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THE GULF DESIGN HEMIHYDRATE PHOSPHORIC ACID PROCESS 1/

by

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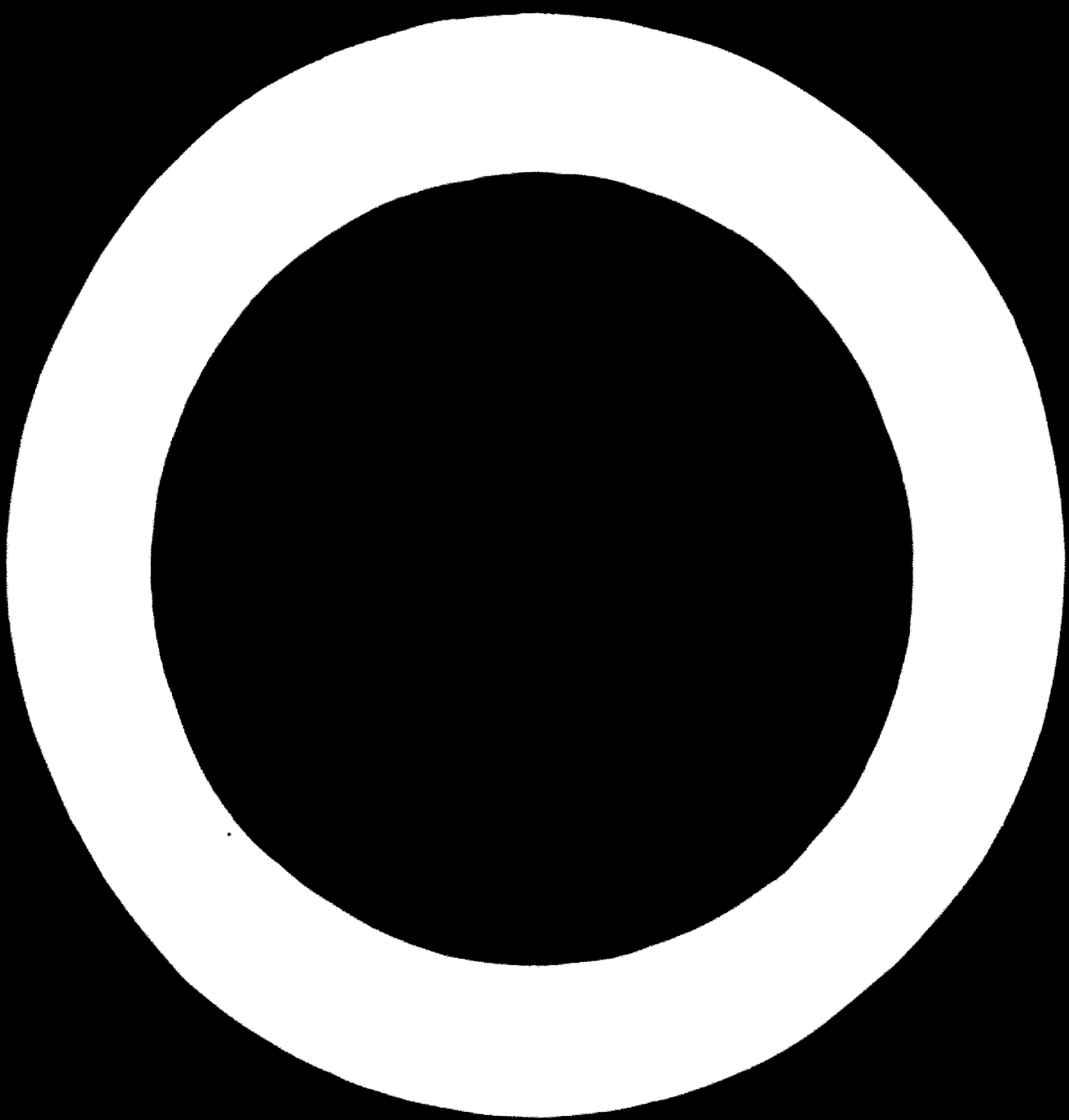


CONTENTS

PREFACE

The Gulf Design Company is indebted to the Swenson Division of the Whiting Corporation, the A.F.C. Corporation, and to Farmland Industries, Inc., for their interest and assistance in the preparation of this paper. In particular, we wish to acknowledge the contribution of Mr. W. E. Rushton of Swenson whose basic paper served as the format for Gulf Design's efforts with this presentation.

We trust that the successful start-up in November of Gulf Design's Isothermal Phosphoric Acid Process at the new Farmland Industries plant will signify a major step forward in phosphoric acid technology.

1. INTRODUCTION

1. Crude phosphoric acid to be used in fertilizers is manufactured by a technique commonly referred to as "the wet process". A wet process phosphoric acid plant consists of a reaction system for reacting phosphate rock and sulfuric acid and a filtration system for separating the liquid and solid phases produced from the reaction. Production efficiency, in terms of P_2O_5 recovery and operating costs, is directly dependent upon filtration efficiency. Filtration efficiency is directly related to the ability of the reaction system to extract P_2O_5 values from the rock and to produce a solid phase capable of rapid and thorough filtration and washing.

Evolution of the isothermal process

2. Process design trends over the last twenty years reflect the attempt of designers to provide operating controls over the process variables that have the major effect on extraction and filtration efficiencies. These efforts have produced a general similarity in the reaction system designs used in the more successful phosphoric acid processes. The limitations of this basic design principle have prevented optimum crystallization controls in the reaction systems.

The result has been lower P_2O_5 recoveries at higher capital investments and operating costs than those produced from a system that optimizes crystallization controls.

3. The Swenson Division of the Whiting Corporation, with an extensive background in the design and fabrication of commercial crystallizers and a broad knowledge of the phosphoric acid industry based on their activities with evaporators and fluorine recovery equipment, appreciated the significance of these similar reactor designs. They also recognized their limitations. Swenson's first step was to modify a proven draft-tube crystallizer design so that it could be employed as a wet process phosphoric acid reactor. Their next step was to erect a small, 22 MTPD unit for the American Fertilizer Corporation at Bakersfield, California, U.S.A. Their design proved highly successful and has been in operation since 1967.

Commercial Installation of the Isothermal System

4. The Gulf Design Company recognized the potential of the isothermal reactor and negotiated a world-wide exclusive license with Swenson for the reactor design. Gulf Design is a division of The Badger Company, Inc. Badger is a subsidiary of the Raytheon Corporation. Gulf Design, a leading U.S. engineering firm in fertilizer process technology, employs

the Swenson reactor design in the Gulf Design Isothermal Phosphoric Acid Process.

5. Farmland Industries, Inc., one of the largest farm cooperatives in the U.S., selected the Gulf Design Isothermal Phosphoric Acid Process for its new 640 MTPD phosphoric acid facility. Their decision was based on the conclusions of a comparative evaluation between the isothermal and conventional plant designs and on the results of successful tests completed in the 22 MTPD unit in California.

Advantages of the process

6. The Gulf Design Process offers a number of advantages over conventional designs. Among these are lower capital investment, lower maintenance and operating costs, considerable reduction in spare parts inventories, and elimination of air pollution problems. These advantages are especially important to countries which are in the process of developing or modifying their fertilizer industry while at the same time finding it desirable to conserve foreign exchange capital.

II. THE WET PROCESS

Process steps and objectives

7. In the wet process technique, phosphate rock is reacted

with a mineral acid to produce phosphoric acid. For the purposes of this presentation, only sulfuric acid will be considered due to its greater importance to the industry. The reaction proceeds by the simultaneous liquid phase dissolution and reaction of the rock with sulfuric acid in the presence of a previously formed slurry of phosphoric acid and solids. The primary constituent of the existing solid phase and of the new solid phase produced by the reaction is one or more of the hydrated forms of crystalline calcium sulfate or the unhydrated form referred to as anhydrite. The strength of the phosphoric acid and the particular hydrate of calcium sulfate that is formed during the reaction depend upon existing process conditions.

8. It has become common practice to designate phosphoric acid processes by the type of calcium sulfate hydrate that is produced in the process. Since dihydrate processes constitute the major portion of all the phosphoric acid units in operation throughout the world and since, at this time, more is known of this technique, the statements and descriptions that follow will refer to the dihydrate process unless otherwise noted.

9. The liquid and solid phases produced in the reaction system are separated by filtration in most operations. The efficiency of the filtration step determines the overall plant efficiency. Two criteria are considered in determining filtration efficiency; i.e., filtration rate and P_2O_5 recovery.

The desirable results are high filtration rates with high P_2O_5 recoveries. Both are dependent upon the particle size, the size distribution, and the physical shape of the crystalline solids produced in the reactor. Rapid filtration, efficient displacement washing, and good filter cake drainage can be obtained when the crystalline solids are large particles having pronounced, three-dimensional shapes and a narrow size distribution. Since the filter performance is directly dependent upon the ability of the reactor to produce a solid phase having these desired characteristics, it is obvious that the reactor design and operating principles should be directed toward the control of variables that affect crystal growth.

Similarities and Limitations of Conventional Designs

10. Efforts to accomplish optimum P_2O_5 extraction and particle growth have produced reaction system designs that can be reasonably represented by the highly schematic loop system shown in Figure 1. The loop represents a linear flow path equatable to time. The rate of flow of the slurry mass through the loop is a function of the required production rate and consequent heat removal rate. The path followed by the slurry around this circuit is physically arranged to insure maximum adherence to the path (time) with minimum short-circuiting. The design aim is to have actual retention time

approach nominal retention time.

11. The reactants and recycle acid from the filter are fed into the slurry loop at one or more points in the reaction zone. The feed streams are rapidly dispersed into the slurry by agitation. The reaction and mixing provide an immediate increase in the concentration of $CaSO_4$ in the slurry acid which enters the reaction zone saturated with $CaSO_4$ after cooling. Since $CaSO_4$ exhibits a normal solubility in 30% P_2O_5 acid, the high reaction temperature increases its saturation level and consequently, decreases its degree of supersaturation. The water content of the acid feed streams dilutes the slurry acid which increases the solubility of $CaSO_4$ with a corresponding reduction in the degree of supersaturation. The dilution effect is of short duration in that as the reaction progresses more P_2O_5 from the rock is put into solution, re-establishing slurry acid strength.

12. The limiting factor to supersaturation control in conventional reactor designs is the quantity of slurry in circulation. The present practice is to set this rate at seven to ten times greater than the slurry rate to the filter. This range has been determined in practice as satisfying process heat removal and heat level requirements. For any given production capacity, the quantity of $CaSO_4$ formed by the reaction will exceed the desirable level of supersaturation in the quantity of circulating slurry acid set by conventional

reactor designs. The result of exceeding the desirable level of supersaturation is the formation of excess fines in the solid phases. Since fines cannot grow to a desirable size within the time allowed in the crystal growing zone shown in Figure 1, the effect is to reduce the porosity of the filter cake which in turn reduces production rate and P_2O_5 recovery.

13. The crystal growing zone shown on the schematic loop is that portion of the reaction system where supersaturation produced in the reaction zone is reduced under proper conditions by growth of existing solids in the slurry. The length of the crystal growing zone shown on the loop represents the time required for the liquid to desupersaturate on to the surface of the solids causing them to grow. Conventional design practices in most dihydrate plants require a nominal retention time of six to eight hours in the combined reaction and crystal growing zones.

14. The cooling rate in the crystal growing zone is very gradual and normally will not exceed 6 - 8°C. over a period of hours. Optimum practice for controlling supersaturation is again ignored in the conventional cooling procedure where process heat is removed. Temperature drops of 4 - 8°C. on an instantaneous basis are imposed. The effects of the resulting excessive supersaturation are the same as described earlier. Even with some additional retention time after cooling, the cooled slurry recycled through the system and fed to the

filter is still somewhat supersaturated. The rate at which the filter and its auxiliary equipment build up with solids deposits is a clear indication of the problem.

15. Despite the ability of the inertial loop of circulating slurry to dampen temperature and concentration changes in the system, conventional dihydrate reactor systems cannot achieve optimum results under current design practices.

III. THE ISOTHERMAL REACTOR

Design Bases

16. Swenson has been a supplier of commercial crystallisation equipment to the organic and inorganic chemical industries for many years. As the largest supplier of phosphoric acid concentrators and fluorine recovery equipment to the fertiliser industry in the U.S., they became familiar with the various process designs used to make phosphoric acid. It became apparent to Swenson that the process technology used in the design of reactor systems was still somewhat deficient in imposing optimum conditions for good crystallisation technique. Swenson designers reasoned that a single reactor-crystalliser equipped with a draft-tube and employing a high rate of slurry recirculation while operating under reduced pressure, should be able to digest phosphate rock and grow crystals to a satisfactory size in a more efficient fashion and in a shorter

time than conventional units. These desirable results were expected because of the unique ability of this type of reactor design to provide uniform reactant concentrations at constant temperature. This is accomplished by rapid dispersion of reactants while the resulting process heat load is continuously removed by water evaporation under adiabatic conditions.

It is known that for a solution to nucleate, some degree of supersaturation is necessary. Referring to Figure 2, it has been generally accepted that for any solution two solubility curves can be drawn. The maximum solubility of any solute in any solvent at equilibrium conditions can be represented by the curve AB which defines normal saturation conditions. With certain solute-solvent systems, conditions can be imposed which upset the normal equilibrium and allow the solute concentration to exceed the normal saturation level without the precipitation of solid phase solute. This condition is referred to as supersaturation. As the solute concentration increases in the supersaturation region, a level is reached at which no additional solute can be dissolved without causing spontaneous nucleation and precipitation of the solute. This condition is referred to as the supersolubility limit and can be represented by the curve CD, which is parallel to AB. The area below AB is the unsaturated zone. The area between Curves AB and CD is the supersaturation zone or metastable region in which the solute, though subject to precipitation, tends to resist

precipitating. The area above curve CD is generally referred to as the labile region or region where the solution is very likely to nucleate spontaneously. It can be seen from this curve that increases in either temperature or concentration can cause nucleation. The closer a crystallization system is operated to the supersolubility curve, the more likely it is to produce nuclei.

17. If we are to produce crystals of a size that can be easily handled, it is a primary rule of crystallization that excessive nucleation must be prevented as much as possible. Nuclei take many hours to grow to a satisfactory size. If a large number of nuclei are present, the amount of material required to grow these nuclei to a satisfactory crystal size may be greater than the amount of material being precipitated. Therefore, it is extremely important that any well-designed reactor prevent any sudden change in temperature or concentration. The concentration effect refers to the components that cause saturation; these are primarily Ca ions and SO_4 ions in the case of a phosphoric acid reactor.

18. Another important consideration in a well-designed reactor is the slurry density. A heavy slurry density decreases the distance between crystals and therefore favors the dissipation as new nuclei. Retention time is also important to grow crystals to a satisfactory size. An ideal reactor should maintain conditions of temperature, concentration and

circulation that limit supersaturation levels to a point where crystal growth occurs but spontaneous nucleation does not. Ideally these conditions would be completely isothermal and the reactants would be instantaneously dispersed and reacted, so there would be only minimal changes in concentration.

Isothermal Reactor Performance - First Installation

18. At this point it may be of interest to examine the results from an isothermal reactor design which is currently in operation. Table 1 shows typical P_2O_5 losses from conventional plants operating on both Western and Florida rocks. These are compared to analyses from tests run on acid produced in the 22 MTPD isothermal reactor now in operation in Bakersfield, California. The recoveries shown for the isothermal reactor are appreciably better than normally expected from conventional reactors. With a filter sized in accordance with present practices for conventional reactors we would expect that the water soluble loss could be reduced to the additional water available for cake washing and the better draining crystals that would be on the filter. The isothermal reactor shows a marked decrease in the citrate soluble losses over a conventional plant producing Western acid. In a conventional system relatively high citrate soluble losses are dictated by the recirculation rates and mixing efficiencies.

The design of a conventional reactor leaves many localized areas where there will be either a higher or lower than normal sulfate concentration due to the efficiency of the mixers. These localized pockets tend to increase both citrate soluble and citrate insoluble losses. Such conditions are virtually non-existent in an isothermal reactor.

20. The citrate soluble loss that is presently showing up in the 22 MTPD isothermal reactor is due to the rock premix system. This loss can be reduced further by using a coarser grind rock and by decreasing the retention time in the premix tank.

21. The data does not show as great an improvement in recoveries when Florida rock is used. This data is the result of only a very few days of operation on this rock several months past. The rock grind was finer than for Western rock which would account for the higher citrate soluble loss. With a coarser ground rock the citrate soluble loss would be improved to where it was comparable to Western rock and probably better. The data from both Western and Florida rock was obtained while the reactor was operating with a total sulfate analysis of 2.0% or less in the acid.

IV. COMMERCIALIZATION OF THE GULF DESIGN ISOTHERMAL PHOSPHORIC ACID PROCESS

22. After the successful start-up and operation of the

22 MTPD unit in California, Gulf Design and Swenson negotiated a world-wide licensing agreement. This agreement grants Gulf Design the exclusive rights to use the Isothermal Reactor in its phosphoric acid plant design.

Farmland Industries, Inc.

23. Farmland Industries selected Gulf Design in 1965 to design and erect a plant which was considered at that time to be the "world's largest grass roots phosphoric acid fertilizer complex". This plant was constructed in Central Florida, U.S.A., and was put in operation in late 1966. The first phosphoric acid units for Farmland were Gulf Design's conventional dihydrate process design. Two parallel phosphoric acid units were constructed. Each of the units had the capacity to produce approximately 350 MTPD of P_2O_5. These wet process units were installed as a part of a total complex including sulfuric acid, phosphate rock grinding, a phosphoric acid clarification system, a 300,000 ton per year diammonium phosphate plant, a 200,000 ton per year granular triple superphosphate plant, and all of the necessary support facilities.

24. Gulf Design was again selected by Farmland in 1969 to assist them in planning for their new facilities currently being constructed. As a part of the feasibility study, Gulf Design prepared a detailed cost comparison of the conventional

dihydrate design for producing phosphoric acid and the Gulf Design Isothermal Reactor Process design. The evaluation included a comparison of capital costs and a comparison of operating costs.

25. Actual tests were performed in the 22 MTPD phosphoric acid unit in California. The purpose of these tests was to demonstrate the reactor process and its performance with unground phosphate rock. Flotation cell concentrates from the Florida phosphate mining area were shipped to California for the tests. Calcined and uncalcined Florida rock was used in the test program. The particle size of the flotation cell concentrates used in the tests was 100% −0.420 MM + 0.105 MM. The tests were carried out over a period of several weeks. The information gathered during the test run furnished Gulf Design engineers with specific data on various grades of Florida phosphate rock. This data was gathered and used for the design of larger units.

26. After the tests had been completed and the data analyzed, the comparison of the conventional system versus the isothermal process was completed. Farmland Industries, as a result of the comparative study, and the successful test results, elected to use the isothermal process. Farmland Industries awarded the engineering and construction contract to Gulf Design-Badger in 1970. The single reactor system, currently under construction, will supply the 640 MTPD of P_2O_5 required

for the new plant facilities. Figure 3 represents schematically the isothermal process being installed at the new Farmland plant site. The phosphoric acid reactor unit is approximately 55 feet in height. The single agitator has been sized to provide a pumping rate which will circulate the entire contents of the reactor more than once every minute. This is a dramatically higher recirculation rate than any of the existing conventional type units. The pumping rate for the 640 MTPD unit is approximately 72,000 cubic meters per hour. Due to the very low head loss in the system, this circulation rate is maintained with a single 200 HP motor. This motor slowly turns the agitator which is suspended in a vertical draft tube located in the center of the reactor vessel. The 200 HP requirement is substantially less than the horsepower required in conventional dihydrate reaction systems of the same P_2O_5 capacity.

27. The entire reactor is under a vacuum so that the recirculating slurry is constantly exposed to the vacuum atmosphere. The heat of reaction which is generated in the reactor, and the heat of dilution of the sulfuric acid, are continuously removed through the vacuum system. The use of the vacuum reactor, with the extremely high recirculation rate, makes it possible to maintain a maximum temperature differential throughout the entire vessel of 0.3°C.

28. The phosphate rock grinding step, which to date has been required in all U.S. phosphoric acid operations, has been omitted in the new Farmland plant. The unground phosphate rock is slurried with recycle phosphoric acid from the filter section of the plant. The mixture of the recycle acid and phosphate rock is introduced into the reactor at the entry to the draft tube. At this point, there is extremely high turbulence, therefore making it possible for the phosphate rock/phosphoric acid slurry to be quickly dispersed into the entire reaction mass. In the 640 MTPD unit, the phosphate rock is fed at a rate of 1900 MTPD. This is equivalent to approximately 1320 kilograms per minute. This quantity of unground phosphate rock is dispersed in 1200 cubic meters per minute of slurry or approximately 2,140,000 kilograms per minute of slurry.

29. In conventional wet process phosphoric acid plants, either 93% or 98% sulfuric acid is pre-diluted with water prior to being added into the reactor section. This dilution step lowers the concentration to a level of approximately 55% - 70% H_2SO_4. In the new Gulf Design system the 1835 MTPD of 93% sulfuric acid is added directly into the slurry at the top of the reactor. Again, because of the extremely high internal recirculation rate, it is not necessary to dilute the sulfuric acid. Dilution is normally used to minimize local concentrations of sulfuric acid. Sulfuric acid is

sprayed onto the surface of the reaction mass in the isothermal reactor. The spray breaks the acid into many droplets which are distributed across the entire surface of the reactor. In the case of the Farmland reactor, this is equivalent to approximately 90 square meters. In addition to the large cross sectional area available, the phosphoric acid slurry within the reactor is boiling, so that the boiling surface itself greatly increases the area available for acid distribution. The sulfuric acid sprays have a secondary advantage of helping to break any foam that might occur, thereby reducing the quantity of defoamer required in the reactor. The heat of dilution resulting from the addition of concentrated sulfuric acid is removed in the vacuum condenser system.

V. ADVANTAGES OF THE ISOTHERMAL REACTION SYSTEM

30. There are many advantages which result from the use of the isothermal reactor system in the production of wet process phosphoric acid. These advantages yield immediate savings in capital costs in the phosphoric acid plant itself. Other advantages occur immediately upon start-up in the form of lower operating costs. There are long-range continuing advantages such as better overall operation and lower maintenance costs. Listed below are some of the many advantages which result from the use of the new isothermal process.

1. Lower power requirements

In a conventional wet process phosphoric acid unit it is necessary to have a number of agitators. For a plant producing approximately 640 MTPD of P_2O_5, eight to nine agitators are normally required. These agitators will generally have 150 HP motors on each, for a total of approximately 1200 HP. It is also necessary to have phosphoric acid slurry pumps for pumping the slurry to the flash coolers. Each of these pumps will have 50 to 75 HP motors. The total requirement for conventional phosphoric acid plants with this capacity would be approximately 1300 to 1400 HP. In the isothermal reactor system, a total horsepower for this P_2O_5 capacity of 225 HP would be required. This includes the small agitator in the pre-wetting unit for mixing the phosphate rock with the recycle phosphoric acid. The above comparison indicates that the isothermal reactor lowers the horsepower in the reaction step alone by approximately 1,000 HP. This results in a continuing annual power savings. It also lowers the capital costs for motors and agitators, as well as the capital costs for the electrical system. There is also a substantial savings in maintenance costs.

2. Elimination of the sulfuric acid dilution system

A conventional sulfuric acid plant will utilize diluted sulfuric acid. Normally, karbate tube and shell heat exchangers are utilized for diluting and cooling the sulfuric acid solution.

These units are equipped with instrumentation for controlling the dilution as well as cooling water. To minimize scaling in the tubes, it is often necessary to use treated water for diluting the sulfuric acid. For the cooling side of the heat exchanger, contaminated water from a recycle pond system is usually utilized as the coolant. The isothermal reactor system utilizes concentrated sulfuric acid directly into the reactor. This completely eliminates the need for the dilution cooling equipment. This is a substantial reduction in capital and in operating costs. It also lowers the long-range maintenance costs by eliminating the need for tube cleaning and changing as well as maintenance to pumps, valves, instrumentation, etc.

3. Reduction of atmospheric pollution

The reaction system is a totally enclosed unit. Any gases evolved during the reaction between sulfuric acid and phosphate rock leave the reactor and pass through a barometric condenser. This total enclosed system eliminates completely any pollution of the atmosphere during the reaction step. The process also eliminates the need for a fume control system. Conventional phosphoric acid plants have large induced draft fans for gathering the gases which are evolved during the reaction step. These gases then pass through rubber-lined or plastic duct to scrubber systems. The isothermal reactor eliminates the need for the collecting system, scrubber,

and the induced draft fan.

4. Elimination of separate reaction cooling facilities

The reactor itself operates under vacuum. Absolute temperature control with the removal of the heat of reaction and the heat of dilution is achieved. Conventional plants have separate cooling systems for controlling the temperature of the slurry. In Item No. 2 above, the need for the sulfuric acid diluter cooler was discussed. Some plants have utilized air flow systems for achieving this temperature control. The elimination of the separate cooling system not only eliminates the flash coolers but also the necessity for slurry pumps, piping and control. Again, this results in a substantial savings in capital and operating costs.

5. Improved filter cake washing

The use of concentrated sulfuric acid directly into the reactor makes it possible to utilize the normal water of dilution at other points within the process. It has been found that substantial amounts of this extra quantity of water can be used on the filter, increasing the filter washing efficiency and lowering the losses of soluble P_2O_5. The extra quantity of water added to the filter is then returned as recycle acid into the phosphate rock wetting tank.

6. Elimination of phosphate rock drying and grinding

It has been found that Florida phosphate rock can be fed directly into the reactor without the necessity for drying or

grinding. In the Farmland plant, the phosphate rock grinding unit has been completely eliminated from the project. In the Gulf Design process, wet phosphate rock can be received directly from a mining operation and fed into the reactor system. Any water which is present in the rock can be easily compensated for as discussed in the above section. The maximum size of unground rock has not yet been determined. It is felt, however, that in no instance would it be necessary to install phosphate rock drying and the normal ball mill or roller mill grinding systems. Even with very coarse rock, it is felt that an impact mill handling wet rock would be satisfactory to prepare the feed for the reactor. These two items dramatically reduce capital costs, as well as operating costs. There are other advantages which can accrue through being able to use wet unground rock. Freight and handling savings should result from this process flexibility.

7. Additional reduction in capital costs

The above items are specific examples of the reduction in capital costs through the use of the Gulf Design process. There are also other items which will lower the cost for the phosphoric acid production unit. The reactor itself is a relatively simple design. It is normally a steel tank. There are no interior baffles or underflow/overflow partitions, which are normally brick-covered. The unit itself is rubber-lined and has acid brick below the liquid level. The only interior

BAFFLE IS THE VERTICAL DRAFT TUBE WHICH IS SUSPENDED AROUND THE AGITATOR. BECAUSE OF THE EXCELLENT AGITATION WITHIN THE UNIT, IT IS POSSIBLE TO LOWER THE RETENTION TIME FOR THE REACTION. THIS MEANS A SMALLER REACTOR FOR ANY GIVEN ANNUAL P_2O_5 PRODUCTION.

31. ONE OF THE BASIC MOTIVES BEHIND THE CURRENT TREND FAVORING HEMIHYDRATE PROCESS TECHNOLOGY OR COMBINATIONS OF HEMIHYDRATE AND DIHYDRATE TECHNOLOGY IS THE DESIRE OF PROCESS DESIGNERS TO PROVIDE SYSTEMS HAVING LESS OF THE CONTROL PROBLEMS INHERENT WITH CONVENTIONAL DIHYDRATE UNITS. THE APPARENT DISADVANTAGES OF THESE SYSTEMS, SUCH AS THE REQUIREMENT FOR HIGH GRADE PHOSPHATE ROCKS, DO NOT OFF-SET THE POTENTIAL GAINS IN TERMS OF INCREASED RECOVERIES AND HIGH GRADE FILTER CAKES. THE INCENTIVES ARE PRESENT FOR USING THE ISOTHERMAL REACTOR TO PRODUCE HEMIHYDRATE AND HIGH STRENGTH PHOSPHORIC ACID OR FOR RECRYSTALLIZING HEMIHYDRATE UNDER OPTIMUM CONDITIONS FOR GROWING LARGE DIHYDRATE CRYSTALS WITH LOW CITRATE SOLUBLE P_2O_5 CONTENTS. THE PERFORMANCE QUALITIES THAT MAKE THE ISOTHERMAL REACTOR SUPERIOR TO CONVENTIONAL DIHYDRATE REACTION SYSTEMS APPLY IN OTHER AREAS AS WELL. GULF DESIGN IS CURRENTLY INVOLVED IN A NUMBER OF PROJECTS WHERE HEMIHYDRATE PRODUCTION IS REQUIRED. WE ARE LOOKING FORWARD TO ANNOUNCING THE FIRST SUCCESSFUL PRODUCTION OF HEMIHYDRATE FROM THE GULF DESIGN ISOTHERMAL PHOSPHORIC ACID PROCESS.

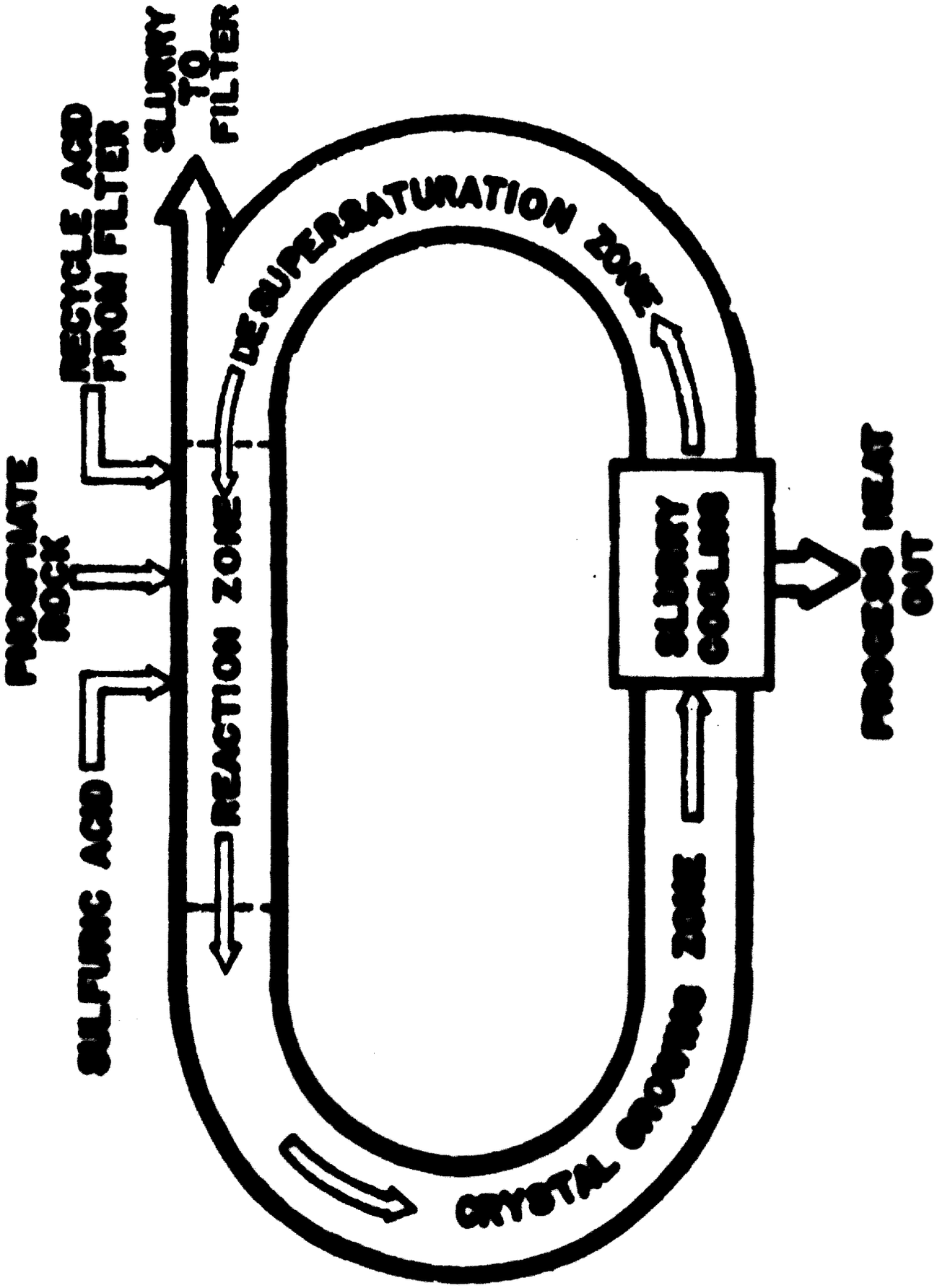
TABLE 1

FILTRATION LOSSES

BASED ON DRY CAKE WEIGHT

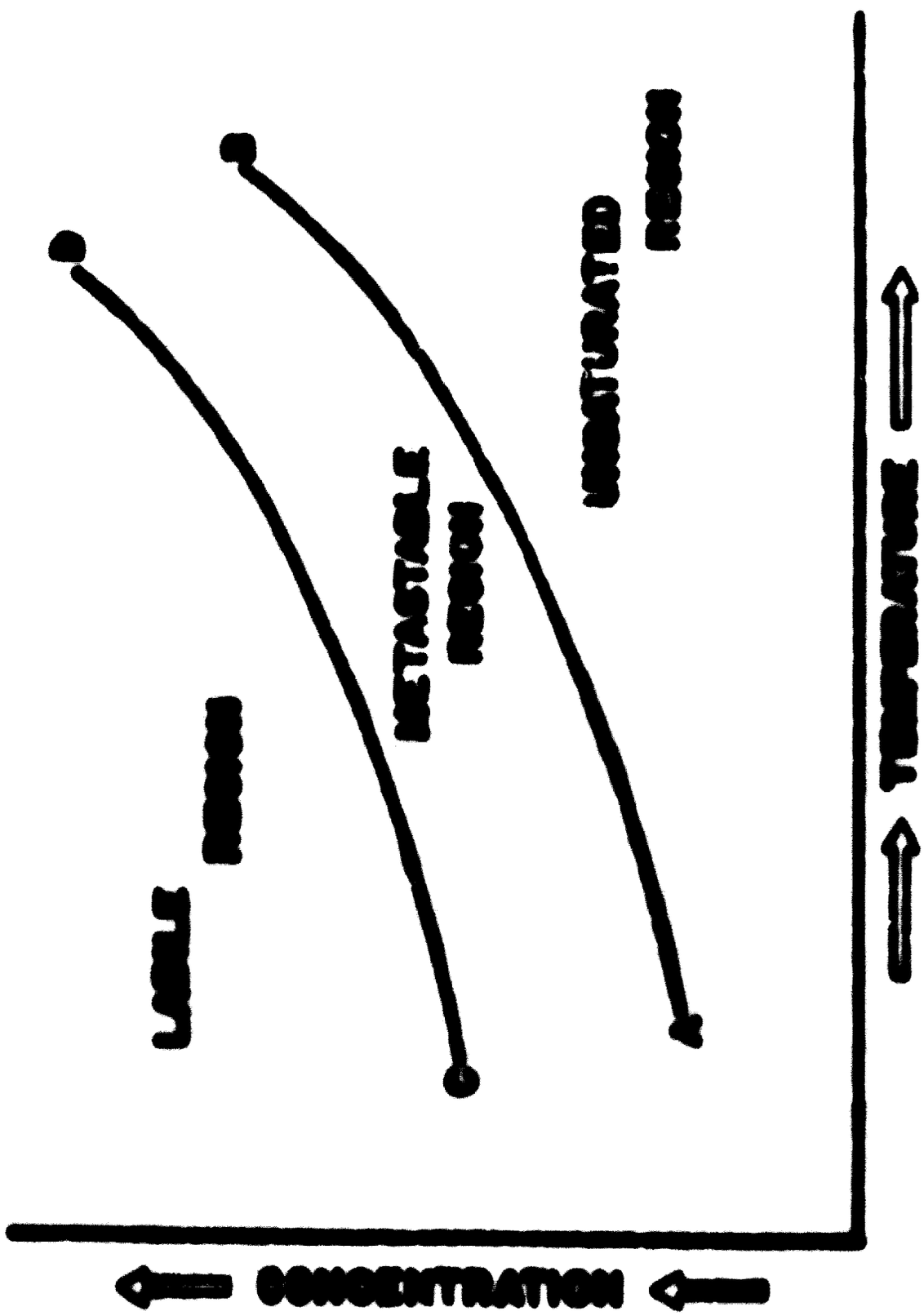
P_2O_5 LOSSES WEIGHT %	WESTERN U.S.A. PHOSPHATE ROCK	
	ISOTHERMAL REACTOR	CONVENTIONAL REACTOR
TOTAL	2.34	7.5
WATER SOLUBLE	0.85	1.7
CITRATE SOLUBLE	0.85	4.45
CITRATE INSOLUBLE	0.64	1.35

P_2O_5 LOSSES WEIGHT %	FLORIDA, U.S.A. PHOSPHATE ROCK	
	ISOTHERMAL REACTOR	CONVENTIONAL REACTOR
TOTAL	3.11	4.25
WATER SOLUBLE	0.90	0.85
CITRATE SOLUBLE	1.84	2.96
CITRATE INSOLUBLE	0.37	0.44



DIHYDRATE PROCESS SCHEMATIC

FIGURE 1



PRECIPITATION OF NORMAL SOLUBILITY

FIGURE 2

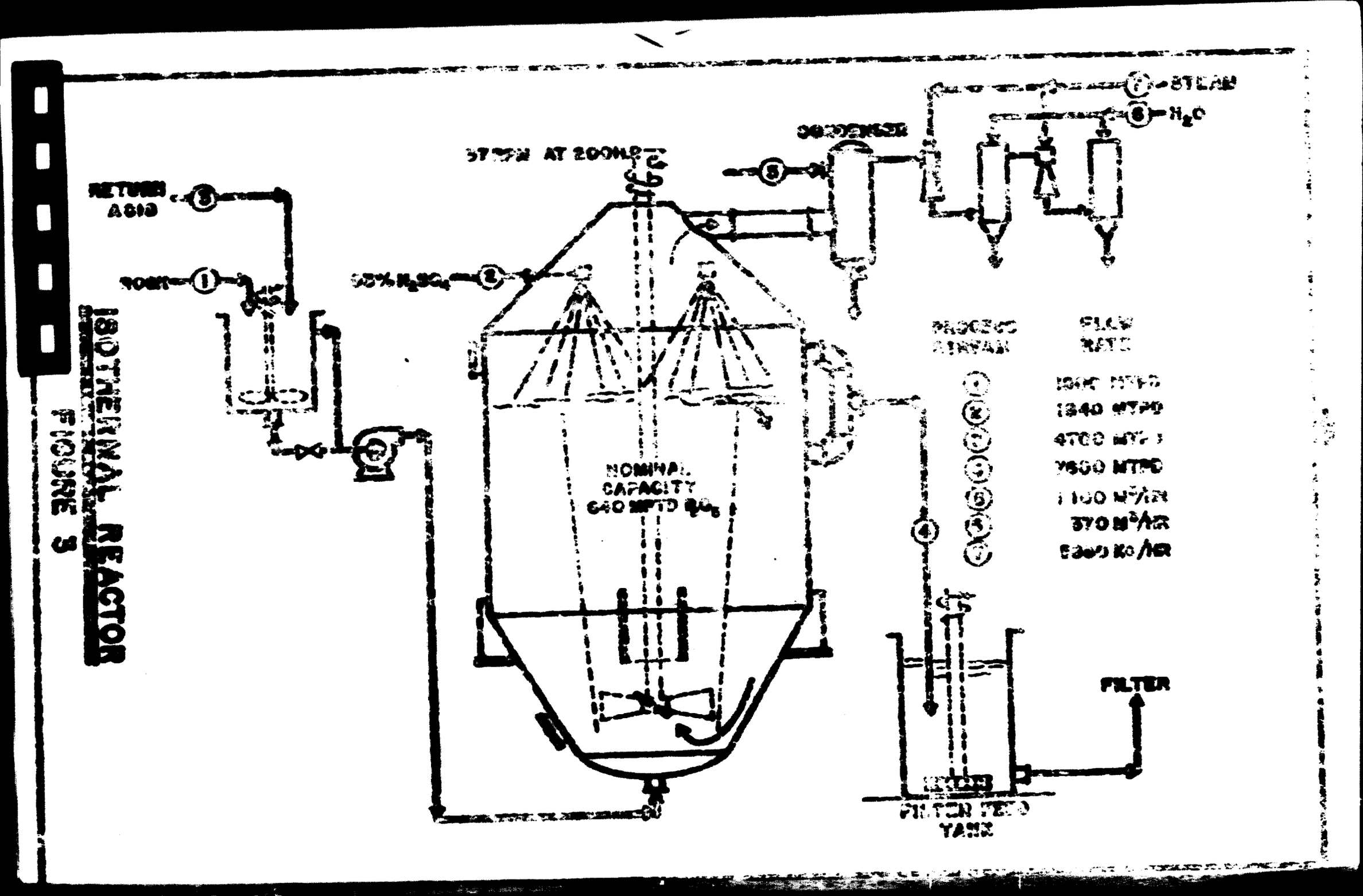
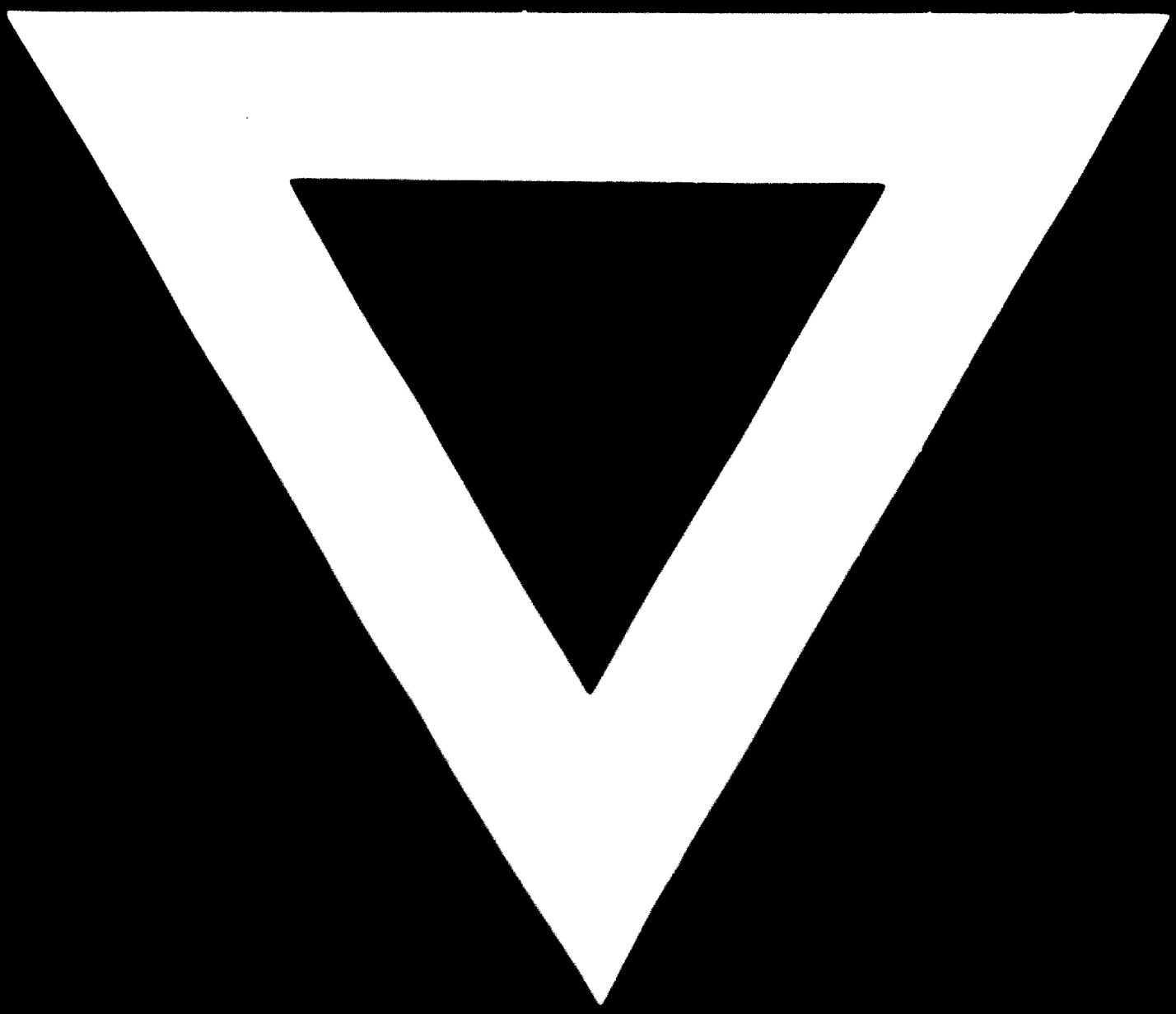


FIGURE 5
ISOTHERMAL REACTOR



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