annually, which provides a justification for the capital cost of a DPHS revamp, based on power cost alone.

In summary, we believe that the DPHS technology is an alternative process for the direct production of high-strength acid when there is an incentive to save steam for use in a cogeneration system, or when steam has to be generated with expensive fuels.

FIG 1

PROCESS FLOW SHEET



LEGEND:
NEW
EXISTING

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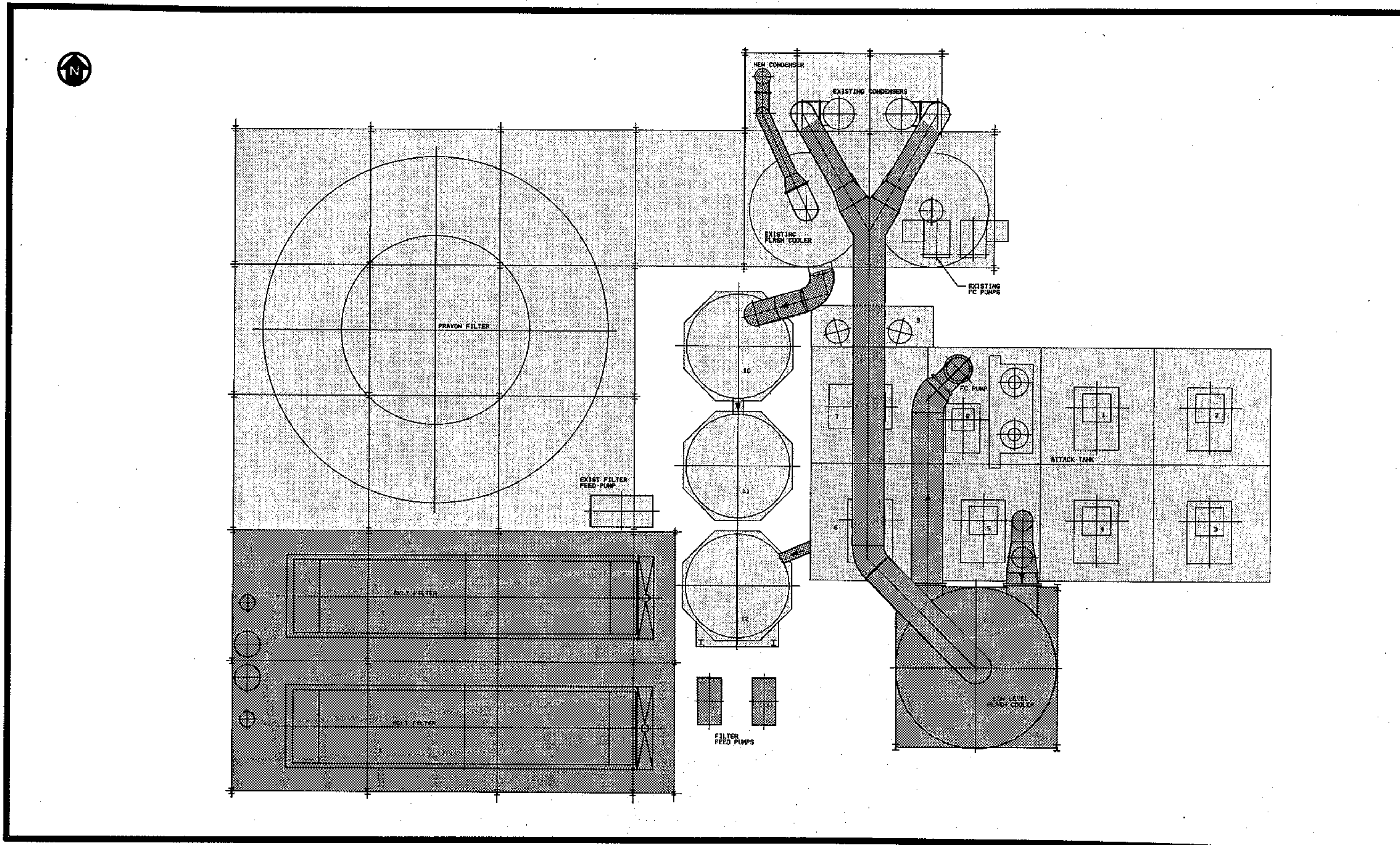
FIG 2

1500 TPD PLOT PLAN

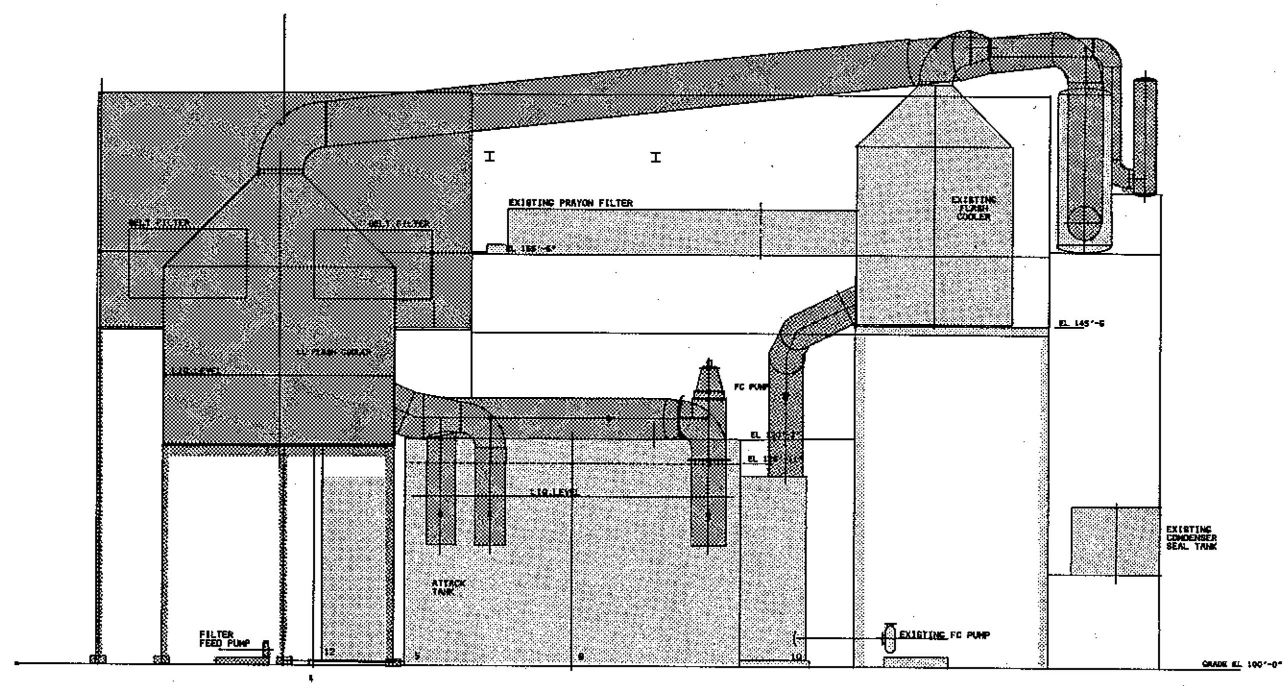


LEGEND:
NEW
EXISTING

Davy

FIG 3

1500 TPD ELEVATION



LEGEND:
NEW
EXISTING

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