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OPERATING EXPERIENCE OF PROCESSING LOW GRADE JORDANIAN PHOSPHATES IN THE MANUFACTURE OF WPA PRODUCTION[1]

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SUMMARY

This article focuses on the production of wet process phosphoric acid (WPA) using different blended low grades of Jordanian phosphates. Studied the impact of F, Al_2O_3 and SiO_2 contents in raw materials on the specific filtration capacity (SFC), qualities of downstream products, calcium sulfate (CS) crystals and P_2O_5 recovery. The aim of the rock impurities study is to obtain data on the influence of F, Al_2O_3 and SiO_2 on the SFC in WPA production and also to optimize their contents in blended 66-68% BPL grade. Studied influence of inorganic modifiers on the SFC when using low SiO_2-Al_2O_3 phosphate and evaluate different types of filter cloths used for PA production. Investigate the effect of slurry temperature, permeability, mechanical strength and the tonnage of P_2O_5 produced on the cloth lifetime.

RESUME

Cet article se focalise sur la production d'acide phosphorique de voie humide, utilisant des mélanges de phosphates jordaniens à bas titre. On étudie l'impact des teneurs en F, Al_2O_3 et SiO_2 dans les matières premières sur la capacité spécifique de filtration (CSF), les qualités des produits d'aval, les cristaux de sulfate de calcium et le rendement en P_2O_5. Le but de l'étude des impuretés du phosphate est d'obtenir des données sur l'influence de F, Al_2O_3 et SiO_2 sur le CSF dans la production de l'acide phosphorique et aussi pour optimiser leurs teneurs dans les mélanges à 66-68 % BPL. On étudie l'influence de modificateurs inorganiques sur le CSF quand on emploie des phosphates pauvres en SiO_2-Al_2O_3 et on évalue différents types de toiles filtrantes utilisées pour la production de l'acide phosphorique. On étudie l'effet de la température, de la perméabilité, de la résistance mécanique et du tonnage de P_2O_5 sur la longévité de la toile.

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Introduction

Aqaba Industrial Complex has the following international scale process and production facilities:

- SA: Monsanto Four Beds - Double Conversion, 1.485.000 MTPY.
- PA: Dihydrate Rhone Poulenc & Prayon Processes, 432.000 MTPY.
- DAP: Gulf Process, Badger INC, 800.000 MTPY.
- ALF_3: Alusuisse, 20.000 MTPY.

PA Plant (PAP) started life as a Rhone-Poulenc dihydrate unit, originally built in the beginning of 1980's with a capacity of 1250 MTPD P_2O_5, designed to operate on 73 - 75% BPL Jordanian phosphate [1].

The plant is characterized by a large table filter with an effective area of 205 m^2 and single compartment tank reactor with central agitator having rotation speed of about 31 rpm and power absorbed 0.52 kw/m^3 slurry. The specific reaction volume (SRV) is 1 m^3 /tpd P_2O_5 thus, the reactor would have a holding time of about 165-170 minutes and maintaining a crystallization rate of calcium sulphate at level 0.22-0.24 t/m^3hr. 80% SA is introduced onto a disc on the shaft of a surface cooler and is thus sprayed across the reactor surface together with the droplets of slurry. The reactor slurry temperature is kept 82.5°C by means of drawing air across the surface of the reactor. Moreover, maximum feed rate to reaction volume ratio is 0.14 with overall plant efficiency of about 95$\pm$0.5%. It has been established, that with smaller SRV higher supersaturation will take place, higher nucleation rate will occur. This reduces crystal sizes and thus filtration quality [2].

In 1993 major debottle-necking in the reaction, concentration and as well as cooling pond sections were undertaken which has substantially increased capacity to 1310 MTPD .

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[1] *Expérience opératoire dans le traitement des phosphates jordaniens de différents titres dans la fabrication d'acide phosphorique*

For a detailed review of PAP revamp see Rehabilitation of JPMC - PAP in Aqaba IFA Technical Conference 1994 Amman - Jordan [3].

Figure 1 is a flow sheet showing the dihydrate PAP at Aqaba complex.

The revamp included the addition of three digesters and a separate Prayon II compartment reactor with two 98.5% sulfuric - recycled acids mixers; a low level flash a cooler and axial flow circulator creating a very high rate of slurry circulation 8500 m^3/h across the LLFC itself as well as throughout the reactors, so as to maintain a temperature of 76-78°C in the reactor and 74-75°C at the filter. All these provide numerous benefits to JPMC including relatively high phosphate rock processing flexibility.

The total reaction volume, nominal feed rate to reaction volume ratio and SRV are 2618 m^3, 0.068 and 2 m^3/tpd P_2O_5 respectively. The latter is equivalent to some 6 hours retention time. Becker [4] reported, that when the SRV is in this case within the range 1.8 to 2 m^3 /tpd P_2O_5, ideal conditions for crystallization are achieved at 0.09-0.125 t/m^3 hr. However, the average energy consumption of the total reaction tanks increased to some 0.62 Kw/ m^3 slurry.

Beside, the rock grind required for Rhone - Poulenc process works on a specification of 75% passing 200 mesh initially but this specification was changed to 50% minus 100 mesh.

A further important point to note is that , the plant has excellent production results and efficiencies even operating above design rate. The annual global efficiency is within the range of 95-95.12%.

Finally, the PAP modification was changed from a single reactor dihydrate Rhone-Poulenc process route to a multicompartment reactor and three digesters of **Prayon Mark IV** dihydrate process.

1. Quality of Jordanian phosphates

Essentially, the BPL percentage determines the price of phosphate rock but the quality of phosphate cannot be measured in terms of the P_2O_5 content or BPL grade. The type of impurities and their effect on the downstream chemical process are far more important than the concentration of P_2O_5 in the plant operation and final PA production. As example, CS filterability is a major economical factor when selecting commercial phosphate rock, since filtration is the most critical and expensive step in the process [4,5].

The author [6] studied the effect of impurities on WPA production and comparative evaluation of Jordanian phosphate rock. Others [7] reported the flexibility in phosphate flowsheets not only to fulfill the needs of traditional and international customers but also to meet the specific requirements of individual plants.

On the bases of these studies, conclusively, have proved that Jordanian phosphate is soft, porous and friable rock of marine sedimentary origin having high surface area (16-22cm^2/g). Chemical composition of various grades of the phosphate ores is given in Tables 1 and 2. As seen, Jordanian phosphates can be considered as a high quality and flexibility ranging started from low-grade 65 up to high grade 76.5% BPL [8,9]. The presence of impurities such as **Fe_2O_3**, **SrO**, **organic matters** and **rare earth element** (**Ln2O3)** are quite low.

The level of CO_2 is within the range of 3 to 4.8%, which gives an optimum rate for sedimentary phosphates in low foaming tendency.The content of alkaline oxides does not exceed 0.65%. Further, the MgO content of 0.2-0.3% is low enough not to cause problems with high acid viscosity and reduce filtration rate .

In terms of the potentially hazardous elements, (Table 2), Jordanian phosphates are characterized by low levels of **Cd, Pb, As, Mo, Cu, Mn, Cr, V** and the absence of Hg.

Taking PA technology into the consideration the quality of the Jordanian phosphate rock used can be considered satisfactorily performing by three key factors:

- High rate of slurry filtration,
- Acceptable level of SA consumption,
- Low rate of corrosion and abrasion.

The major factors affecting the above mentioned are:

F, Al_2O_3, SiO_2, Cl and **CaO/P_2O_5 Ratio**

This article is a sequel to a previous work presented at the AFA Techical Conference - Jordan 1996 [10]. It presents additional information and data generated in the operation of Jordanian low grade phosphates at Aqaba PAP in recent years.

Table 1 shows the presence of fluorine and chlorine contents in phosphate ores are within the range 3.5 to 4.0% and 200 to 650 ppm respectively , whereas SiO_2 and Al_2O_3 contents fluctuates from very low of 1.95 up to 10.16%. Moreover, CaO/P_2O_5 ratio ranges 1.457 to 1.64.

More than 16 years of extensive plant experience based on industrial scale experiments which have been systematically conducted at Aqaba PAP using various grades of phosphate have shown that the plant capacity and P_2O_5 recovery rate is directly linked to the level of these impurities. Moreover, the extremely wide range of fluctuating causes affect production results, equipment's conditions and processing characteristics.

So the objectives of the rock impurities studies are to obtain data on the influence of F, Al_2O_3 and SiO_2 on the SFC in WPA production and also to optimize their contents in blended 66-68% BPL grade in order to keep production rate, product specification, equipment's status within almost acceptable tolerances.

2. Influence of F, Al_2O_3 and SiO_2 Contents

The inorganic elements in sedimentary rock that are well known to affect considerably the crystal habit and size of $CaSO_4$ are F, Al_2O_3, SiO_2 and to a certain extent MgO.

Becker [5] mentioned that these impurities in WPA, are of particular importance in that, they combined and formed complexes with fluorine ions which affect $CaSO_4$ crystallization.

However, a study of published literature [11,12,13] shows that, the presence of free fluorine ions leads to the formation of long thin needle crystals, which are difficult to filter. Al_2O_3 and SiO_2 are beneficial to crystallization because they reduce the free fluorine ions concentration and improve the form of $CaSO_4$ crystal. Moreover, it has been reported [4,11,14] that the presence of active silica has a positive effect on the reduction of corrosion and crystallization of $CaSO_4$. By changing F/SiO_2 ratio, needle - type crystals can be modified to agglomerates. The best crystals look like balls, because of their surface to volume ratio is at minimum [4].

As reported by Kopilev [15], a high concentration of Al^{3+} ions in slurry liquid phase regulates the $CaSO_4$ crystal growth uniformly in all direction yielding thicker crystals, with low surface - to volume ratio. It can also can promote the formation of cluster type crystals, which has a significant effect on $CaSO_4$ filterability [4,12]. Karmishov [16] found that the optimum condition for dihydrate $CaSO_4$ crystallization occurs when maintaining the level of free $SO^{2-}{}_4$ 3.5%, SiF_6^{2-} 1.5% and Al_2O_3 0.8%.

As reported by researchers [5,17], displaying the effect of Al_2O_3 and F on crystallization is explained with formation especially aluminum fluorides complexes type $AlFx^{3-X}$ where x has value ranges between 0 to 6 according to molar ratio Al/F dictates which type will be dominant. $AlF^{2-}{}_5$ is existing and can be substituted $SO^{2-}{}_4$ in the gypsum lattice. The solubility of these complexes depend on P_2O_5, free $SO^{2-}{}_4$, reactive silica and REE contents [16].

Furthermore, important fundamental information about the effect of these impurities on the corrosion rates, crystallization of the precipitated $CaSO_4$ and the calculation method of fluoride complexing ratio (FCR) can be found in the literature by M.Schorr [13].

On the basis of this, FCR is calculated from the phosphates analysis data obtained taking into account the solubility factors of these impurities in PA and are presented on Table 3. As seen, the results of computation are highly fluctuating from between 1.378 to 0.286. Then, we have studied the effect of FCR on the SFC within this interval.

2.1 When the ratio of FCR higher than one:

2.1.1 Processing low silica - Alumina phosphate

Operating experience when treating several grades at Aqaba PAP has shown that using phosphate which contains extremely low levels of Al_2O_3 (0.18 -0.2%) and SiO_2 (1.8 - 2.4%) suffers from lack of SFC and leads to the following observations:

- Poor slurry filtration characteristics, low filtration capacity and washing efficiency. When increasing the SFC higher than **4.6 t /m^2 pd P_2O_5** and after hours of retention time, the quality of slurry filtration deteriorates, completely uncontrollable, and consequently the attack. On account of bad filtration, the water - soluble P_2O_5 losses in gypsum increase asymptotically to higher than 5.0%. Microscopic examination discloses that the gypsum consist of long thin needle shaped crystals: (length 250-300; width 30-50 and thickness 2-3 microns). Beside it is in dark colour, very sticky with 33-37% of free water content and high thixotropic properties. Surface area of cake is about 3400 cm^2/g.

- The maximum P_2O_5 content attainable of the filtrate acid is between 25.5 to 26% of P_2O_5. Further, it is becoming difficult to filter the slurry while increasing the P_2O_5 higher than 26% because of high slurry viscosity.

Interesting data are given in unpublished report [9] about treating the same type of phosphate but using single reactor having 2 m^3/tpd P_2O_5 of SRV. The phosphate was ground to 59% minus 200 mesh. The average P_2O_5 and free sulfate content of the filter acid were 28.2 and 2.4% respectively, whereas, the SFC was reached only 3.9 t /m^{2}pd P_2O_5. The dominant length and width of the dihydrate $CaSO_4$ crystals were 40 to 130 and 10 to 30 microns, which gives an average L:W ratio of 5.9:1 and an average surface area of 3044 cm^2/g.

Moreover, it is important to mention, that the Al_2O_3 content in the PA produced is found to be less than 0.05%, which seems to be low proportion to the acid available for the formation of complex salts.

The unusually high corrosion on equipment is due to high F/SiO_2 ratio (1.7 - 2).

2.1.2 Application of Inorganic Modifiers

The above mentioned process problems have been successfully overcome by international and local experiences, study and research activities. Consequently, from industrial experience, as an improvement, Al_2O_3 and SiO_2 contents can be adjusted in a proper ratio by adding:

(a) Aluminum hydroxide $Al(OH)_3$, (b) clay and kaolin minerals, (c) SiO_2 as cheaper by product from the AlF_3 plant, (d) in the case of high silica content, blending various grades at different ratios is more favourable and applicable.

In addition, it has been investigated the effect of the addition of various inorganic modifiers on the SFC for the phosphate containing low Al_2O_3 and SiO_2 .

The trials involved the addition of reactive SiO_2 and clay minerals. (Jordanian clay contains on dry basis, wt.% 14.8 - 21.1 Al_2O_3, 6.4 - 7.8 Fe_2O_3, 54 - 61.3T. SiO_2 , 35.3 SiO_2 reactive 35.3 and 1.2 - 1.8 TiO_2) .

Treatment took place in a reactor having 1m^3 /tpd P_2O_5 of SRV. The P_2O_5 concentration of the filtrate acid was controlled at the level of 27%. The results listed below showed, that there were changed in physico-chemical properties of dihydrate $CaSO_4$ crystals in particular, increased the surface area and its permeability, so as the SFC increased as much as 1.35-1.5 times. Moreover it must be pointed out, that in this way the unusually high maintenance costs have been reduced considerably.

SFC t/m^2 pd P_2O_5	Permeability cm^2 X 10^{-9}	Porosity %	Surface Area $cm^{2/}g$	Raw Material
4.3	24.55	70	3397.7	low Al_2O_3 and SiO_2 Phosphate
7.6	36.6	62	1278.7	Adding SiO_2
8.5	53.77	64	1193	Adding Clay Mineral
>7.0	35 - 56	58 - 63	1027 - 1155	high Al_2O_3 and SiO_2 Phosphate

2.2 Reduction of FCR to 0.83 in the phosphate used

This causes some improvements with plant performance:

- Increase the SFC from 4.6 to 5.5 **t/m^2 pd P_2O_5**.
- Increase acid concentration of the filtrate acid to 27% P_2O_5.
- Improve marginally the filterability and washability of gypsum. Washing efficiency can be maintained at the level of 98.5%.
- Produced gypsum containing big rhombic shaped crystals with 26-28% free water content.

Moreover, it has been observed that, when Al_2O_3 content in slurry liquid phase is less than about 0.08%,the gypsum becomes waxy, soft and white in colour consists of needle shaped crystals. Further increases in the content to higher 0.1% changes crystals habits from needle to rhombic shape.

3. Processing blended low grade rock

Today different phosphate grades come to supplement Aqaba PAP as a blended 66-68% BPL containing such as 60-62% fines phosphate, 58-60% high carbonate, 60-62% high insoluble silica phosphate, 68-70% and 70-72% grades from different mines. The latter grade is a master controller of blending the rock.

The summaries of their chemical compositions are (on dry basis, wt.%): 27 - 32.2 P_2O_5, 42.5 - 50 CaO , 4.0 - 14.1 SiO_2, 0.35 - 1.5 Al_2O_3, 3.4 - 3.8 F^- and 1.475 - 1.818 CaO/P_2O_5.

Blending the above mentioned grades could be done in various proportions at the plant site, according to qualities of the final blended rock and economic consideration (P_2O_5, CaO/P_2O_5 ratios) or plant capacity, qualities of downstream product or economic flexibility: P_2O_5 prices, SA consumption and P_2O_5 recovery. For these reasons, blending is one of the problems standing in the way of the utilization of such blended phosphate at Aqaba PAP.

3.1 Reduction of FCR to 0.42

This ratio offers certain advantages over the other three. In this case, the results of processing blended rocks show that a SFC is reached higher than **7.4 t/m^2 pd P_2O_5** with a 27-28% of P_2O_5 content of the filtrate acid. This has been possible, in part, by using a phosphate with high content of Al_2O_3, by keeping the solid content in reactors slurry at high levels 37-39%, adjusting the flow quantities of phosphate and SA distribution through the reactors, replacing the old filter perforated sheets and reducing the clearance between gypsum screw and **UCEGO** filter table which should be lower than 10 mm. In addition to that, the rotation speed of the table filter can be kept at higher rate. The technological indicators such as P_2O_5 extraction and cake washing efficiencies are maintained at the level of 95.8-96.3% and 99-99.3% respectively Thus, the plant efficiency in excess of 95.0 up to 95.5.

Moreover, gypsum contains about 23-26% free water with low surface area 1200-1500 cm^2/g. Gypsum crystals are either in big rhombic and twin crystals or mostly granular, sandy and cream in colour consisting of prism hexagons crystals and mainly small spheres which agglomerate to form cluster type crystals having surface area of about 1027 - 1155. cm^2/g .

For a brief period, while using low grade 68% BPL with the composition (wt.%) of 67.7 BPL, 30.98 P_2O_5, 49.5 CaO, 5.78 SiO_2, 3.7 F and 0.45 Al_2O_3 a rate equivalent to 1525 t/d was achieved, (or 7.44 **t/m^2 pd P_2O_5**) which means 16.4% in excess of guaranteed output rate. The results of industrial trails are listed below. As seen it is easy to understand why water soluble P_2O_5 is a little high 0.44%.

R-6301	Flash cooler		YIELD	P_2O_5 Losses in gypsum				MTPD	Plant	P_2O_5 in
˚C	T	Pr mmHg	%	w.s%	Co.Cry%	Unr. %	Ins%	P_2O_5	Capacity%	acid, %
76.40	1.96	334	95.033	0.20	0.82	0.25	1.07	1430	109.2	27.18
75.80	1.89	331	95.029	0.16	0.88	0.19	1.07	1350	103.1	27.77
76.82	2.07	349	95.172	0.14	0.86	0.18	1.04	1380	106.5	27.81
77.3	2.18	275	>94.5	0.44	0.817	0.13	0.947	1525	116.4	~27.00

3.2 When Blending with Fines Phosphate

It is more complicated dependency of SFC upon the FCR when further reducing below 0.32. The difficulties are certainly in relationship with mineralogical structure of phosphate containing high SiO_2 (soluble and insoluble forms).

Operation of blending the fines at unloading station and grinding section causes serious problems from the economical and as well as environmental point of view because of spillage. According to that, it has been decided to introduce this type of material once the plant on stream across the ground silo in order to avoid the mentioned problems and to keep away from developing overgrinding phenomena. The fines contain 10-15% particle size minus 50 microns and characterized by low P_2O_5 content (20 to may be 7%), high SiO_2 content (25 up to 50%), kaolinite and carbonate as $CaCO_3$ contents ranging from 5 up to 13% and 6 up to 10.5% respectively. Moreover the specific surface area of these particles is between 37.7 up to 59.2 cm^2/g. It has been confirmed that phosphate rock containing fines higher than 10% < 50 microns has viscosity which dose not follow Poiseuille laws [9]. Also, it has been established that increasing the percentage of the smaller sized crystals below minus 40 microns from 20 to 40% will show 50% worse filtration rate [2].

A number of PA production industrial trials were carried out at PAP to treat low grade blending with fines at different feed rate with the composition of 65.1 BPL, 29.8% P_2O_5, 47.5% CaO, 9.5% SiO_2 and 0.66% Al_2O_3. Serious technical problems were faced when 13-15 t/hr of fines have to be blended. The bad filtration of the slurry could be attributed to the high viscosity and high percentage of SiO_2 fines (minus 50 mic). In the other respects, increase the P_2O_5 in downstream product seems to be impossible. It was found that even a reduction of dosing rate to 3-4 t/hr was not sufficient to obtain a slurry that could be filtered properly. Moreover, experience and studies have indicated the following:

Extremely low SFC 3.5 - 3.7 t/m^2pd P_2O_5 because of poor slurry filtration characteristics. In this case, the filtration step becomes the process bottle-neck of PA production. The gypsum consist of a very small, broken mixed between rhombic and amorphic crystals would normally result in lower cake washing efficiency 97%. Even so the concentration of P_2O_5 in acid was reduced to less than 25%. High SA consumption (2.98- 3.2 t sa\t P_2O_5) owing to high CaO/P_2O_5 ratio and low overall P_2O_5 recovery 92-93%. Also, the high stability of foam which it was very difficult to destroy on the surface of slurry. These reasons can may be explained either because of the presence of SiO_2 and kaolinite or in connection with specific area. It is obvious, that fine particles of SiO_2 which interfere by increasing the slurry filtration time, disturb the filtration operation by developing blocking phenomena the pores of gypsum cake and increasing the viscosity of the slurry. The practical use of this blended phosphate seems not to be possible. Moreover, blending was discontinued because of lack of adequate equipment and finally, decision has been taken to stop feeding the fines.

3.3 When Blending with High Insoluble Silica Phosphate

Another example of blending is using a low grade but containing high abrasive silica of about 64.5 BPL, 29.5% P_2O_5 and 7 to 9% SiO_2 or higher. The SFC was fluctuating between 4.8 - 5.2 t/m^2pd P_2O_5. On the other hand, it must be pointed out that blended phosphate needs high grind. However, the presence of silica in the insoluble quartz form or chert causes a serious erosion problem similar to that encountered in PAP.

- Increased erosion of the rotating equipment. It has been reported that 904 SSL agitator blade of the second digester was damaged due to high abrasion.

- Further difficulties were due to the sedimentation of quartz to the bottom of the reactors, digesters, flash cooler and on the surface of reactor, scrubbing fans depending on particle size of SiO_2.

The average SFC is to some extent improved due to the adjusting of SiO_2 and Al_2O_3 contents in the blended rock by 70-72% grade. The high content of Al_2O_3 and acceptable level of SiO_2 resulted in quite a high SFC and further a high P_2O_5 in the down stream product.

Consequently, full SFC of the plant 6.4 **t/m^2 pd P_2O_5** was obtained from using low blended grade rock containing (on dry basis wt.%) 66.8 PBL, 30.55 P_2O_5, 50.01 CaO, 5.9 SiO_2, 0.4 Al_2O_3 and 0.21 Fe_2O_3. In this case the gypsum consisted of very small (5-10 microns) crystals which form large (40-80 microns) cluster. The water soluble, cocrystallized and unreacted P_2O_5 losses in gypsum were respectively 0.39, 0.67and 0.04 in gypsum.

The plant has performed satisfactorily with this feed stock, thanks to a multicompartment reactor and three digesters system.

As a result of employing 66-68% BPL grades, unfortunately, the SA consumptions are high 2.90-2.98 depending on CaO/P_2O_5 ratio, SO_3 content in the rock and P_2O_5 recovery.

4. Effect of Filter Cloth

An additional factor influencing slurry filtration and plant performance is the filter cloth. Over the years, a number of filter cloth types including polyester and monofilament polypropylenes, have been employed and tested at Aqaba PAP.

Polypropylene cloth is relatively commonly utilized, but some several are unsuitable for huge plants because of the short durability caused by weakness in mechanical strength. The choice of a correct filter cloth poses difficult problems on account of the corrosive and scaling properties of PA slurry.

Consequently, when evaluating the economics and operating life of such a cloth, various points have to be taken into consideration and weighted according to each particular situation.

- Material

Polypropylene monofilament cloth is the most suitable. Though polyester is suitable for P_2O_5 filtration and has better mechanical features than polypropylene, the relative price to usage length makes polyester expensive, especially for table filter.

- Weaving Pattern

Should provide a smooth and flat surface on the cake side so as to make the cake discharge as good and easy as possible.

- Calendering

Calendering is required for thermofixation of the cloth and also to help to obtain a smoother surface and if necessary to reduce the permeability. But calendering reduces the resistance of the cloth drastically. This is why a cloth with calendering should rarely be chosen.

Calendering should be just a finishing touch. The reason why many filter cloths are very much calendered is purely economical. It is possible to take a light and very open cloth (Table - 4, type A), thus very cheap but such a cloth has a very poor mechanical resistance .

- Permeability

In general, the permeability of cloth used for PAP is within the range of 4000-8000 m^3/m^2.hr to air under 20 mm of H_2O gauge [4]. According to our experience, the permeability must be at least 6500 m^3/m^2 hr.

- Wire Diameter

To obtain the required permeability and filtration rate features mostly by weaving pattern with only little calendering, the cloth must be made with wires of not less than 0.35 mm (35/100) diameter. A good mechanical resistance also requires wires of minimum 0.35 mm to may be 0.4 mm.

- Weight

For the same reasons as those mentioned here above, the cloth may not have a weight less than 400 gr/m$^{2.}$.

- Mechanical Characteristics

Tensile strength and elongation depends on wire diameter, quality and number of wires and calendering. Actually, the resistance of the filter cloth is a result, of these mentioned items. The cloth should have as much as possible mechanical resistance in order to have the longest possible life span. Thus, it should have a tensile strength of not less than 390 in warp and not less than 240 da N/5cm in weft.

- Flexibility

The cloth should show enough flexibility to be fitted and maintained in the groves of the **UCEGO** filter. Finally, the cloth should provide the best relation price to durability.

Technical specification of various types of polypropylene monofilament woven cloth utilized for **UCEGO** Filter are presented in Table 4.

Factors Influencing Filter Cloth Life Span

On the basis of the results obtained from numerous different cloths trials have shown that three major factors are responsible for filter cloth life span.

- Filter slurry temperature,
- Permeability and mechanical strength of the cloth used,
- The tonnage of P_2O_5 produced per total filter surface area.

4.1 Filter Slurry Temperature

Until1993 PAP operated at extremely high filter slurry temperature in excess of 82 up to 83.5°C. The reason, however, was to achieve the designed daily production of P_2O_5.

Thereby, the scaling tendency depends not only on the levels of impurities from the rock employed, but mostly on the filter slurry temperature. Moreover, the latter is one of the most important factor governing the rate of scale formation.

The dependence of the slurry temperature on the filter cloth life span was studied with a range of temperature intervals from 74 up to 83.5°C, depending on the adopted process route and differences in process conditions. The rate of scaling increases as the filter slurry temperature rises simultaneously, the cloth life span drops (Table 5). Our results conclusively show that the basic reason for the short of operating time is the clogging by chukhrovite and alkaline fluosilicates Therewith, the plugging itself is caused by the excessively high slurry temperature.

Furthermore, as a result, after a couple of months there is a high risk of considerable scaling of the filter grids and 30% product pipes which are the most sensitive to scaling.

A series of experiments were carried out to study the impact of temperature on various types of cloth utilized. Clearly (Figure 2), it has been confirmed that any new cloth used had to be taken off after approximately 12 days only, because of quick plugging while still in perfect mechanical conditions.

However, to obviate a build up of encrustations a systematic daily short washing open cycle of about 2 hours was periodically carried out with hot water 75-80°C and at pressure 6.5 bars. This technique was recommended by Rhone-Poulenc.

Consequently, from the conventional filter cloth type A maximum achievable tonnages of the near 16479 tons of P_2O_5 was obtained, from 316.4 hours compared with the average of 11676 tons during and 224 hours (Figure 2).

In addition to that, with the object of improving the washing condition, and eliminating the clogging of the filter grids and cloths an additional high pressure spray water oscillator was installed at the filter dam under 50 to 80 bar and consuming at most 5 m^3/hr. In such cases of highly scaling slurry, it is necessary to use it continuously.

The performance had been described as good and the plugging problems was decelerated. As a result seen in Figure 2, Cloth types A, C and D produced 16479, 17414 and 18796 tons of P_2O_5 during 316.4, 334.4 and 360.9 hours respectively (one hour = 52.08 ton) giving 40 to 60% longer services. But when the oscillator was out of order, which happened many times, therefore, any type of filter cloth employed had to be removed as fast as the conventional cloth type (A), after 12 to may be 14 days.

Eventually, it was decided to use basically Cloth A that was exceptionally cheaper in spite of poor mechanical resistance.

The main points of the PAP revamping is to reach the designed capacity while processing at low temperature so as to limit the degree of supersaturating of the filter acid. The rate of encrustation, thus, the degree of scale formation on the cloth, is progressively reduced with the decrease in slurry temperature from 83.5 to 74°C.

As shown from the comparison in Table 5, the cloth service increases sharply with temperature. Cloth type B at high temperature only produced 12329 tons 236.7 hours. Whereas, at 74°C the production increased by as much as 2.25 times.

Also the operation times for replacing the cloth reduced to approximately 50%. Therefore, it completely changes the washing cycle procedure.

4.2 Permeability and Mechanical Strength

Table 1 shows the blended phosphates of 66-68% BPL grades containing less in total cationic impurities such as iron, aluminum and magnesium. Relatively the produced PA is of the highest quality. Moreover, the average solid content is less than 0.8% passing with filter acid.

To investigate the effect of cloth permeability on the gypsum washing efficiency a series of industrial trials were performed with permeability between 2500-3500 and 6500-7500 m^3/m^2.hr. The results showed (Figure 3), a cloth with high permeability gave better filter performance and higher washing efficiency 99-99.5%.

Moreover, it is easy to obtain up to 28% P_2O_5 of the filter acid while maintaining high gypsum washing efficiency at level of about 99.1% as compared with filter cloth having low permeability. Thereby, average washing efficiency was between 98.59-98.7. Increasing the P_2O_5 content to 27.69 in the produced acid caused higher, water soluble P_2O_5 and 0.86% in gypsum level. In this case washing efficiency dropped to 96.43%.

Thus, our philosophy is to use filter cloth with high permeability with as much as 6500-7500 m^3/m^2 hr.

The mechanical resistance is another important property of filter cloth. The effect of strength was studied on the cloth life span at constant temperature.

The results of comparative testing based on utilized phosphate grade 66-68% are given here below. On account of outstanding mechanical resistance and to illustrate its long service, the new cloth type B can produce 50% higher compared with the light weight cloth A.

The test was considered satisfactory and the cloth gave 4 weeks of service.

Type of cloth	weight g/cm^2	mechanical strength daN/5cm		Tonnage of P_2O_5	Running Hrs
		warp	welf		
A	**260**	**235**	**135**	**13208**	**242**
B	**440**	**460**	**225**	**> 27721**	**> 507.9**

Providing such an efficient, high performance and good physico-mechanical characteristics of cloth type B thereafter, have been approved as new standard cloth for Aqaba PAP. The annual order was reduced from 900 to 400-450 pieces.

4.3 Tonnage of P_2O_5 Produced

According to reference [4], it demonstrated that rotary table filter have a shorter cloth life of 700 hours on account of the gypsum removing scrolls. It has recommended that when the longevities of filter cloths from two different types of filters are compared, the correct index is the tonnage produced of P_2O_5 per unit of total filter surface area (total surface area of Ucego 12 is 255 m^2).

A number of studies have been performed on the tonnage of P_2O_5 produced of several types of cloth. Consequently, whereas Figure 4 shows that maximum obtainable tonnage of P_2O_5 produced is 27721 tons which equivalent to 108.7 ton per unit of total filter surface area.

Finally, whatever the washing cycle used, at the end of a certain period of operation the cloth become unserviceable owing to blocking, mechanical wear (perforation or tears due to abrasion) and thermal deterioration.

Conclusion

The most important conclusion that can be drawn from the results of industrial experiments is that the F, Al_2O_3 and SiO_2 affect the quality criteria of Jordanian phosphates and are confirmed by our experiments.

The required minimum level of alumina in the slurry liquid phase for agglomerate formation of dihydrate CS should be higher than 0.15 Al_2O_3.wt.%.

Depending on the content of F, Al_2O_3 and type of SiO_2 present in the phosphate rock the filter loading requirement should be in the range of 3.5 to 7.4 t/m^2pd P_2O_5.

In order to reach the highest figure of SFC with minimum corrosion and erosion problems, the FCR is found to be within the range of 0.75-0.54.

Keeping the high SFC by using 66-68% BPL phosphate the FCR can be reduced from 0.54 till 0.47 with acceptable level of erosion rate.

Working with phosphate containing 0.327-0.286 FCR is the worst condition from the economic point of view in PAP.

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Table - 1 Analysis of Different Grades of Jordanian phosphate Rock , Wt% .

BPL	73.85	74.00	72.98	74.99	74.99	74.51	76.48	70.01	72.00	71.01	72.11	65.11	65.83	69.46	67.69	66.08
P2O5	33.80	33.87	33.40	34.32	34.32	34.10	35.00	32.04	32.95	32.50	33.00	29.8	30.13	31.79	30.98	30.55
CaO	50.50	52.00	51.00	53.00	50.00	51.00	52.00	49.50	49.00	49.00	51.00	47.5	48.52	48.2	49.5	50.01
SO_3	1.15	1.20	1.40	1.10	1.00	1.20	0.80	1.40	1.10	1.35	1.20	...	1.37	1.08	...	...
SiO2	6.10	2.60	3.50	2.4	3.00	4.00	2.00	6.50	4.50	5.50	4.20	9.5	8.34	7.12	5.78	5.90
CO2	3.42	4.00	5.00	4.00	3.00	4.00	3.00	5.00	4.00	5.50	4.00	...	5.28	4.45	...	...
F	3.74	3.50	3.90	3.60	3.50	4.00	3.80	3.80	3.50	3.90	3.60	3.65	3.65	3.80	3.7	3.74
Al2O3	0.39	0.28	0.20	0.18	0.20	0.30	0.20	0.40	0.25	0.40	0.30	0.66	0.53	0.52	0.45	0.40
Fe2O3	0.26	0.18	0.32	0.20	0.15	0.40	0.20	0.35	0.15	0.32	0.23	...	0.34	0.26	0.24	0.21
MgO	0.25	0.25	0.40	0.20	0.10	0.20	0.10	0.45	0.30	0.40	0.30	...	0.28	0.20	...	...
Na2O	0.54	0.40	0.60	0.40	0.40	0.60	0.40	0.60	0.40	0.60	0.40	...	0.52	0.52	...	...
CaO/P2O5	1.494	1.535	1.527	1.544	1.457	1.466	1.486	1.545	1.487	1.487	1.545	1.594	1.61	1.516	1.598	1.64

Table - 2 **The content of Uranium , Heavy Metals And Rare Earth Elements In Jordanian Phosphates .**

(Heavy Metals and Uranium in ppm , REE in %).

	As	Cd	Pd	Hg	Cu	Zn	V	Cr	U3O8	Ti	Mo	Mn	Sr	Y	Th	REE
El-Hassa **73 to 75% BPL**	7 - 9	4	2	0	19	190	70	50	80-124	60 - 70	1 - 2	<15	1640	66	<10	0.60
El-Shidiya **75 to 77% BPL**	4 - 6	4 - 5	1	0	15.5	200	40 - 60	50 - 66	40 - 60	...	...	...	1800-2200	...	...	...
Blended **66-68% BPL**	...	...	...	...	...	145 - 162	67 - 73	67 - 84	65-70	143 - 145	...	...	1216-1227	...	...	...

Table - 3 Flouride Complexing Ratio For Jordanian Phosphate Rocks, Wt %

SiO_2	F	Al_2O_3	Weight Ratio % F/SiO_2	Combined Equivalent Ratio $F/(SiO_2 + Al_2O_3)$
6.10	3.74	0.39	0.613	0.458
2.60	3.50	0.28	1.346	0.971
3.50	3.90	0.20	1.114	0.837
2.40	3.60	0.18	1.500	1.111
3.00	3.50	0.20	1.167	0.870
4.00	4.00	0.30	1.000	0.740
2.00	3.80	0.20	1.900	1.378
6.50	3.80	0.40	0.585	0.438
4.50	3.50	0.25	0.778	0.585
5.50	3.90	0.40	0.709	0.526
4.20	3.60	0.30	0.857	0.637
9.50	3.65	0.66	0.384	0.286
8.34	3.65	0.53	0.438	0.327
7.12	3.80	0.52	0.534	0.396
5.78	3.70	0.45	0.640	0.473
5.90	3.74	0.40	0.634	0.472

Table - 4 Technical Specification of different types of 100%Polypropylene Monofilament Cloth used for Ucego Filter .

Type	Weight g/m2	Wire Thicknesses, mm		Resistance,dan/5cm		Mesh Opening Microns	Air permeability under 20mm of H2O gauge(m3/m2.hr)
		along wrap	across weft	warp	welf		
A	260	30	100	235	235	40x500	6500 - 8500
B	420 - 440	40	100	485	225 - 235	20x500	5000 - 7500
H	435	40	100	460	190	20x500	1700 - 3800
R	290	30	100	333	140	....	2500 - 3500

Table - 5 Effect of filter slurry temperature on the cloth lifetime and PAP performance .

Cloth Type	Tonnage of P2O5 Produced	Filter slurry temperature 'C	Filter cloth lifetime hours	Time for cloth removing & replacing	Procedure of washing Cycle	Scale Tendency	Filter colth Condition
B (1)	12329	82 - 83.5 'C	236.7	1-2 ; 3.5 - 4 Hrs	a systematic daily wash of about 2 - Hrs duration	high scale formation	Completely blinded & thermal deterioation
B (2)	27721	74 - 75.5'C	507.9	30 min. , 3Hrs	a systematic wash 6 - 8Hrs once a two weeks	Relatively little scale formation	Tear due to abrasion & perforation

(1) one hour = 52.08 Ton , (single tank reactor) .
(2) one hour = 54.58 Ton , (multicompartment reactor & three digesters) .

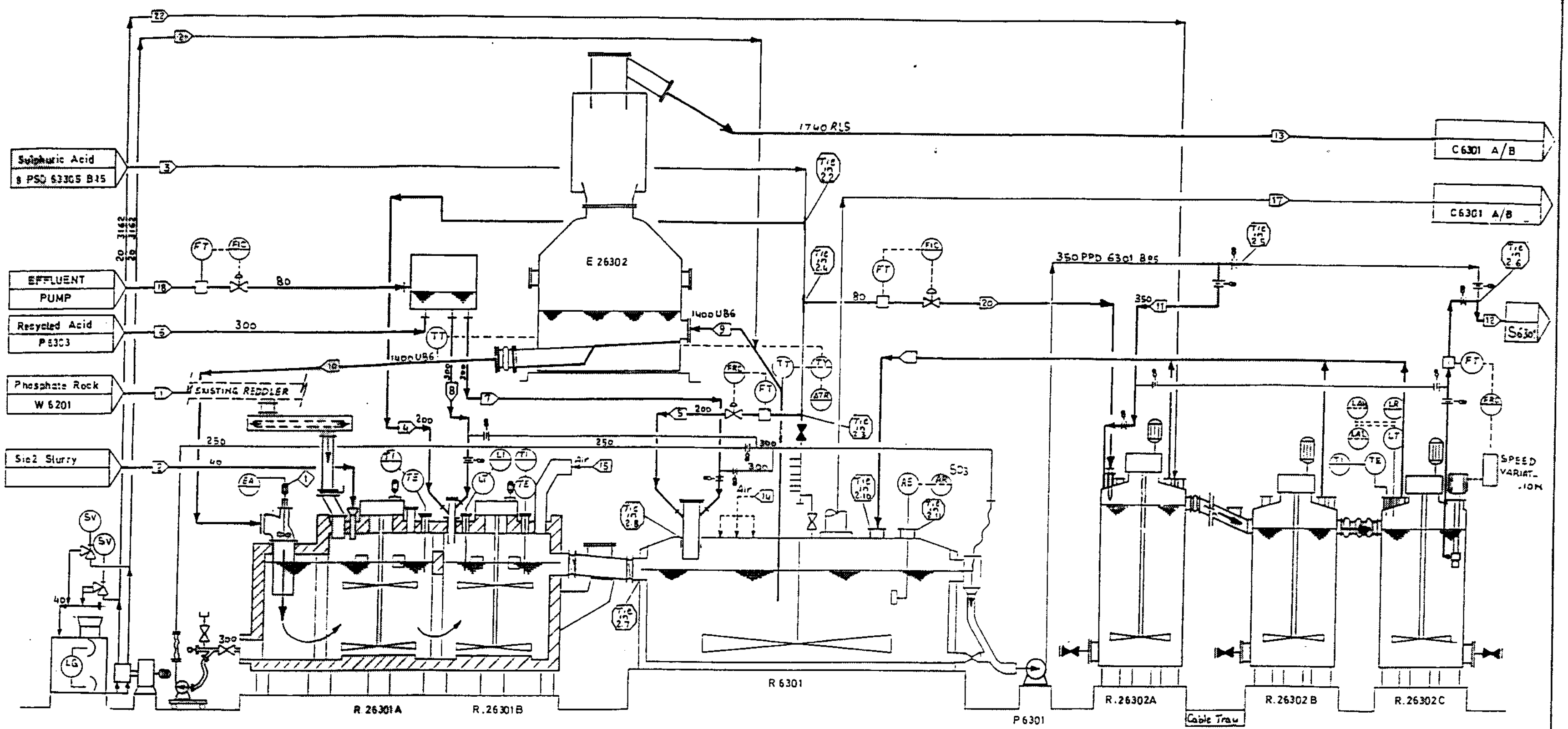

Fig-1 Process Flow Sheet of Aqaba PAP.

NOTES 1-FLOW AFTER SCRUBBER (FEEDWITH WATER A 30cl = 240000 m³/h
2- DESIGN FLOW 22 M3/H

	UNITS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
SOLIDS	kg/h	178610	12074									286657	286657										
LIQUIDS	kg/h		4805									509613	509613										
AIR	kg/h														202500	5000	3000	210500					
H2O	kg/h	3460												42085	6275	155	530	37048	15000				
TOTAL FLOW	kg/h	182070	6012	183703	80351	80351	538824	269462	269462	13950000	13907935	796270	796270	42085	208775	5155	3530	247548	15000			5.6	5.6
TEMPERATURE	°C	80	50	45	45	45	88	88	88	76.5	74	74	74	74	45	45	63	65.4	40			40	40
PRESSURE	Bar Abs													0.240	ATM	ATM							
DENSITY	kg/m3	820	1143	1820	1820	1820	1180	1160	1160	1550	1552	1552	1552	0.149	1.07	1.07	0.91	0.95	1000				
VOLUME FLOW	m3/h		5.26	88.3	44.15	44.15	464.6	232.3	232.3	9000	8963	513	513	282315	193230	4800	3850	261000	15		* *		

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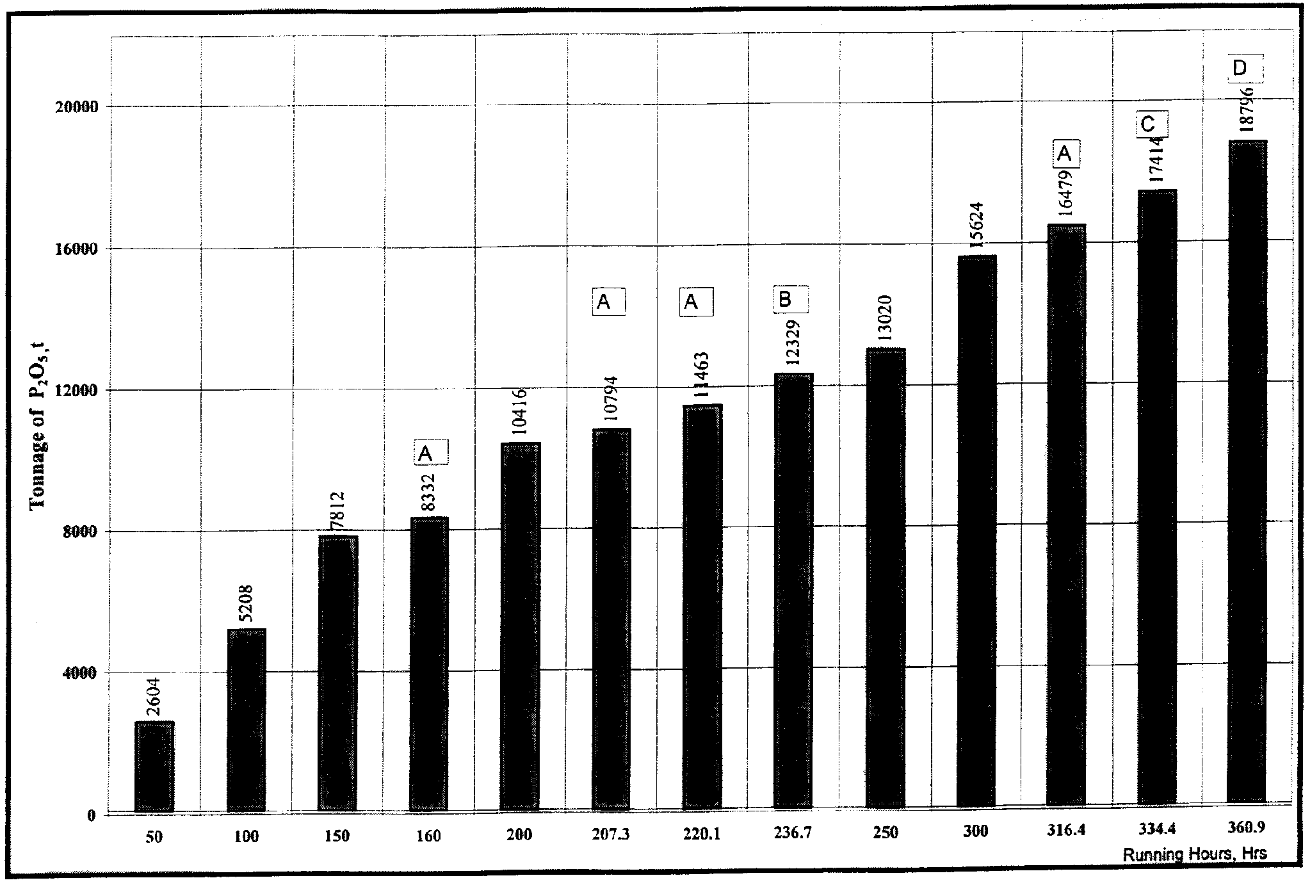
P.A.P REVAMP PROJECT
PROCESS FLOW SHEET REACTION
1310 MTPD P_2O_5

Fig-2 .Effect of Different Type of Filter Cloth on The Tonnage of P_2O_5 Producted , (One Hr=52,08 Ton).

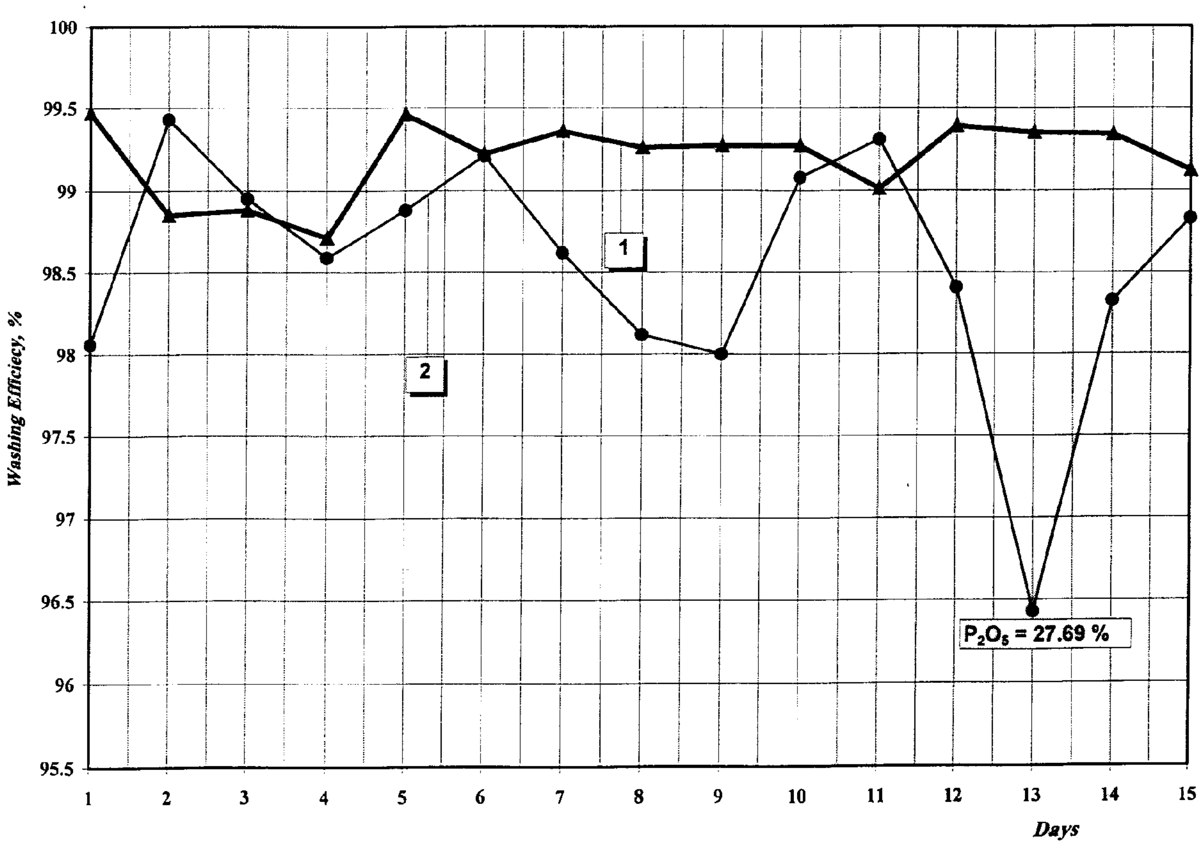
R.Hrs	Prod.	Cloth Type
50	2604	
100	5208	
150	7812	
160	8332	A
200	10416	
207.3	10794	A
220.1	11463	A
236.7	12329	B
250	13020	
300	15624	
316.4	16479	A
334.4	17414	C
360.9	18796	D



Single Tank Reactor, RSV = $1m^3$ /tpd P_2O_5

Washing Efficiency, %		
Days	Cloth B	Cloth R
1	99.47	98.06
2	98.85	99.43
3	98.88	98.95
4	98.71	98.59
5	99.46	98.88
6	99.22	99.21
7	99.36	98.62
8	99.26	98.12
9	99.27	98.00
10	99.27	99.08
11	99.01	99.31
12	99.39	98.41
13	99.35	96.43
14	99.34	98.33
15	99.12	98.83
16	99.46	0
17	99.15	0
18	99.48	0
19	98.95	0
20	99.13	0
21	99.11	0
22	99.24	0
23	99.12	0
24	99.05	0
25	98.67	0

Fig 3 . Effect of Permeability of Filter Cloth on The Gypsum Washing Efficiency.

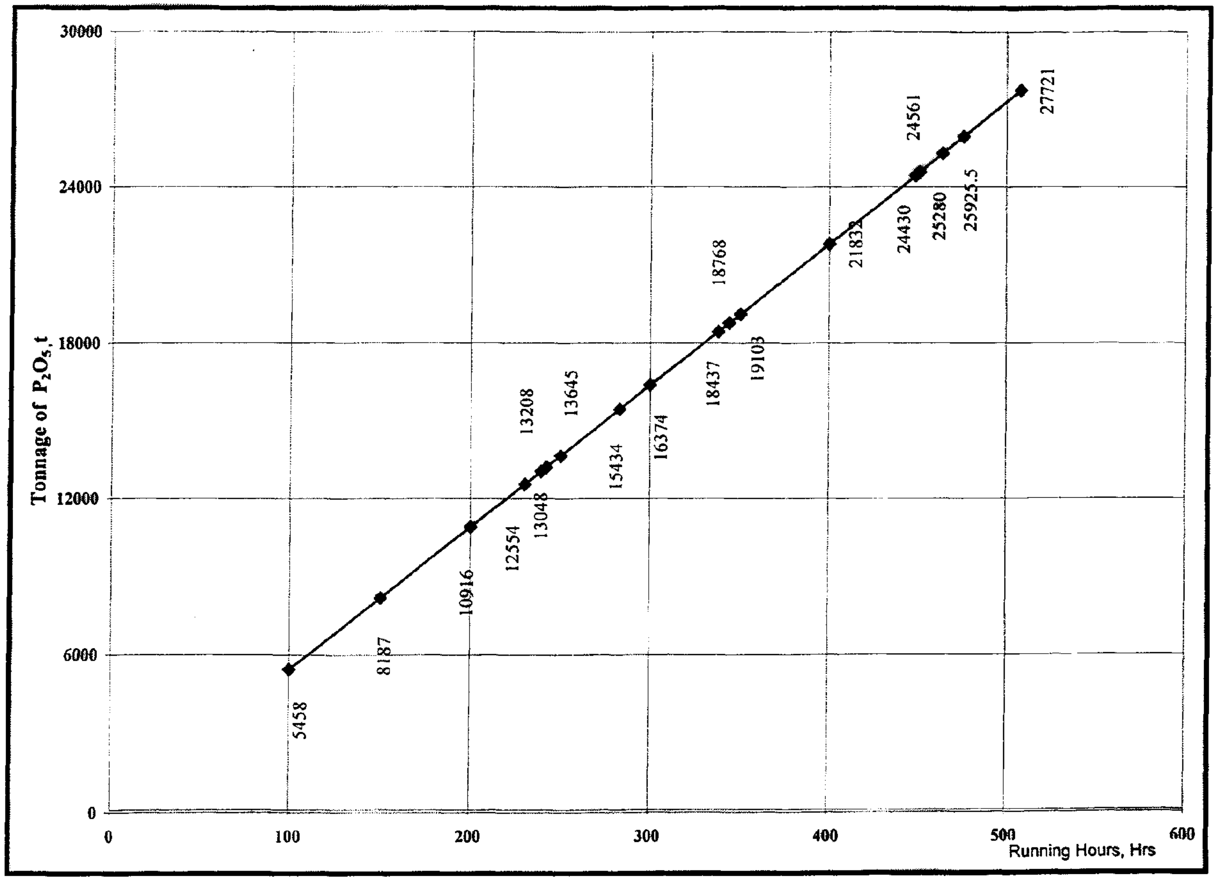


1- Permeability of Cloth B = 6500 - 7500 m^3/m^2 hr

2- Permeability of Cloth R = 2500 - 3500 m^3/m^2 hs

Fig-4 .Effect of Different Type of Filter Cloth on The Tonnage of P_2O_5 Producted , (One Hr=54,58 Ton).

R.Hrs	Prod.	Cloth Type
100	5458	
150	8187	
200	10916	
230	12554	A
242	13208	A
239.1	13048	R
250	13645	
282.8	15434	H
300	16374	
337.8	18437	F
343.9	18768	R
350	19103	
400	21832	
447.6	24430	G
450	24561	
463.2	25280	B
475	25926	B
507.9	27721	B



Multicompartment Reactor And Three Digesters ; RSV = $2m^3$ /tpd P_2O_5