

IFA Technical Conference

**Amman, Jordan
2-6 October 1994**

REHABILITATION OF JPMC PHOSPHORIC ACID PLANT IN AQABA

N. Hummadi, JPMC, Jordan
P.A. Smith, Société Chimique Prayon-Rupel and
P. Pluvinage, Coppée-Lavalin, Belgium

RESUME

L'unité d'acide phosphorique située à Aqaba a été conçue à l'origine pour produire 1250 t/j de P₂O₅ suivant le procédé au dihydrate avec un seul réacteur et un seul filtre.

Après réception en juin 1982, l'unité n'est pas parvenue à atteindre la capacité nominale en raison de certaines déficiences de procédé et d'équipement.

Comme l'unité phosphorique faisait partie intégrante de l'ensemble du complexe d'engrais, comprenant en amont l'acide sulfurique et en aval une installation de DAP, tout déficit de la capacité de l'unité d'acide phosphorique se répercutait sérieusement sur le complexe dans son ensemble.

En 1989, Jordan Phosphate Mines Company, propriétaire du complexe d'engrais a décidé de réhabiliter l'unité d'acide phosphorique et les installations connexes pour atteindre la capacité nominale.

Après examen de plusieurs options disponibles, JPMC a décidé de convertir l'unité en une unité basée sur le procédé Prayon Mark IV à compartiments multiples.

Dans cet exposé, les performances de l'unité avant et après réhabilitation sont examinées ainsi que les principales difficultés rencontrées au cours des années antérieures de fonctionnement.



INTRODUCTION

The JPMC phosphoric acid plant located in Aqaba was originally designed to produce 1250 MTPD of P₂O₅ based on dihydrate process incorporating a single reactor and single filter, Figure 1.

After commissioning in June 1982, the plant was unable to reach its nominal capacity due to several process and equipment deficiencies.

Since the phosphoric plant was an integrated part of the overall Fertilizer Complex, comprising of two lines 1800 MTPD upstream sulphuric acid and two lines 1150 MTPD, the shortfall in capacity of the phosphoric acid plant seriously affected the operation of the Complex as a whole.

In 1989, Jordan Phosphate Mines Company, owner of the Fertilizer Complex decided to rehabilitate the phosphoric acid plant and its-related facilities in order to achieve the nominal capacity, product quality and yield.

After reviewing several available options, JPMC chose to convert the plant to one based on the multi-compartment Prayon Mark IV process.

In this paper, the performances of the plant before and after rehabilitation are reviewed along with the major bottle-necks encountered during the former years of operation. Section 1 "Process description and review of major technical problems" was prepared by N. Hummadi of JPMC. Sections 2 & 3 "PRAYON philosophy and PRAYON features incorporated into the plant modifications" were prepared by P.A. Smith of PRAYON whilst Section 4 "Performance of the plant after rehabilitation" was prepared P.A. Smith of PRAYON and P. Pluvinage of COPPEE LAVALIN.

SECTION 1 A

ORIGINAL PROCESS DESCRIPTION AND REVIEW OF MAJOR TECHNICAL PROBLEMS

1. Phosphate rock storage and grinding

Phosphate rock is delivered to the plant by trucks from JPMC mines and stored in a 45,000 MT hanger type warehouse. The rock from the warehouse is sent to a dry rock grinding facility where it is ground to a fineness of 75% passing 200 mesh (80 microns) before being stored in a 1500 MT ground rock silo.

The Problems

- Rock storage and reclaim

The rock storage warehouse is a hanger type building of dimensions 127 m long by 49 m wide. Rock is reclaimed by gravity through two openings in the floor of 1 m by 1 m into a hopper beneath which then feeds a belt conveyor located in an underground gallery before being finally transported by a further belt conveyor to the rock grinding plant.

Whilst the storage capacity of the warehouse is 45,000 MT, the quantity reclaimable by gravity is barely 8,000 MT leaving the difference as "dead stock".

Use of heavy vehicles such as bulldozers and payloaders did not solve the problem due to excessive spillage from the reclaim hopper and accumulation in the underground conveyor belt gallery which further impeded the reclaim operation. The pressure caused by movement of the heavy vehicles on the rock pile inside the warehouse building eventually led to the collapse of the external walls resulting in the emission of large quantities of phosphate dust to the surrounding areas.

- Rock Grinding

Grinding of the phosphate is achieved by passing the unground rock through a dry ball mill system rated at 200 MTPH capacity also including associated conveying, classification and air dedusting systems. The mill was designed to grind the rock to a fineness of 75% passing through 200 mesh as required by the process.

During the first two years of operation, several mechanical difficulties were encountered including failure of the mill bushings, the lubrication equipment, the classifier and other parts of the grinding system which caused interruptions to the operation and consequent time loss (approx. 1950 hours in total).

For these reasons the weight of balls in the mill was reduced from the design load of 230 MT to 180 MT. Consequently, the fineness of the ground rock produced was less than that required by the process (only 65-70% passing 200 mesh instead of the specified 75%).

2. Reaction and Filtration

Ground phosphate rock, sulphuric acid (diluted from 98.5% to 80%), and cooled to 45°C, recycled phosphoric acid and recycled sludge from the storage and settling tanks are continuously metered and fed to the reactor.

The reactor is a single tank with 1250 m³ effective reaction volume, fitted with baffles and agitated by means of a single central agitator designed to mix the rock into the slurry and diffuse it rapidly through the mass. The design temperature for the reaction contents is 82.5°C.

Screw type agitators acting as surface coolers disperse the slurry into droplets which fall through the air stream in an umbrella shaped pattern, thus achieving simultaneous cooling of the slurry and foam breaking.

Cooling air is introduced through a series of openings located around the periphery of the reactor on one side, covering half of the circumference. The air then leaves through outlets on the opposite side of the reactor roof which are connected to two exhaust fans located on the discharge side of the gas scrubber system.

Phosphoric acid produced in the reactor is separated from the gypsum slurry by means of a UCEGO No. 12 rotating table filter. The required vacuum for the filter is produced by a single liquid ring vacuum pump.

The weak phosphoric acid filtrate is pumped from the filter to desaturation, decantation and storage facilities. The gypsum cake is washed countercurrently in three stages to maximise the recovery of P_2O_5 , the final wash of medium strength acid being recycled to the reactor.

The Problems

The reaction filtration system was designed to produce 1250 MTPD P_2O_5 at 30% concentration at the exit of the filter when processing the Jordanian 73/75 BPL rock.

Having conducted extensive pilot plant tests and also taking into consideration the well known characteristics of Jordanian phosphate i.e. high reactivity, softness and low content of impurities, the process licensor designed the plant with the following major features:

- Use of ground rock with a fineness of 75% passing through 200 mesh.
- Reaction temperature of 82.5°C.
- Intensive agitation by means of a powerful central agitator.
- Use of cooled dilute sulphuric acid (45°C) to assist the reaction air cooling system.

A residence time of two hours was specified together with a required reaction volume of 1 m³ per MTPD P_2O_5 .

The filtration rate established from the pilot plant test results was 10.3 MTPD P_2O_5 per m². A plant designed based on the above criteria would therefore be able to achieve:

- 1250 MTPD P_2O_5 capacity on average with 23 hours per day running time giving an instantaneous capacity of 1304 MTPD P_2O_5 .
- Acid strength exit the filter of 30% P_2O_5 .
- Recovery based on losses in the gypsum cake of 95.5%.

These performance figures were ultimately guaranteed.

During actual operation of the plant; none of the above characteristics were achieved for the following reasons:

- Poor performance of the sulphuric acid dilution package (lower capacity, higher acid outlet temperature, excessive fouling).
- Poor reaction temperature control due to insufficient surface cooling.
- Poor filtration when operating in excess of 60% of the rated capacity (higher P_2O_5 losses). Also wet gypsum is very difficult to handle on the belt conveyor system.
- Low product acid strength (27% instead of 30% P_2O_5).

Several equipment failures also occurred, notably:

- Excessive damage to the surface coolers even though made of UB6.
- Frequent scaling of the scrubber fans, adding further limitations to an already restricted reactor cooling system.
- Filter vacuum pump damage due to carry-over from the pump demister.
- Frequent damage to the gypsum removal screw on the filter.

3. Decantation, settling and storage of dilute acid

Phosphoric acid from the UCEGO filter is stored in an agitated tank to maintain the crystals in suspension as the acid cools. The desaturated acid overflows to a settling tank which is equipped with a bottom raker where the settled impurities form a sludge deposit in the bottom of the tank. The sludge is continuously removed and returned to the reactor system whilst the decanted acid overflows to the weak acid storage tanks.

The Problems

The main function of the desaturation/settling system is to remove dissolved solids from the dilute acid before concentration in the evaporation section of the plant. In order to achieve this objective properly, the residence time in the ageing tank should be around 24 hours and the temperature of the acid flowing to the settler around 50°C.

In actual operation, the acid temperature of 60-65°C was higher than expected with the result that the precipitation of the dissolved solids was incomplete resulting in excessive scaling in the evaporator heat exchangers at a later stage in the process (refer to point 5).

Several failures of the settler tank raker added further constraints to the plant operation. In addition, the ageing tank was often found full of gypsum probably as a result of poor agitation. Since both were closed roof tanks to prevent the emission of fluorine to atmosphere, their cleaning and repair was both time consuming and inconvenient.

4. Gypsum Disposal System

The washed gypsum cake is mechanically removed from the filter and conveyed by a system of belt conveyors to the gypsum disposal pile located about 3 km from the plant.

The Problems

The disposal system consists of a gypsum removal screw, a hopper, a system of belt conveyors (about 2.5 km in length) and a rail travelling stacker installed on the gypsum pile.

During the first year of operation, the stability of the pile was questionable. Several slides occurred jeopardising the safety of the personnel and heavy vehicles working at the edge of the pile pushing the gypsum to the tipping point.

Wet gypsum coming from the filter caused several mechanical and electrical operational problems resulting in frequent plant shutdowns.

At a later stage and in order to alleviate the situation, a crawler type secondary stacker was added but did not entirely solve the above mentioned problems.

5. Evaporation/Concentration

The decanted dilute acid is concentrated in three steam heated vacuum evaporator systems operating in parallel. The evaporators are forced circulation type with external carbon block exchangers and high capacity centrifugal circulation pumps. Low pressure desuperheated steam is supplied to the exchangers. The feed acid is pumped directly into the evaporators, and concentrated acid overflows from the evaporators and is pumped to storage tanks equipped with agitators which maintain the solids formed on cooling and desaturation in suspension.

The phosphoric acid required for the production of DAP is fed directly from these tanks to the granulation plant.

The fluosilicic acid vapour and entrainment generated in each evaporator is removed in the absorber train consisting of two fluorine absorbers operating in series with a high recirculation of washing liquid. Water is made up to the system and blown down as fluosilicic acid product which is pumped to the fluosilicic acid storage tanks. The fluosilicic acid is used for the production of aluminium fluoride on the site.

The remaining vapours from the final absorber, consisting mainly of steam, are condensed in a direct contact water cooled barometric condenser which also provides the vacuum for the evaporator system. Recirculated pond water is used for cooling the barometric condenser.

The Problems

The evaporation lines were designed to concentrate 1250 MTPD P_2O_5 from 30 to 54% in three parallel lines.

The main features of the design were:

- Use of graphite polyblock heat exchangers with 16 mm dia. holes allowing forced circulation of acid with higher velocity and the use of relatively high pressure steam (3 bar).
- Use of centrifugal circulation pumps.
- Use of demisters to remove acid entrainment.
- Condensation of steam to create the vacuum without the use of ejectors or pumps.
- Fluorine recovery.

During the operating of this plant section, several problems were encountered with the following result:

- The capacity was limited to a maximum of 60-70% of the design.
- Product acid strength was lower than the design (46-47% instead of 54% P_2O_5).
- Lower on-stream time factor than guaranteed due to frequent failures of the heat exchangers and also a shorter boiling out cycle than originally predicted (every 3 days when operating at higher product strengths and 5-6 days when operating at 46-47% product acid).

Two main reasons were seen for these problems, one being the excessive scaling and plugging of the heat exchangers and the other reason being the high temperature of water used for condensation.

Scaling of the heat exchanger tubes is a consequence of poor desaturation of the dilute acid fed to the evaporation system coupled with a high delta T of the acid circulating through the exchanger (9°C).

High cooling water temperature is a consequence of the poor performance of the cooling pond system. To achieve the desired vacuum in the system, a cooling water temperature of 30°C is required for the condenser whereas in practice the actual return pond water temperature was between 45-48°C.

Scaling, plugging and restricted throughput of the heat exchanger system was further aggravated by the use of small diameter blocks and limited heat exchange surface area. Excessive failures of these graphite blocks required lengthy shutdown (average 4-7 days for dismantling and reassembly of each heat exchanger) causing further serious capacity restrictions of the system and the plant as a whole.

Since the strength of the feed acid was only 27% instead of the design 30% then this meant that there was more water to evaporate and a consequent reduction in capacity in terms of P_2O_5 .

6. Acid Clarification

Clarified acid required for export is produced by filtering the concentrated acid on a rotary drum vacuum type filter. The sludge produced on the filter is recycled to the unclarified acid system and becomes part of the acid feed to the granulation plant.

The Problems

The system was designed to clarify 200 MTPD P_2O_5 for export as merchant grade phosphoric acid with a maximum content of 0.5% w/w solids. The following problems were encountered during the short trial run period:

- The acid fed to the system was diluted due to improper action of the filter seal system.
- The solids content of the clarified acid was 1.5% w/w instead of the design of 0.5%.
- The achievable throughput of the unit was considerably less than the design capacity.
- Higher losses of P_2O_5 were encountered due to the excessive carry over in the scrubbers.
- Frequent mechanical failures occurred on the compressed air system.
- Great difficulty was experienced with the removal of the abnormally thin filter cake on the filter cloth.

In summary therefore the clarification package could never be properly operated.

7. Cooling Pond System

Hot effluent water from:

- Reaction/filtration
- Sulphuric acid dilution coolers
- Evaporation condensers
- Tank farm washing.

Together with hot water from the other plants of the Complex are collected in a plastic lined U-shaped cooling pond. The hot water should have been cooled down to 30°C. The cooled water is mixed with fresh make up water and recycled to the phosphoric acid plant. Blowdown to an evaporation pond is also provided to adjust the solids content of the circulating cooling water.

The Problems

The cooling pond system was conceived to meet certain specific requirements other than assuring the heat removal duty. These were as follows:

- Utilise minimum surface area.
- Reduce drift losses to a minimum.
- Provide minimum environmental impact.

The pond consisted of two channels providing flow and return and had a total volume of 23,000 m³. The total length of the pond was 208 m, the width of the flow channel 50 m and the width of the return channel 13 m.

The spray pattern, water jet height, evaporation rates, drift losses, etc., were all calculated using empirical formulae which did not result in the anticipated performance in practice. Indeed, the estimated heat removal capacity of the pond calculated shortly after the start up was only 60% of the design requirement.

A total of 12 spray modules were originally installed and distributed in the northern part of the main channel. The addition of one further spray module, relocation of spray modules from the north to the south end of the pond plus a change to the spray height did not resolve the problems.

Although drift losses were not a major problems from a water balance point of view, the effect on the surrounding installations and on the personnel working in the adjacent aluminium fluoride plant was very serious.

The poor performance of the cooling pond was aggravated by the entrainment of large quantities of gypsum with the return hot water since no provisions had been made in the design for gypsum decantation or separation. The gypsum deposited in the cooling pond reduced the effective operation of the sprayers and resulted in repetitive failures of the pumps, electrical motors and other parts of the system.

After only 38 months of operation, the pond became full of gypsum and thus inoperable. Due to the very nature of the gypsum deposited inside the pond area, any technique other than reclaim by mechanical means would not have been appropriate.

Removing some 20,000 MT of gypsum from a plastic lined pond without damaging the lining and in a limited time period was never an easy task. Yet in order to keep the plant running, removal of the gypsum has had to be carried out three times in the past ten years.

The poor performance of this system has always seriously jeopardised the operation of the phosphoric acid plant and consequently the operation of the Fertilizer Complex as a whole.

SECTION 1 B

REVIEW OF PLANT PERFORMANCE BEFORE REHABILITATION

As previously described, it is clear that the many technical difficulties and other deficiencies have severely restricted the operation of the plant and consequently its ability to operate according to the design performance. This has had a significant effect on the operation of the Fertilizer Complex as a whole and as a result the Company has suffered badly over the years in terms of:

- shortfall in the production forecasts;
- loss of marketing opportunities;
- higher costs of production.

All this has resulted in financial losses for the Company.

For ten years, JPMC has tried to mitigate the damage inflicted on the Company by operating the plant under the most suitable conditions and also by trying to find solutions to some of the technical problems encountered.

For example, the reaction/filtration section was operated to produce lower acid strength ex-filter (26-27% P_2O_5) which in turn reduced the strength of the product acid from the concentration units to (46-47% P_2O_5). To counter this reduction in product acid strength, the process parameters of the DAP granulation plant had to be changed to allow continued operation but of course to the detriment of the process efficiency, overall recovery, product quality and other aspects of environmental protection.

Several other process adjustments and modifications to the equipment were made by the plant engineers over the years but without significant improvements. These included, for example, the use of various additives in the reaction/filtration, concentration and clarification plant sections to try to improve the operating conditions.

With all the above restrictions, the average capacity of the plant was restricted to only 60-73% of the name plate capacity and the recovery of P_2O_5 only ranged between 93.0 - 94.3% based on losses in the gypsum.

Tables 1 and 2 which follow summarise the operational performance of the phosphoric acid plant over the past ten years.

Table 1 : Annual Production and acid strengths achieved

YEAR	PRODUCTION *	% NOMINAL**	RECOVERY %	DIL. ACID %	CONC. ACID %
1983	188542	45.71	93.84	27.48	50.34
1984	294089	71.29	93.91	27.18	49.41
1985	259612	62.93	94.00	25.85	47.25
1986	281944	68.35	94.34	26.91	45.48
1987	283384	68.70	94.29	26.20	45.03
1988	303298	73.52	92.81	26.22	45.71
1989	303303	73.53	93.70	26.18	46.78
1990	296975	71.99	93.79	26.10	46.94
1991	271000	65.70	93.43	25.57	46.80
1992	281240	68.18	93.73	26.56	47.46
1993	214750(x)	52.06	93.95	26.27	46.66

* MTPY of P₂O

** Compared with the nominal name plate capacity of 412,500 MTPY P₂O₅

x Recovery of P₂O₅ based on W.S. losses in gypsum cake

From Table 1 it can be seen that the highest annual production was achieved in 1989 which amounted to 73.53% of the name plate capacity. However, the acid strength ex-filter averaged only 26.18% P₂O₅ (design 30%), the product acid from the evaporation only 46.78% P₂O₅ (design 54%) and an average recovery of 93.7% (design 95.4%) based on losses in the gypsum.

Repeated equipment failures also made a significant contribution to the shortfall in annual production. For example, in 1989, the plant experiences 2092 hours of shutdown time which contributed to about 60% of the shortfall in production. The remaining 40% shortfall resulted from the limitations in the process.

Table 2 which follows provides a summary of the running time and shutdown time together with the shortfall in production attributable to both process limitations and time loss due to equipment problems.

Table 2 : Running and shutdown hours and production shortfall in MT/Y of P₂O₅

YEAR	RUNNING HOURS	SHUTDOWN HOURS	PRODUCTION SHORTFALL
1983	4826	3934	223958
1984	6207	2577	118411
1985	5738	3022	152888
1986	6114	2646	130556
1987	5946	2814	129116
1988	6783	2001	109202
1989	6668	2092	109197
1990	6747	2013	115525
1991	6308	2452	141500
1992	6508	2253	131260
1993	(5032)	(3728)	(197750)

Table 3 : provides a summary of how the time loss is distributed.

TABLE 3 - PHOSPHORIC ACID PLANT DOWN TIME ANALYSIS (1982 - 1993)

YEAR	RUNNING HOURS	S/D HOURS	REASON FOR SHUT DOWN										
			SLURRY PUMP	ROCK WEAHER	VACUUM PUMP	BALL MILL	PLANNED S/D	UCEGO FILTER	SACID DILUTOR	CONC. SECTION	GYPSUM SYSTEM	ROCK RECLAIM.	OTHERS (**)
1982	2005	3299	52 2 %		239 7 %	1436 44 %					919 28 %		653 20 %
1983	4826	3934		278 7 %	75 2 %	514 13 %	871 22 %	562 14 %	353 9 %		249 6 %	76 2 %	956 24 %
1984	6207	2577			75 3 %	117 5 %	469 18 %	431 17 %	123 5 %	136 5 %	468 18 %	266 10 %	492 19 %
1985	5738	3022					446 15 %	560 19 %	189 6 %	645 21 %	664 22 %	212 7 %	306 10 %
1986	6114	2646					936 35 %	330 12 %	185 7 %	390 15 %	377 14 %	78 3 %	350 13 %
1987	5946	2814						337 12 %	190 7 %	316 11 %	1621 58 %	169 6 %	181 6 %
1988	6783	2001						483 24 %	249 12 %	294 15 %	415 21 %	201 10 %	359 18 %
1989	6668	2092						580 28 %	235 11 %	170 8 %	709 34 %	85 4 %	313 15 %
1990	6747	2013	13 1 %	66 3 %	2	12 1	514 26 %	186 9 %	59 3 %	155 8 %	270 13 %	24 1 %	713 35 %
1991	6308	2452		60 2 %	1		261 11 %	108 4 %	71 3 %	29 1 %	1070 44 %	8	844 34 %
1992	6532	2252	1	135 6 %	5	0	584 26 %	119 5 %	84 4 %	51 2 %	561 25 %	224 10 %	488 22 %
1993	5032	3728	3	27 1 %	1	8	2092 56 %	70 2 %	44 1 %	287 8 %	82 2 %	302 8 %	813 22 %

(*) Including shutdown for cooling pond cleaning & removal of deposited gypsum.

(**) Others include mainly shutdowns for filter washing & frequent cloth change due to reactor high temperature.

Note : Most of the "Planned" shutdowns were dictated by maintenance required on plant's major equipment such as reactor (cover, main agitator, internals...etc.), UCEGO filter (scale removal, maintenance of rollers, pipes etc.), and other equipment in concentration section & tie in works for revamp project (1993).

In conclusion, it is clear that the process and equipment deficiencies of the phosphoric acid plant have resulted in the JPMC Fertilizer Complex in Aqaba being unable to operate according to the design performance.

As a result, a complete study was carried out covering in detail all the deficiencies of the phosphoric acid plant. From an analysis of this study, it was decided to undertake major changes to the plant which was later to be called "Rehabilitation Project".

The Rehabilitation Project was aimed at solving the major technical problems to allow the plant to operate at its design performance. The modifications, changes and alterations which were carried out within the scope of the Rehabilitation Project are described in Sections 2 & 3.

SECTION 2

PRAYON PHILOSOPHY

Flash-cooling

The PRAYON process, since its origins, has been characterised by a multi-tank design with flash-cooling, which has proved to have greater flexibility than air-cooling especially when cooling rates above the nominal capacity are desired.

The low level flash-cooler, LLFC, was incorporated into the Mark 4 design to enable the operation of the flash-cooler circuit without scaling and with a low energy consumption even at cooling rates above the design capacity. The high recirculation rate is ensured by a low head, high flowrate axial flow pump consuming 85 kW and giving a δT of about 2°C [4°F] under design conditions.

Dilution cooling

Although the Mark 1 and 2 PRAYON designs had dilution of H₂SO₄ to 50-60% H₂SO₄ and removal of the heat of dilution in coolers, since the 1970's the PRAYON Mark 3 and subsequent Mark 4 designs have been characterised by the feeding of strong (93 - 98%) H₂SO₄. To attain this aim the Mark 3 design was specifically modified by the deletion of the dilution coolers and included the boosting of the flash-cooler capacity to balance the total cooling load, this also enabled the feeding of phosphate slurry. The H₂SO₄ dilution cooling system previously used had a very bad image and many operators of Mark 1 and 2 units are well aware of the maintenance headaches that these units have caused.

Digestion Section

The Mark 3 units also heralded the provision of a digestion section to ensure full de-supersaturation or maturing of the slurry prior to the filtration stage thus minimising filter scaling and down-time, due to less frequent washing and cleaning. The normal standard split for a PRAYON reactor is 66% for attack and 34% for digestion this is shown in Figure 3. By changing the point of introduction of the sulphuric acid the volume of, or the residence time in, the "Low Sulphate Zone" can be adjusted to be larger or smaller.

Obviously the original design at Aqaba had none of these features

As such the proposal for the rehabilitation of the JPMC unit in Aqaba required a great deal of creativity to incorporate the existing equipment into a flowsheet that resembled a PRAYON unit and more importantly was able to perform as well as a PRAYON unit.

SECTION 3

PRAYON FEATURES INCORPORATED INTO THE REHABILITATION DESIGN

During the conceptual phase, PRAYON and COPPEE LAVALIN sought to modify the existing reaction system Figure 2 to incorporate the standard PRAYON features Figure 3.

The plan layout of the rehabilitation is shown in Figure 4 and the flexibility of the "Low Sulphate Zone" can be adjusted as in the PRAYON standard design, see Figure 5.

Reaction Volume

The reaction volume was increased, almost doubled, by the provision of five additional tanks, two in the attack section and three in a newly created digestion section. The final total volume was 2530 m³ [670,000 US Gal] giving a specific volume of 1.9 m³/mtpd P₂O₅ [455 US Gal/stpd P₂O₅]. The final split of volumes was 67% for the attack and 33% for the digestion. Although the split follows the PRAYON standard, the large size of the existing tank means that this is equivalent to a number of smaller compartments. An overall view of a 3-D computer layout is shown in Figure 6 - New Reaction Section.

Phosphate feeding

Two highly agitated square tanks were added each with a volume of 220 m³ [52,700 US Gal] both fitted with a three stage agitator, two PRAYON 4-PHT helicoidal sets of blades in the slurry and one PRAYON GTA at the surface, the agitator drawing 119 kW. The phosphate was diverted from the old reactor to the first of these tanks where it was mixed with the cooled recycle flow from the flash-cooler. The return acid from the filter is fed to the second square tank pre-mixed in a Mixing Tee with part of the 98% H₂SO₄.

The slurry returns to the main reaction tank by two overflow channels. The layout of the New Attack Tanks is shown in Figure 7.

Main Reactor

Very few changes were made to the main reactor except for the deletion of the dilution coolers, the balance of the 98% H₂SO₄ may be added, if desired, to the dispersers fitted to three of the surface agitators. The suction pipe to the flash-cooler was inserted into this compartment and the flow to the flash cooler is effected by the suction of the vacuum in the flash body.

Flash Cooler

The low level flash cooler, LLFC, of approximately 7 metres [23 ft] diameter was installed between the main reaction tank and the two additional tanks. The recirculation pump was fitted on the outlet and provides a large flow of 10,600 m³/h [42,300 US GPM] with an axial flow pump having a TDH of less than 0.9 metre [3 ft], absorbed power 91 kW. The vacuum system was oversized considerably compared with the standard quantity of non-condensibles expected in the multi-tank PRAYON reactor but even so, it was found that the gassing in the existing reactor was much greater than expected and the capacity of the vacuum system had to be increased to cope with the greater load of non-condensibles.

Digestion Section

The existing filter feed pump was re-routed to feed a battery of three digestion tanks in line each with a useful volume of 280 m³ [74,000 US Gal]. The level of agitation in these tanks required being solely that to ensure solids suspension, each tank was fitted with a one stage agitator with a power of 51 kW. The computer layout of the Digestion Section is shown in Figure 8.

Filter

The filter was converted to a two-wash design.

Concentration Units

These three units suffered the most radical changes, the original units had low circulation block heat exchangers with a high δT and the conversion to Sigrü carbon fibre reinforced tubes with a high recirculation meant that many changes had to be made. The circulation ducts had to be increased in size and this included the branches on the flash-chamber. In order to reduce the δT to 3.3°C [6°F] the pump capacity had to be increased to 8,500 m³/h [37,400 US GPM] and the existing mixed-flow centrifugal pump was replaced with an axial flow design. The heat exchanger was fitted with 805 x 50/37mm [2/1.75 inch] (id/od) tube of 7 metre length giving a total effective heat transfer area based on od of 870 m² [9360 ft²]. The layout of the new shell and tube heat exchangers is shown in Figure 9.

Cooling Water

The existing cooling pond was greatly undersized and also caused pollution problems within the complex due to the drift of the acidic water. As such it was decommissioned and a new 18 cell forced-draught cooling tower system was installed.

The performance of the unit after modification is described in Section 4.

SECTION 4

PERFORMANCE OF THE PLANT AFTER REHABILITATION

The rehabilitation project was completed on time and a test-run was performed at the end of February 1994.

The performance of the plant was outstanding with all sections surpassing capacity, quality and efficiency guarantees, except for one item. The original sheets signed by the client and contractor are included in Annex 1 and show the level of performance attained.

Some comments on these results are required to fully understand the extent of the success of this project. The guarantee values are in brackets.

The main guarantee parameters were measured during a 72 hour period, the capacity of the unit was tested during a 7 day period including one wash cycle (7 hours for the Reaction and Filtration (R&F) section and 12 hours for the Concentration section).

CAPACITIES

The following Table shows the performance of the Reaction & Filtration and Concentration Sections during the test run.

	mtpd P ₂ O ₅		stdpd P ₂ O ₅	
	Attained	Guarantee	Attained	Guarantee
R & F				
Inst. capacity	1371	1310	[1511]	[1444]
Weekly capacity	9176	8760	[10115]	[9645]
CONCENTRATION				
Inst. capacity	4528	4290	[4991]	[4729]
Weekly capacity	9618	9310	[10600]	[10260]

Cooling Tower

Attained the design duty of 90×10^6 kCal/h [357×10^6 BThu/h], giving a cold water temperature of 29.8°C [85.6°F].

QUALITIES

- Dilute phosphoric acid

The average P_2O_5 content was 28.13% (28) and the sulphate expressed as H_2SO_4 was 2.15% (2), this value was slightly above design but in fact the SO_4 in the concentrated acid was below the guarantee value, see below.

- Concentrated acid

The P_2O_5 was 52.53% (52) and the H_2SO_4/P_2O_5 ratio was 0.0634 (0.0715) whilst the solids content was 2.38% (3.5).

- Fluosilicic Acid

The strength of the Fluosilicic Acid was 22.32% H_2SiF_6 (20) with a P_2O_5 content of less than 100 ppm (150).

YIELDS

- Reaction and Filtration

On filter cake basis, the efficiency was 95.83% (95.5).

- Concentration

The efficiency was over 99.99% (99.8).

SECTION 5

CONCLUSION

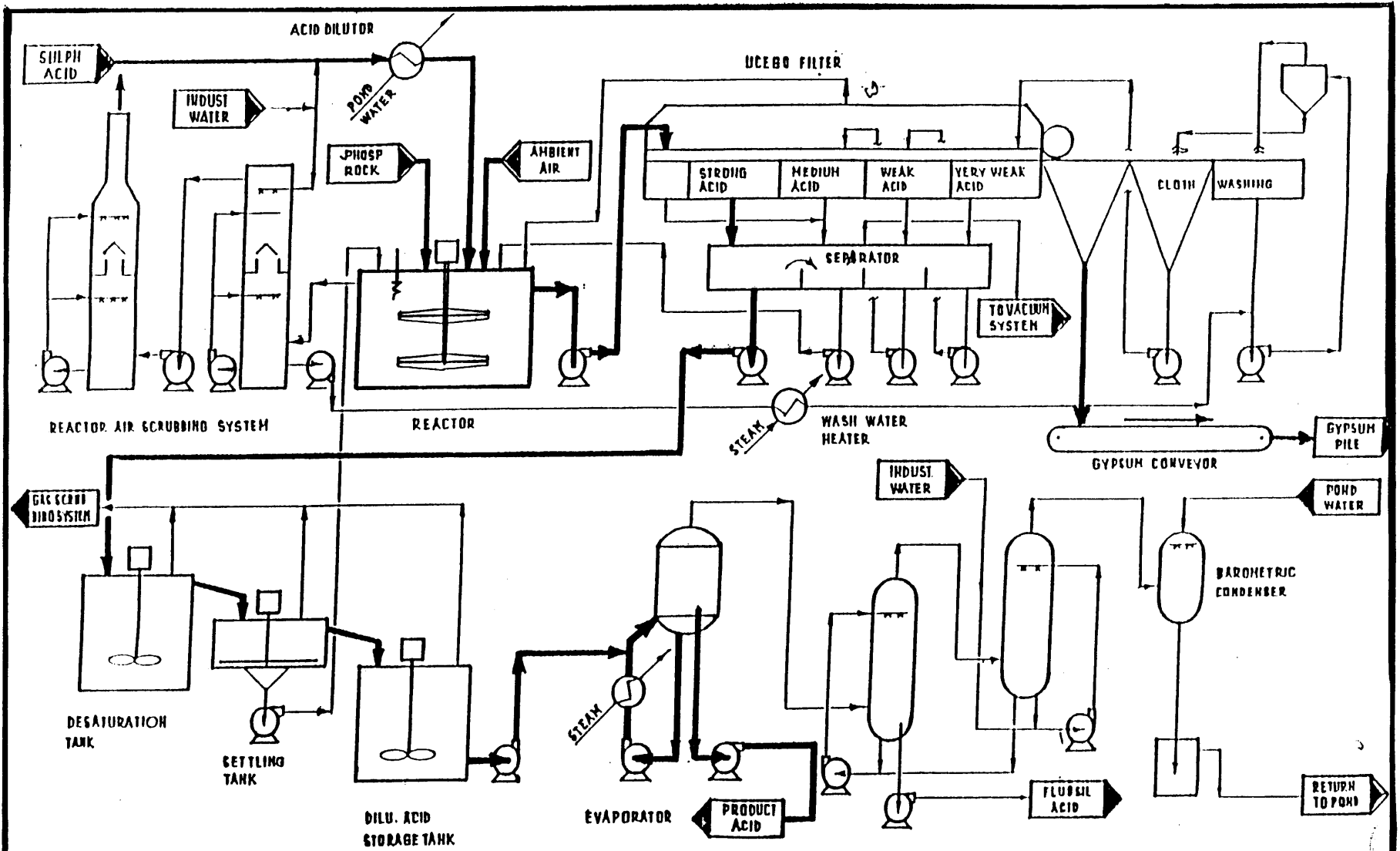
The challenge of a "fixed price turn-key" revamp is not an easy one to accept, particularly due to the unknown quality of equipment at the time of bidding. COPPEE LAVALIN, BOUYGES and PRAYON managed to complete this difficult task, within schedule, whilst easily attaining the guarantee values. JPMC took a calculated risk on the rehabilitation but have been well rewarded, now having a unit easily capable of meeting the original design capacity.

The client JPMC, after the test, made a maximum performance trial and managed to obtain over 1500 mt [1650 stpd] P_2O_5 in a 24 hour period, this whilst maintaining the acid strength above 28% P_2O_5 and an efficiency over 95%. These values also show that JPMC should be well pleased with the future potential of this unit now converted to the PRAYON philosophy.

There are many other cost savings besides these concrete figures, that could be expected following the philosophy of PRAYON, but could not be guaranteed being difficult to quantify. The reduction in down-time and increase in overall efficiency, due to the extension to weekly washing of the filter means that the annual capacity will be increased and the production cost will be decreased. The consumption of filter cloths also shows signs of being at least a half and probably a third of the previous figure. The concentration units designed by COPPEE also show that they are capable of running at a washing cycle of almost double the design figure of once/week and will of course also give reduction in maintenance costs due to the integrity of this design of exchanger.

Other than solving the technical problems and upgrading the production capacity / performances, the conversion to the PRAYON process has now enabled JPMC to process Jordan rocks from any of its mines. The commercial rocks which have been treated during the trials have shown industrial performances similar or superior to the ones achieved when processing equivalent grades of Florida, Morocco and other internationally well known rocks.

JPMC is now equipped with the tools in phosphoric acid production to make the most of the other units on their complex and are at present implementing a programme to revamp their sulphuric acid units to match the increased performance of their phosphoric acid units and a project to increase their granulation capacity.



JORDAN PHOSPHATE MINES CO. LTD. AQABA CHEMICAL INDUSTRIES COMPLEX AQABA - JORDAN			
DRN	E. M. ERISHMAN	12.3.66	PHOSPHORIC ACID PRO CESS FLOW DIAGRAM
ENKD			
APPD			
CALC			
			DWG. NO. ENG-PRO-020

FIGURE 1

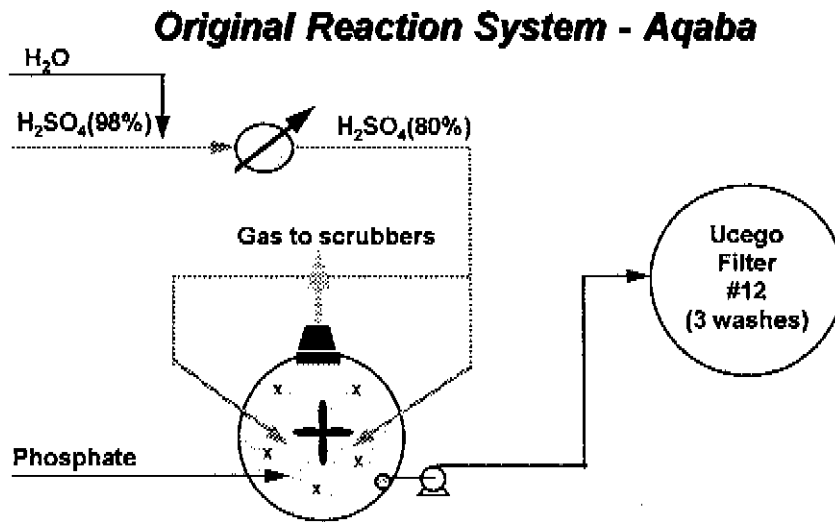


Figure 2

COPPEE LAVALIN

JPMC

Prayon

Prayon Mark 3/4 - 6 Compartments (2 of Digestion)

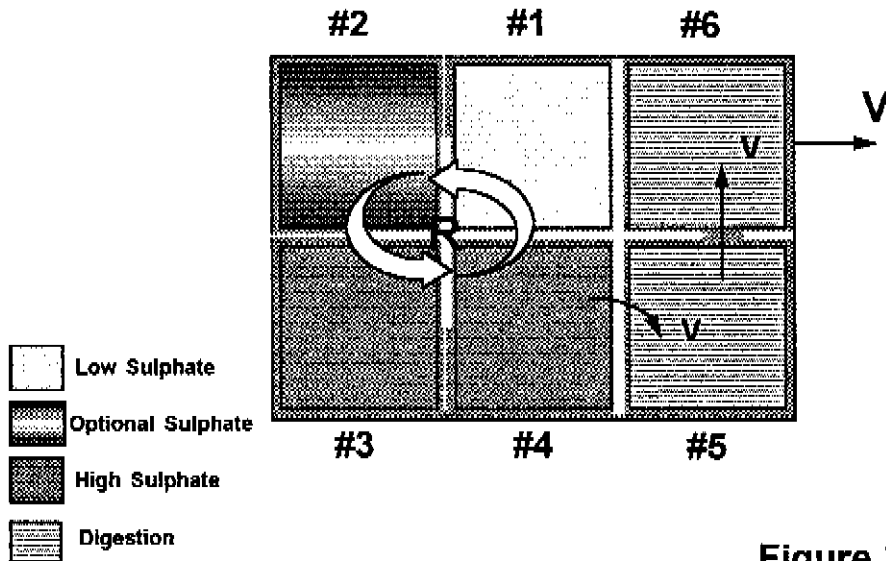


Figure 3

COPPEE LAVALIN

JPMC

Prayon

Modified Reaction System - Aqaba Layout

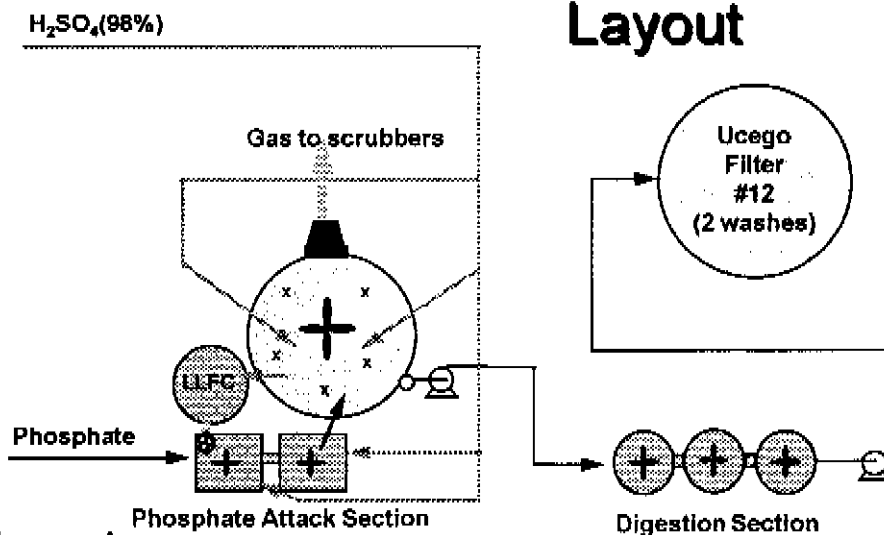


Figure 4

COPPEE LAVALIN

JPMC

Prayon

Modified Reaction System - Aqaba

Sulphate Profile

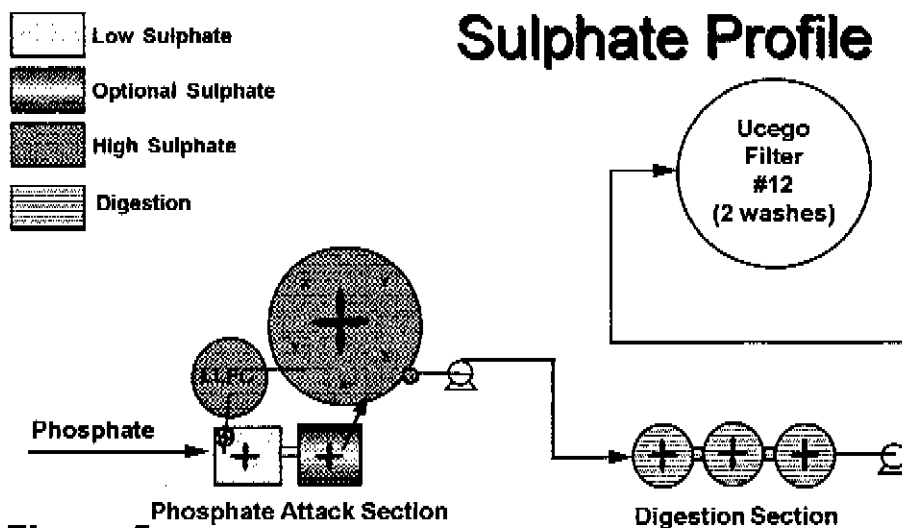
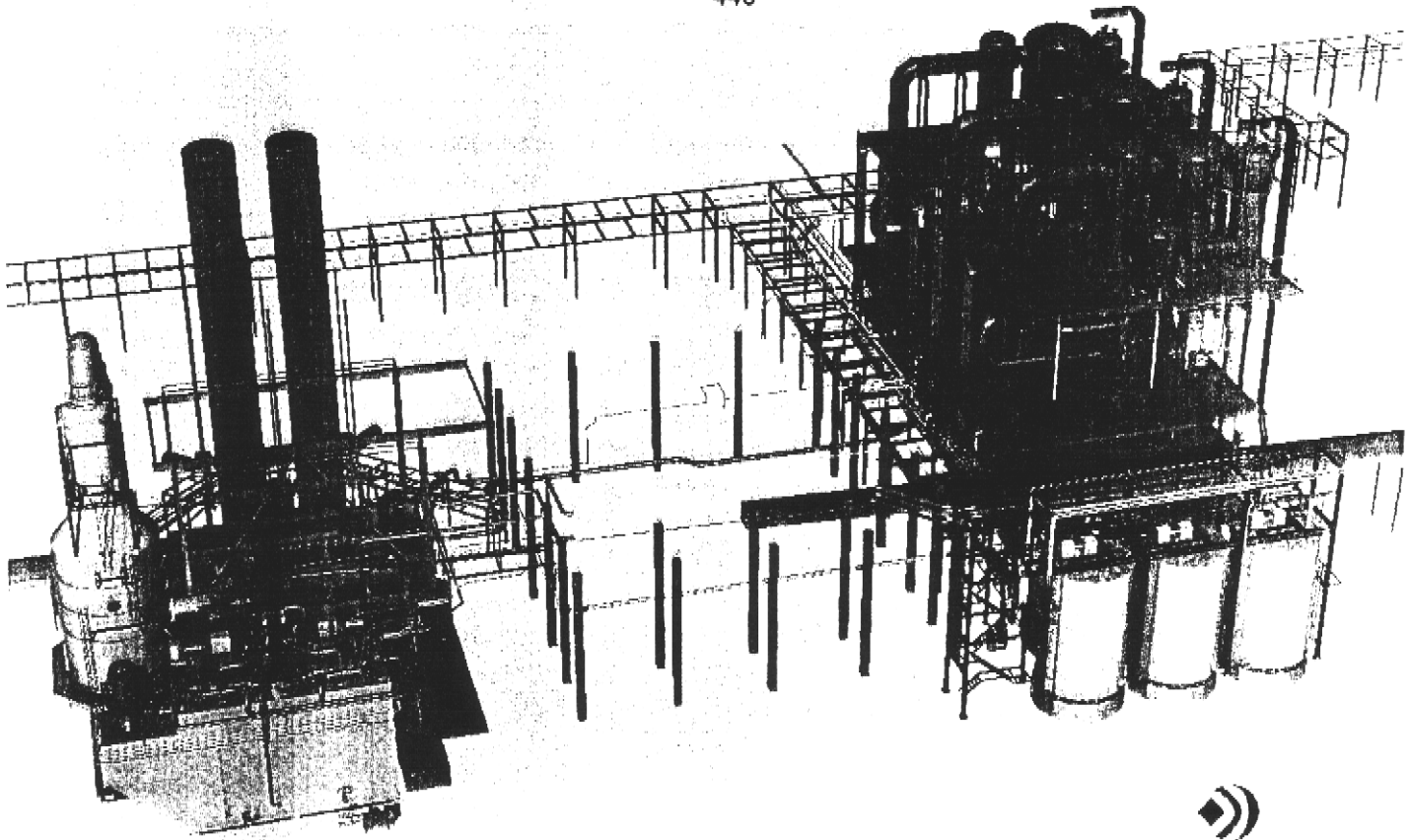


Figure 5

COPPEE LAVALIN

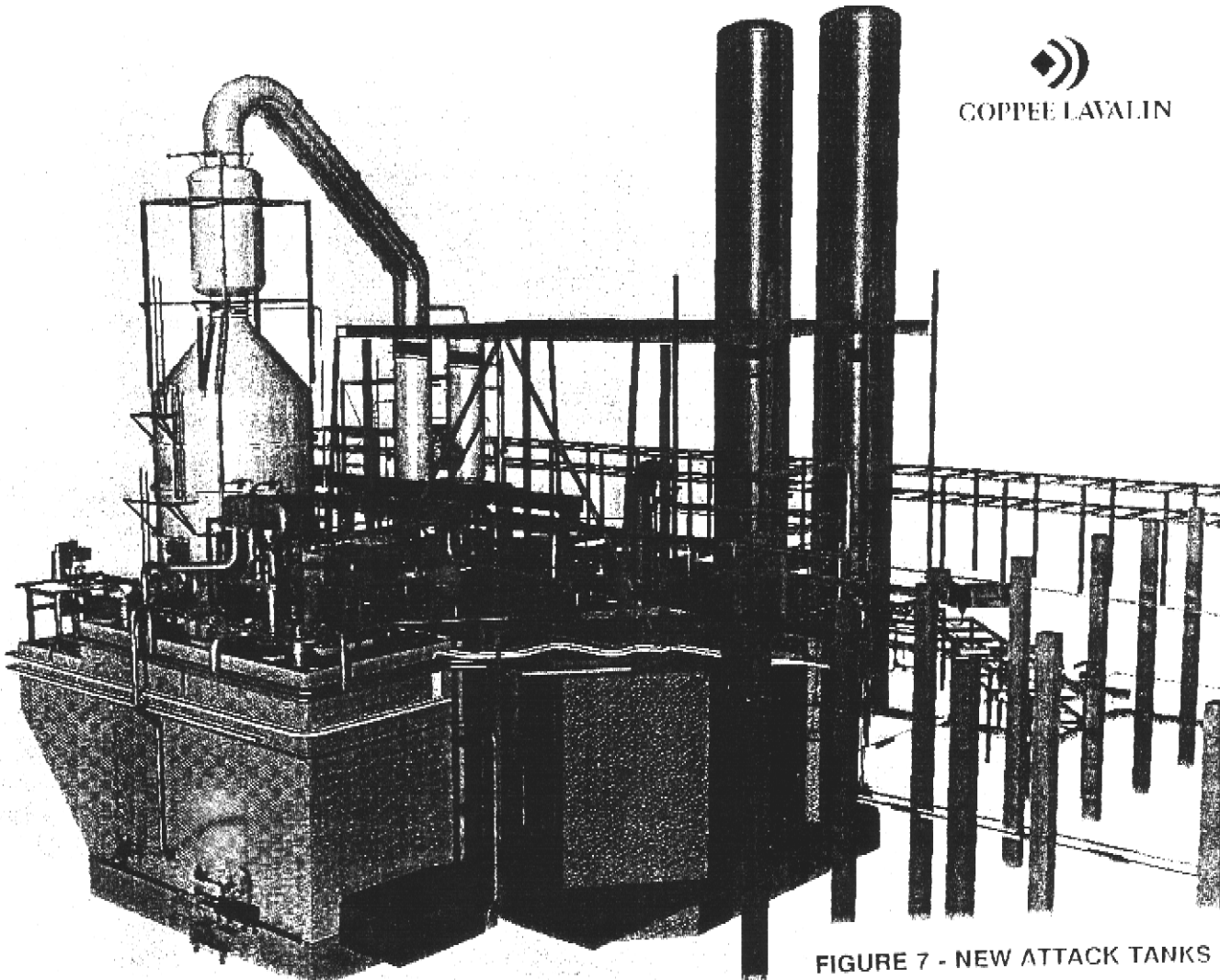
JPMC

Prayon



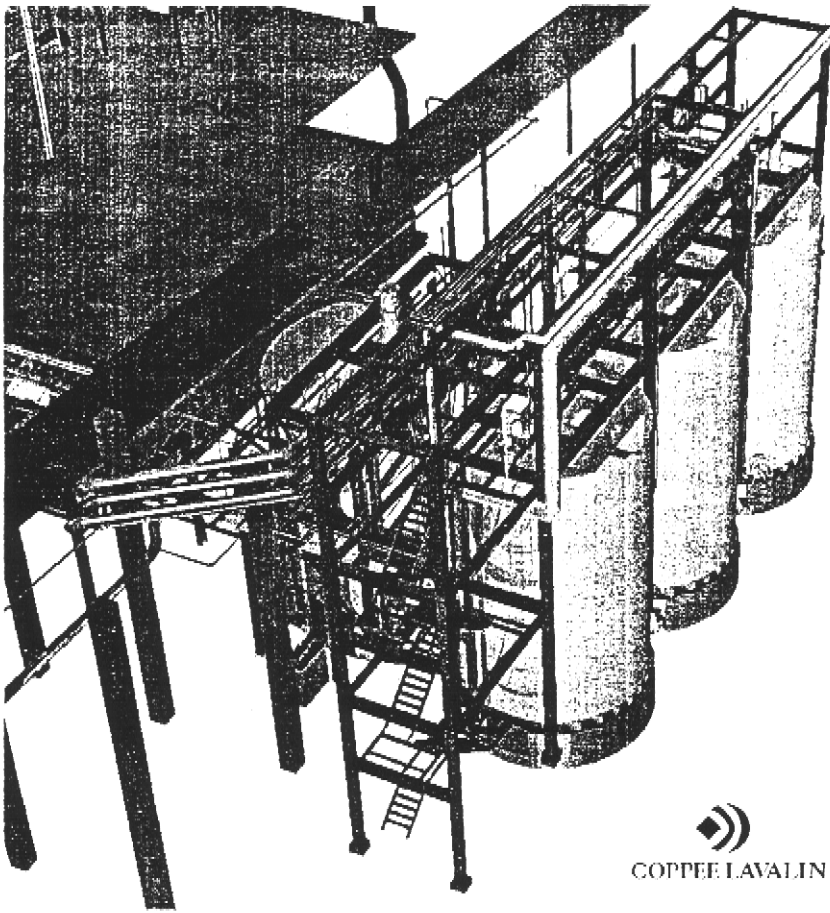
COPPE LAVALIN

FIGURE 6 - NEW REACTION SECTION



COPPE LAVALIN

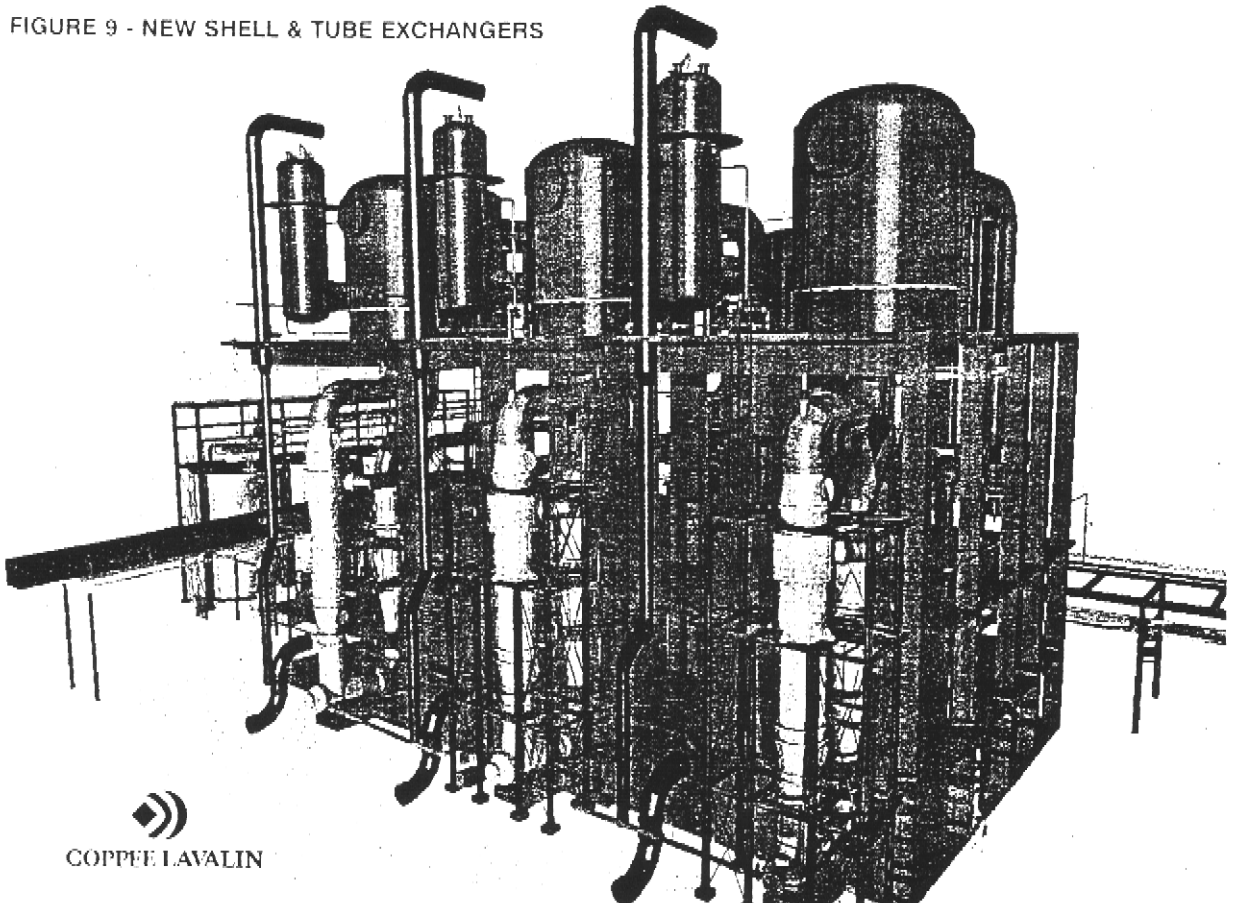
FIGURE 7 - NEW ATTACK TANKS



COPPEE LAVALIN

FIGURE 8 - DIGESTION SECTION

FIGURE 9 - NEW SHELL & TUBE EXCHANGERS



COPPEE LAVALIN