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EXPERIENCE WITH DRY STACK MANAGEMENT OF GYPSUM (HEMIHYDRATE CALCIUM SULPHATE) (a)

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1. Preamble

Indo Jordan Chemicals Company Ltd. (IJC), a joint venture company promoted by M/s. Southern Petrochemical Industries Corporation Ltd. (SPIC) - India, M/s. Jordan Phosphate Mines Co. Ltd. (JPMC) - Jordan, and The Arab Investment Company SAA (TAIC) - Saudi Arabia, has established a phosphoric acid complex in the Special Industrial Free Zone in Eshidiya, Jordan.

The phosphoric acid complex consists of a 2,000 MTPD sulphuric acid plant, based on Monsanto's Double Conversion and Double Absorption process, a 700 MTPD P2O5 phosphoric acid plant based on Hydro Agri's single stage hemihydrate process, and associated utilities and off-sites.

IJC commissioned its plants early 1997 and crossed 100% capacity utilization of its plants for three years in succession during 1998 – 2000. However, the capacity utilization was affected during the year 2001, due to recession in the phosphoric acid market.

Considering that the location of phosphoric acid plant is in dry desert area where virtually there is no rainfall and the water resources are precious, dry stacking of hemihydrate calcium sulphate, the byproduct from the phosphoric acid plant was selected.

This paper describes the operating experience of five years with Dry Stack management of gypsum (hemihydrate calcium sulphate), with specific reference to the following.

- Basis of selection of dry disposal method.
- Brief description of the system.
- Design features incorporated to have better operational flexibility.
- Characteristics of hemi-hydrate-calcium-sulphate produced/stacked.
- Experience with the first stack.
- Problems faced with stacking equipment.
- Reliability and capacity improvement jobs carried out.
- Advantages and limitations of dry stacking.

2. Basis of Selection of Dry Disposal Method

The selection of mode of disposal of filter cake (gypsum), wet or dry, for any phosphoric acid plant greatly depends on three factors, viz, the location of the plant, the climatic conditions and the investment cost (although the operating cost cannot be neglected).

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2.1 Location of the plant

The plant is located in the desert area close to the phosphate mines in the southern part of Jordan, with no inhabitants within 50 km. The space required for stacking gypsum does not pose as such any constraint. There are no water bodies in and around the plant. The static water level in the region is 279 m below the ground. In the geological structure of the area, there is practically an impermeable layer of more than 10 m of hard coquina. From the location point of view, both wet and dry modes of discharge are feasible.

2.2 Climatic conditions

The climatic conditions are extreme with ambient temperature varies from minus 7.4 deg C in winter to 42 deg C in summer. The air is dry with relative humidity between 29% and 57% during the year. The evaporation rate is quite high during summer. The rainfall is extremely low at 44 mm per year. Though the climatic conditions are favorable for both wet and dry modes of discharge, dry discharge of gypsum is more suitable considering the fact that the water resources are limited in the project location.

2.3 Investment cost

The initial investment cost will be lower for dry disposal system when compared to wet discharge since around 50,000 m2 area per year needs to be provided with lining for wet discharge for a 700 MTPD P2O5 plant, which is costlier compared to the cost of extension of the conveyor in case of dry discharge.

One of the key factors for the selection of hemihydrate process was minimization of water consumption since only half molecule of water is attached to CaSO4. Taking the advantage of the geographical factors, disposal of gypsum in dry mode has been judiciously selected in order to further reduce the water consumption and to minimize the investment cost of the project.

3. Brief Description of the System

Phosphoric acid is produced using different grades of Jordanian rock phosphate by a single stage hemihydrate process. The reaction takes place in a battery of three reactors in series. The slurry containing 40 – 42 % P2O5 and hemihydrate gypsum from the reaction system is filtered in two totally independent streams of belt filters of 60% capacity each. The filter cake is transported by a series of belt conveyors in dry mode and stacked (The process scheme for Gypsum Handling system is enclosed as Exhibit -1).

The filter cake from each belt filter is fed to a common belt conveyor (M 451-10) through the independent discharge chutes, which are provided with automatic hammering devices. The filter cake from this belt conveyor can be diverted in two ways. If the filter cake is of normal quality, it is fed to another belt conveyor (M 451-20). If the filter cake is of poor quality, it is diverted to emergency stack directly, from which it is transported to the main stack using pay loaders and trucks.

The filter cake from the second conveyor (M 451-20) can be diverted in two ways. During normal operation, the filter cake is fed to stack gypsum conveyor (M451-30). This conveyor consists of a fixed part which is anchored to the ground, and a part moving on rails which is linked to the belt tensioning device with counter weight. The initial length is 184 m with the last 80 m sloped at 10 0. The length of the conveyor can be extended periodically in steps up to maximum of 50 m per step without addition of belt and structural supports. The conveyor can be extended for a maximum of 1000m total length.

The filter cake from the stack gypsum conveyor (M451-30) is fed to a gypsum stacker (M 451 –40). This is equipped with a boom which can slew on a range of 180 0 , which enables to feed the filter cake on either side of the stack, since the stack gypsum conveyor (M 451-30) is located at the center line of the stack. From the gypsum stacker (M 451-40), the filter cake is fed to gypsum swiveling conveyor (M 451-50), which is mounted on caterpillars, and equipped with a fixed boom and a retractable belt thrower device slewing on 180 0, that is totally movable.

Finally, the filter cake is thrown from the thrower device at a trajectory of 12 – 16 m, and stacked automatically by suitable positioning of the gypsum stacker and the gypsum swiveling conveyor, and by using pay loaders / bulldozer as and when required.
Each stack is designed to meet three years of plant operation and subsequently a new stack is to be used.

4. Design Features Incorporated for Better Operational Flexibility

Based on the experience of operating phosphoric acid plants of SPIC and JPMC, special emphasis has been given during the design to maximize the onstream factor of the phosphoric acid plant. Accordingly, two totally independent streams of filtration have been provided. To maintain the same level of operational flexibility, the following features are incorporated in the design of gypsum handling / stacking system as well.

Conservative design of stack with 2,880,000 m3 capacity for three years of operation of phosphoric acid plant.
Emergency diversion at the outlet of first gypsum conveyor (M 451-10), should the filter cake be very wet / sticky during plant start ups / upsets. The storage capacity is for about 16 hrs, and the material is trucked to the main stack.
Diversion of filter cake at the downstream of second gypsum conveyor (M 451-20) to an auxiliary stack using movable conveyor (M456-10), should there be any blockage of chutes or maintenance of stacker conveying system. The storage capacity is for about 24 hrs, and the material is trucked to the main stack.
Bypass arrangement for the gypsum swiveling conveyor (M 451-50), and the material is stacked using pay loaders /bulldozer, for short duration.
Modular tables, hydraulic jacks and additional belt with winch and tension device for the stack gypsum conveyor (M451 - 30) for easy extension and minimum down time during each extension.
Level adjusting device to allow to compensate the slope of the ground level (5 0) to maintain the slewing ring horizontal for the gypsum stacker (M451 - 40).
A local mobile control room, which is shifted automatically along with the stack gypsum conveyor (M 451-10) during each extension, near to the stacking area for better monitoring.
Video monitoring device in the central control room to monitor the stacking system.

5. Characteristics of Hemi–Hydrate-Calcium-Sulphate Produced / Stacked

As envisaged in the design stage, different types / grades of rock phosphate (both wet and dry) such as 70 –72 BPL, 60-65 BPL and dryer fines, etc, have been processed during last five years of operation. The filter cake at the exit of belt filters contains 18-22% W/W free moisture, with an average value of 20% W/W. Though filtration was normal, variation in the cake / crystal characteristics was noticed which was obviously due to the type of rock processed and the plant parameters.

5.1 Conversion of hemi- to dihydrate during transportation

Samples are collected from the filter feed slurry, the cake at the discharge of belt filters and at the outlet of thrower device, and analyzed for hemi hydrate content. The typical results are tabulated below.

TEST NO.	FILTER FEED SLURRY	EXIT OF BELT FILTER	OUTLET OF THROWER	REMARKS
1	98.28 %	98.20 %	98.12 %	New Stack
2	99.68 %	99.58 %	99.50 %	New Stack
3	99.85 %	99.82 %	99.78 %	New Stack

From the above, it is noted that the conversion from hemi to dihydrate during filtration and transportation is low (maximum 3% was observed earlier), though the hemi content in filter feed slurry, at times, was as low as 95 %.

5.2 Conversion of hemi- to dihydrate during storage

In order to check the degree of conversion, two cake samples were collected. One sample was stored under controlled ambient conditions inside the room (indoor) and the other one in natural atmosphere (outdoor). The content of hemi hydrate in the cake from each sample is analyzed every day for ten days, and the results are plotted in Exhibit -2.

It is noted that the rate of conversion was rapid in case of cake stored indoor and followed polynomial of third order as below.
$Y = -0.187 X3 + 3.902 X2 – 27.394 X + 96.64$
The rate of conversion of the sample stored out side was lower and followed polynomial of fifth order as below.
$Y = -0.0054 X5 + 0.1195 X4 – 0.810 X2 – 9.565 X + 100.07$

The data on the permeability of the cake stored indoor and outdoor is also measured and furnished in Exhibit -3. The permeability of the cake stored outdoor is maintained almost constant, while that of the cake stored indoor increased rapidly and crossed 200 cm2.

Based on the above experimental results, it is inferred that the climatic conditions have significant influence on the conversion from hemi to dihydrate.

5.3 Characteristics of filter cake stacked

Several samples have been collected from both sides of the gypsum stack at top and sides at a depth of around one foot (circa 30cm), and analyzed for hemihydrate content, permeability and specific surface area. The data is enclosed as Exhibit -4.

The average hemihydrate content varied between 8% – 27% W/W, while the permeability varied between 7 – 25 cm2 and the specific surface area varied between 1200 – 2000 cm2 / gm.

5.4 Size distribution of filter cake stacked

The typical size distribution of filter cake stacked during the years 1998 to 2002 is plotted and brought out as Exhibit -5. It is noted that more than 95% of the filter cake staked, passed through 150 micron mesh.

6. Experience in the first Gypson Stack

Though the stack was designed for three years of plant operation, it was used for five years (1997-2002) with total estimated quantity of 2,062,750 m3 filter cake, corresponding to 1,011,654 MT P_2O_5 production, due to the increased width of the stack (110-115 m actual vs. 100 m design), the natural compaction and the cushion provided in the design (such as the bulk density, moisture content). The second stack, adjacent to the first one, is in operation since April 2002. The observations made during the five years of operation with first gypsum stack are summarized hereafter.

6.1 General observations

- There was no major problem faced with the stack. No percolation of liquid was noticed either within the layers of the stack or at the ground level. The surface area of the stack, both on top surface and on side walls, was dry (Exhibit -6).
- The undisturbed areas (side walls and a part of top surface) varied from hard to very hard, while the top surface, where vehicle movement was present, was dry and powdery.

6.2 Settlement

Uneven settlement of stack was noticed especially adjacent to the stack gypsum conveyor, due to natural compaction, stacking equipment and partial conversion of filter cake to dihydrate, Due to this the slope of the stack could not be maintained at 5 0 as envisaged in the design. The actual elevation of the stack at the central axis versus the projected / theoretical elevation of the stack is shown in Exhibit -7.

6.3 Cracks

Cracks up to 5 - 10 m deep and 20 - 150 mm wide were noticed (Exhibit -8) since second year of operation, especially at end of the stack, which is most likely due to self weight of filter cake at the edge of the stack and conversion to dihydrate. As such no problem has been encountered during stacking, since material was filled and compacted as the stack was periodically advanced.

7. Problems Faced with Stacking Equipment

During commissioning and initial stage of operation, frequent problems were encountered with the stacking equipment. Some of them are highlighted below.

1. Frequent blocking of conveyor discharge chutes, leading to tripping of the conveyors. It was found that the cross section of the chutes was not adequate to take in to account the trajectory of the material discharged at different plant loads. The chutes were modified suitably.
2. Off centering of stacker gypsum conveyor. This was due to settlement of gypsum stored and frequent spillage of material. Periodical level measurements were taken for correction and self aligning rollers were provided.
3. Premature failure of conveyor belts. The belts were replaced in stages with chemical and oil resistant belts of higher strength.
4. Derailing of stacker gypsum conveyor due to high wind speeds. Additional supports / rollers were provided.
5. Problems with advancing of gypsum stacker conveyor. This was due to settlement and ineffective hydraulic jacks. The portable hydraulic jacks were replaced with self mounted hydraulic jacking system.
6. Conventional problems associated with belt conveyors and heavy equipment. Traditional periodical maintenance and preventive maintenance methods were adopted.

8. Reliability and Capacity Improvement Jobs Carried Out

In additional to troubleshooting, some modifications were carried out, in order to improve the reliability of the stacking system as well as to handle the higher quantity of filter cake generated at higher plant loads. Some of the major modifications carried out are described below.

1. Replacement of original conveyor belts (multiply – polyamide +polyester + rubber lining) with oil resistant ROS grade with higher strength EP 630/3.
2. The speed of the conveyors was increased to 1.6 m/sec to handle higher quantity of filter cake.
3. The gear boxes and motors for some equipment were replaced with higher capacity.
4. The diameter of the head drums was increased from 500 to 560 mm for improved reliability.
5. The thrower device was replaced with the one of higher capacity.
6. Automatic hammering devices were installed for the critical conveyor discharge chutes to minimize the choking tendency.
7. Chutes were provided with motorized ram for the two diversion chutes for ease of operation / quick action.
8. Rubber flaps were installed for the belt filter outlet chutes in addition to the hammering devices to minimize the build up of material, which is found very effective.

9. Advantages and Limitations of Dry Stacking

9.1 Advantages

- Transportation of gypsum in dry mode is simpler when compared to handling of gypsum slurry, which poses problems of pumping and plugging of pipelines.
- The initial cost for dry stacking is less compared to wet stacking, as the lining of the ponds and the complex under drain systems are not required.
- The problems of percolation and flooding of acidic water from the dry gypsum stacks are less in most of the cases, and virtually absent if the stacks are located in dry climates.
- The down time of phosphoric acid plant will be lower in case of dry stacking, if suitable provisions are made for diversion.
- The specific consumption of water will also be lower, which is most important factor, where water resources are limited.

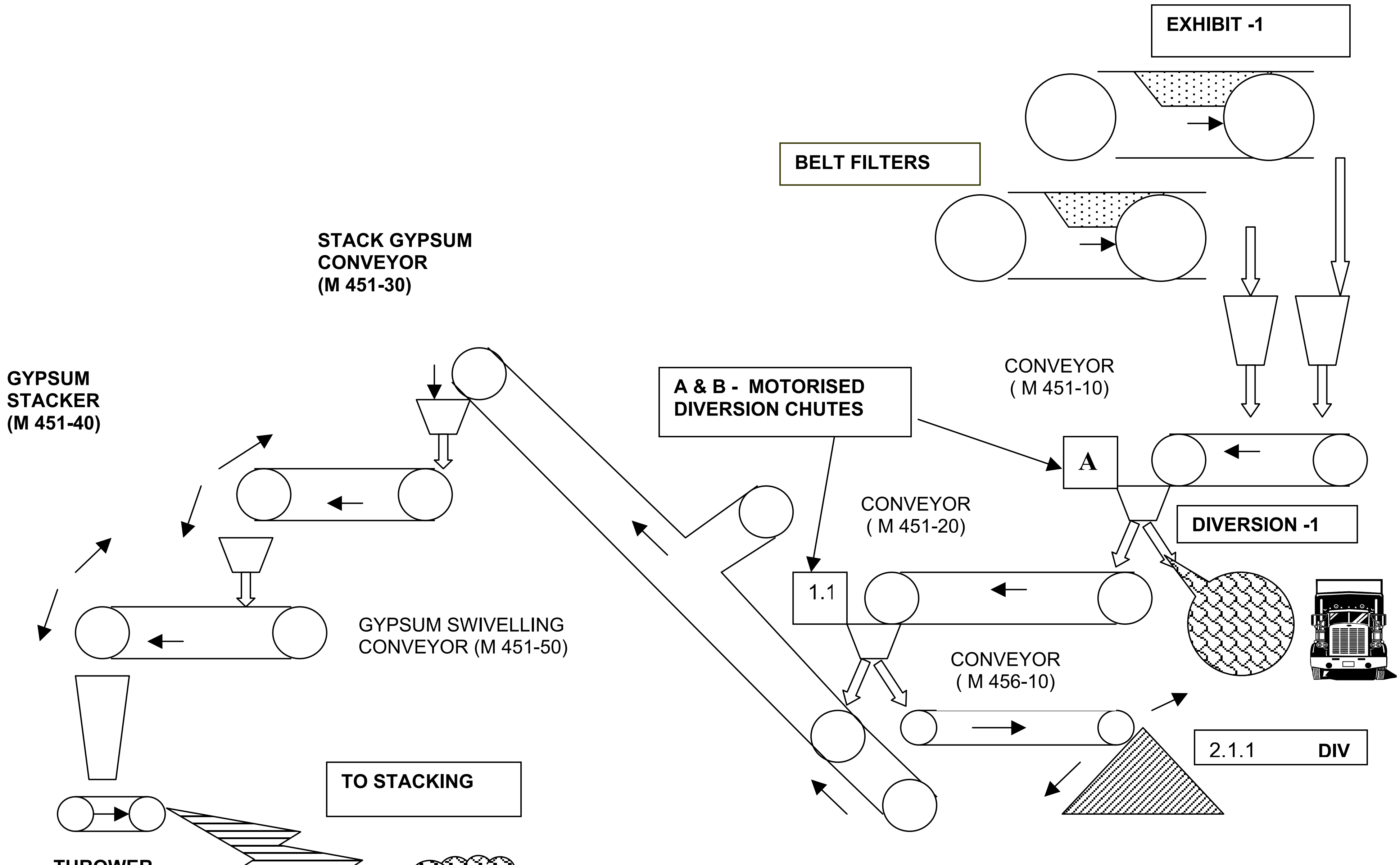
9.2 Limitations

- Hemihydrate cake becomes hardened if stored for few days, and requires to be shifted at the earliest from the temporary storage to permanent storage.
- Dust problems are encountered during movement of vehicles and during windy days, which requires spraying of water.
- The operational flexibility with respect to water balance in phosphoric acid plant is less in dry stacking, especially during routine washings and plant shut downs, particularly when wet rock phosphate is used as feed.
- No recovery of P2O5 from filter cake is possible as in some of the wet gypsum ponds.

10. Conclusion

On the basis of the operating experience for five years, the overall performance of dry stacking of hemihydrate calcium sulphate has been good as evidenced by the fact that the down time of phosphoric acid plant due to Gypsum handling system was 2% only, though maintenance problems with the equipment have been faced.

The selection of dry or wet stacking for any project is closely linked to geographical factors as well as project economics. In IJC’s case, considering the limited water resources in Jordan, both factors have played an equally important role, and the experience confirms the appropriateness of the decisions made.



2. PROCESS SCHEME FOR GYPSUM HANDLING SYSTEM

EXHIBIT - 6

Longitudinal view of the stack

Rear view of the stack at maximum height

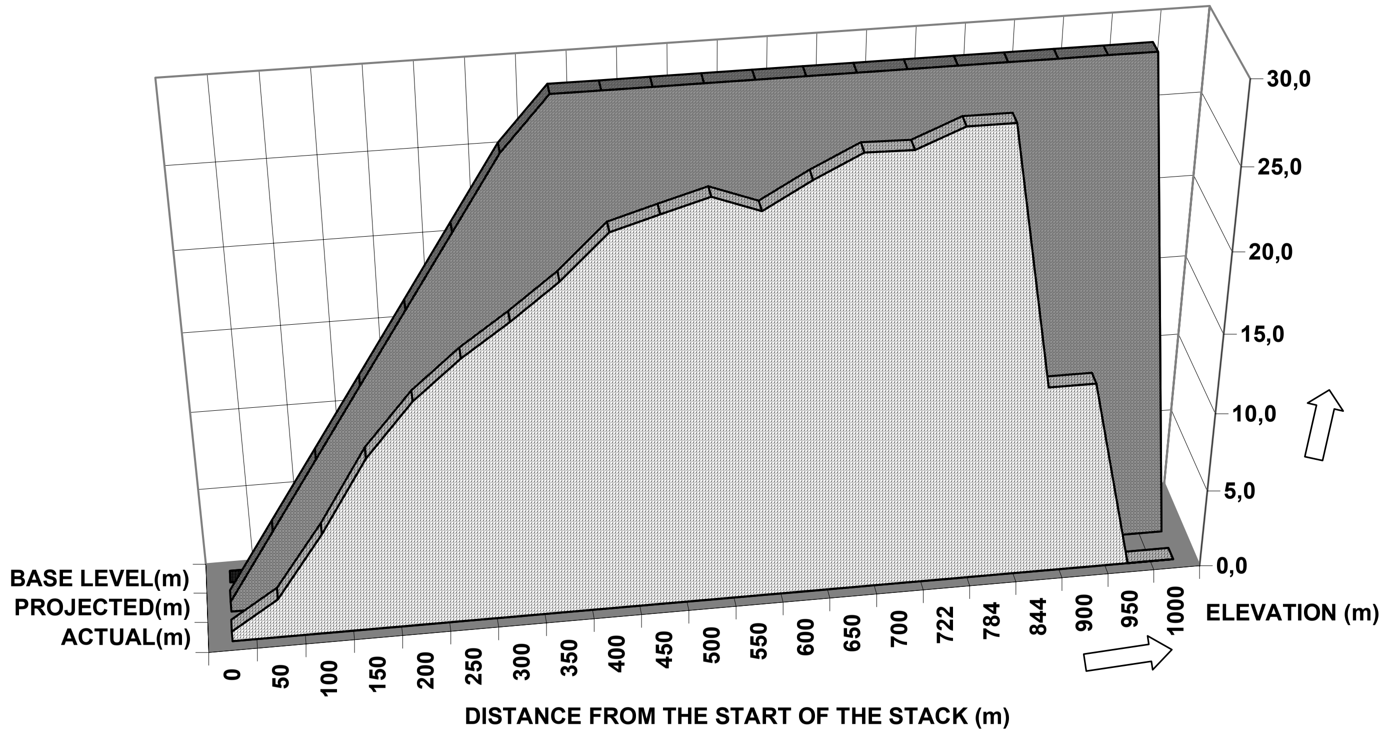
EXHIBIT - 8

Long crack near the edge of the stack

Wide crack near the edge of the stack

EXHIBIT -7

GYPSUM STACK - PROJECTED vs ACTUAL



	0	50	100	150	200	250	300	350	400	450	500	550	600	650	700	722	784	844	900	950	1000
ACTUAL(m)	0,6	2,5	6,5	11,0	14,3	16,7	18,6	20,8	23,4	24,3	25,1	24,0	25,6	26,9	26,9	28,0	28,0	12,0	12,0	0,0	0,0
PROJECTED(m)	0,6	5,0	9,4	13,8	18,1	22,5	26,9	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	30,0	0,0
BASE LEVEL(m)	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

ACTUAL(m) PROJECTED(m) BASE LEVEL(m)