

Technical Committee Meeting

Forum & Technical Field Visit

Abu Dhabi, UAE



2003
30 September - 2 October



International Fertilizer Industry Association



JOINT MEETING OF THE TECHNICAL SUB-COMMITTEE AND COMMITTEE

FORUM & TECHNICAL FIELD VISIT

Abu Dhabi, U.A.E.
30 September – 2 October 2003

All sessions will be held in the Hilton Abu Dhabi

PROGRAMME

Tuesday, 30 September 2003

14.00 - 17.00 hrs Joint meeting of the Technical Sub-Committee
and Committee *Oakroom*

Wednesday, 1 October 2003

08.30 – 12.00 hrs Registration

09.30 - 12.00 hrs **PLENARY SESSION I** *Oakroom*

Chairman: Saif Ahmed Al-Ghafli, Fertil, U.A.E.

1. Utilizing agriculture run-off water and subsurface drainage water for potash production
Ala'a Omari and Jamal Amira, The Arab Potash Company, Jordan
2. A case study on rotor damage due to electromagnetic shaft currents and subsequent coupling
installation problems faced on synthesis gas compressor of an ammonia plant.
K.L. Singh and K.J. Patel, IFFCO, India

10.30 - 11.00 hrs Coffee break

3. Fluid bed granulation technology for urea
Hans van Baal, Stamicarbon B.V., The Netherlands
4. Ammonia loading lines replacement at Ruwais Fertilizer Industries (FERTIL)
Mohamed R. Al Rashid, Hashim M. Lari, Hussain I. Bukhari and V. Balashubramanian,
Ruwais Fertilizer Industries – FERTIL, U.A.E.

12.30 - 14.00 hrs Lunch *Terrace Hall*

14.30 - 17.00 hrs

PLENARY SESSION II

Oakroom

Chairman: Bjarne Christensen, Kemira-GrowHow, Denmark

5. Purity of phosphoric acid: a review
Tibaut Theys, Prayon S.A., Belgium
6. Reverse osmosis of phosphate plant pond water by use of novel pre-treatment technology
Vaughn Astley, IMC Global, U.S.A

15.30 - 16.00 hrs

Coffee break

7. Safety Milestone: Implementation of HSE Management system at FERTIL
Mohamed R. Al Rashid, Hussain I. Bukhari and Mohamed Fikry,
Ruweis Fertilizer Industries – FERTIL, U.A.E.
8. Product stewardship within EFMA
Tore Jenssen, Norsk Hydro, Norway and Hans van Balken, EFMA, Belgium

17.30 – 20.30 hrs Tour of Abu Dhabi

21.00 hrs Dinner at the hotel

The tour and dinner are both kindly hosted by FERTIL.

Thursday, 2 October 2003

Field visit to the Fertil plant.

A technical visit to FERTIL Plant will take place on Thursday, 2 October 2003. Departure at 08.00 hours from the hotel, returning by 19.00 hrs at the latest. Hosted lunch.

Delegates taking part in this visit are kindly requested to provide their passport details. A form (appendix B) is attached for your convenience.

FERTIL PLANT COMPLEX

Ruwais Fertilizer Industries (FERTIL) was established in 1980, as a joint venture between Abu Dhabi National Oil Company (ADNOC) and Total-Compagnie Francaise des Petroles (Presently known as TOTAL). ADNOC and TOTAL hold shares in the company in the ratio of 2 : 1 respectively. Construction of the complex commenced in October 1980 and production started in December 1983.

The prime objective of establishing the company has been to utilise associated gas coming from the onshore fields of Bab, Asab and Thammama "C" to manufacture fertilizers and sell these in the local and international markets.



FERTIL's installations are located in the Ruwais Industrial Zone on the Arabian Gulf coast about 240 Km west of Abu Dhabi city. The complex comprises ammonia and urea processing plants with installed capacities of 1050 MTPD and 1500 MTPD respectively. The plants have fully integrated utility units with product handling and shipping facilities. The seawater, desalinated water and power are imported from ADNOC utilities plant.

The original 1000 MTPD ammonia plant was designed and constructed by Chiyoda Engineering Corporation under licence from Haldor Topsoe. The process licence for the carbon dioxide recovery unit is from the Benfield Corporation. The plant was commissioned in December 1983 and the hydrogen recovery unit, licensed by Costain, was added to the plant in 1988. This increased the design capacity to 1050 MTPD.

The urea plant was designed and constructed by Chiyoda Engineering Corporation with the process licence from Stamicarbon with a design capacity of 1500 MTPD of prilled urea.

The existing operating rates of the two units are 130% for Ammonia and 120% for Urea.

Prilled urea is stored in two Bulk stores, each having a storage capacity of 45,000 MT. These are equipped with a reclaimer and a conveyor system, which transports the product to bulk transport ships, or to the bagging plant for high-speed packing and then onward movement to FERTIL's jetty.



Ammonia is stored in two 20,000 MT each atmospheric storage tanks. Approximately 80% of the total ammonia production is converted into urea, and 20% exported as ammonia.

FERTIL's jetty is capable of accommodating simultaneously two ships of 5,000~35,000 DWT. The terminal is equipped with following loading facilities:

- Two modern vertical discharge type, dual function bag & bulk ship loaders, having loading capacities of 200 MT/H and 400 MT/H respectively.
- Liquid Ammonia loading Arm capable of loading ship at 500 T/H
- Liquid Ethylene loading Arm capable of loading ship at 250 T/H (This operation is carried out on behalf of BOROUGE the Ethylene producer located in Ruwais Industrial complex)

The ammonia and urea production facilities are serviced by the following utility systems:

- Raw water storage and BFW treatment systems
- Steam generation package boilers (2 x 140 Tons/Hour capacity at 40 Kg/Cm²)
- Instrument and plant air systems
- Nitrogen and hydrogen generation plants
- Fire water storage and distribution system
- Sea water and closed circulation cooling systems
- Effluent treatment system

Product sales are geared toward the international export markets mainly Philippines, Pakistan, USA/Italy, Far East, Vietnam, Sri Lanka, Iran, Africa, India and Myanmar.

USING AGRICULTURAL RUN-OFF "SUBSURFACE DRAINAGE WATER" FOR POTASH PRODUCTION

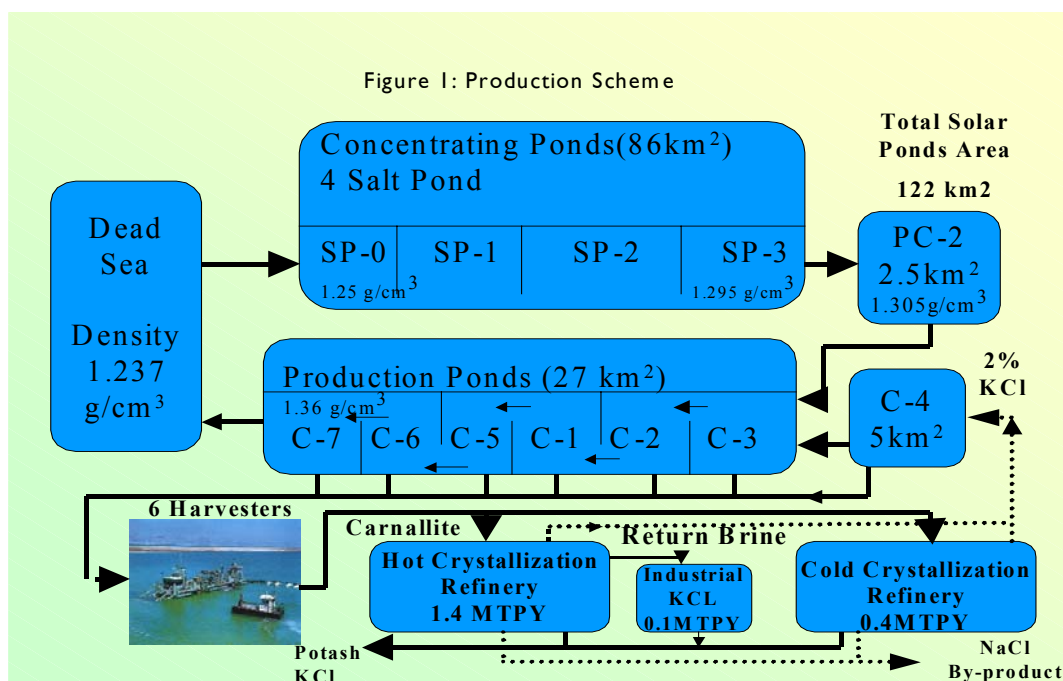
by: Ala'a Omari & Jamal Amira, The Arab Potash Company, Jordan

Introduction

The Arab Potash Company (APC) was founded in 1956, by the Jordanian Government to execute the project for the production of potash (KCl) and other minerals from the Dead Sea, with minimum impact on the environment.

The location of APC is 110 km south of Amman, the capital of Jordan. The adjacent project area is farming intensive. The Company utilizes two of Jordan's most abundant natural resources: solar energy and the minerals of which the Dead Sea is rich.

The Arab Potash Company operates one of the largest man-made solar pond system built on the land and is part of the Dead Sea, to prepare the raw material known as carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$), to feed two refineries to produce potash at the annual capacity of 2.0 MMTPY. Different processes are applied in order to produce high quality potash and these are: Hot leach and Cold leach (Figure 1).

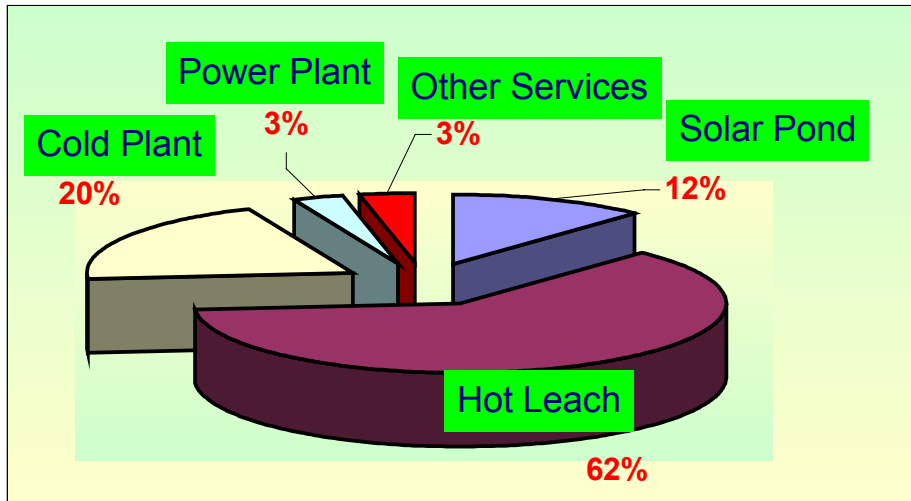


Water is a major and essential element in potash production. To produce one ton of potash about five cubic meters of water is required. Potash refineries consume about 9-10 million m³/year. Process water is used mainly in decomposition of carnallite (Process nature requirements according to brine chemistry), dissolution of sodium chloride in crystallization unit, washing of the sylvinitic cake, cooling of pump seal and general purposes such as cleaning. This high consumption uses up mainly the good quality water on the account of farming and local community domestic uses (Figure 2).



Presented at the meeting of the Technical Committee on October 1, 2003 at the Hilton Abu Dhabi
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Figure 2: Distribution of Process Water Consumption in APC Facilities



And due to the climatic conditions prevailing in the south of the plants and the neighboring agricultural area within the proximity of the complex, damage to the vegetation in the surroundings of the plants may raise strong reactions by the farm owners, the people living in the neighborhood, as well as the mass media. These reactions can easily harm the company's image on the long run.

Series of dry years have become a common phenomenon in Jordan. The fact that the water supply system in Jordan is designed to suit average rainfall conditions, series of dry years (drought condition) may result in a collapse of the water supply system, inability to meet the minimal water demand for maintaining reasonable hygienic life, water quality degradation, food stuff shortages, health detriments, unemployment and eventual social unrest.

The population pressure on the water resources of Jordan today has never been as intense. Since the 1980s, water consumption has exceeded the renewable resources, leading to groundwater depletion; Jordan's available water resources are, on a per capita basis, among the lowest in the world.

Water supply deficiency is constraining Jordan's economic development and is therefore limiting the achievement of a higher standard of living. The lack of renewable water resources is seriously hindering economic and social development as well as the quality of life for residents. Water scarcity will result in a national crisis unless significant measures are taken to use all water resources to satisfy growing demands. Jordan's water development strategy through 2010 requires the country to invest approximately \$5 billion in constructing facilities to close the growing gap between supply and demand. Investment in the water sector is projected to account for one third of all expenditure in the country's 5-year economic strategy.

Since water is also a limited resource in the area, a special attention has been given from The Arab Potash Company to water securing. Even though the Company has its own resources there is a gap between its water needs and the current available water resources, and this gap is expected to be increased with the potash planned expansion.

To bridge this gap, secure water for expansion, prevent the decrease of good quality water consumption and to protect the surrounding area from pollution, The Arab Potash Company has executed a planned program which is summarized as follows:

- ❑ Recharging existing wells.
- ❑ Drilling more wells.
- ❑ Collection of water by traditional methods such as harvesting of water from the surface.
- ❑ Brackish water is targeted water even from underground wells such as Haditha or from subsurface drainage water for potash production. (This water is not suitable for domestic use).

The principal goal of The Arab Potash Company has been to attain the best performance consistent with environmental compatibility at APC sites in both Safi and Aqaba and reduce environmental impact as far as possible in accordance with highest international standards.

Arab Potash Company's Environmental Policy

Evolving from The Arab Potash Company's commitment to sustainable development, of which the environment protection is one of its main elements, APC, at all its management and executive levels, commits to comply with local environmental laws and regulations related to its extraction and production operations of various types of potash, and does its utmost to reduce pollution through the following methodologies:

- Minimizing the adverse environmental impacts through the efficient management of solid, liquid wastes and gaseous emissions.
- Conservation and rationalizing the consumption of energy, water, and natural resources.

This paper will highlight further details on the reuse of subsurface drainage water in potash industry at The Arab Potash Company.

Methodology

The Jordan Valley Authority originates the agricultural run-off water from the return flow of the irrigated land project in the Safi area that was commissioned in 1986. The irrigated land has served mainly from the base flow of Wadi Hasa at Safi. This water is collected by subsurface drainage system and conveyed via open collective channels towards two main sites at Sammar and Ain Abatta (Figure 3).

The two main sources are:

Sammar Source

It is about fifteen 15 kilometers south of the APC Plant site.

Ain Abatta Source

It consists of four streams that flow in open channels towards the border line. The streams are located north of Safi city and four to five (4-5) kilometers away from the plant site.

Figure 3: Project Components Water Channels & Pipelines Layout

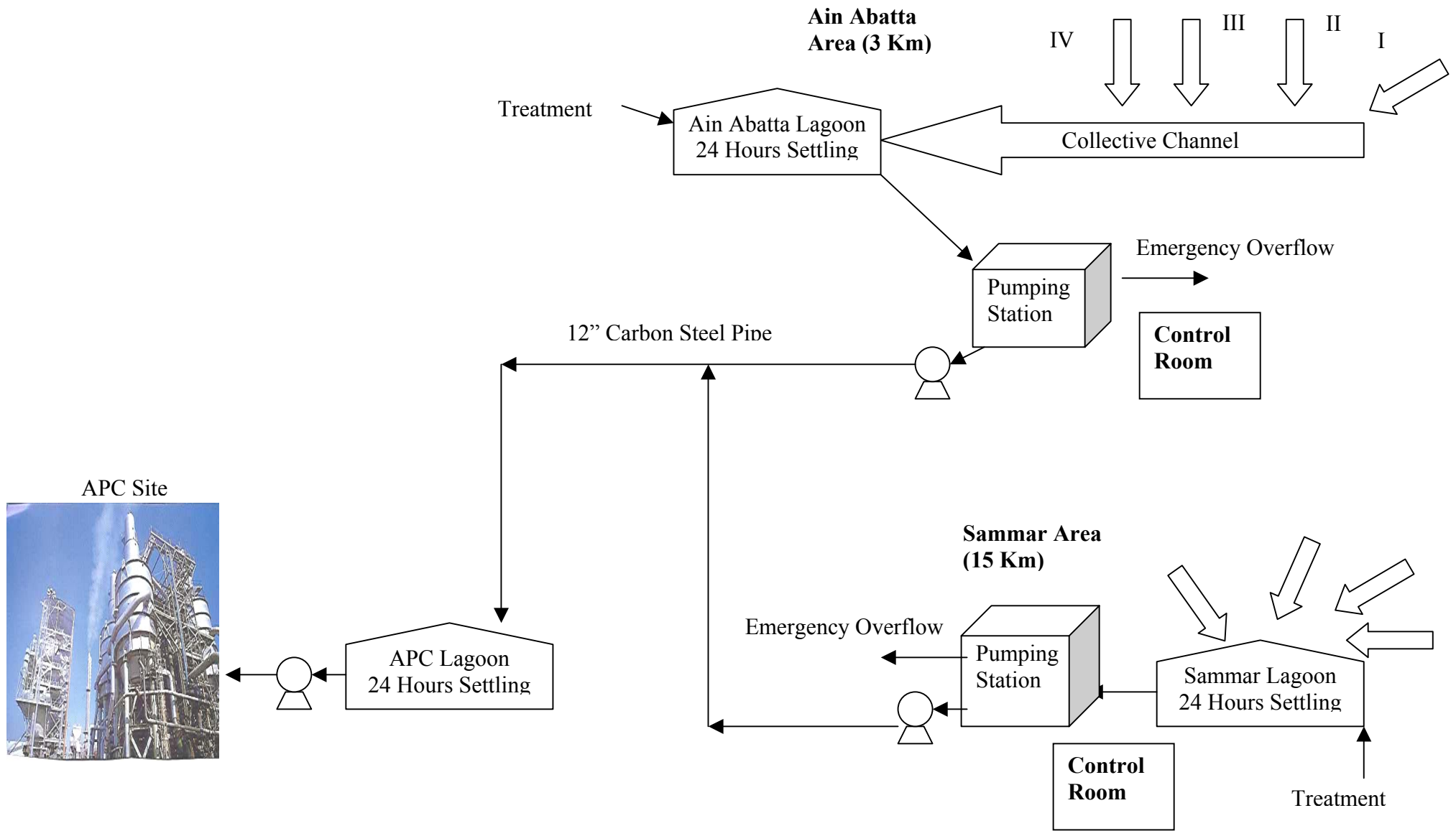


Photo I: Combination of channels at Ain Abatta



The main objectives of using subsurface drainage water for potash industry are divided into two main categories: -

Environmental objectives

- ✓ Protecting ground water from contamination by bad quality agricultural runoff water. Project area is an intensive farming area resulting in high usage quantity of chemical and biological fertilizers.
- ✓ Preventing the formation of local swamps resulting from unused agricultural runoff surface water accumulation, which help to transfer many diseases among citizens, by flies and insects.

Economic objectives

- ✓ Reuse of drainage water in potash production.
- ✓ Reducing of fresh water consumption in potash production, and increasing availability of fresh water to domestic usage.
- ✓ Low cost relative to other sources.

Water from these sources are not suitable for domestic uses and/ or agricultural reuse, and so The Arab Potash Company has expressed interest in using this water as process water in its plants to augment its existing resources. Upon this, The Arab Potash Company has signed an agreement with Ministry of Water and Irrigation / Jordan Valley Authority to pump these free of charges waters from its sources to The Arab Potash Company plants.

It is probable that the use of low quality water may result in an inferior quality of potash, diminished production and lower equipment life (increase maintenance cost), therefore, The Arab Potash Company decided to study the potential hazards, its impacts and how these might be reduced.

Water Suitability for Potash Industry

Scientific approach was the core elements for The Arab Potash Company technical staff to decide if this water is suitable for potash industry before endorsing its usage.

Measuring quantity of targeted water

Measurement of water quantities for Al-Sammar and Ain Abbata streams depended on the following procedures:

- Available data and information were collected and reviewed.
- New data was obtained from monitoring program for different seasons.
- Study and analysis of the results of the water statistically.

Quality and suitability for potash production

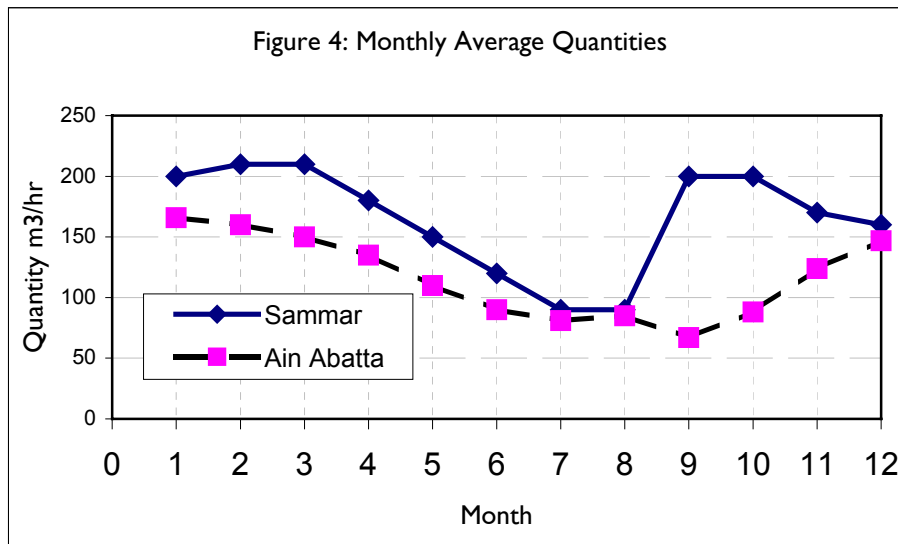
The study of the quality and suitability for potash production from Al-Sammar and Ain Abatta streams was carried out with the following approach to assess the usage of such water in potash production:

- Analysis of available data concerning the water quality parameters for both water sources. Physical, chemical and biological parameters were considered during that analysis (Table 1).
- Taking representative samples of the water from Sammar source and the discharge of the four channels of Ain Abatta source and analyzing these samples in an internationally approved reputable laboratory specialized in water analysis (Table 2).
- Laboratory tests were carried out on decomposition of carnallite and dissolution of sodium chloride, after that this water was transferred to The Arab Potash Company plants, and was added to decomposition unit itself (Pilot Test).
- Monitoring the quality of subsurface water drainage and collecting all the data required to set the design parameters for a selected period. New data were continually obtained during the monitoring program to study water quality variation versus the irrigation water application in the Safi area.
- Study and analyze the results of the water quality its suitability for potash production with its impact on potash quality and quantity produced and suggests any treatment necessary for the water.
- Study the effect of water in increasing the potential for corrosion on APC plant system.
- Study the feasibility of transferring the water through pumping from the source of Al-Sammar and Ain Abatta to the APC plants.
- International and local consultants review the results to ensure that the water is suitable for potash industry.

Technical Staff Evaluation of Drainage Water

Quantity

- The total water quantities at Ain Abatta and Sammar are 2 4 million cubic meters per year.
- The daily quantities vary between 100 to 250 m³/hr for Sammar source and 60 to 200 m³/hr for Ain Abatta throughout the year.
- The monthly average quantity varies according to irrigation season; the peak value is remarkably higher from September to April in which farming is taking place.



Water quality of the targeted sources

The evaluation of the sub-surface drainage water consisted of three main tasks as follows:

- Chemical modeling of the thermodynamics equilibrium relationships between the water and the various mineral phases to potash production.
- An evaluation of the corrosion potential of the water in question on the pipes and equipment of APC's plants.
- An evaluation of the biological contamination of the water.

Water quality itself

The analysis of water shows that the water is saline because it contains a high percentage of salts, chemical elements and compounds, and some biological matters.

Physical water- quality parameters

The main physical parameters that have been studied in this category were suspended solids, turbidity, color, odor and temperature. Because this water is agricultural runoff water, so it contains solids; the analysis shows that these solids were divided into inorganic or organic materials and/or live organisms.

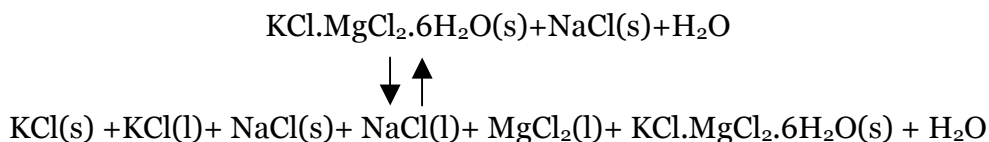
The existence of these solids causes, sometimes, odor as a result degradation of organic solids. So filtration and sedimentation were a must, the pathway of water involves self-purification since its open channels and two big lagoons were built in order to surge water, the settling pond shall preferably hold at least one day's usage.

Chemical water- quality parameters

As it is known, water is an universal solvent, and the chemical parameters are related to the solvent capabilities of water. The main chemical parameters that have been studied in this category were total dissolved solids, alkalinity, hardness, fluorides, metals, organics and nutrients.

Chemical modeling of the thermodynamics equilibrium relationships between the water and the various minerals phases to potash production was the base to calculate potassium chloride loss. With regards to the thermodynamics equilibrium, excess potassium chloride must be discharged as a purge due to increasing magnesium and calcium chloride added in the agricultural runoff water, plus the increase of insoluble (sodium chloride and calcium carbonate) in the tailings cake.

Extraction of sylvite from carnallite is achieved by two main steps; the dissolution of carnallite and the precipitation of sylvite. It is required to obtain complete carnallite decomposition with minimum water usage, carnallite decomposition discharges magnesium chloride, potassium chloride and water. Magnesium chloride solubility is higher than potassium chloride solubility. Magnesium chloride entering the brine causes potassium chloride to precipitate from the brine.



Here water is added in the crystallization process to prevent the precipitation of sodium chloride and to dissolve the entrained fine crystals.

Loss of potassium chloride product was estimated to be 0.00057 ton KCl per m³ drainage water, so Channel I is eliminated, this gives just 0.00014 ton KCl per m³ drainage water as losses in hot leach refinery and 0.0043 ton KCl per m³ drainage water in cold crystallization plant.

Based on the above product losses: -

- Drainage water use in cold crystallization plant was not recommended due to product loss and / or product contamination. All channels could be used for carnallite decomposition.
- Use Channel I water in potash industry is questionable because it contained high concentration of sodium, calcium and magnesium chloride. Also the use of Channel V water in potash industry is questionable because it contained high sulfate.
- Channels II through V could be used for carnallite decomposition in hot leach refinery.

Biological water- quality parameters

Aquatic organisms range in size and complexity from the smallest single-cell microorganisms to the largest fish that may live in water, thus all members of the biological community are, to some extent, dependent on water quality parameters.

In view of the fact that the water source in question is intended to be used as process water only, the potential health hazards that are associated with handling and processing were considered.

The biological analysis of water shows that Stream II contained 740 MPN/100 ml E.coli that is higher than the allowable limits, while Streams I, III, IV and V contained E.coli population below the standard limits.

Consequently, effective disinfections are required as a result of presence of E.coli and pathogens.

Corrosion Study

The electrochemical behavior of steel in the target water had been studied; using the potential current technique by applying anodic potential. As a result of that small amount of densities was measured and the current density increases as potential increases in the same solution, upon comparison the effect of the chloride ions percentage a shift toward the active direction (less anodic) was observed as the concentration of chloride ions increase.

Accordingly, stainless steel or non-metallic or lined carbon steel is recommended as material of construction for pumping system.

Project Component and Implementation Works

Project components (Fig 3) consist of the following:

- ❑ Collecting lagoons.
- ❑ Pumping station consists of three (3) pumps.
- ❑ Pipelines with a diameter of 12" and a length of 15 km and its accessories such as valves, joints, and pipeline.
- ❑ Electrical transformer combined with electrical cables and control room in the project area.

Work Plan

Project time schedule (fourteen months) is envisaged to be of four (4) phases: -

- ❑ Preparing engineering design.
- ❑ Implementation of civil works such as (Collecting pond, control room building, pipeline path preparation, pipes, joints, valves, pumps, motors, transformer cables.
- ❑ Procurement of mechanical and electrical equipments and pipes.
- ❑ Construction and installation of equipments and commissioning at start-up.

Work progress

- ❑ All hydraulic, strength, elongation and water hammer calculations were prepared and reviewed by an international engineering company.
- ❑ The specification of pumps, pipes, valves and accessories were prepared and reviewed according by an international engineering company.
- ❑ The quality study was prepared by APC's technical staff and a local consultant and reviewed by the international engineering company.
- ❑ Pipeline route survey, pumping station survey and soil investigation has been completed.
- ❑ Civil works, water pumps supporting system, excavations for the concrete ponds and steel structure had been completed

Photo 2: Collection Lagoon For Drainage Water At Sammar Site



Photo 3: Refinery Collection Pond For Sub-Surface Drainage Water



Photo 4: Refinery Collection Pond For Sub-Surface Drainage Water (side view)



Project Cost

The feasibility study showed that the total capital investment (Table 3) of the project would be 2.5 million JD (USD 3.5 million), 2.0 million JD for Sammar and the rest for Ain Abatta.

Conclusion and Recommendations

The expected results after implementation of this project would be the reduction of fresh water consumption in potash production; utilizing the recovered water from agricultural runoff water in potash production, improving local environment, and make the local farmers more aware to environmental issues, and contamination of ground water by chemical pollutants.

References

- George T. Austin: " Shreve's Chemical Process Industries" New York 1976. Fifth edition. P. 833
Gilbert M. Masters:" Introduction to Environmental Engineering and Science", New Jersey 1991. P. 451
Papers, Memos, and Reports of Technical staff at The Arab Potash Company.

Appendix

The Arab Potash Company

Table I Comparison Between The Average Analysis of Summer vs Winter Seasons for Agricultural Runoff Water between Year 1993 until 2002

Parameter	Unit	Average Concentrations Results			
		Summer *	Winter **	Difference	Control
Con.	MS/cm	13740	12300	1439	-
PH	SU	7.63	7.40	0.23	7.72
T.D.S	ppm	8729	7264	1465	1330
T.H (ppm)	CaCO ₃	4141	3768	373	-
ALK.	ppm	208	188	19	-
SiO ₂	ppm	170	70	100	NIL
Na ⁺	ppm	1822	1504	318	188
Cl ⁻	ppm	4065	3333	733	652
TUR	NTU	30	4	26	-
Ca ⁺⁺	ppm	635	594	40	135
Mg ⁺⁺	ppm	660	552	108	80
K ⁺	ppm	188.81	164	25	23
NH ₃	ppm	8.90	1.65	7.25	<0.03
SO ₄ ⁻	ppm	2422	2255	167	168
HCO ₃ ⁻	ppm	250	220	30	206

* Summer Season from March through September

** Winter Season from October through February

Table 2 Analysis of Summer Season for Agricultural Runoff Water in the Year 1995 through 2002

Test Sam. Date	Con. /cm	PH	T.D.S	T.H (ppm) CaCO ₃	ALK. ppm	SiO ₂ ppm	Na ⁺ ppm	Cl ⁻ ppm	TUR NTU	Ca ⁺⁺ ppm	Mg ⁺⁺ ppm	K ⁺ ppm	NH ₃ ppm	SO ₄ ⁻⁻ ppm	HCO ₃ ⁻ ppm
11/6/1995	10670	7.22	6307	3168	191.9	89.7	1405	3401.97	3	541.2	440	-	-	1579.17	-
3/5/1996	13180	7.72	7776	4207.5	247.5	27.65	1734	3908	111	844.8	508	-	-	2121	-
13/4/1997	11650	7.82	6874	3861	209.8	44.4	1643	3620	1	593	516	157.6	0.46	1983	251.51
6/4/1997	10930	7.54	6449	3671.25	172.5	25.3	1350	3282.5	20	561	550	148.6	0.11	2091	210.24
12/9/1997	9430	7.38	5564	2417.11	-	25.85	1004	2133.78	6	389.1	347.7	122.1	0.066	1819	-
3/9/1998	16000	7.31	9440	5533.1	-	2953	2005	4201	3.5	745.4	875.8	175.2	-	2527	-
17/7/1998	7510	7.88	4421	2021.25	-	42.6	867.9	2029	1.5	343.2	282	101.6	-	736	-
21/3/2000	14090	7.62	8313	4283	193	76	1770	3930	-	607	672	186	-	2500	235
4/4/2000	13350	7.21	7877	4280	219	47	1683	3305	-	706	612	213	-	3000	267
9/4/2000	8320	7.83	4909	2685	188	75	888	2223	-	462	372	116	4.4	1400	229
11/4/2000	14030	7.3	8278	4447	198	92	1702	3934	-	627	700	194	4	2500	242
16/4/2000	13210	7.66	7793	4001	229	72	1629	3451	-	561	630	184	17	2550	280
23/4/2000	14050	7.63	8289	4414	191	94	1725	3533	-	527	696	192	-	3150	233
26/4/2000	13180	7.71	7775	4166	192	91	1639	3374	-	594	650	195	2.6	2920	234
30/4/2000	13670	7.36	8065	4349	216	77	1608	3805	-	693	636	222	8	2441	264
4/5/2000	14180	7.36	8366	4283	230	79	1795	4100	-	746	588	209	-	2300	280
8/5/2000	14800	7.66	8730	4530	225	98	1850	3800	-	627	720	220	-	3150	274
13/5/2000	15900	7.5	9450	4579	249	89	2278	4500	-	653	716	228	-	3000	304
17/5/2000	15300	7.46	9027	4779	215	97	1971	4212	-	710	700	233	-	3020	262
27/5/2000	16400	7.77	9676	5024	137	85	2050	4505	-	693	800	227	6	3133	167
4/6/2000	16300	7.75	9617	4942	204	112	2042	4771	-	640	812	255	13	3400	249
10/6/2000	13060	7.84	7836	3660	240	100	1800	3538	-	520	610	169	--	2500	293
17/6/2000	14150	8	8348	3795	195	78	1710	3650	-	561	580	185	16	2358	238
28/6/2000	15700	7.34	9263	4694	167	87	2000	4360	-	838	632	229	7	2320	204
27/6/2001	-	8.19	12188	-	-	83.9	2410	5645	70	598	855	212	4.9	2210	212
2/7/2001	-	7.42	15244	-	-	51.3	2995	6956	36	749	1033	240	7.4	2542	247
8/7/2001	-	8.07	14846	-	-	48.1	2700	6760	43	719	1002	274	6.4	2474	250
10/4/2002	15900	8.02	9540	-	207.8	101.25	1910	4406	-	701.25	712.5	180	15.6	2625	253.3
25/4/2002	16180	7.79	9708	-	245.81	55	1951.25	5038.8	-	679.8	648	161.25	30	1900	299.88
16/6/2002	19830	7.6	11898	5735.45	218.97	112.4	2558.51	5590	-	807.6	902.49	57.28	17.24	-	266.92
Average	13740	7.63	8729	4141	208	170	1822	4065	30	635	660	189	8.90	2422	250
Maximum	19830	8.19	15244	5735	249	2953	2995	6956	111	845	1033	274	30.00	3400	304
Minimum	7510	7.21	4421	2021	137	25	868	2029	1	343	282	57	0.07	736	167

Table 3 Analysis of Winter Season for Agricultural Runoff Water in the Year 1993 through 2002

Test Sam. Date	Con. /cm	PH	T.D.S	T.H (ppm) CaCO ₃	ALK. ppm	SiO ₂ ppm	Na ⁺ ppm	Cl ⁻ ppm	TUR NTU	Ca ⁺⁺ ppm	Mg ⁺⁺ ppm	K ⁺ ppm	NH ₃ ppm	SO ₄ ⁻⁻ ppm	HCO ₃ ⁻ ppm
29/2/1993	15490	7.73	9103.7	4702.5	359.1	41.5	1757.5	4559.4	5.1	627	760	-	-	2100	-
9/12/1994	8000	7.97	4720	2095.5	164.6	42.61	863	2112.92	3	478.6	224	-	-	-	-
18/10/1994	7490	7.99	4655.1	2095.5	209.7	19.6	826	2195.9	3	528	188	-	-	-	-
9/10/1996	17600	7.21	10384	4834.5	306.9	56.78	2239.38	5306.13	1.55	805.2	684	192.5	0.22	2147	374.04
10/10/1996	10900	7.67	6431	3324.75	190.1	38.6	1374.5	3081	2	521.4	480	134	0.25	1642	231.69
1/11/1997	9810	7.45	5788	2821.5	205.1	35.72	1185	2590.72	0.92	528	364	142	0.41	1754	250.7
10/10/1997	14510	7.78	8561	4207.5	174.1	24.4	1918	4158	10	619.91	644.3	178	0.079	2119	212.19
10/10/1998	13690	7.43	8077	3601.53	-	22.2	1949	3711.97	4	414.9	612	152.5	-	1850	-
5/11/1998	16400	7.47	9676	4552.18	-	27.28	2174	906.3	1.8	676.5	682.8	196.6	-	3924	-
8/12/1998	13640	7.33	8048	3795	-	30.6	1737.9	3680.8	6.8	693	500	163.1	-	1943	-
13/11/1999	13040	7.61	7693	4009	214	91.4	1540	3784	-	600	572	168	-	2200	261
15/11/1999	12430	4.6	7334	3953	199	106	1491	3764	-	587	604	207	4.9	2200	243
22/11/1999	14740	7.63	8697	4180	203	98.6	1584	3692	-	561	660	167	2.5	2900	248
27/11/1999	11310	7.63	6673	3547	187	97.5	1350	3121	-	502	556	154.5	-	2000	228
29/11/1999	10870	7.63	6413	3399	180	55	1400	3185	-	548	492	155.7	3	1865	220
4/12/1999	10420	7.65	6148	3597	175	103	1150	2876	-	560	560	145	1.5	1900	214
7/12/1999	9890	7.64	5835	3464	177	48	1200	2897	-	528	520	146	-	1850	216
11/12/1999	10320	7.62	6088	3410	180	42	1212	2897	-	520	500	146	2	1800	220
25/12/1999	13600	7.36	8024	4184	169	96	1662	3950	-	627	636	174	-	2200	206
28/12/1999	11450	7.56	6755	3854	139	102	1250	3180	-	568	592	164	-	2039	170
2/1/2000	11740	7.3	6927	3739	152	108	1437	3162	-	640	520	150	-	2300	185
5/1/2000	12930	7.25	7629	4198	165	57	1630	3325	-	713	588	179	-	3000	201
11/1/2000	12140	7.27	7163	3953	166	97	1514	3264	-	627	580	185	-	2600	203
15/1/2000	11310	7.35	6673	3588	146	109	1340	3723	-	624	488	149	-	2500	178
18/1/2000	12410	7.15	7322	3986	157	104	1529	3266	-	555	632	162	-	2600	192
22/1/2000	12810	7.46	7558	4250	152	104	1595	3672	-	726	592	166	-	2500	186
25/1/2000	12760	7.2	7528	4052	149	95	1553	3590	-	587	628	162	-	2300	182
30/1/2000	12710	7.2	7499	4102	183	104	1654	3671	-	680	584	167	-	2409	223
Average	12300	7.40	7264	3768	188	70	1504	3333	3.82	594	552	164	1.65	2255	220
Maximum	17600	7.99	10384	4835	359	109	2239	5306	10.00	805	760	207	4.90	3924	374
Minimum	7490	4.6	4655	2096	139	20	826	906	0.92	415	188	134	0.08	1642	170

A CASE STUDY ON ROTOR DAMAGE DUE TO ELECTROMAGNETIC SHAFT CURRENTS AND SUBSEQUENT COUPLING INSTALLATION PROBLEMS FACED ON SYNTHESIS GAS COMPRESSOR OF AN AMMONIA PLANT

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Abstract

Excessive stray currents in the high-speed turbo machinery lead to catastrophic failure of the equipment. This is a fact known to the engineers long since. Unsafe conditions are generated as a result of such incidents if the actions are not taken in time. This paper describes an incident which resulted in to heavy damage to the high pressure steam turbine rotor of synthesis gas compressor of ammonia plant although the grounding brushes were installed and the plant personnel were aware of the phenomenon and all care was being taken to avoid induction of any magnetizing force during maintenance actions. Subsequent experience on the assembly trouble during coupling installation on the new rotor shaft, detailed investigation and systematic approach to rectify the discrepancies and coming out with the reliable and practical solution was the need of the time which was met by all round efforts of the plant personnel. The actions taken to overcome the typical maintenance problem faced during the assembly are also narrated in this article.

Introduction

IFFCO, Kalol unit is one of the best maintained, 28 year old Ammonia-Urea manufacturing complex with a capacity of 1100 MTPD ammonia and 1650 MTPD urea. The ammonia plant process is based on M.W.Kellogg steam reforming process. The process employs four important high speed compressor trains viz. air compressor, synthesis gas compressor, refrigeration compressor and a pair of natural gas booster compressor units. The failure was faced in the Synthesis gas compressor drive turbine, which is discussed in this paper.

Synthesis Gas Compressor Train

The synthesis gas compressor train consists of a barrel type LP and HP compressor cases driven by two turbines running in tandem, one out of which is a back pressure turbine and the other one is a condensing turbine. The machine train diagram is shown at Figure 1.

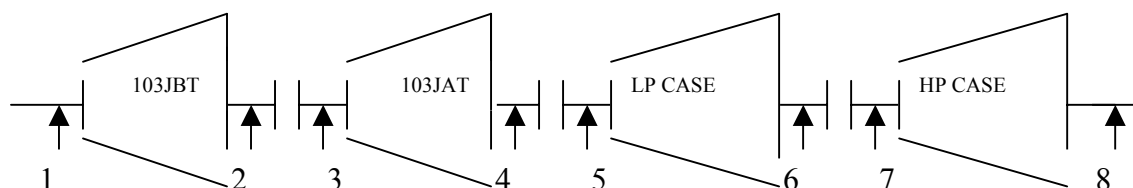


Figure 1: Machine Train Diagram

The operating parameters, design specifications and relevant details of the back pressure drive turbine, 103JAT which suffered the damage are described below:

1. Manufacturer: Demag Delaval, USA
2. Year of commissioning: Jan, 1974
3. Number of stages:2
4. Inlet steam pressure: 105.4 Kg/cm²g
5. Exhaust steam pressure: 38.3 Kg/cm²g
6. Normal operating steam flow: 275000 Kg/h
7. Normal BHP/KW: 14800 BHP
8. Normal operating speed: 10348 RPM
9. Critical speed: 6700 RPM
10. Lubrication: light turbine oil, rust and oxidation inhibited
11. Journal bearing type: babbittlined, multiple tilting pad type
12. Thrust bearing type :Kingsbury (segmental type) thrust bearing

The turbine is equipped with a non-contact shaft vibration surveillance system series 7200 and the data analyzing software DM2K supplied by Bently Nevada, USA. The trip system is confined to the axial position of the shaft only and the radial vibration levels are not connected to the trip logic. The higher lube oil temperature conditions are also not defined for trip.

The Incident

Just before the incident, the plant was operating normally. The lubricating oil temperature for the steam exhaust end bearing at point No. 4 suddenly crossed the alarm level of 80 deg C. The normal operating lube oil temperature was 68 deg C. On observing the alarm, the oil flow to the bearing was checked by the operator through gauge glass in the field. It was found normal and action was taken to verify the temperature on the local gauge installed on the pipeline.

The field temperature gauge was also showing high temperature, which was continuously increasing. By this time the vibration levels on the non contact vibration surveillance system increased to 2.27 mils from normal level of 0.8 mils on exhaust end bearing with heavy fluctuations on the display monitor for both the journal bearings of the turbine.

The vibration levels further increased beyond 5 mils (scale limit) when the decision was taken to shutdown the unit. At that time, the temperature of the lube oil went as high as 98.2 deg C, which clearly indicated the damage to the bearings.

There was abnormal sound heard from the turbine, which supported the prediction. Just before the train was shutdown, housing vibration levels were also measured using the accelerometer and a portable vibration analyzer, which showed the peak velocity levels as high as 15 mm/sec in radial mode.

The lube oil temperature and the high radial vibration parameters were not defined for the tripping of the machine. It is worth to be mentioned that the pre-reformer section of the plant was tripped just before the incident due to which there was impact on the steam flow through the HP turbine. The lube oil temperature in the exhaust end bearing drain started increasing soon after the tripping of Pre-reformer Section.

Observations

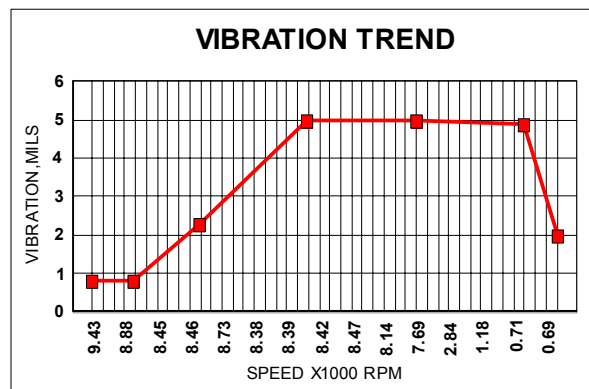
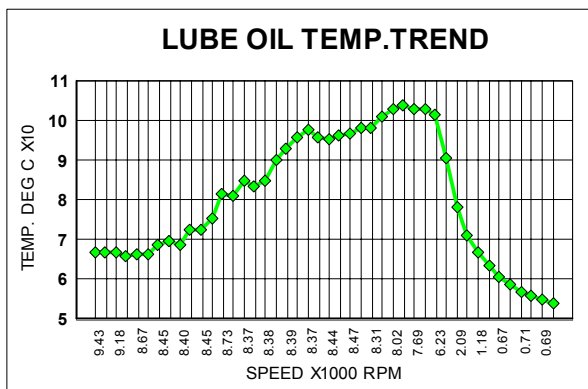
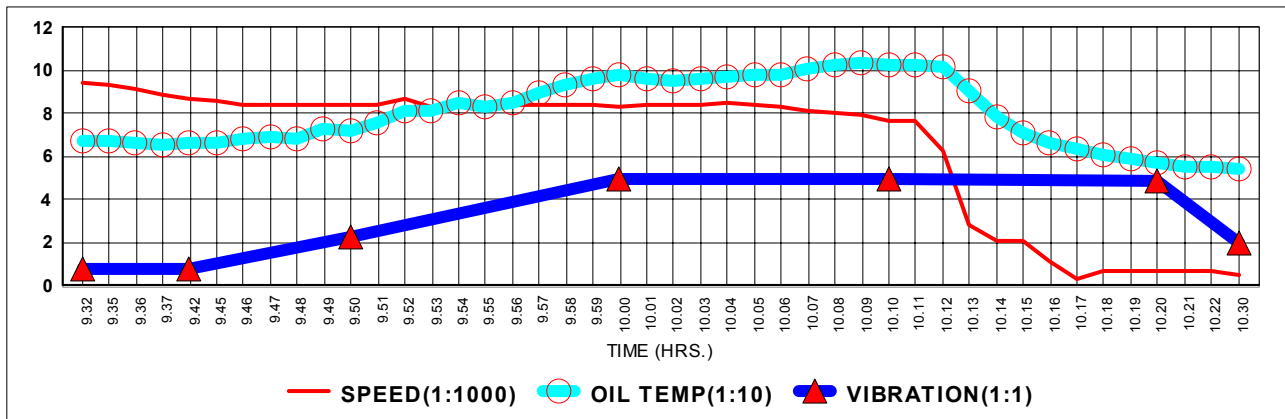
The turbine bearings were inspected immediately on shutdown. The exhaust end bearing was found badly damaged causing total loss of white metal lining. The shaft surface on the journal area was observed to have 1 mm to 1.5 mm deep scores due to heavy friction. The bearing at the other end showed little rubbing marks.

Subsequently the turbine casing was dismantled and the rotor assembly was taken out for inspection. No appreciable damage was observed to the thrust bearing located at the steam inlet end as well as on the thrust collar. However all the labyrinth seals were found badly rubbed out.

The three critical parameters viz. speed, lube oil temperature and the vibration levels on the steam exhaust end bearing, just before the incident and during the process of shutdown were recorded and these are given at the Table-1 below. Graph 1 shows the multiple variable trends for the parameters viz. Speed, vibration amplitudes and lube oil temperatures. The Graph 2 (Speed vs. Oil Temperature) and Graph 3 (Speed vs. Vibration) show the individual trends.

Table-1: Speed, vibration and lube oil temperature data.

Time	Speed RPM	Exhaust end Bearing oil, Temperature, Deg C	Vibration levels On Exhaust end Bearing, mils	Remarks
9.32	9430	67	0.81	
9.35	9320	67		
9.36	9182	66.7		Pre-reformer Section tripped Speed came down.
9.37	8884	66		
9.42	8667	66.3	0.81	Speed reduced by 500 rpm from normal.
9.45	8562	66.4		
9.46	8449	68.6		
9.47	8438	69.6		
9.48	8401	68.8		
9.49	8462	72.6		
9.50	8448	72.5	2.27	
9.51	8395	75.7		
9.52	8373	81.6		Oil temperature exceeded alarm level.
9.53	8364	81.3		
9.54	8373	85		
9.55	8381	83.4		
9.56	8375	84.8		
9.57	8378	90.2		
9.58	8385	93.2		
9.59	8389	95.9		
10.00	8367	97.8	5.0	
10.01	8421	95.9		
10.02	8442	95.5		
10.03	8416	96.6		
10.04	8467	96.9		
10.05	8441	98.2		Compressor train stopped
10.06	8307	98.4		
10.07	8135	101.2		
10.08	8018	103.1		
10.09	7930	103.9		
10.10	7693	103	5.0	
10.11	7628	103.2		
10.12	6234	101.8		
10.13	2844	90.5		
10.14	2091	78.3		
10.15	2116	71		
10.16	1180	66.9		
10.17	354	63.6		
10.18	665	60.7		
10.19	710	58.8		
10.20	714	57	4.89	
10.21	710	55.8		
10.22	690	54.9		
10.30	500	54.0	1.97	



Recent Maintenance History

The existing rotor of the turbine was in operation since January 1995. The bearings of the HP turbine were inspected during the planned turnaround about a month ago. At that time the bearing clearances were measured and the same were found within OEM recommended value for the inlet end bearing whereas there was increased clearance in case of exhaust end bearing i.e. 0.30 mm against 0.15 to 0.20mm (6 to 8 thou) recommended by OEM. Exhaust end bearing was replaced due to increased clearances.

Diagnosis of the Problem

Detailed survey of all the possible reasons for the failure was made. The failure of the bearing was not due to gradual deterioration but the catastrophic failure of the bearing was evident from the vibration data and trend shown in the Table 1 and Graph 1 respectively. Just before the incident, vibration levels were 0.8 mils on non-contact surveillance system. The rise in bearing drain oil temperature took place very rapidly. At 9.48 AM, it was normal i.e. 68.8 deg C while within the time gap of only four minutes, temperature reached 81.6 deg C i.e. there was a rise of 13 deg C in drain oil temperature. The metal temperatures are predicted to have reached very high levels beyond the melting point of white metal. The reason for keeping the turbine running for quite some time was evident from the fact that the temperature gauge on the pipeline in the field was being changed to ascertain the correctness of the reading. The time gap between 9.52 AM to 10.05 AM was long enough to show the temperature reading of 98.2 deg C. Even after stopping the compressor unit, the temperature continuously went up and reached the highest level of 103.9 deg C at 10.09 AM.

The study of the data revealed that the failure of the bearing was spontaneous. The reasons that can be attributed to such spontaneous failure could be

- (a) Sudden loss of lubrication
- (b) Failure of the white metal lining of the journal bearing pads
- (c) High electromagnetic shaft currents causing arcing and loss of lubricating film inside the bearing.

Out of the above referred three reasons, the first one is ruled out as there was no sign of any choking/restriction to the lube oil flow path in the lube oil inlet piping, oil distributing holes in the bearing casing and the drain pipe line when they were examined after dismantling the bearings. The filter elements in the lube oil supply line were found free from any deposits and the elements were in good condition.

The failure of the white metal lined bearing pads under load cannot be explained as the plant has the well set inspection procedure of the incoming materials including the bearings. The bearing pads were examined for the white metal lining bond using the Hoyt bondmeter and ultrasonic examination. The spares used for the replacement were procured from the OEM and had undergone all kind of rigorous testing before being despatched to the customers. Spontaneous failure of the bearing after the operation for about one month can not be attributed to the bearing metal failure when the machine was in steady state condition after successful startup.

Subsequently the third prediction was critically examined for the evidence. The following points supported the predictions of exorbitantly high shaft currents.

1. The residual magnetism levels were checked on the failed shaft journal on the exhaust end. The magnetic field strength of 25 Gauss max. was recorded on the journal after disassembly of the rotor. The photograph below shows the measured readings on the rotor at different areas. This level is very high as compared to the normally permissible levels of 3 to 4 gauss on the shaft journals, which is a close clearance zone of the high speed turbine shaft.



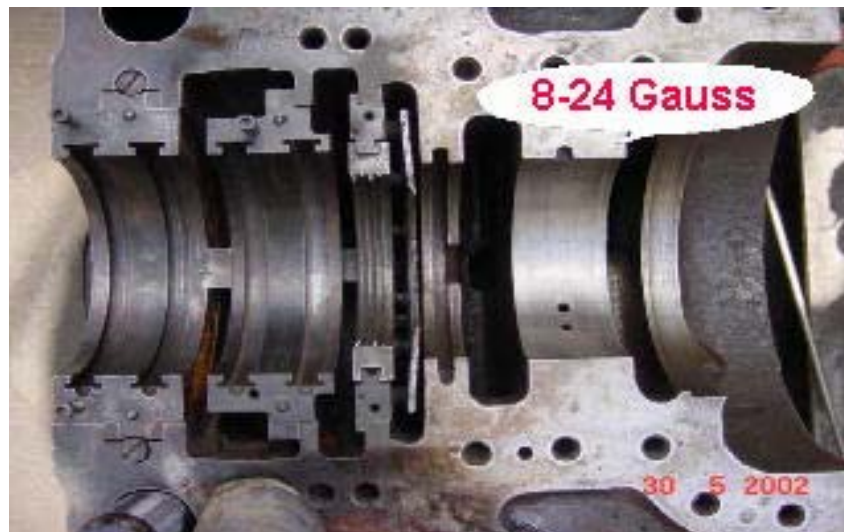
Photograph 1 Damaged Shaft Journal

2. On the damaged white metal lined bearing pads (from where white metal lining was badly rubbed out and barely any amount of white metal could be visible on them) , max. strength of the magnetic field density was 15 gauss. The photograph below shows the readings.



Photograph 2 Damaged Bearing Pads

3. The casing, on which the bearing shell was fitted, was also checked for the residual magnetism levels. The levels were recorded as high as 24 Gauss. Photograph 3 shows the readings.



Photograph-3 Journal Bearing Shell Casing

4. The grounding brush provided on the shaft was inspected and found badly worn out resulting in loss of contact with the shaft. The space available for the installation of the brush was a limitation and it did not allow for the suitable arrangement to measure the developed voltages and current.

All the above symptoms lead to the conclusion that the failure was a result of excessive magnetically induced currents. It is worth mentioning that the level of magnetism was found to be concentrated on only the exhaust end bearing journal/casing and there was no sign of appreciable amount of residual magnetism on the other parts of the rotor as well as casing.

Vibration Data

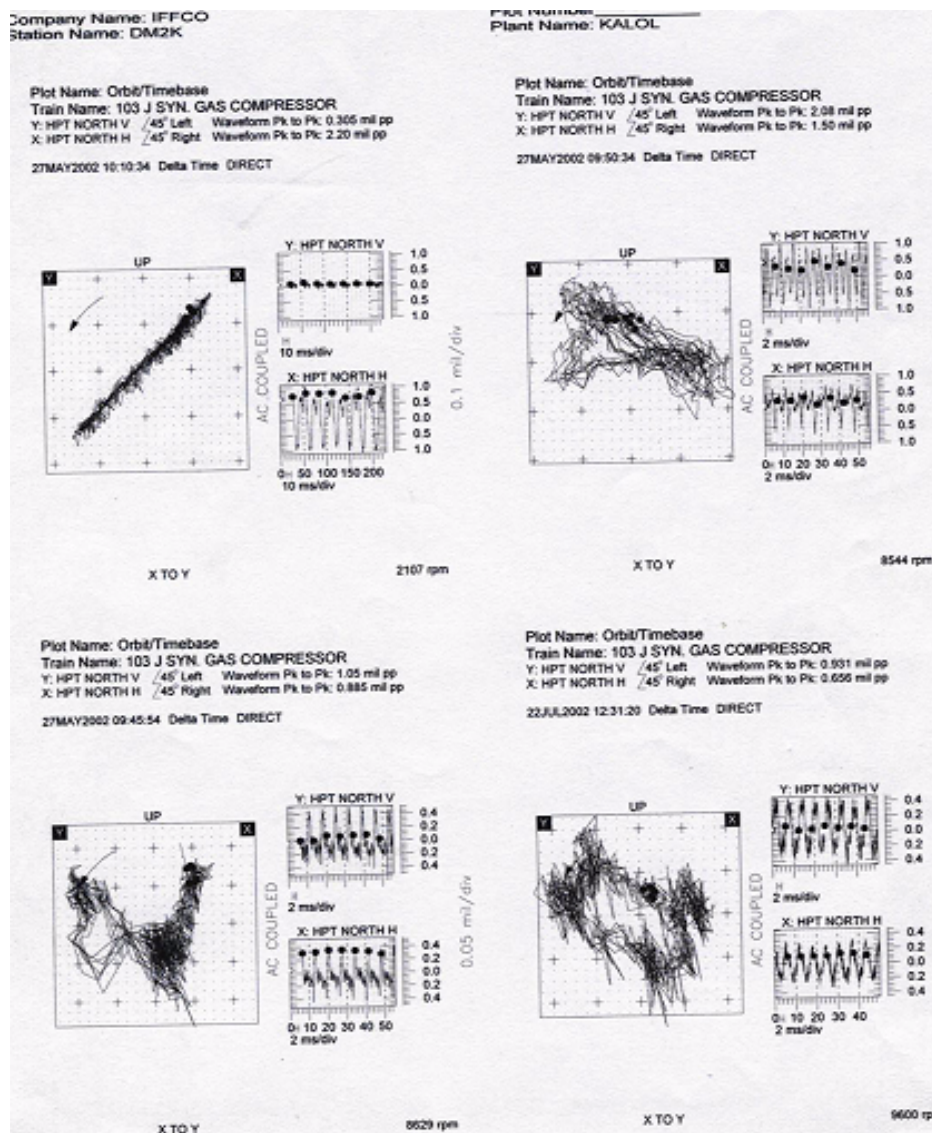
The machine is connected to the data Manager 2000 vibration analyzing software which draws the vibration data from the 7200 series non-contact vibration monitoring system supplied by Bently Nevada.

The trend of the vibration levels is shown at Graph 1. It is revealed from the data that the shaft vibration levels were just 0.8 mil till 9.42 am which increased to 2.27 mils at 09.50 am. After two minutes, at 9.52 am, bearing drain oil temperature crossed the alarm levels and shot up to 81.6 deg C from a normal level of 66.3 deg C recorded at 9.42 am i.e. rise in drain oil temperature by 15.3 deg C within a span of 10 minutes.

This confirms spontaneous failure of the bearing, which is a common phenomenon for the failure due to high magnetism levels in turbo machinery. Also there were spikes seen on the time wave form as well as on the unfiltered orbit as if there was the presence of the electrical run out just before the incident which are indicative of the flow of magnetic currents through the shaft near the probe area.

Figure 2 shows the unfiltered orbit and wave form shapes at different speeds of the unit during the failure (27.5.2002) and during the normal plant operation (22.7.2002).

Figure 2 Vibration data viz. Orbit and waveform plots prior to, during and after failure



Demagnetisation

It was a challenging task to undertake degaussing of the bearing housing which was the part of the huge casing. Portable demagnetizing equipment was used to undertake the degaussing. The magnetized surface was scanned with electromagnetic yoke (normally used for the purpose of magnetic particle inspection) while keeping the demagnetizing current 'ON'. The instrument got the facility to perform demagnetizing with AC currents producing reversing fields. Since the direction of the magnetic field was of complex nature showing irregular distribution of the field polarity, about six scans were required to be performed to bring down the level from 25 Gauss to 5.8 Gauss. Permissible magnetism levels are given at Table-2 below for reference.

Table 2: Permissible magnetism levels on different machine components

Machine Components	Maximum Permissible level of magnetism
Close clearance components viz. bearings and shaft journals, pad retainers, seals and gears as well as teeth of gear coupling	3 Gauss
Bearing Housings accommodating the pad retainer assembly, diaphragms, impellers etc	6 Gauss
Casings, pipe lines closely connected to the machine, other areas of the machine	10 Gauss

Actions Proposed to be Taken

1. The online voltage/current monitoring instruments are available in the market. It has been decided to install the suitable instrument, which will continuously display the values, which are to be considered as a critical parameter for the operation of the compressor train.
2. The temperature measurement of the drain oil is a very poor monitoring practice to know the condition of the bearing. It has been decided to install the suitable RTD on the journal bearings of the complete train to display the bearing metal temperature.
3. Measurement of the magnetism levels on all the components of the high-speed turbo machinery will be performed during each overhaul/inspection without fail.
4. 7200 Series vibration monitoring system is to be replaced by advanced vibration surveillance system, 3300 Series of Bently Nevada and the shaft vibration levels will be included in the trip logic to safeguard the machine against high radial vibrations.

Good Maintenance Practices to Avoid Catastrophic Failures due to Shaft Currents

Offstream practices

1. During all inspection opportunities, it should be made a practice to inspect the bearings, journals and other accessible components for the residual magnetism levels. If these levels are found beyond the above referred maximum permissible levels, it is highly recommended to perform degaussing using the suitable instrumentation and expertise.
2. During shutdown, the inspection of the bearings shall be performed to identify if there is any sign of spark erosion on the bearings or journal. The maintenance

technician shall be made aware of the patterns of spark erosion of the bearings. This would help in diagnosing the impending trouble in advance and the measurements of the magnetism levels can be performed with great care.

3. The tools and tackles used for the assembling/disassembling the high-speed equipment during maintenance shall be inspected for not having excessive magnetism levels which may otherwise get transferred to the machine components during use.
4. Any repairs are done using the welding techniques, it must be ensured that the earthing cable is connected to the part as close as possible to the area where weld deposits are to be made. The current flowing through the welding cables can introduce magnetism in the machine if it is wrapped or kept in close contact with the machine surface. The current between the welding electrode and the earthing electrode can also cause the induction of magnetism in the closeby components.
5. The grounding brushes shall be inspected and repairs shall be performed if required. The suitable reliable instrumentation shall be installed to avoid failure of the current draining system.

Onstream practices

1. Regular measurement of shaft currents and voltage (preferably once in fortnight) is advisable. Online measurement systems are available which may be studied and suitable protective equipment shall be installed for proper monitoring of the shaft current and voltage levels.
2. Inspection of the grounding brush shall be done, if possible at regular intervals otherwise at least whenever high currents/voltage levels are observed.

Coupling Assembly Problems

The synthesis gas back pressure turbine 103 jat lets down the 105.4 Kg/sq.cm steam to 38.3 Kg/sq.cm and uses this power to drive the synthesis gas compressor unit consisting of two barrels via continuous lubricated gear coupling. The technical data of the turbine are given on Page 1. The coupling details are given below:

1. Manufacturer: Kop-Flex Inc. USA
2. Coupling Type: Keyless hydraulically fitted gear type coupling
3. Hub Bore taper diameter, Inch: 3.8188 to 3.9115
4. Hub material: AISI 4140 Low Alloy Steel
5. Recommended Mounting and Dismounting Pressure, PSI: 20,000
6. Max. allowable assembly pressure, PSI: 26,600
7. Interference required: 0.002"/inch diameter of shaft

Subsequent to the damage to the rotor, it was decided to replace the same with the spare rotor available as an insurance spare. The installation of the coupling on both the ends of the new rotor shaft was an important activity as the mounting of the gear coupling sometimes lead to the damage to the shaft if proper procedures are not followed or if there are incorrect dimensions/surface finish either on the shaft or on the coupling hub bore.

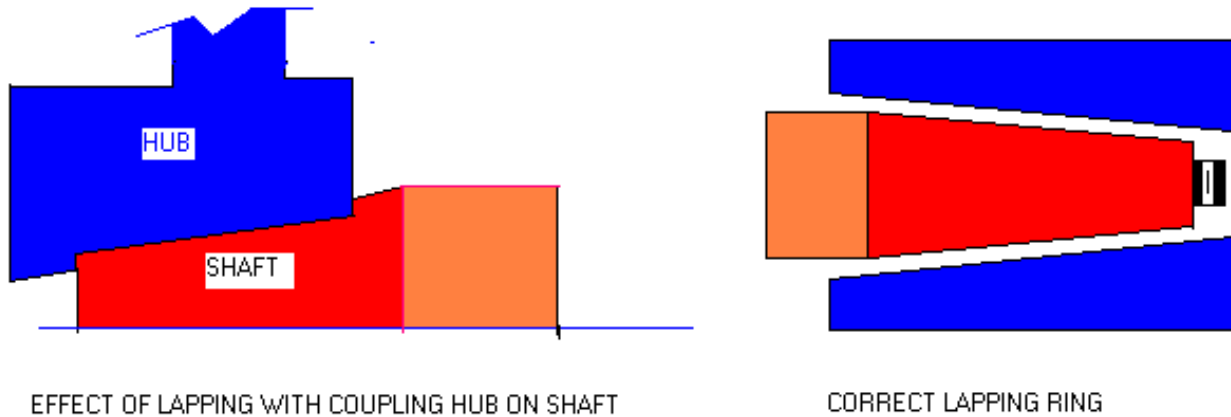
During the installation of the coupling hub on opposite thrust end (exhaust end) of the turbine rotor shaft, it was experienced that the drive required for the coupling was not

achieved even after raising the pressure to 26000 PSI on the hydraulic coupling installation unit. In order to transmit the torque from one shaft to the other through friction, the hub must grip the shaft tightly which can only be accomplished by advancing the hub on the tapered shaft by a specific amount called, 'drive' (0.400 inch in this case). The lapping of the coupling was performed prior to installing the coupling hub on the shaft, as required blue match was not available. Prior to lapping, approx. 45 to 55 % contact was available when checked using Prussian Blue. In absence of the ready made lapping gauges, the coupling hub itself was used to clear the minor high spots observed on the shaft during the blue match. A little lapping on the shaft using the coupling hub itself helped to improve the contact area to approx. 90 %.

After lapping operation and achieving the better contact area, the coupling hub was again taken up for installation. The drive required after expansion, using the hydraulic coupling installation device, was still not available. As against 0.400 inch drive required, only negligible drive could be achieved even with very high installation pressures on the hydraulic tool. It was concluded that the reason for the difficulty in the installation of the coupling hub was the improper lapping practice.

Figure 3 below shows the condition when the coupling hub itself was used to lap the taper surface on the shaft for removal of minor high spots. The localized steps created on the shaft as well as on the hub bore prevented the hub to get the required drive. Even micro step cut during lapping by coupling was so deep that the pressure exerted by the hydraulic installation device was insufficient to drive the coupling hub on the shaft with specified interference fit.

Figure 3 Result of lapping the shaft with the coupling hub



In order to remove the steps created by lapping with the coupling itself, suitable lapping tools (ring and plug tools) of cast iron were prepared to lap and match the taper of the shaft and the hub. These lapping tools were checked for the perfect match and then were used to lap the tapered surface of the coupling seat area on the shaft as well as for lapping the tapered surface of the coupling hub bore. It was ensured that the tool length covers the entire tapered length of the hub and shaft so that no step shall be cutting during the process of lapping. This procedure resulted in the successful installation of the coupling.

Conclusion

Knowledge gained out of the experience on failures of high speed machinery in the past has been greatly utilized to protect the equipment by installing suitable instruments/gazettes on old generation high speed turbomachinery (which were not provided with voltage-current monitoring system by the OEM) for avoiding high electrostatic and electromagnetic currents in operation. Reliability assessment and regular maintenance of the shaft grounding installations is a very critical activity and no efforts shall be spared to ensure the effectiveness of such system.

The use of instrumentation for monitoring the critical parameters viz. shaft vibration level, lubricating oil temperature, etc., shall be made more effective by designing suitable and practically feasible interlocking trip logic. This can help to avoid serious machinery damages and add safety to the operation. The spare turbine rotor and coupling hub could be utilized by creative approach and technical skills of the plant personnel in exhibiting the work capabilities demanded by the situation. The quality checking of the insurance spares and components shall be meticulously done to avoid occurrence of any emergency when these are required in service.

STAMICARBON'S GRANULATION TECHNOLOGY DIAMONDS, PEARLS & STAMICARBON GRANULES

by: Jo Meessen and Hans van Baal, Stamicarbon B.V., The Netherlands



I. Introduction

The name Stamicarbon is synonymous with know-how. Know-how in chemical processes, operations and training. As such, Stamicarbon has achieved a leading position in urea process licensing and continuously improved and innovated the urea technology resulting in the successful Urea 2000 plus technology. This innovative technology is commercially proven and applied in all recently awarded urea projects with capacities up to 3500 mtpd.

The changing market situation, with one of the major licensors of the fluid bed granulation withdrawing from the market, made Stamicarbon that commercialized its patented fluid bed urea granulation technology recently developed in the seventies and eighties, recently applied it in a 280 mtpd plant in GPO Azot, Grodno.

This plant is operating at or above design capacity with superior product quality meeting all product quality standards.

Stamicarbon is now in the position to license the total package urea technology: urea melt plant and finishing sections either prilling or granulation.

This paper will shed some light on the Stamicarbon granulation technology, the spraying nozzle principles, the process characteristics and the advantages of the Stamicarbon process.

2. History of DSM/Stamicarbon Research and Development of the Urea Granulation Technology

History

- 1976 DSM/Stamicarbon: orientation on granulation technologies
- spouted bed granulation
 - fluid bed granulation
 - pan granulation
- 1977 Research project within Fertiliser Division and Stamicarbon started
- 1978 Pilot plant testing (200 kg/h) in closed granulation loop
- 1979 Semi-commercial granulation unit (50 t/d) in operation at DSM urea unit in Geleen. Day to day operations by urea production department.
- 1980 Development and testing low pressure "film" sprayer concept 200 kg/h. Process design for a 1000 mtpd fluid bed granulation unit.
- Granulation development costs more than Euro five million
- Stamicarbon started cooperation with HFT
- 1994 HFT announces a restrictive licensing strategy for its fluid bed granulation
- 1997 Stamicarbon started cooperation with GPO Azot in Grodno, Belarus to install a 280 mtpd fluid bed granulation unit.
- 2002 Commercial production of high quality product in GPO Azot
- HFT announces again a restrictive licensing strategy.

During the late seventies and early eighties DSM/Stamicarbon developed and tested a new fluidized bed granulation process for urea and ammonium nitrate. At the time, similar processes were being developed by a number of our competitors. More specifically, some of them were looking for a shaping technology that would give better performance than prilling.

The research project into fluid bed granulation was initiated and directed by the Fertilizers Division of DSM. Other participants in the project were DSM's Fertilizer Research Department, DSM's Equipment Testing Department and Stamicarbon BV.

In 1994 HFT, who was market leader in the granulation technology announced a restrictive licensing policy, leaving its licensed contractors and several prospect without a finishing technology. This was a drive for Stamicarbon to restart its research and development of its patented granulation technology. This resulted in the cooperation with GPO Azot, Grodno and in a joint effort an existing but partly scrapped plant was re-designed and installed.

Now that HFT again decided to restrict its licensing in the future, Stamicarbon has its own commercially proven technology ready for licensing and design packages for scaling up to world capacities have been prepared.

3. The GPO Azot, Grodno Fluid Bed Granulation Plant

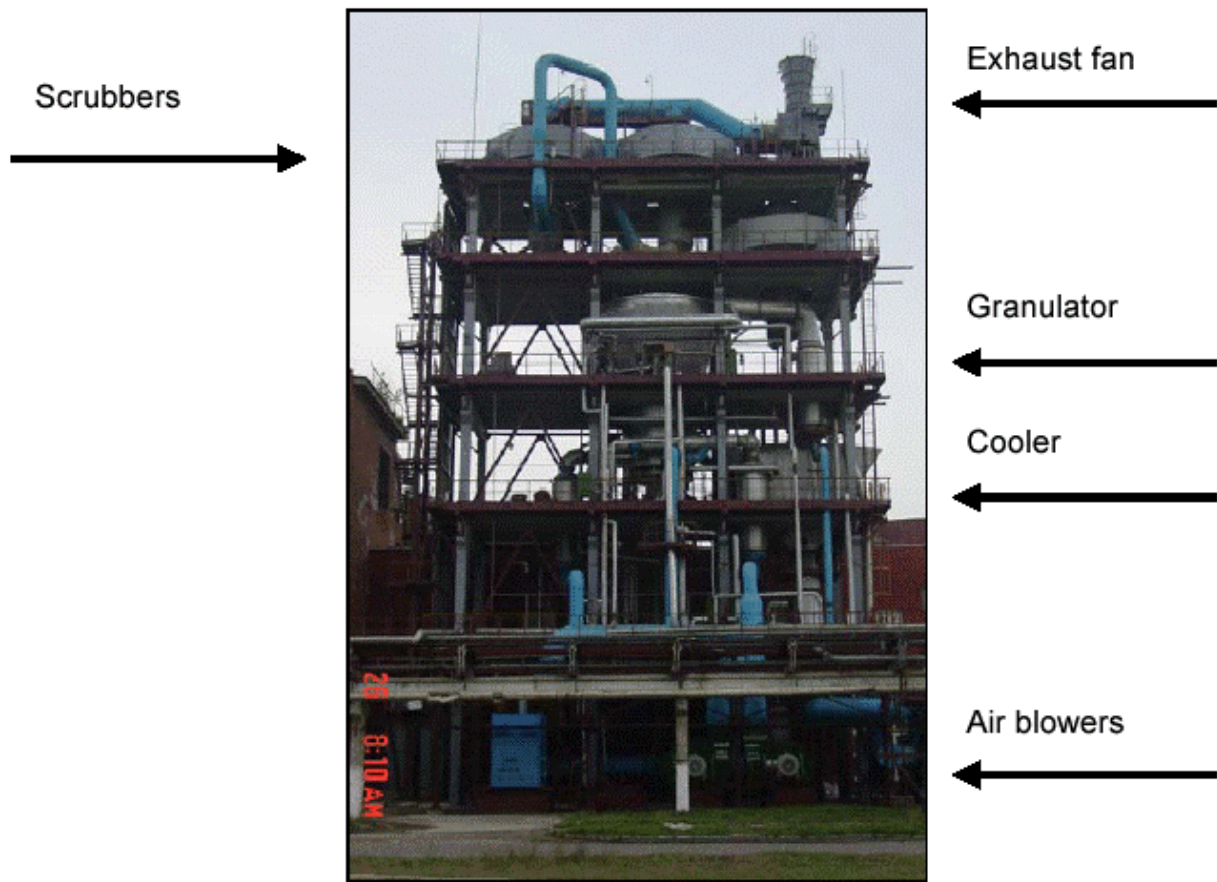


Figure 1: GPO Azot plant

With scrubbers, exhaust fan, granulator, cooler, air blowers, GPO Azot operates two urea plants in Grodno, Belarus. They happened to have its own designed granulation plant but this plant stood idle and was partially scrapped. GPO Azot and Stamicarbon decided to cooperate and to rebuild the Grodno granulator with Stamicarbon's technology. The design capacity for this unit is 280 mtpd. Use was made of the Grodno granulator housing but with the Stamicarbon designed fluidization plates and spray nozzles installed.²

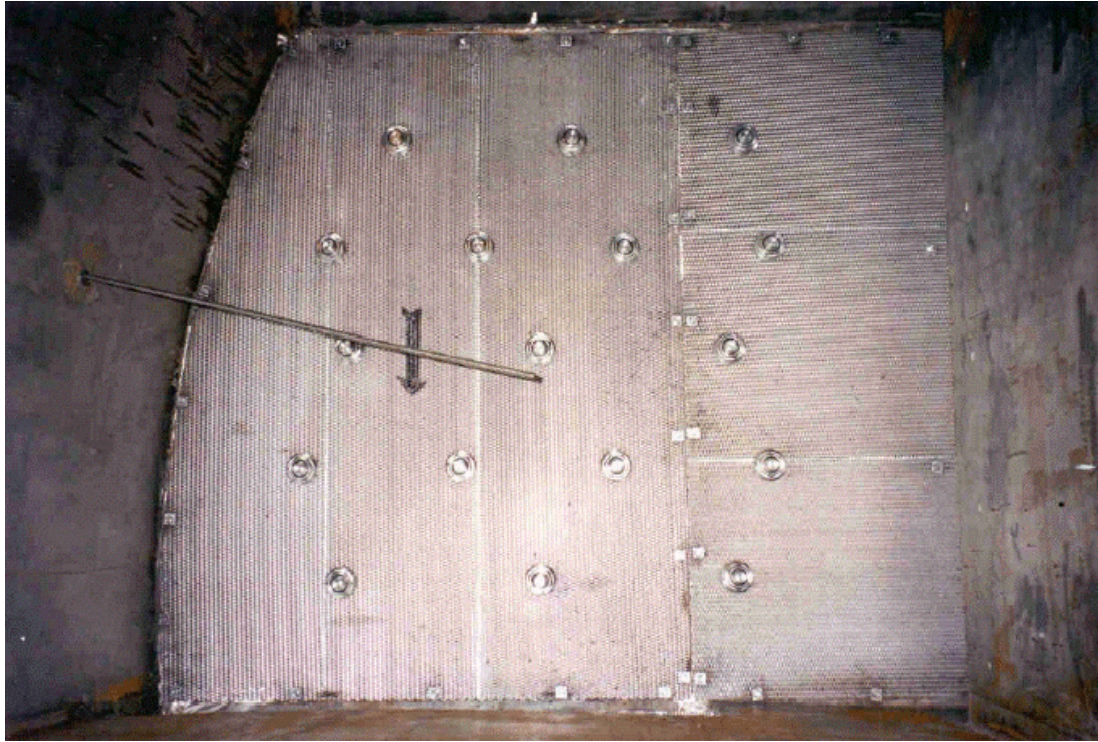


Figure 2: Internal fluid bed granulator

The plant went in operation in February 2002 and has been successful in operation at or above the design capacity since. The longest continuous run has been 25 days and was terminated due to problems in the urea melt plant. The product is of a high quality with a good roundness, good crushing strength and excellent size distribution.



Figure 3: Grodno granular urea

Typical Grodno product quality:

Nitrogen content	46.3	wt %
Moisture content	0.25	wt %
Biuret content	1.1 (note 1)	wt %
Crushing strength	3.	kg (on 2.8 mm dia granule)
Roundness	> 80	%
Formaldehyde content	0.20	wt %
Size distribution (2-4 mm)	> 95	%

(Note 1: Grodno operates with extreme long urea melt feed line to the granulator. Expected figure biuret for a new plant: 0.8 wt %)

4. Process Characteristics

In the Stamicarbon fluid bed granulation process, granular urea is produced by low-pressure 'film' spraying of liquid urea onto seed material in fluidized state.

The basic characteristics of this process are:

- the liquid urea is a concentrated solution (melt);
- the spraying occurs in the core of a fluidized bed by means of a large number of spray heads;
- the particle size enlargement is achieved by scale granulation, i.e., growth of the seed or nucleus granules by continuous solidification of very thin layers of urea melt onto the initial particles;
- formaldehyde (in the form of urea/formaldehyde pre-condensate) is added to the urea solution before spraying, as an anti-caking agent.

In order to spray onto a large number of solid particles simultaneously with no agglomeration, it is necessary to keep them apart. Fluidization is a very effective method to avoid contact between particles over a long period of time until they have cooled down enough.

During the entire residence time in the granulation zone of the granulator, each granule is repeatedly covered with a thin film of urea melt. The particle size growth is uniform and progressive with the residence time and results in a uniform shape and good quality granules.

5. General Process Description

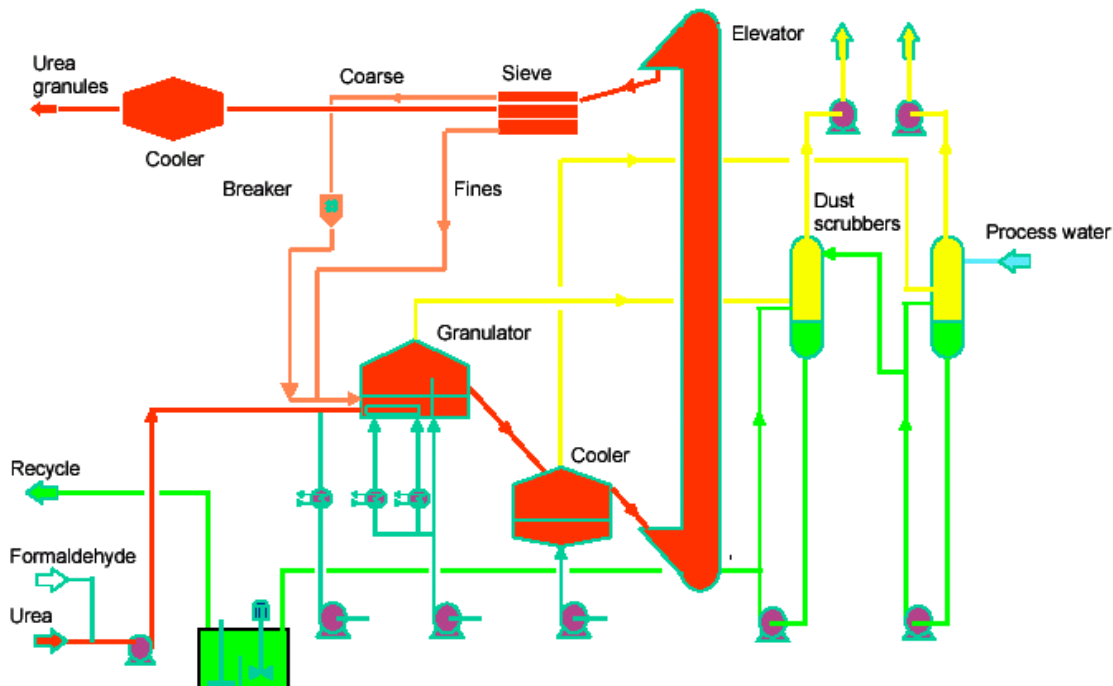


Figure 4: Process flow sheet granulation section

Urea melt, with a concentration of about 98.5 wt %, is transferred from the urea melt plant to the granulator by means of a urea melt pump

In the suction line of the pump urea formaldehyde is added. This injection of urea formaldehyde is used as granulation additive and anti-caking agent. It also improves the granule crushing strength and reduces dust formation during handling.

The formaldehyde containing urea melt is sprayed as a very thin film in a fluidized bed of urea particles in the granulator.

The granulator is divided in a granulation section and a cooling/conditioning section.

In both sections fluidization air is evenly distributed by a perforated plate to fluidize and cool down the granules. The fluidization air is delivered by a granulator air fan.

The seed (recycle) material is introduced into the first chamber of the granulation section, where it is sprayed upon by urea solution. As granules move along through the granulation section, their size steadily increases by layering to reach the required granule diameter at which the product finally flows out the granulator.

The urea melt is fed to the injection headers. The injection headers are connected to the urea melt line and the secondary air system.

Each injection header features vertically placed risers fitted with spray nozzles spraying the urea melt onto the seed particles. The secondary air, necessary to transport the granules through the urea melt film, is delivered by a sprayer air blower.

The granulated product flows from the granulation section into the cooling section (without spray nozzles) of the granulator to cool down and harden the granules before further processing.

The fluidization and secondary air and some urea dust are exhausted from the top of granulator by means of an off gas fan in the off gas line of granulator scrubber.

In the scrubbers the air is separated from the scrubbing solution. The clean air is thereafter exhausted to the atmosphere.

The scrubbing solution (diluted urea solution) is partly recirculated as scrubbing solution to the scrubber and partly pumped to urea dissolving vessel and recycled to the urea melt plant.

The product from the granulator is extracted by a extractor and flows through a lump screen which screens off any lumps to the granulate cooler.

The granulate cooler is a fluid bed cooler type. The fluidization/cooling air is delivered by a granulate cooler air fan.

The fluidization/cooling air, containing some dust, is exhausted from the top of granulate cooler and combined with the air from the product cooler and the dedusting air. This combined stream is cleaned in the cooler scrubber system.

By means of bucket elevator the cooled urea granules are lifted into main screens where granule selection occurs. The granules are classified in coarse product (oversize), final product (on-size) and fine product (undersize).

The final product is transported to the product cooler. In the product cooler the product is cooled down to a temperature of 40°C with air in a fluidized bed cooler. After the product is cooled down to the required temperature the final product is directed to the storage.

The dust loaded air from the granulate cooler, the product cooler and the dedusting air with some urea dust are exhausted from the top of granulator coolers and the dedusting points into a scrubber. The film type sprayer used in the granulator does not produce any fine size particles. The dust present in the granulator off-gas originates only from some attrition in

the fluid bed, as well as from some fine product produced in the crusher. Therefore relatively little dust is present in the off gas, and the dust that is present is relatively coarse (> 10 μm) Because of this (little, coarse dust) cleaning the off-gas from urea dust is relatively easy in our granulation technology.

The fine product is recycled to granulator and is used as seed material.

The coarse product is directed to crushers. After crushing the small-sized product is discharged to the granulator, or, alternatively to the granulate cooler.

In the urea-dissolving vessel the urea lumps from the lump screen are dissolved in the urea solution from the granulator scrubber.

6. Principle of the Low Pressure 'Film' Sprayer

After initial pilot plant tests using a single sprayer the process was tested in a 50 mtpd unit in DSM's urea plant. The regular shift operators of the urea plant operated this unit. The unit produced lots of about one thousand tonnes of product. This product was tested prior to shipping. The performance of this unit was highly satisfactory and yielded a lot of operating experience.

The 50 mtpd fluid bed granulation unit was designed on the basis of sprayer know-how available at DSM/Stamicarbon.

Concurrent with this project a new sprayer design was developed for an urea fluid bed granulation project. This new sprayer design, known as the low pressure 'film' sprayer, gave promising results and showed distinct advantages over the sprayer design used in the 50 mtpd unit.

The low pressure 'film' sprayer for urea fluid bed granulation was tested by DSM's Equipment Testing Department in a fully closed 200 kg/h granulation loop. This loop comprised all equipment normally encountered in a granulation loop, such as a granulator, granulate cooler, bucket elevator, screens, crusher, transport equipment, off-gas washing, fans, etc. These tests were very successful.

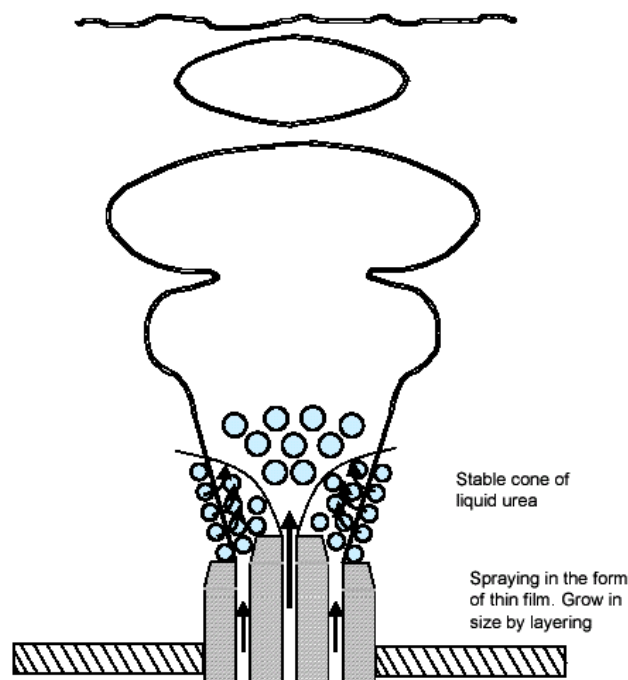


Figure 5: Cross section low pressure film sprayer

The 98.5 wt % urea solution is sprayed in the form of a thin film. Secondary air, supplied through an annulus surrounding the melt sprayer sucks the urea granules through this film. Each time a granule passes the liquid film it grows in size by layering.

Granulation by means of low pressure film spraying results in much less dust generation in the granulator as compared to high pressure spraying or two phase flow atomizing spraying, in which case the urea is atomized in a fine mist.

The low-pressure spraying technique as applied implies also that hardly any nuclei are formed in the granulator. To satisfy the number balance of granules in the granulation loop a certain number of nuclei are prepared by crushing and subsequent screening of the oversize particles.

Summarizing the advantages of low-pressure film spraying are:

- limited dust production in the granulator
- low spray energy per ton of urea
- formaldehyde content can be low
- low urea dust emission

7. Proprietary Equipment

The granulator and its internals are proprietary equipment and can only be purchased from the Stamicarbon approved suppliers. Stamicarbon will inspect points during the fabrication of the granulators.

The low-pressure 'film' sprayers can only be procured from Stamicarbon.

All other equipment has comparable dimensions as in other processes because the unit operations such as transporting, cooling, screening, crushing, scrubbing are comparable.

8. Emissions

The film spraying technique applied in the granulator ensures that no fine dust is produced in the granulator.

Because of the absence of fine dust present BAT values for urea dust in the granulator stack easily can be obtained using simple, low pressure drop, washing technologies.

If required, the ammonia concentration in the off-gas can be reduced using acidic washing technologies.

9. Conclusions

- Stamicarbon has a well proven fluid bed granulation technology
- Product quality achieved is excellent:
 - high roundness and uniformity
 - low formaldehyde content
- Low urea dust formation
- Overall investment cost is estimated to be comparable with all other processes on the market

- And last but not least the Stamicarbon granulation technology is available for licensing

Figure 6: Overall view Grodno granulation with direct loading facility.



AMMONIA LOADING LINES REPLACEMENT AT RUWAIS FERTILIZER INDUSTRIES (FERTIL)

by: Mohamed R. Al Rashid, Hashim M. Lari, Hussain I. Bukhari and V. Balashubramanian, Ruwais Fertilizer Industries – FERTIL, U.A.E.

Abstract

This paper describes the findings of Under Lagging Corrosion on our cold insulated ammonia loading lines, which are in cyclic service for a period of time and have given us a cause for concern. It also describes the actions taken to replace the lines and the future plans for maintaining the lines reliability and integrity.

Even though Fertil have adopted the preventive & predictive maintenance & inspection philosophy for the ammonia loading lines, it was surprising to find, that on close visual inspection after opening the insulation, approximately 56% of the lines length was observed with severe under lagging corrosion, leading to full replacement of the lines. (The length of the supply and return line each is 1900 meters).

Analysis of the reasons for the under lagging corrosion, concluded that moisture from the air was allowed to condense or freeze on or within the insulation, or on the cold pipe surface, as a result of the following contributory factors:

- Initial project follow-up deficiency.
- Deterioration and insufficient thickness of the insulation.
- Deterioration of the vapour barrier
- Damage / loosening of the metal jacket.

Replacement of the supply line was carried out on adhoc basis, by procuring the materials from various sources. The shipments have resumed without compromising on safety and integrity of the tanks.

Introduction

Construction of Ruwais Fertilizer Industries (FERTIL), commenced in 1980 and production started in 1983. Fertilizer products comprising liquid and urea are manufactured from the associated lean gas supplied from the onshore fields. The plant comprises of ammonia and urea processing units, having installed capacities of 1,050 MTPD and 1,500 MTPD respectively.

The plants have fully integrated utility units and storage/loading facilities. With consistent production above the design capacity and extensive process optimization, the company has continually improved its technology & productivity. Today FERTIL has become a very competitive company in the fertilizer industry worldwide.



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The complex was designed and constructed by Chiyoda Corporation of Japan, based on the technology, license and know-how of:

- Haldor Topsoe A/s, Denmark [Ammonia]
- Benfield Corporation, USA [CO₂ Removal]
- Costain Engineering, UK [Hydrogen Recovery]
- Stamicarbon b.v, Netherlands [Urea]



The ammonia plant initially had a rated capacity of 1,000 metric tons per day, which was later increased to 1,050 metric tons per day by incorporating the Hydrogen Recovery Unit.

Liquid ammonia is stored in two atmospheric storage tanks each having 20,000 MT capacities. The tanks, of double wall-integrated design, are kept at atmospheric pressure by a refrigeration system. Liquid ammonia from the tanks is transferred by 500 T/H capacity pumps, through the 12" (30cm) diameter supply and return ammonia loading lines directly to the ship. The lines are approx. of 1900 meters length each and cold insulated by polyurethane foam and metal lagging.

Under Lagging Corrosion

This paper describes the preventive and predictive maintenance of the ammonia loading lines and their replacement as a result of severe under lagging corrosion.

The management of FERTIL is committed to maintain the assets of the company in excellent physical condition even though operating the plants at much higher than the design

capacities. Safety and reliability are the key words of the company policy and accordingly, the preventive and predictive maintenance programmes are in place.

Preventive Predictive Maintenance Program

During the early years since installation, with the lines found in good condition visually, the maintenance program was mostly based on reactive monitoring as a result of any evidence of deficient corrosion control and unacceptable visual damage.

Maintenance based on active monitoring of the lines, was regularized a short time later when regular checks and planned inspections were done to evaluate and ensure the agreed criteria were being met before things could go wrong.

In 1994, as a result of this active monitoring, all the vent tappings and drain points including the smaller diameter branch lines (4" diameter and below) from the main 12" diameter loading lines, found with severe under lagging corrosion and pitting due to condensation and also with considerable wall thickness loss as measured by ultrasonic testing, were replaced as recommended. No replacement of the 12" diameter piping was done.

Some other random locations on the 12" loading lines, where the insulation was found either loose or damp with moisture and condensation, mainly on the jetty deck, were opened for inspection. The exposed line sections at these locations were found with moderate coating damage, surface corrosion and isolated pitting within acceptable limits.

After surface cleaning, re-coating was done and the insulation was renewed. Based on the trend monitoring from Visual and Ultrasonic testing on the lines, predictive maintenance thereafter was increased proportionately.

Damage and loosening of the insulation, insufficient insulation thickness and inadequate vapor barrier applied to piping operating at temperatures lower than the ambient air temperatures, will allow moisture and marine spray (in our case also mixed with urea dust) to condense or freeze on or within the insulation surface, or on the cold pipe surface. The inadequacy of the insulation and vapor barrier will lead to moisture migration through the joints, seams, penetrations and supports allowing the insulation to get wet, causing under lagging corrosion and causing it to become ineffective.

The insulated ammonia loading lines are in operation since 20 years and are constantly subjected to the following stresses and detrimental conditions:

- Movement of the lines due to expansion / contraction from extreme weather conditions in the area.
- Movement of the lines due to contraction / expansion when they are charged with liquid ammonia.
- Flow induced vibrations.
- Structural vibrations transferred to the lines during operation of the adjacent Urea conveyor gallery.
- Structural vibrations transferred to the lines on the jetty, due to tidal movements.
- Structural vibrations transferred to the lines from other operating lines.
- The corrosive action of marine spray.
- The effect of wash down on the Jetty deck.
- Extreme humid conditions with the moisture and condensation mixed with large amounts of Chloride and Urea dust.

In 2001, to check and ensure the reliability, safety and the integrity of the complete length of the Ammonia loading lines, the "Long range low frequency guided waves" technique to inspect insulated lines, was carried out through an external inspection agency. This method

of inspection was considered suitable, as it saved on downtime of the loading operations and also that the more tedious part of complete insulation removal was avoided.

The principal advantage of this technique is that it provides thorough initial screening and only requires local access to the pipe surface (i.e. removal of a small amount of insulation) at those positions where the transducer unit is to be attached.

This method uses low frequency guided ultrasonic waves, which can propagate over long distances. Depending on the attenuation caused by the insulating material, pipe condition or contents, it is possible to screen up to 30 ~ 50m of pipe from a single location.

The response to the metal loss feature, such as, corrosion or erosion, is a function of both the depth and circumferential extent of the material loss. Analysis of the waves distinguishes, symmetrical features such as circumferential welds, bends or flanges, but at the same time asymmetric features of local metal loss are identified by this technique, as top/bottom or mid-side wall losses.

The total length of approx. 3800 meters covering both lines, were inspected in 10 days, using this technique.

As a result of this exercise, a total of 250 meters of the line found with severe metal loss was earmarked for replacement.

Apart from the above long range guided wave inspection, visual inspection and ultrasonic wall thickness checks were also carried out at all locations on the pipe, exposed for placement of the transducers.

The findings are as follows:

- The metal lagging itself was found with few thru holes and showed signs of deterioration from aging.
- The vapor barrier and mastic compound were damaged.
- The polyurethane foam insulation was mostly damp from condensation & rust coloured, due to the line corrosion.
- The coating applied to the pipe was mostly deteriorated.
- The pipe surface was found with external moderate scaling corrosion & random pitting, with depths up to 4.0 mm, against the sound wall thickness of 6.4 mm.
- The welds, heat affected zones, anchor points and saddle supports wherever exposed, were also found in a similar condition with moderate external corrosion & pitting.

UT wall thickness measurements were carried out where the pipe surface was found satisfactory and the thickness loss was to a minimum as compared with the nominal pipe thickness.

Maintenance actions as follows, were carried out after the inspections:

- The pipe surface was hand cleaned by wire brushing.
- Deep pitting and external corroded areas on the pipe, welds and HAZ were reinforced with the application of supermetal compound.
- Re-coating of the pipe surface was done.
- Existing insulation and metal lagging was re-used over the application of new vapour barrier and mastic.

Having reservations about the inspection results of the Long Range Guided Wave technique, plans were drawn not only to replace the recommended 250 meters of pipe section recorded with metal loss and the full length of insulation and metal lagging due to its aging factor, but also to carry out a thorough visual inspection of the complete lines after they were sweep blasted.

A bench marking study was carried out with few other producers of ammonia in GCC and Asian countries. No serious problems were reported except for corrosion at the branch piping joints, vents and drains. Some of the producers checked the lines at random by removing the insulation, whilst some others monitored the lines with the help of wall thickness surveys using the radiographic technique at selected locations.

The work was initially planned for execution and completion in October 2002 between two consecutive ammonia shipments, but was extended up to end December 2002 due to the following:

The results from the thorough visual inspection concluded that 2,128 meters (56%) of the total line length was found in a severe condition, with extensive external corrosion and deep pitting. At one location after removing the external scaling corrosion on top of the pipe by sweep blasting, 3 holes were also found. The external corrosion on the pipe was more severe at the insulating joint locations, (both circumferential and longitudinal insulation layer joints and at the insulation contraction joints), as well as at the heat affected zones, where the ingress of moisture with dissolved salts had accumulated over time due to damage of the insulation joint sealer. The under lagging corrosion at these locations, was found with wide and deep grooves, having depths up to 4.0 mm. Pitting also with depths ranging from 0.5 mm to 5.5 mm was found randomly located throughout the lines length.

This problem was found to be unique to Fertil plant as compared with other producers of ammonia, using similar loading operations. The worst affected locations due to under lagging corrosion on both the supply and return lines, were in the off-plot areas up to the loading arm, (1700 meters line length each). The lines here are routed alongside the urea conveyor gallery. These sections need to be replaced.

The on-plot section of the lines (approx. 200 meters line length each), suffered little and isolated damage from under lagging corrosion and pitting. Replacement work required in these sections was minimal.

The problem of pitting over the pipe surface was found scattered randomly over the full line length, where a few meters were found in absolutely good condition, intertwined with areas where the pipe was found with moderate or severe pitting. No internal corrosion was observed at any section of the piping.

The original replacement plans were changed thereafter and it was decided to replace the off-plot sections of the lines with new pipes and the total line insulation, in phases.

This sudden change of plans made it difficult to source piping suppliers with available stock of better grade pipes, as only 300 meters of pipe had been procured to meet the line replacement recommended, following the long range guided wave inspection technique.

As the total requirement of replacement pipe (3,400 meters) of special material and of wall thickness as per original (Sch.20 pipe) were unavailable with the local stockists, it was decided to procure the length of pipe and fittings, sufficient to replace only the off-plot section of the supply line (1,700 meters). The available pipes procured were of Sch. 20, Sch.30, Sch.40 & Sch. STD. wall thickness.

Phase-1 : Was acted upon immediately, and the supply line was replaced at a cost of US\$ 1,254,000 inclusive also of initially sweep blasting the return line.

Phase-2 : For replacing the return line the following year, was based on the availability of pipes. The same is now scheduled for Oct ~ Nov. 2003. As we wish to maintain the original

project planning of using either of the lines for loading, the same size and insulated line is planned

Replacement activities of the supply line during Phase-1 included the following:

- Cutting and removal of the damaged pipes and insulation to the scrap yard. This included initial cold cutting of the line.
- Material verification of the new pipes at the vendors yard and on site.
- Stringing / erection of the new pipes. (The heavier wall thickness pipes were laid only at the ground level to avoid overloading the overhead steel piperacks.)
- Qualification of required number of welders to the specific WPS.
- Welding of the pipes and fittings on site.
- NDT requirements as per the line class including, preheat temperature checks, hardness tests, dye penetrant, ultrasonic tests and radiography, carried out by an external third party inspection agency.
- Inspection and testing of the isolation and remote operated isolation valves.
- Flushing, filling, hydrotesting and dewatering the line in sections of approx. 250~300 meters each for the complete off-plot replaced line. In case of the existing on-plot section of the line where only minimal replacements were carried out, this section
- was pressurized and depressurized in a cyclic manner, reaching 50%, 75% and finally 100% test pressure of 17Kg/cm²G.
- Surface preparation and coating of the reinforced concrete pipe sleepers.
- External coating after grit blasting, insulation and metal lagging application.
- Re-commissioning activities including drying of the lines after hydrotest, air blowing to remove dust, weld slag and internal debris, nitrogen purging, ammonia purging.
- Cooling down of lines after connecting the loading arm to the ship.

The return vapour line was taken in operation as it is, without any external insulation, since it serves just to return the liquid ammonia contained within the loading arm and any ammonia vapour from loading operations, to the evaporation tank / compressors, to be returned back to the storage tanks. The loading arms are then purged by inert gas or ammonia vapour. Some plants are using the return line without insulation. In our case, our original proposal was to use either of these lines for loading with minor modification, hence the same size line with insulation was installed.

Ammonia loading operations are on-going without any problems so far, even though the return vapour line is temporarily left un-insulated.

This paper has mainly highlighted the importance of inspection to check for corrosion under insulation right from follow-up of the contractors job at the plant construction stage.

As a result of our experience on the ammonia loading lines, other critical insulated piping of similar service within the process and off-plot areas, for both high and low temperature service, are under rehabilitation.

The following activities are on-going:

- Long sections of the piping insulation found ineffective where ice formation and condensation are observed are being replaced with new insulation of higher thickness, improved vapor barrier and metal jacketing.
- Some sections of the piping were also replaced in the last turn around in 2001, where moderate under lagging corrosion was found.
- Planning to inspect such critical lines line periodically , utilizing the development of pigging technique for the inspection of piping with lower diameter with short radius 90 degree elbows.

The following table includes the basic information & specifications for the above ground Ammonia, Supply and Return loading lines:

ITEM	As constructed (both supply & return lines)	As replaced (Phase-1, supply line only)
Line Diameter & Number	12" LA-41015 / 16	No change
Line Class	A2	No change
Line Length M	1900 each.	1700 (Supply line only)
Line Installation & Routing	Routed off-plot in Marine Environment and in parallel close proximity with the Urea Conveyor Gallery.	No change
Insulation type	Cold Insulation (C45)	Cold Insulation
Design Pressure Kg/cm ² G	17 Kg/cm ² G	17 Kg/cm ² G
Design Temperature °C	-35~70°C	-35~70°C
Operating Pressure Kg/cm ² G	Kg/cm ² G	Kg/cm ² G
Operating Temperature °C	-33°C	-33°C
Test Pressure	Piping on-plot : 25.5 Kg/cm ² G off-plot : 31.5 Kg/cm ² G	(Old)Piping On-plot : 17.0 Kg/cm ² G (New)Piping Off-plot: 25.0 Kg/cm ² G
Fluid	Liquid ammonia / ammonia vapor	Liquid Ammonia / Ammonia Vapor
Line Pipe Material / Schedule.	ASTM A-333 Gr. 6 / Sch. 20	Dual Spec..ASTM A-333 Gr-6, API 5L X52 / Sch.20,30,40,STD
Line Fittings Material	A420 WPL6, SMLS, BW	A420 WPL6, SMLS, BW
Welding Process (Root/ hot pas	GTAW	GTAW
Filler wire	ER70S-2 (only root pass)	ER70S-2 (Root & Hot)
Welding Process (Fill & Cap)	SMAW	SMAW
Electrode	E7018	E7018-G
Line Expansion taken care by	Expansion Loops (7 Nos.)	No change
Line Supports type	Saddles, mounted on concrete sleeper	No change
No of Anchor Points	11 Nos. on each line	No change
Line External Coating	Primer 50 microns after grit blasting	Solventless 2 component amine cured epoxy. Carboguard 703 , 600 microns DFT. after grit blasting SA 2.5
External Insulation Material	Polyurethane foam 45 mm thk. x 1 layer. Density : Min. 2 lbs/cu.ft (6 lbs/cu.ft) at supports.	Polyurethane foam 45 mm thk. 60 Kg/m ³ outer and inner layers. (120 Kg/m ³ at supports)
Weather Proofing	Mastic weathercoat, reinforcing fabric and vapor barrier.	Fibre Glass Fabric + Vapor barrier Mastic
Metal Jacketing Material	Aluminium Jacket, 0.4 mm thk. with moisture barrier.	Stainless Steel grade 316L Jacket of 0.8 mm thk with moisture barrier.

INFLUENCE OF THE ROCK IMPURITIES ON THE PHOSPHORIC ACID PROCESS, PRODUCTS AND SOME DOWNSTREAM USES

by: Tibaut THEYS – Prayon Technologies S.A., Belgium

Summary

Production of phosphoric acid and phosphatic fertiliser is influenced by soluble impurities contained in the phosphate rock. They will influence the process, the quality of the acid and the gypsum produced as well as the downstream units using this phosphoric acid. This article, through a review of existing publications, summarises their impact on the corrosion, filtration, scaling, phosphoric acid, gypsum, and fertiliser qualities.

Introduction

Phosphate quality has always been a subject of concern and numerous articles have been written treating the impact of some foreign ions on the production of phosphoric acid and fertilisers.

Considering the production of phosphoric acid, all the elements that are not PO_4^{3-} or Ca^{2+} are considered as “impurities”. If not soluble, these impurities have a very limited impact on the process; erosion of stainless steel equipment and an impact on the filtration of gypsum as these are the only phenomena that can be detected.

Once the ions are in solution in the acid, other problems such scaling, corrosion, production of sludge, increase of acid viscosity and process instability can occur. Such phenomena can be produced by the presence of one single ion but also by the combination of several of them. For example, if the conditions are favourable, a small increase of the potassium, aluminium or iron content of an acid can produce a large quantity of sludge made of so-called X compound.

These effects are not always detrimental to the process. Silica and aluminium, for example, are often added to the reactor to improve filterability. With such addition, filterability will not be the only improved factor; corrosion speed will be reduced due to the reduction of free fluorine in the reactor.

When the production of phosphoric acid was in its early days, rock quality was an issue in order to find the raw materials giving the best performances. Nowadays, the task of the production staff is to use the phosphate rock they have in their warehouse, to understand its impact on the process and to choose the blend of rock or the appropriate additive that should possibly be added to compensate for any deficiency.

The impact of impurities on the process will be considered through the following aspects:

- process chosen to produce phosphoric acid;
- corrosion;
- filtration;
- phosphoric acid quality;



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- gypsum quality;
- scaling;
- fertiliser production

At the end of the article, charts will summarise the different observations.

Process Choice

Choosing a phosphoric acid process has always been a difficult task. It is based on the overall investment cost, the energy requirement, the calcium sulphate produced, the intended use of the acid ... and the raw materials. Impurity content of the phosphate rock can in some case disqualify a process from the initial selection. It is the case, for example, of the lanthanide content of the rock (La, Ce, Y) which, even in very limited quantities, slow down the conversion of Hemihydrate to Dihydrate (Witkamp, 1989). Rocks containing this element thus disqualify Hemihydrate – Dihydrate processes.

Phosphate containing a high Al content can also cause problems with Hemihydrate – Dihydrate processes as it slows down the re-crystallisation of Hemihydrate to Dihydrate. Indeed, aluminium fluoride (AlF_5^{2-}) increases the HH solubility by up to 40% close to the DH solubility (Martynowicz et al, 1996). To temper this problem silica is sometimes added to the rock (Anonymous, 1993).

CO₂ content can also be a limitation with a process having a vacuum flash chamber as the reactor. Indeed, the high CO₂ content in the rock produces a very large quantity of foam inducing a slurry carry over that can hardly be controlled by the use of high quantity of defoamer. Note that a limited amount of carbonate is often seen as a positive feature as it “chemically” grinds the rock during the reaction increasing the speed of reaction and preventing coating (Smith and Bourgot, 1991). A content of 3 to 5% of CO₂ is often appreciated in the rock even though it would result in higher sulphuric acid consumption.

Corrosion-Erosion

Impurities contained in the phosphate rock have positive or negative impact on the corrosion of the stainless steel parts used in the process. Those increasing the corrosion or erosion are: F, Cl, S or S²⁻, SO₄²⁻, insoluble SiO₂ (erosion) and in some case ions (salts or complex) capable of oxidation - reduction reactions as Fe³⁺.

Impurities increasing the speed of corrosion-erosion

In the reactor, the presence of chlorides can cause severe increase in corrosion rates, especially in the case of the high strength-high temperature processes. The chloride being increased "pro rata" to the P₂O₅, if this is linked with a higher operating temperature, the corrosion rate is greatly increased. PRAYON's PH range of processes have different operating parameters from the other High Strength processes, operating at a lower temperature in the second zone of the Hemihydrate Attack section, and as such are much less sensitive to the chloride level in the phosphate (Smith, 1991).

In the case of under vacuum concentration unit %P₂O₅ and Cl content are not anymore linked. Independently of the Cl content in the weak acid the chlorine content in a 54% P₂O₅ acid leaving the concentration is always between 150 and 300 ppm.

The corrosive effect of chloride is greatly reinforced by the sulphate and fluor content in the acid. F- and SO₄⁻⁻ ions have a synergical effect on the corrosion and, for a given chlorine

content, greatly increase the speed of corrosion of stainless steel alloys (Becker, 1997 and Becker, 1980)

Considering corrosion, three groups of phosphates, according to their chlorine content, can be defined: low, <300 ppm; medium, 300 to 700 ppm and high, > 700ppm (Schorr, 1993).

Stainless steel alloy withstand corrosion once they are passivated. The usual explanation of Passivity is that a thin protective film – either metal oxide or chemisorbed oxygen- forms on the surface of the metal, preventing further contact with the electrolyte (i.e. the phosphoric acid) (Anonymous, 1965). This layer can be destroyed in the presence of reducing substance.

Certain rocks contain pyrite which is converted to H₂S, HS⁻, S₂⁻ during the reaction. Some calcined rocks contain organics matter not fully oxidised during calcination. These reducing substances impair the corrosion resistance of the passive alloys utilised in phosphoric acid service. In some cases MnO is added to maintain the passive condition (Schorr, 1993). When Simplot went to calcined rock, (Bierman and Long, 1981) they had serious corrosion problems (due to the change of redox potential of the acid) which were initially resolved by the addition of MnO₂ and permanently by the aeration of the reactor generated by the foam breaker blades on the agitators.

If the SiO₂ source is from a solid insoluble in phosphoric acid, erosion can be observed. It is mostly observed once the insoluble silica level is high (Halaseh and Naber, 1996).

F⁻ is also a very corrosive anion. Its corrosiveness is considered similar to the chlorine. Often it is “passivated” by reacting with silica or aluminium (either contain within the phosphate or add as an additive) and others forming much less aggressive complex ions.

Impurities decreasing the speed of corrosion-erosion

All forms of SiO₂ are not equally soluble in the phosphoric acid (and thus able to react with F⁻): it depends on the mineralogical characterisation of the ore. Diatomite and kaolin are very soluble while olivine, or muscovite are almost insoluble in phosphoric acid (Smith, 1991).

Soluble SiO₂ has a very positive impact on the corrosion as it complexes free fluorine. The reaction products H₂SiF₆, a strong acid with medium corrosive capability (Smith, 1991; Halaseh and Naber, 1996). Besides silica, other elements such as Al, Mg can also form complexes with fluorine reducing its corrosive capacity. The fluorinated complexes produced are (AlF_x) where x = 1 to 6 and MgF₂.

Schorr (1993) has demonstrated the impact of the free fluorine on corrosiveness. He defined a fluorine complexing ratio : F / (SiO₂ + Al₂O₃ + MgO) and showed that the higher this ratio, the higher the corrosion speed.

Filtration

The main impurities having an impact of filtration are silica, aluminium and fluorine. Depending upon its content and under which form it is found in the filtration section silica can have a positive or negative impact on the filtration. If the silica source is made of quartz or other insoluble salts in the phosphoric acid and if its particle size is quite small (less than 50 µm), it can impede the filtration requiring larger surface of filtration (Halaseh and Naber, 1996). If soluble, by reacting with the free fluorine it will impede the production of gypsum needles and promote formation of gypsum crystals, which are easy to filter (ratio length on width of the crystals close to 1, cluster).

Combined with F, Na or K, silica can form fluosilicate salts scaling on filter cloth, pans and piping reducing the filtration rate. Chukrovite is a precipitate also commonly found that has similar scaling properties. Process parameters, mostly temperature can emphasize these scaling.

If it is linked with fluorine, aluminium improves filtration. It seems to form AlF_5^{2-} salts that are incorporated in the calcium sulphate crystal. This incorporation retards the growth of the crystal along the fast growing direction promoting the formation of crystal having a square or cluster shape, easier to filter (Martynowicz et al, 1996).

High aluminium containing rocks offer the best filtration rate. This filtration effect however depletes somewhere beyond 1.4% Al_2O_3 content in rock (Becker, 1997). Considering several sedimentary phosphate, Becker (2001) shows that the increase of filtration rate due to the presence of Al is about 1 t $P_2O_5/m^2/day$.

Magnesium in phosphoric acid has a dual effect on the crystallisation, initially combining with the fluorine it improves crystallisation but above a certain threshold its effect in increasing the viscosity of the acid phase causes a rapid deterioration of the filtration rate. This value depends on the presence of other impurities but is of the order of 2-3% (Smith, 1991). With Florida rock, the presence of 1.2% MgO already decrease the filtration rate and the recovery. Once the content reach 1.83%, the reduction is very important (Leyshon, 2000).

Halaseh (1997 and 1998) defines a Fluorine Complexing Ratio as:

$$FCR = \frac{\frac{\%F}{19}}{\frac{\%Al_2O_3}{17} + \frac{\%SiO_2}{15}}$$

He has tested several phosphates of different FCR ratios. He observed that for FCR values between 1.378 and 0.42: as the ratio decreases filterability of the slurry increases, % P_2O_5 of the acid increases and corrosion decreases. For ratio lower than 0.42 filterability decrease due to the presence of un-dissolved silica salts and poor crystallisation.

Similar work was performed on Zin and Oron phosphates showing the positive impact of clay addition (Schorr, 1996).

Kruger and Fowles (1998) showed that Na and K has an effect on the supersaturation curve of calcium sulphate promoting the production of smaller crystals. On the other hand, they observe that if aluminium initially promotes crystals growth and thus filtration rate, brings also some disadvantages. At high aluminium to fluoride ratios, Al increases the acid viscosity and density and therefore has a detrimental effect on filtration at those levels. Concerning Mg, they observe that this element has little effect on the crystal morphology itself.

Organic matters present in the phosphate ore, those used for the beneficiation of the phosphate, those added to the reaction section as defoamers or crystal habit modifier, can also affect the gypsum crystallisation (Smith 1991, Theys and Roblin, 2002).

Rare earths in the slurry liquid phase above 0.18%, impair and also eliminate the advantageous effect of aluminium fluoride complex on crystallisation of calcium sulphate and consequently, deteriorate slurry filtration when using Kola rock (Halaseh and Naber, 1996).

In the case of igneous phosphate rock, potassium and iron seems to have a positive effect on the filtration of gypsum within a narrow range of concentrations (Kruger et al, 2000). This effect is not observed with Brazilian rock (Sinden, 2003).

Phosphoric Acid Quality

Once the soluble impurities contained in the phosphate are found in the acid they will have an impact on the physico-chemical characteristics of the acid but also will influence the down stream production.

Main soluble impurities as MgO, Al₂O₃, Na₂O, CaO, K₂O, Fe₂O₃, SO₄²⁻, SiF₆²⁻ have an impact on the density and the viscosity of the acid. This effect can be forecast from analysis of the acid (Becker, 1997).

MgO is often found in the sedimentary rock as dolomite (Astley 2001). It increases the viscosity of the acid produced. Acids with a higher MgO content have often a lower P₂O₅ in order to ensure the filterability of the slurry. The amount of gypsum solid present in the slurry is also lower to overcome this problem. For example if the high MgO Karatau phosphate is used, to ensure the production of phosphoric acid, reactor must run at 20-23%P₂O₅ and at 90-95°C in order to reduce the viscosity (Halaseh and Naber, 1996).

If the rock contains a high quantity of carbonate and some organic matters, the acid produced can form foam (Halaseh and Naber, 1996). If these foams which appear in the flash cooling section they can be carried over to the condenser causing a pollution of the cooling water. This phenomenon can be reduced or avoided by the injection of a defoamer. Hemihydrate processes are more susceptible to foaming as they have a more viscous acid and thus need a higher defoamer addition rate.

If acid is being produced for animal feeds, such as dicalcium phosphate, low levels of fluorine must be obtained by defluorination. It is usually done by an addition of Silica to the acid in order to promote the stripping of SiF₄. Nevertheless, if Al and Mg are present in the acid, they form stable complexes with the fluorine, SiF₄ formation will be reduced and defluorination will be more difficult or even impossible. It explains why when feed grade acid is produced an organic crystal habit modifier is preferred to clay.

Cadmium and other heavy metals can be an issue on the acid quality (Van Kauwenbergh 2002) when downstream production is considered. The main impact is the level of heavy metals in the fertiliser. Acid produced by the Hemihydrate route contains less Cd than by the Dihydrate route. The Cd cocrystallise in the calcium sulphate. This uptake of Cd by co-precipitation is even higher if anhydrite is considered.

Cd removal is possible by calcination of the phosphate, co-precipitation or ion exchange extraction. Davister (1992) did an evaluation of these routes and their respective cost.

Depending upon the P₂O₅ content of the acid, several other salts beside calcium sulphate can precipitate in the acid. In the case of 27-30% P₂O₅, major co-precipitation examples are: fluosilicate of Na or K, fluo-aluminate (Ralstonite) [AlF₆MgNa], Chukrovite [(SO₄Ca)_x(SiF₆Ca)_y(AlF₆CaX)_z12H₂O]. During / after concentration the major precipitate are: X-compound [(Fe,Al)KH₁₄(PO₄)₈ 4H₂O]; Mg,Al (SO₄)₂F nH₂O, fluosilicate of Mg, Ca, Al and others (Becker, 1997).

Where acid must be shipped for international consumption, the acid must normally meet MGA (Merchant Grade Acid) specifications. The suspended solids content should be less than 1% on arrival. Florida acid, with its high Al₂O₃ content, suffers post-precipitation during several weeks after concentration. A low Al₂O₃ content in the acid simplifies the clarification process and reduces the inventory, as shorter retention times are required for

ageing (Smith, 1991). Some igneous rocks suffer of the same post-precipitation problems. In the case of the expansion of Foskor plant in Richards Bay, large desupersaturation and settling tanks were installed for the merchant grade acid (Kirsten et al, 2002).

Acid can have a dark colour due to organic matters. Depending on the use of the acid, this colour has to be removed in some case. This removal can be done by the addition of adsorbents to adsorb the carbonaceous impurities followed by filtration (Schorr, 1993). Another option is to use active carbon or oxidising agents such as nitric acid, H_2O_2 ...

H_2S can cause health hazard if present in the acid. PCS Phos acid units operating on the calcined N.Carolina rock monitor the presence of H_2S on the filter (Sinden, 2003).

Calcium Sulphate

Phosphogypsum can in some cases be used in the construction industry. The four main uses are:

- as a retarder in the production of cement
- for the production of wallboard/plasterboard
- for the production of gypsum blocks
- for the production of Stucco plaster

Depending each of the usage gypsum quality requirement varies. The main impurities that are considered are: P_2O_5 , F, Cd (ppm), Na_2O , pH, organic matters, radioactive elements (Smith and Theys, 2000).

Even if the produced calcium sulphate is not used for other applications, its impurities content can have an impact on the Phosphoric acid production. Al_2O_3 and Fe_2O_3 form salts that contain P_2O_5 (Halaseh and Naber, 1996). They thus increase the P_2O_5 co-crystallised loss. In the case of aluminium this effect can mainly be observed with Hemihydrate process.

For Becker (1997), the major ions entering the calcium sulphate by co-precipitation are: HPO_4^{2-} , AlF_5^{2-} , Cd^{++} , Rare earths and Y^{+++} . In the case of Cd, the portion of this ion that precipitates is a function of the calcium sulphate form. In the case of Dihydrate, about 20% of the Cd of the phosphate co-precipitates. This value increases to about 50% for Hemihydrate and 95% for Anhydrite. The Prayon phosphoric acid plant of Engis is a Central-Prayon Process (Dihydrate – Hemihydrate process) using mainly igneous rock. They observe that about 85% of the rock Cd is contained in the Hemihydrate leaving the filter.

In the case of Dihydrate processes, aluminium has a stabilising effect on the dihydrate phase. High Al containing rock (1-1.5% Al_2O_3) can still operate within Dihydrate precipitation phase at temperature over 90°C and with a phosphoric acid concentration around 29% P_2O_5 (Becker, 1997).

Considering the radioactive elements, about 80% of the Ra-226 follows the phosphogypsum, while about 86% of the U-238 and about 70% of the Th-232 are found in the phosphoric acid (figures vary with the process). Due to the chemical separation the radioactivity of phosphoric acid is significantly lower than that of the phosphogypsum (Anonymous, 2000). Radioactivity level of gypsum can be an issue especially if the gypsum is used undiluted for down stream application according to the radioactivity level of its phosphate source.

Scaling

Silica in the acid is considered as a positive feature as it combines with fluorine reducing the corrosion potential of the acid, improving the slurry filterability and enhancing defluorination. Nevertheless, if in too high content (or the amount of fluorine too low) it can cause scaling problems in degassing ducts or cooling water systems (Anonymous, 2001). Indeed, silica reacts with fluorine to form H_2SiF_6 that can evolve from the acid in the form of SiF_4 . Once this product enters into and contacts with water it is solubilised and forms H_2SiF_6 and SiO_2 precipitates. In degassing ducts these silica solids can form very hard scaling especially if the condensation occur in a place where the temperature is above 60°C . Hemihydrate plants are especially susceptible to this phenomenon.

When this absorption is done by the condenser cooling water, depending on the quality of water, several types of scaling can be observed. If the water contains a high amount of Na or K (like in the case of sea water) fluosilicate scale will be form. They are essentially formed at the inlet of the condenser where the flow of water is high enough to bring the sodium and potassium ions and small enough to be under the solubility constant of fluosilicate salts. If process water is used silicate salts (CaF_2 or fluosilicate) can be formed that can accumulate in the cooling towers. This point emphasises the interest in using Fluorine recovery tower in concentrations units to avoid the fluosilicate precipitation solids in the cooling system.

Some plants that use pond water containing Na or K to stack the gypsum face fluosilicate scaling in their return water piping system. These scaling are remove by swapping the slurry pipe and the return water pipe on a regular basis, the erosive effect of gypsum allows the removal of the scaling.

Fluosilicate salts of sodium and potassium can also lead to the formation of scaling in the filtration circuit. This is mainly due to the sudden cooling of the slurry during the filtration (Halaseh and Naber, 1996).

To slow down this problem table filters are fitted with hot and high pressure cloth wash and, sometime, a direct injection of steam on the filter cloth. In Prayon filter, the scaling are reduced by a fast separation of the gas and the liquids and the possibility to inject steam in the central valve to maintain the temperature in the filtration circuit. Moreover, the Prayon "Digestion" section design ensures that the slurry fed to the filter is fully de-supersaturated (Smith, 1991).

If the soluble SrO content exceeds 0.5% it can cause serious problems of scaling in concentration heat exchanger section (Halaseh and Naber, 1996). These scalings can hardly be removed by washing and needs mechanical cleaning to be removed. Prayon's plant in Engis had been confronted with that problem in the past. It was solved by using stainless steel pipe submerged in an acid bath, that scale from the outside of the tube and thus could easily be washed with high pressure water.

All the Brazilian igneous rocks contain significant levels of SrO, 0.5-1.1% but it is present in the form of the mineral celestite (the natural SrSO_4). As this form is a highly insoluble mineral they do not face scaling problems.

One of the most surprising scales is chukrovite: $(\text{SO}_4\text{Ca})_x(\text{SiF}_6\text{Ca})_y(\text{AlF}_6\text{CaX})_z12\text{H}_2\text{O}$. These crystal have the shape of a small double size pyramids (two pyramids on a common basis), which precipitates from filter grade acid while cooling but essentially clogging filter cloths (Becker, 1997).

Another crystal having a similar form is a solid having the composition: $\text{Ca}_3\text{Al}_3(\text{RE})\text{SO}_4\text{F}_{13}$. Where RE can be formed from rare earths or Yttrium. In some case Al^{+++} can be replaced by other cations as Ca^{2+} or Si^{4+} and F^- by OH^- (Robinson, 1978).

Fertiliser Production

Depending upon the type of fertiliser produced, impurities can directly influence the quality of the product or the production itself. Hallsworth and Enriquez (1980) show the impact of the main impurities on the DAP quality.

MgO, Fe₂O₃, and Al₂O₃, also called MER, affect (Palm 1986, Astley, 2001) the DAP grade by taking the place of H⁺ ions thus reducing the room available for nitrogen or phosphate (if they are linked with other anions than PO₄³⁻). Moreover, MgO by its impact on the viscosity can increase the scaling speed of pipe reactor.

Although both R₂O₃ and MER are used frequently they have little scientific value as they do not fully express the different effects of Al, Fe and MgO.

MER (minor element ratio) is defined by the formula :

$$\frac{\text{Iron + Aluminium + Magnesium}}{\text{P}_2\text{O}_5 \text{ in phosphate.}}$$

The higher the ratio, the higher the risk problems during the production of DAP. Astley (2001) considers that this ratio should be corrected depending upon the type of acid used. If 54%P₂O₅ acid with low solids content is used to produce DAP, part of the iron is removed with the sludge, then the formula should be corrected.

The new formula becomes:

$$\frac{0.5 \text{ Iron} + \text{Aluminium} + 1.5 \text{ Magnesium}}{\text{P}_2\text{O}_5}$$

The higher ratio on the MgO showing its higher impact on the production of DAP is due to its total solubility and its low tendency to produce post-precipitate.

Iron produces phosphate salts that are citrate insoluble during the production of DAP (Lloyd, 1988). The iron salts can have the form of the X compound or a pseudomorphs of FeNH₄(HPO₄)₂. Another compound that could be formed due to presence of impurities is MgAl(NH₄)₂H(PO₄)₂F₂.

The iron phosphates are only citrate insoluble if they are kept at low Mole Ratios for significant time 10-20minutes at elevated temperatures. It has been possible to produce MAP/DAP and ASP with very low CI's using very contaminate acids (Sinden, 2003)

MAP, due to its lower ammoniation requirement, is less influenced by the presence of impurities in the acid. Al and Fe are considered as positive impurities in this production as it improve the mechanical resistance of granules (Brownlie, 1978). Sinden (2003), does not consider that iron has this positive effect. For him aluminium (with at least 0.2%) and MgO are the impurities improving the mechanical resistance.

Impurities content in the phosphoric acid used for the production of TSP can be an issue as they take the place of protons and reduce the water-soluble content of the phosphoric acid. Indeed, this lack of H⁺ reduces the ability of the phosphoric acid to react with the phosphate rock (Sinden 1993). In some cases this problem can be overcome by adding some Sulphuric acid.

Phosphoric acid analysis is thus essential for the production of TSP. Sinden (1993) considers that a good TSP can be done with a "poor" phosphate provided that the purity of the acid is good enough. Beside iron and aluminium, MgO is also considered as a major impurity. These elements have an impact on the physical properties of the TSP.

A less known impurity known to have a negative impact on the production of TSP is Titanium. Some Brazilian rocks contain a high level of this element. It reacts with the phosphate to form a calcium-titanium phosphate salt lowering the water soluble P_2O_5 content of the TSP (Sinden, 1993).

Cd and other heavy metals are becoming a quality concern in the fertiliser production. SSP only contains the Cd inherited from the phosphate, in DAP the Cd is included in the acid and in some case the sludge (containing a high content of Cd due to coprecipitation), MAP as it is often produced from sludge contains also a relatively high content of heavy metal, even higher than that in the DAP produced from the same acid. TSP has the Cd content of the acid and of the phosphate (Van Kauwenbergh, 1992).

Legal limitations on Cd in fertiliser start to appear. These limitations vary wildly from one country to the other and are subject to regular changes. European Community has not yet define a legal limit. Belgium and Luxembourg voluntarily limit the Cd content in fertiliser to 90 mg Cd/kg P_2O_5 . In California (Anonymous, 2001), the limit will be reduced to 400 mg / kg P_2O_5 on Jan.1, 2004 ! Indeed, a recent report (Anonymous, 1999) on fertiliser risk assessment shows that Cd is not an health issue in fertiliser.

Besides Cd, almost all the impurities contained in the fertiliser have greater or less impact on the health and / or the environment. Dylevskaya (2002) as well as Kiiski and Milbone (2003) lists the main one as well as their potential negative impacts.

Depending upon the content of radioactive elements in the fertiliser, radioactive element as Rd, U_3O_8 , K_4O , Th could be regulated in the future (van der Westhuizen 2002). In 2000, under the EU legislation, none of the phosphoric acid or phosphate in the world will see their commercialisation restricted by their radioactivity (Anonymous, 2000).

Organic matters contain in the acid or the phosphate can cause odour problems during the production of fertilisers. These odours are mainly due to the Mercaptan (MSH where M is an organic molecule) evolving. They can be strongly reduced by an addition of an oxidising (as $NaClO$) in the scrubbing system.

Conclusion

Considering their impact on the process, the product qualities, their interaction between them, impurities contained in the phosphate can be considered either as positive or negative factors.

It is thus always a difficult task to evaluate a phosphate rock and to define its implication on the process. One can then understand why phosphoric acid and fertilizer productions have always been considered more as an art than a science.

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Overview charts

Impurities	Process choice	Corrosion	Filtration	Acid quality	Gypsum quality	Scaling	Fertiliser production
CO ₂	Produces slurry carry over if phosphate reacts with sulphuric acid in a vacuum chamber.						
Lanthanide	Impedes the conversion of Hemihydrate to dihydrate.		Decreases filterability.		Rehydration of Hemihydrate to Dihydrate is longer.	Causes scaling	
MgO		Reduces corrosion (complex with F)	Low content: improves filterability by complexing with F. High content decreases filterability (viscosity increase).	Increases viscosity and density of the acid. Keeps F in the acid. Can cause post precipitation.			Impact on DAP and TSP capacity and quality.
Cd	Anhydrite or Hemihydrate crystallisation to remove Cd from acid.			Quality issue in some countries	Quality issue in some countries if gypsum is sold.		Quality issue in some countries.
Al ₂ O ₃	Impedes Hemihydrate to Dihydrate conversion.	Reduces corrosion (complex with F).	Low content: improves filterability. Very high content: decreases filterability (viscosity increases).	Increases viscosity and density of the acid. Retains F in the acid. Can cause post precipitation	Stabilises Dihydrate. Form Phosphate salt that co-precipitate in the calcium sulphate.	Causes scaling (Chukrovite and others).	Content should be limited if DAP and TSP are produced. Positive impact on MAP production.

Impurities	Process choice	Corrosion	Filtration	Acid quality	Gypsum quality	Scaling	Fertiliser production
Fe ₂ O ₃		Neutral or negative (depending oxydation stage).	Can improve filterability	Increases viscosity and density of the acid. Can cause post precipitation.			Content should be limited if DAP or TSP is produced. Positive impact on MAP production.
Na ₂ O			Fluosilicate scaling reduces filterability and promote small crystal (negative impac.t on filtration)	Increases viscosity and density of the acid. Cause post precipitation.	Quality issue if gypsum is sold for plaster.	Causes fluosilicate scaling.	
K ₂ O			Can improve filterability but considered having a negative impact due to Fluosilicate scaling and promotion of small crystals	Increases viscosity and density of the acid Can cause post precipitation		Causes fluosilicate scaling.	
SrO	Impede conversion of HH to DH					Hard scaling on heating elements.	
F		Increases corrosion speed.	Free F decreases filterability because elongated gypsum crystal.	H ₂ SiF ₆ increases viscosity and density of the acid. Can cause post precipitation.	Quality issue if gypsum is sold	Causes fluosilicate and chucrovite scaling.	
Cl		Increases corrosion speed.					
SO ₄ ²⁻		Increases corrosion speed – synergy with Cl.		Increases viscosity and density of the acid		Form calcium sulphate and Chucrovite scalings.	
S ²⁻		Increases corrosion speed.		Health hazard (H ₂ S)			

Impurities	Process choice	Corrosion	Filtration	Acid quality	Gypsum quality	Scaling	Fertiliser production
SiO ₂		If insoluble: increases erosion speed. If soluble: reduces corrosion (complex with F).	If insoluble: decreases filterability. If soluble: improves filterability.			Cause fluosilicate scaling.	
Organic matters			Depending their composition, filterability can be increased or decreased.	Produce foam. Colour the acid.	Quality issue if gypsum is sold.		Odour
Radioactive elements				Potential environmental and health problems.	Potential environmental and health problems. Quality issue if gypsum is sold.	Potential environmental and health problems.	Potential environmental and health problems.
TiO ₂							Impact on DAP quality.

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REVERSE OSMOSIS OF PHOSPHATE PLANT POND WATER BY USE OF NOVEL PRE-TREATMENT TECHNOLOGY

by: Vaughn Astley, IMC Global, U.S.A.

Phosphate plant pond water or process water is an acidic mixture of ions, and saturated with many compounds. In an operating plant this water is normally recycled internally and the discharge of water is not necessary. However, during extended periods of heavy rain or when a plant is shut down, as in the case of Piney Point, this acidic water must be treated and discharged. The traditional method of treating pond water has been lime treatment in two stages (double liming). However, double liming suffers from several disadvantages. Large settling ponds are required for the second stage solids separation. Only about 50-60% of the water ends up being discharged, but even after lime treatment, air stripping is often required to reduce the ammonia concentration to acceptable levels.

We have developed a pre-treatment method that allows phosphate plant pond water to be treated using reverse osmosis without the usual scaling problems. The advantages of our method are that large settling ponds are not required; upwards of 75% of the water can be discharged; the discharge water is of exceptionally high quality (exceeds Class III Groundwater Standards); up to 75% of the P_2O_5 in the water can be recovered as a non-scaling liquid and operating costs are lower than double liming. Our process is flexible and can be adapted to dilute pond water, such as at Piney Point, or more concentrated pond water, typically found at an operating phosphoric acid plant.

We have demonstrated this technology at the bench and on a small pilot scale, and hope to operate at several hundred thousand GPD at Piney Point to both demonstrate the viability of the pre-treatment process and to assist in the remediation of the facility.

Reverse Osmosis of Phosphate Plant Pond Water by Use of Novel Pre-Treatment Technology

Vaughn Astley

IMC Phosphates

Uncle Sam Idled in La

- **Needed Double Lime Plant Built to Handle water.**
- **\$15MM Construction**
- **High Operational Costs**
- **There Must be a Better way**



Presented at the meeting of the Technical Committee on October 1, 2003 at the Hilton Abu Dhabi

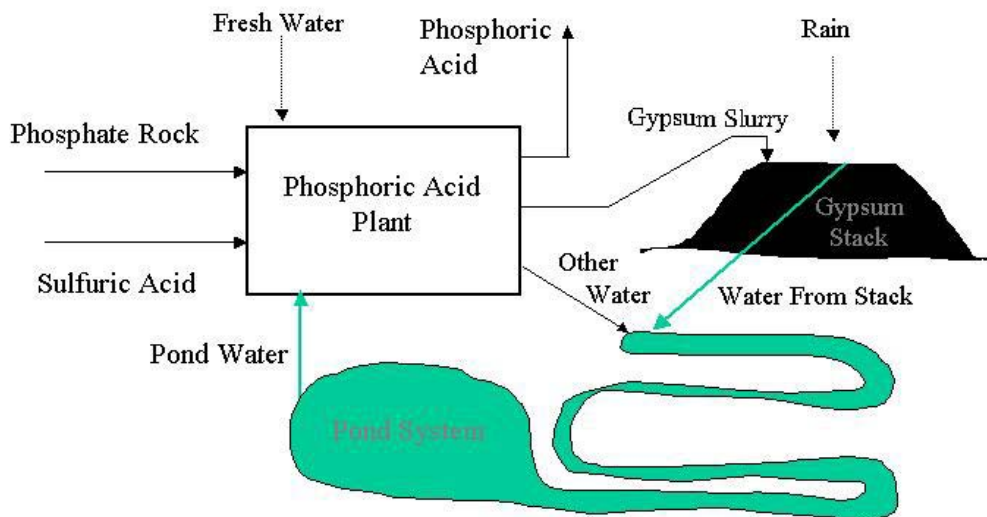
* Received: 22.07.2003

email address: vastley@IMCGLOBAL.COM

Pond Water – Source



Phosphoric Acid Process Origin of Pond Water



“Typical” Pond Water

CHEMICAL COMPONENT	RANGE OF CONCENTRATION
P	1700-12,000 ppm
SO ₄	4300-9600 ppm
F	200-15,000 ppm
Si	100-4100 ppm
(ammoniacal) N	40-1500 ppm
Na	1200-2500 ppm
Mg	160-510 ppm
Ca	450-3500 ppm
K	80-370 ppm
Fe	5-350 ppm
Al	10-430 ppm
Cl	10-300 ppm

Traditional Treatment

“Double Liming”

- Lime Slurry Addition to pH ~5.5
- Settling and Sludge Separation
- 2nd Lime Addition to pH 12-12.5
- Settling and Sludge Separation
- Air Stripping for NH₃ Removal
- Sulfuric Acid Addition to pH 8

Double Liming

Limitations

- Clear Water Recovery Only 50-60%
- Remaining Sludge Difficult to Dewater
 - Large Impoundment Ponds
- Precipitated Phosphate Difficult to Recover
- Difficulty Meeting Ammonia Limits
- High Cost

Pond Water – Reverse Osmosis

- Previous Efforts (~1980's)
 - Failed Because of Irreversible Membrane Fouling
- Pretreatment is Essential
 - Pond Water is Normally a Saturated Solution
 - Saturation Must be Relieved to Allow Removal of Water Without Precipitation
 - Pretreatment Allows Higher Recovery of Permeate

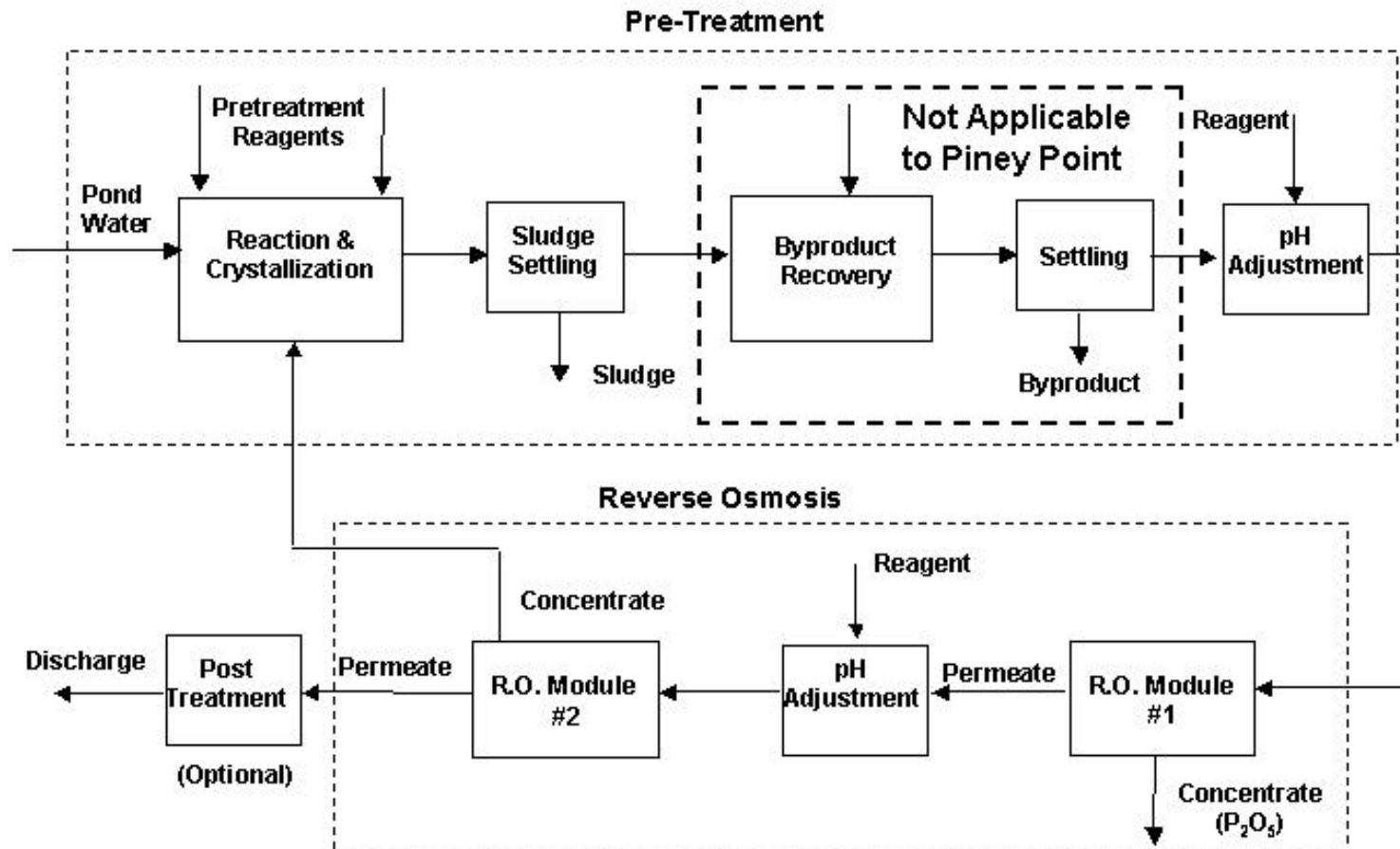
Pond Water – Pretreatment

- Previous RO Work Identified Compounds Responsible for Membrane Fouling
- Objectives of Pretreatment
 - Economically Reduce Saturation of the Species Causing Scaling
- Retain as Much Phosphate as Possible in Solution

Pond Water – Pretreatment

- Pre-Treatment Developed that Allows Pond Water to be Processed Through R. O. System
 - Up to 75% of Feed Volume meets (exceeds) discharge requirements
 - Sludge Volume reduced ~75% (vs. Double Liming)
 - ~70% of P₂O₅ Can Be Recovered in Concentrate
- Process Chemistry Confirmed at Bench Scale (Including R.O. System)
- Three Patents Filed (Have Provisional)

Overall Process



**Bench Scale Results
Uncle Sam LA Pond Water**

	Raw Pond Water	R.O. Final Permeate
Volume %	100	74.4
P ₂ O ₅	1.61%	0.5 ppm
CaO	0.167%	0.1 ppm
F	0.470%	0.8 ppm
SiO ₂	0.440%	1.0 ppm
Na ₂ O	0.310%	10.9 ppm
SO ₄	0.440%	1.0 ppm
NH ₃ N	0.200%	0.92 ppm
As	2.76 ppm	<0.010 ppm
Cond. umhos/cm	19,800	63

Reject P₂O₅ – 5.65%

Cost Comparison

Uncle Sam

Reverse Osmosis vs Double Liming

- Capital Investments Will Run Around \$15 to \$20MM for 2MM Gal/Day DL projects.
- For Temporary Remediation Projects by RO, \$3 to \$5MM Invested for 1MM Gal/Day
- Capital Recovery over One to Three Years
- Project Fixed Costs/000 Gals Defined by Plant Capacity

Cost Comparison

Uncle Sam

Reverse Osmosis vs Double Liming

- 2 MM GPD of Permeate
- Variable Costs
 - Double Liming \$13,
 - P₂O₅ Credit \$3
 - RO with Pre-Treatment \$11.40,
 - Credit \$7.40

Uncle Sam Restarted

**Project Shelved
2001**

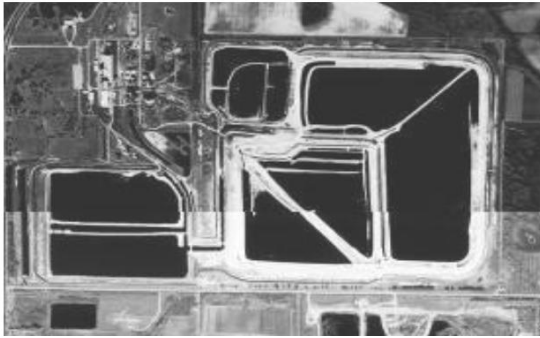
IMC Technology

- 1986-88 Testing with Reverse Osmosis to Concentrate Pond Water, Failed
- 1999-2001 Developed Pretreatment Technology for Uncle Sam, Success
- 2001-2002 a Provisional and Two Applications

Piney Point

- Mulberry Phosphates Declares Bankruptcy Early 2001
- Water Inventory Concerns End of 2001
- DEP, FIPR

Piney Point



Piney Point

- Bankruptcy Trustee
- FDEP, Receiver, Shaw Environmental
- Originally 1.2 Billion Gallons
- Environmental Liability

Current Water Treatment

- Trucking \$40-60 per kgal)
- US Filter \$18.90/kgal (Bonus \$25.00/kgal)
- Double Lime Aerated (\$15.00/kgal)
- Evaporator Systems \$25.00/kgal
- Barging \$35-\$40 per kgal

Results for Piney Point Pond Water - Pilot Tests

Component	Initial Process Water	Feed to R.O. Systems	R. O. Reject	Final Permeate
Total P ₂ O ₅	0.3267%	0.2072%	0.8815%	0.37 ppm
Ca	0.0405%	0.0117%	0.0557%	0.01 ppm
F	0.0099%	0.0099%	0.0400%	3.5 ppm
SiO ₂	0.0207%	0.0194%	0.0760%	3.0 ppm
SO ₄	0.6014%	0.7612%	2.8022%	1.0 ppm
Na	0.0978%	0.2390%	0.7370%	6.2 ppm
Total N	0.0666%			
NH ₃ N	0.0662%	0.0739%	0.7874%	<1.0 ppm *
Nitrate-Nitrite	0.0001%			
As	0.48 ppm	0.47 ppm	2.51 ppm	<10 ppb**
TDS	11 970			
Conductivity (umho/cm)	12 002	9 600	>20,000	37
pH	3.21	3.01	~3.0	~6.8

* With Optional Post Treatment
 ** Limit of Detection

Cost Comparison

Piney Point

Reverse Osmosis vs Double Liming

- 800M GPD of Permeate
- Variable Costs
 - Double Liming \$10.00,
 - P₂O₅ Credit \$0
 - RO with Pre-Treatment \$5.00,
 - P₂O₅ Credit \$0

Commercialization Partners

- Florida Institute of Phosphate Research
- Mobile Process Technology

Piney Point Project

Others Involved

- **Florida Institute of Phosphate Research – Capital Grant for Non-RO Equipment & Construction**
- **KEMWorks Technology Inc. – Preliminary Engineering**
- **FDEP – Operating Costs**

Pond Water R.O.

IMC Phosphates Contribution

- **R.O. Pretreatment Technology**
- **R.O. Equipment**
 - Two 1st Stage R.O. Modules
 - Two 2nd Stage R.O. Modules
 - Multimedia Filter System
- **R.O. Equipment Modification**
- **Technical & Engineering Assistance, Continued Research**

Equipment



Mobile Process Technology

- **Experienced in industrial water treatment**
- **Over 30 years of Operation**
- **Originally worked in the Petrochemical Industry**
- **Annual sales \$10 million (approx.)**
- **Small, Aggressive, Entrepreneurial**
- **Service Oriented**

Reverse Osmosis

Piney Point Project

- **Design Flow 800,000 GPD Final Permeate**
- **Design Permeate Recovery 70%**
 - Medium Pressure (600 psi) 1st Stage RO
- **Re-Use as Much Existing Equipment as Possible**

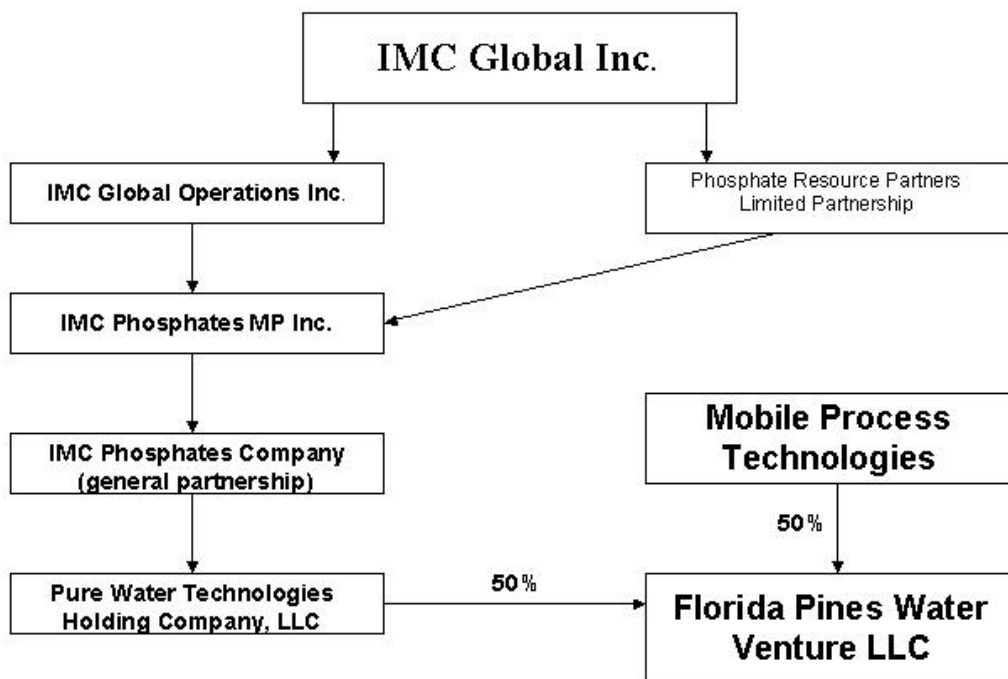
Piney Point Project

Status

- **Reverse Osmosis Equipment On Hand**
 - Modifications in Progress
- **Preliminary Engineering Finished**
 - Detail Engineering in Progress
- **Contracts and Agreements in Negotiation**
- **Start of Operation Anticipated Late 2003**

**PINEY POINT
POND WATER TREATMENT
JOINT VENTURE**

Project Structure



SAFETY MILESTONE - IMPLEMENTATION OF HSE MANAGEMENT SYSTEM AT RUWAIS FERTILIZER INDUSTRIES (FERTIL)

by: Mohamed R. Al Rashid, I. Bukhari and Mohamed Fikry, Ruwais Fertilizer Industries – FERTIL, U.A.E.

Preface

FERTIL is committed to conduct its activities in a manner designed to minimize health, safety and environmental risks, protect the health and safety of its employees, contractors, customers, the community at large and the environment in which its operational activities are conducted.

FERTIL has achieved an excellent health, safety and environment performance record. To sustain such achievement, FERTIL has adopted a structured and comprehensive HSE management system to ensure that it carries out operational activities mindful of the environment, in which we work and live.

On 1st July 2003, FERTIL completed 10 years without Lost Time Incidents and by December 2003, the milestone of 9 million man-hours without LTI is expected to be achieved. It reflects FERTIL's commitment to conduct its activities with full concern to the safety and health of all employees and contractors alongwith safeguarding the environment. This was achieved due to the whole-hearted compliance to the safety rules and regulations by the Management, employees and the contracted personnel. It also reflects the excellent working environment due to the positive attitude, team spirit, dedication and sincere commitment from all concerned.

This high safety performance is a remarkable and proud achievement and we at FERTIL legitimately feel that it should be recognised as a significant achievement in the HSE field.

Introduction

FERTIL believes that HSE training is the first line of defence against accidents. Therefore, the company has adopted a systematic and pro-active program that provides appropriate HSE training and encourages participation of all employees and contractors to safely perform their duties with the objective of preventing occupational injuries, illness and losses due to accidents.

It is the policy of FERTIL to ensure the safety and occupational health protection of all employees/contractors. Compliance with the principles of HSE related to the prevention of occupational illness and accidental injuries and losses is an important factor in the performance evaluation of each member of FERTIL.

Executive Summary

FERTIL conducts its activities with the aim of prevention injuries and occupational health hazards. FERTIL, through comprehensive and competent HSE training, ensures that personnel reporting for duty (employees and contractors) are aware of hazards associated with their work, safe performance of their job and know the procedures to be adopted in the event of emergency.

FERTIL provides qualified HSE staff and appropriate equipment to support the employees in this regard. The company fully takes into consideration the development aspirations and potential of employees, the current and future business and operating needs of the organisation. However, the



Presented at the meeting of the Technical Committee on October 1, 2003 at the Hilton Abu Dhabi

* Received: 05.08.2003

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priority is always given to the up-to-date set of requirements to maintain effectiveness, efficiency and a safe working environment.

On 1st July 2003, FERTIL completed 10 years without Lost Time Incidents and by December 2003, the milestone of 9 million man-hours without LTI is expected to be achieved.

We shall strive to maintain this excellent record through commitment and participation of all levels of Management, employees and contractors. We shall continue with our efforts to further improve the HSE performance and our motto is “Work Safely With No Accident”.



HSE Training of Human Resources

General

FERTIL through regular assessment, ensures that all positions are filled by personnel who have knowledge, skills, experience and potential to meet its objective.

I. Recruitment and selection criteria

FERTIL ensures that systems are in place for recruitment, job description, policy, performance appraisal and development training including, where appropriate, consideration of HSE responsibilities and awareness for particular positions.

Criteria for selection and competency reflects the basic physical suitability, knowledge and skills appropriate to activities of the post.

1.1 Induction and Orientation

1.1.1 New Employees

Induction is the process of assisting the new employees to settle into the company environment and become an effective and useful member of his/her department.

Induction of the new employees on HSE issues should commence as soon as possible. It is the responsibility of the new employee's department head to ensure the employee receives induction course and a formal safety training on HSE subjects applicable to all personnel.

Formal induction, both general and job specific is provided to all personnel new to the plant, post or activity so that they become aware of the FERTIL HSE policy. A person should not be allowed within a plant area, or be placed in a position of responsibility without an appropriate safety induction.

1.1.2 Visitors and Contractor Staff

Arrangements are made for all visitors to go through a brief safety induction course, in which they are informed about emergency evacuation procedure and principal "Do's" and "Don'ts" applicable to the plant.

Contractor personnel filling company established posts are provided training courses arranged by the company as applicable.

Contracted personnel, employed as Technicians/Labours working under company direct supervision, are provided suitable company training.

1.1.3 Senior Personnel

All Senior Personnel are given formal training in HSE management and refresher courses as and when required.

1.1.4 Departmental Training

Department Managers are responsible for ensuring that Supervisors/ Engineers take every opportunity to provide training advice on HSE topics at their place of work. This is achieved by carrying out tool talks.

2. Training Modules

The formal safety induction on the day of arrival and job orientation will include the following:

- Policy and Regulation
- Site familiarization
- Emergency Procedure
- Emergency Response Team (ERT)
- HSE procedure (e.g., first-aid, safety standards, occupational hazard awareness)
- Fire prevention and protection
- Permit-to-Work System
- Incident Investigation and Analysis Procedure
- Environmental Protection

3. HSE Training (Advanced)

3.1 Training Needs

There are a number of different sources for the identification of training needs:

3.1.1 Compliance with Legislative Requirements

In compliance with company/ADNOC group of companies safety regulations, local, national, international lines and codes, all or specific designated personnel need to be trained and certified as a pre-requisite for assuming their duties.

3.1.2 HSE Management System/Programs

Specific training and skills are imparted for conducting HAZOPS, Risk Assessment and Environmental Protection Techniques.

3.1.3 Emergency Response Team

Specific categories of personnel with designated emergency duties are trained in handling of various emergency situations that require special skills such as fire fighting, first-aid NH₃ leak emergency etc.

3.1.4 Incident Investigation Analysis

Analyses of incident causes reveal the gaps in knowledge and skill that are required to avoid repetition.

3.1.5 Modifications/New Technology

The modifications or the introduction of new technology such as the installation of new machinery or detection system necessitate specific safety training to be given to personnel involved.

Examples: Fire / gas detection / protection system etc..

3.2 Advanced Training of HSE Personnel

An advanced HSE training is imparted to members of HSE Department. Therefore, the department not only has responsibility for the general safety training of others but for in-house training also.

4. Fire Service Drills

The program for fire service drills is as laid down by the Fire and Security Section Head in liaison with HSE Superintendent. Included in the program are:

- ❑ Responding to Alarms
- ❑ Hose Running
- ❑ Use of Firefighting Appliances
- ❑ Use of Pumping Appliances
- ❑ Toxic/Flammable gas release
- ❑ Firefighting Techniques
- ❑ Communications
- ❑ Use of Ropes and Lines
- ❑ Use of Breathing Apparatus
- ❑ Search and Rescue Techniques

4.1 Other Drills

The evacuation from buildings is practiced on a regular basis. Guidelines for these drills are given in the evacuation procedures.

4.2 Fire Service Exercises

In addition to the practicing of routine procedures and drills, the Fire Services are given special exercises to test and improve their response to the kind of problems encountered in a real emergency.

The planning of exercises requires imagination but the results are most beneficial, giving those involved a change from routine activities, a broadening of experience and increased confidence in the ability to handle emergency situations.

To simulate an actual emergency, the Fire Services are required to place tags marked “open” or “close” on actual locations to isolate equipment.

After each exercise the results are carefully analyzed.

4.3 Other Exercises

Regular exercises are held by the Operations Department to test and improve site responses to simulated process upsets and emergency conditions.

In liaison with the HSE Department, designated members of the Operations Department are presented with scenarios and asked to take charge of the operations team advising the Incident Controller (IC) and Emergency Main Controller (EMC) regarding available shutdown and isolation options.

4.4 Analysis

A detailed analysis of the outcome of such drills, exercises, rehearsals and incidents is of vital importance to enhance the capability to handle such situation, when they occur in reality. The lessons learned from the feedback from such activities also help to:

- ❑ Improve safety
- ❑ Improve reaction times
- ❑ Develop new methods of operation
- ❑ Expose weak areas
- ❑ Identify the need for further training

The need for accurate reporting and feedback from all personnel is most important, as it determines the outcome of the exercise and is used to make necessary changes.

5. Inductions and Training Record

The HSE Department records the initial and the follow-up induction on an appropriate record sheet. A record is also kept of the training modules attended by each site employee.

The record includes a list of training modules and refresher courses required by each category of employees.

Completed records are maintained in a suitable system and are audited. Effective records allow effective training.

6. Safety Promotions and Environment

Variety is the key to effective safety campaigns as change stimulates interest. A new poster will initially stimulate interest during the early weeks of display, thereafter, interest will decline rapidly.

Posters and wall charts are therefore changed frequently, by rotation of their position or by the introduction of new material. New promotional material such as safety slogans or bulletins are introduced regularly. Site personnel are encouraged to assist in the development of safety themes. Competitions are also held. The active participation of employees ensures continuing awareness of the importance of safety.

6.1 Safety Employee of the Month

To promote interest and attitude in HSE issues with company employees and contractors, a promotion program is conducted with the objective of recognising and rewarding individuals who have made an outstanding performance in one, some or all aspects of HSE and in line with FERTIL HSE competition criteria.

Every month, one person is selected and is designated as 'Safety Man of the Month'. Names proposed by various disciplines in all fields (i.e., operations, maintenance, marketing etc.) are submitted and vetted by the respective divisional/department managers.

The selection criteria is based on HSE concept and/or the contribution to the safety program. It includes the followings wherever applicable:

- ◆ General attitude to company safety rules and regulations
- ◆ Personnel Protective Equipment (PPE) compliance
- ◆ Safety training and exercises
- ◆ Participation in Emergency Response Training (ERT)
- ◆ Attending first-aid course training
- ◆ Reporting near-misses or anomalies and suggestions
- ◆ Attitude towards fellow employees

Due recognition is given to the person, with appropriate publication in the FERTIL News Magazine and his/her photograph displayed on the safety employee of the month board. All selected persons receive nominal gift from the management.

The contest is mainly intended for the workforce of both FERTIL and contractors. Managers and department heads shall demonstrate their commitment through leadership and active and visible HSE performance and participation. However, by exception, Managers and department heads can be included on the basis of their outstanding contributions.

6.2 HSE Posters

The longer a poster stays in position, less interest it generates. In extreme cases the monotony caused by over-exposure to the same poster can result in unconscious resistance to the theme being promoted.

HSE Department coordinates the distribution of new safety posters to the operating areas in the plant. However, plant can contribute to the range of available posters by encouraging personnel to participate in the design of new material.

Choose eye-catching subjects, and above all, when new material is not readily available, change the positions of existing material. Appoint a member of the HSE Department to ensure that no poster stays in the same position for more than one month.

6.3 HSE Slogans

Slogans painted on walls and tanks are visual evidence to employees and contractors of the importance management attaches to the subject of safety. The cost of slogans is high compared to the cost of posters but the principle of regular replacement must still apply. Whilst it is not practical to change safety slogans monthly, every effort should be made to change them at least once a year.

6.4 HSE Competitions/Contributions


In a number of areas, safety and environment campaigns lead themselves to direct employee participation:

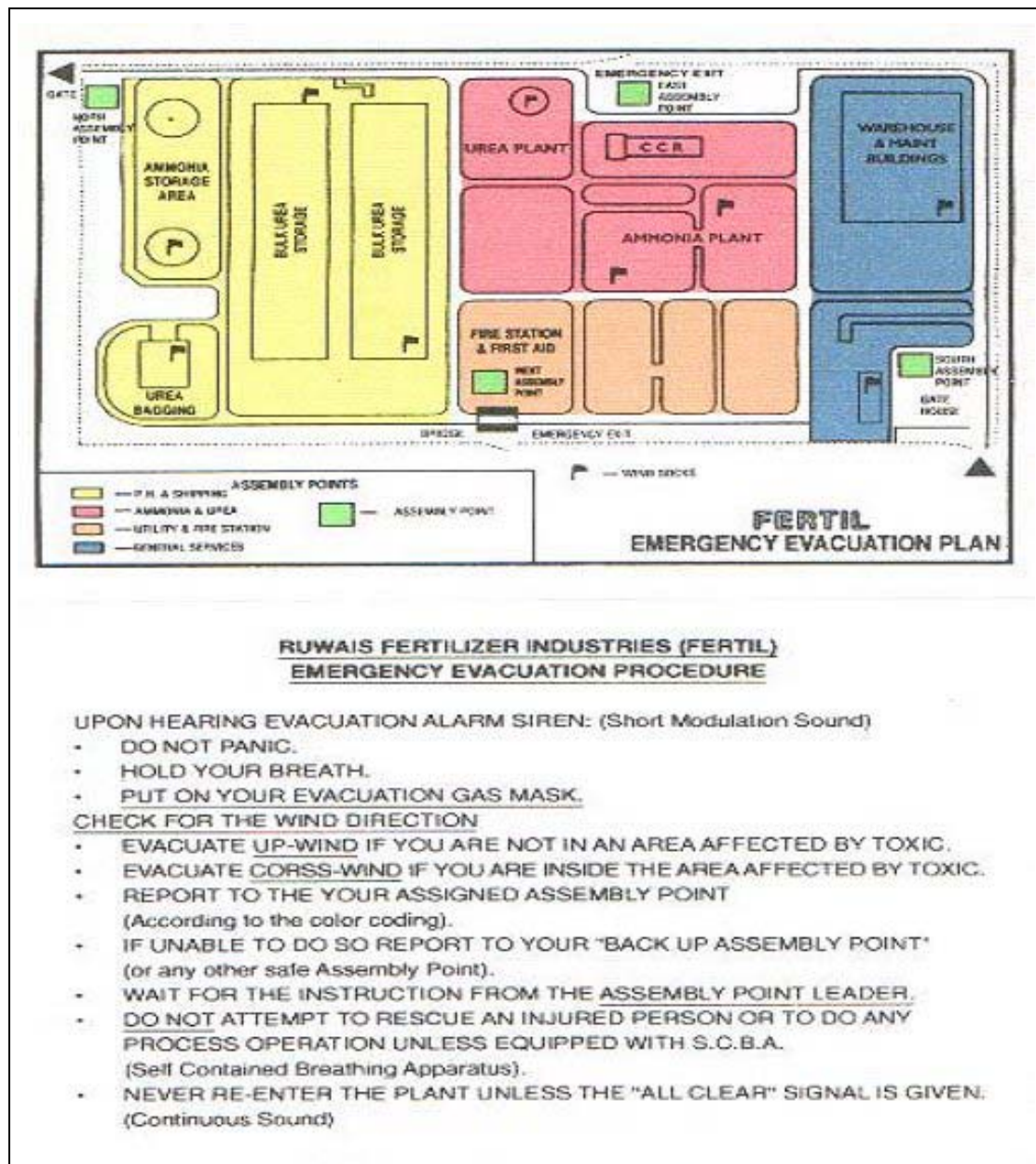
- Design of posters
- Design of safety slogans
- Articles, illustrations and cover designs of newsletters and safety magazines
- Safety themes
- Safety suggestions

Competitions are followed-up by tangible rewards, either in the form of prizes or in expressions of official appreciation by senior management. The contributions received for newsletters (Safety Alert, Safety Flash and Environmental Alert) are also duly acknowledged.

Attachments

- ❑ FERTIL HSE Policy
- ❑ HSE Performance
- ❑ HSEMS
- ❑ Emergency Response Plan
- ❑ Newcomer HSE Induction

	HSE PERFORMANCE
Record without LTI	
ACHIEVEMENT	10 YEARS on 1st July 2003
TARGET	9 MILLION MANHOURS in DEC. 2003
Award	
ACHIEVEMENT	ROSPA Gold Awards in 2002 & 2003 ENVIRONMENTAL CERTIFICATION (ISO 14001) in March 2003
TARGET	OCC. HEALTH & SAFETY CERTIFICATION (OHSAS – ISO 18001) June 2004



RUWAIS FERTILIZER INDUSTRIES (FERTIL)



HSEMS For Employees / Contractors

This card is produced to give employees a quick idea and knowledge about Health, Safety and Environment Management System (HSEMS) & What is expected from employees / Contractors to do.



You also have a role

1. POLICY, LEADERSHIP & COMMITMENT

- ✦ Talk to managers during their HSE high profile tours.
- ✦ Make HSE suggestions to your supervisor.
- ✦ Ask your supervisor to assist you if unsure how to perform a task.

2. SAFETY

- ✦ When performing hot/cold work, excavation and confined space entry, make sure a permit-to-work is in place.
- ✦ Report maintenance problems of equipment, especially leaks and unusual noises.
- ✦ Contact your Supervisor if you believe that equipment has not been regularly/properly inspected and maintained.
- ✦ Wear your P.P.E. If unsure what PPE to wear ask your Supervisor.
- ✦ Report defective or worn out P.P.E. to your Supervisor.
- ✦ Know the proper way to handle or use chemicals.
- ✦ Ask your Supervisor if you do not know that chemical you are handling.
- ✦ Report to Supervisor if you find unlabeled chemicals.
- ✦ Ensure that a Material Safety Data Sheet exists for the chemical you regularly use or handle. If not, tell your Supervisor.

3. OCCUPATIONAL HEALTH

- ✦ Report unhealthy conditions to your Supervisor such as high levels of dusts, fumes, odors or noise.

4. PRODUCT SAFETY

- ✦ Be aware of the product and proper precautions on transport, storage, use and disposal.

5. ENVIRONMENTAL PROTECTION

- ✦ Report any spills, unusual leaks or odors, and garbage dumped in unauthorized areas.
- ✦ Do not dispose of any chemical wastes or containers without approval of Supervisor.
- ✦ Use less water and electricity.

6. RISK MANAGEMENT

- ✦ Report hazards, unsafe conditions, unsafe acts and spills to Supervisor.
- ✦ If in very dangerous situation, report immediately to Supervisor and stop work or leave dangerous area.

7. CRISIS MANAGEMENT

- ✦ Report fires, gas leak, explosions, accidents and spills to Supervisor /control room. Assist in initial response as directed.

8. INCIDENT REPORTING AND INVESTIGATION

- ✦ Cooperate fully with the incident investigations. Give him facts, not who is to blame.
- ✦ Report near-misses and anomalies to your Supervisor.
- ✦ Obey vehicle safety rules (speed limits, seat belt, etc...)
- ✦ Report any vehicle repairs or concerns to Transport Department.
- ✦ Report to your Supervisor if any procedures for a task are missing or need improvement.

9. TRAINING AND COMPETENCY

- ✦ Ensure that you and your fellow workers are properly trained and competent for assigned tasks.
- ✦ Talk safety with new workers. Watch them during their first few weeks.

10. COMMUNITY AND PUBLIC RELATIONS

- ✦ Be aware of the Company Contact Procedures (contacts with local HSE authorities and media).

11. LEGAL REQUIREMENTS

- ✦ Ensure that all applicable HSE legal requirements are known.

سياسة الشركة حيال الصحة العامة والسلامة وحماية البيئة

1. إن السياسة التي تتبناها فرتيل في إدارة عملياتها الإنتاجية برأسية مع نظيرها والعمالين المتعاملين معها تتركز اهتمامها البالغ في الحفاظ على البيئة، كالتأكد من سلامة القوالب البشرية العاملة بها، إضافة إلى الاهتمام بسلامة الجوار المحيط وعمالها القريبين.
- تتبنى فرتيل جدلاً ذاتياً في دستور وتطوير أنشطة الصحة والسلامة والحفاظ على البيئة بأسلوب تكنولوجي متطور من خلال السياسات الإدارية الخاصة بالثقافة الصحية والسلامة والبيئة التابعة لها، وطبقاً لذلك، فإن أهداف فرتيل في الصحة والسلامة والبيئة تتمثل فيما يلي:
 1. الاهتمام بصحة العمال وسلامتهم أثناء العمل وحماية البيئة والحفاظ عليها، أو لولا تسبب تلك الاعتبارات الاقتصادية.
 2. التزام فرتيل فترتها بما يتفق مع سياسات فرتيل في الصحة والسلامة والبيئة في جميع منشآت الإدارة والإنتاج والتوزيعية من خلال سياسة حكيمة تتبناها لتتجهها لتعمل على تأمين البيئات أو برامج مخلفات صناعية عند أو العمل على تطوير استخدام جميع مصادر الطاقة الطبيعية بكفاءة عالية.
 3. التزام فرتيل من خلال أنشطتها الإدارية في إعداد وتدريب كافة موظفيها والعمالين بها في مجالات الصحة والسلامة والحفاظ على البيئة، كالتأكد من أن جميع العاملين في العمل بالسلامة والقياسات عالية الجودة تكون وفق لوائح أو إجراءات أو أمراض مهنية ناتجة عن ممارسة المهنة.
 4. تطوير المستمر والتطبيق لكافة التصميمات الهندسية لوحدة الإنتاجية وإجراء التعديلات اللازمة لتعديلات الصحة والسلامة والبيئة طبقاً للمعايير الدولية وفقاً للاحتياجات التطبيقية لتتبع نظم عمليات الإنتاج والتشغيل والتشرف الهندسي الثابت من المعامل المتواصلة على القوالب والحفلة والمنشآت والبيئة المحيطة بها تماماً.
 5. الاعتناء بالبيئة والتطوير المستمر لإجراءات العمل، وبمعدلاتها وسرعة استجابة التطوير الأخرى له، مع الإبقاء على الاستغلال الأمثل للمعدات والمصاريف المتعلقة في حالات الطوارئ.
 6. التزام فرتيل بالالتزام بالاشتراطات المطلوبة لتتأكد منها طبقاً لليس كالتأكد منها بتطبيق سياسات فرتيل في الصحة والسلامة والبيئة والالتزام بها، كالتأكد من التزامها بالاشتراطات المطلوبة في هذه السياسات والقوانين.
 7. التزام فرتيل بالتعاون المستمر والهادف مع جميع الجهات الحكومية والإدارات الصناعية المسؤولة في الدولة في تعريف الأسس والقوانين الخاصة بسياسات الصحة والسلامة والبيئة والعمل على تنفيذها.
 8. التزام فرتيل التزاماً تاماً بسياساتها حيال الصحة والسلامة والبيئة مع احترامها جميعاً وأهميتها في توفير بيئة عمل آمنة لجميع الفئات العاملة من موظفين وعمالين.


سيف أحمد الغفلي
المدير العام

HEALTH, SAFETY AND ENVIRONMENT (HSE) POLICY

It is the policy of FERTIL to ensure that its activities and those of its contractors are conducted with full commitment for safeguarding the environment, health and safety of the workforce, neighboring community and customers.

FERTIL will strive for continuous improvement of HSE performance through a comprehensive and exhaustive HSE Management System (HSEMS).

In line with the above, FERTIL is committed to the following HSE objectives:

1. No economic priority shall over-rule considerations of health, safety at work, and respect for the environment.
2. FERTIL is committed to integrating environmental, health and safety priorities into its business activities by developing, implementing and managing programs aimed at reducing and preventing the generation of emissions, effluents and wastes and improving efficient use of natural resources and energy.
3. FERTIL through a systematic, positive and pre-active program provides appropriate HSE training and encourages participation of all employees and contractors to safely perform their duties with the objective of preventing occupational injuries, illnesses and accidental losses.
4. The design of old and new installations is continuously reviewed to reduce HSE risks, ensuring all operational activities, regular inspection of equipment and modifications are conducted in a manner that minimizes risks and hazards to workers, property and the community at large.
5. Potential emergency procedures shall be periodically tested, drilled and kept up-to-date systematically to ensure applicability of the emergency response plan and the readiness of resources.
6. FERTIL shall select its industrial partners/contractors on the basis of their compliance with FERTIL or similar HSE policy. The HSEMS of contractors will be subjected to continuous monitoring and auditing by FERTIL.
7. FERTIL will co-operate with industry and local government authorities in identifying and setting environmental goals and in developing effective, reasonable and equitable control programs.
8. Compliance with this HSE policy shall be an important element in the performance evaluation of FERTIL line managers, all employees and contractors.


SAIF AHMED AL-GHAFILI
GENERAL MANAGER

EFMA'S PRODUCT STEWARDSHIP PROGRAM

by: J.A.M. van Balken, EFMA, Belgium and Tore K. Jenssen, Norsk Hydro ASA, Norway

Introduction

Mr. Chairmen, Ladies and Gentlemen. I am very happy that the organizing committee gave me the opportunity to give this presentation. However, before doing so, I would like to start by giving you a brief introduction to the European Fertilizer Manufacturers Association.

EFMA represents the major fertilizer manufacturers in Europe. Its members account for some 90% of their region's nitrogen fertilizer production capacity and some 70% of phosphate fertilizer production, resulting in a market share of about 75% of the Western European fertilizer market (EU plus EFTA).

EFMA's mission is to identify, promote and manage the common interests of its members by explaining and promoting the role of mineral fertilizers in European agriculture and horticulture, anticipating and preparing for upcoming issues that may affect the industry, by being the industry's spokesperson and sounding board and by providing its members with a wide range of statistical information and services.

EFMA is an association under Swiss law and has offices in Zurich and Brussels.

Going back to the topic of my presentation: EFMA's Product Stewardship Program

In the last two years four accidents have happened in the European Fertilizer Industry. "This is enough, we cannot afford more" were the words of EFMA's President in the Steering Committee meeting of 8 March, 2002. Mr Clauw again stressed the importance of a good environmental and safety performance for our industry. With this in mind, he proposed the initiation of a EFMA project, "Product Stewardship in the Fertilizer Industry".

It is not that the Industry does not have enough procedures in place but ensuring Implementation is a key issue. In less than a year and a half an EFMA Task Force has completed the task given by the President of EFMA:

- Development of an EFMA Product Stewardship Program for implementation in EFMA member Companies
- A system to check compliance with EFMA's Product Stewardship Program

Today I like to report on this Product Stewardship Program and on the compliance system. In addition I would like to give a short resume on four examples being part of such a program.

The structure of my presentation is as follows:

1. What is Product Stewardship
2. EFMA's Product Stewardship Program For Fertilizers
3. EFMA's Compliance system
4. EFMA's Product Stewardship Program Launch
5. Examples of EFMA's Product Stewardship Program



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What is Product Stewardship?

Product Stewardship is the management of the safety, health and environmental aspects of a product throughout its lifecycle in an ethically responsible way. It is the Responsible care applied to the product. For the Fertilizer Industry it means to make sure that fertilizers and their raw materials, additives and intermediate products are processed and manufactured, handled, stored, distributed and used in a safe way with regard to health, occupational and public safety, environment, and security. It also means that our plant nutrients shall always satisfy society's requirements to safe food production and animal feed...

The concept of Product Stewardship is not new. Several Chemical companies have a Product Stewardship in place and a good examples is the PS GO Product Stewardship Program of the Chemical Industry Association in the UK.

For EFMA and some of its members however, a Product Stewardship program is new and the necessity to implement one I already explained in my introduction.

EFMA's Product Stewardship Program for Fertilizers

The EFMA's product stewardship program for fertilizers consists of a CD Rom containing all information necessary for implementing such a program in EFMA's member companies. For each element in the program it gives guidance on how to comply with legal requirements, EFMA's requirements and guidance on how to implement the issues.

Official EU legal regulations, UN recommendations, as well as to all EFMA guidance Documents are all accessible on the CD Rom.

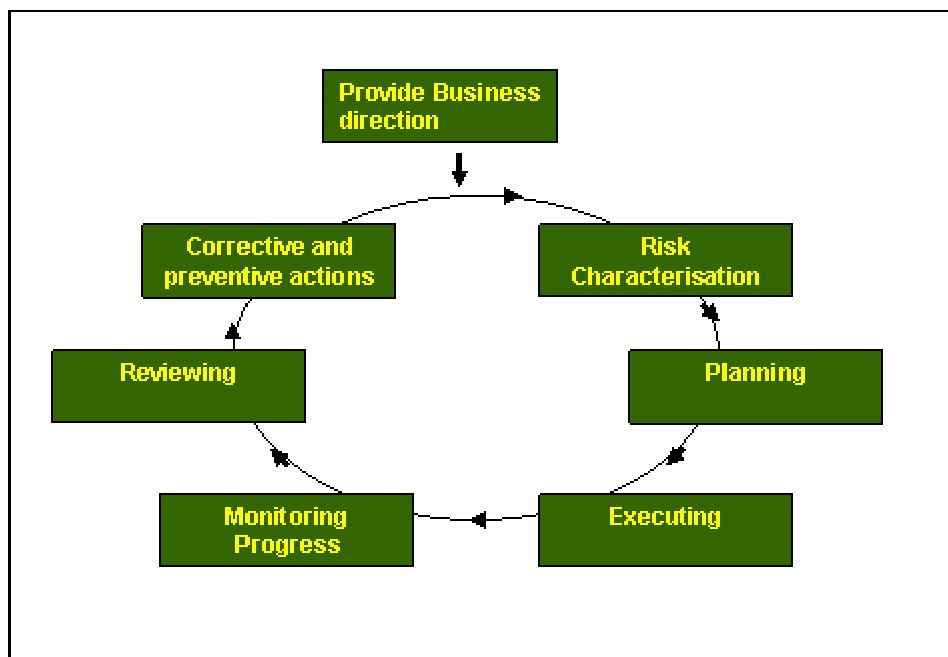
There are 5 main elements in the program:

1. Managing Product Stewardship
2. Product Life Cycle
3. Risk management
4. Communication
5. Partnership

1) Managing Product Stewardship

This chapter addresses the role of the senior management, their commitment and their responsibility not only to implement the program in their company but also to regularly review the program. A tool to achieve this goal is the management cycle. The management cycle starts by providing business direction. All activities in the lifecycle are assessed for their risks. Plans are executed and progress in monitored.

Regularly the process is reviewed and corrective actions are taken if necessary. The cycle starts again.



2) Product Life Cycle

The product life cycle is the core of the program based on the principle “cradle to crave”. It gives further guidance to what to implement in the 9 stages in the product life cycle being:

- a) Sourcing of raw materials, intermediates and additives
- b) Research and Product development
- c) Product manufacture
- d) Packaging and/or storage on site
- e) Product marketing and sales
- f) Product transport and delivery
- g) Product storage at distributor
- h) Customer service, application at the farm.
- i) Re-use, recycling and /or disposal of packaging materials and left-overs

Taking into account the whole life cycle means that the focus is not only on manufacturing operations, but also on the distribution to the farmer... The actions initiated under the umbrella of Product Stewardship require the co-operation of transporters, external storage operators, distributors and customers.

In addition we see the need to address the issue of security and this is part of the EFMA Product Stewardship Program.

3) Risk Management

The purpose of risk management is to ensure that no chemical or process directly related to manufacturing, transport, use or disposal, presents any unacceptable risks to people or the environment, and that any risks that do exist are reduced to the lowest practical level. The process consists of two major parts:

- 1) Risk Characterization
- 2) Risk Reduction and Control

4) Communication

An effective communication process is an important element of any Product Stewardship Program. Comprehensive HSE information should be available and targeted to those who are involved in the product life cycle. Measures should be in place to ensure that this HSE information is understood and implemented by those who are involved.

EFMA will communicate the positive messages the fertilizer industry has to give such as the joint EFMA/TFI testing program on products, EFMA's Best Available Techniques Booklets, members' HSE reports, and EFMA's message that "Fertilizers are Safe and Feed the World".

Main elements in this chapter are:

- a) Implementation of product stewardship by EFMA members

This chapter deals with the members commitment to EFMA's core values. The official signing of EFMA's core values took place on the 28th May, 2003. It also deals with EFMA's compliance system which I will discuss later in my presentation.

- b) Dissemination and implementation of information

A second chapter under communication is the dissemination and implementation of EFMA's product stewardship program, Guidance documents, brochures and leaflets and training program. A training program to inform EFMA's members on how to implement the Product Stewardship Program and how to use the compliance system was given on the 23rd September, 2003.

5) Partnership

The building of effective partnership between a Fertilizer supplier and its customers, suppliers, hauliers, distributors, and others involved in the supply chain is a key aspect of Product Stewardship. The ultimate objective is to extend the recognition of the positive contribution of Product Stewardship to all those involved in the product's life cycle. Examples of partnerships addressed in this chapter are:

Partnership with emergency services, suppliers, contractors, customers, resellers and other downstream users, haulier companies, other industries, authorities, and partnership with the scientific community

EFMA's Compliance System

Having a Product Stewardship Program is not enough. It is a prerequisite for EFMA's membership to comply with EFMA's Product Stewardship.

How do we measure this compliance?

1. Self assessment
2. Inspection
3. Reviewing

1. Self Assessment

Self-assessment is done under the responsibility of the CEO of the company. For that purpose EFMA has developed a questionnaire consisting of about 143 questions, covering all the elements of EFMA's Product Stewardship program.

The questionnaire has been developed with Det Norske Veritas a world-wide recognized independent third part specialist in these matters. The questionnaire enables the companies to get an idea on where they stand with the implementation of the program.

The self assessment questionnaire is signed off by the CEO and sent to EFMA for further review.

2. Inspection

For the first year EFMA has chosen for inspecting the Product Stewardship program by an independent department of the company such as a corporate SHE department. For the purpose of auditing EFMA, together with an independent third party (Det Norske Veritas) has developed 5 inspection check lists to validate that day-to-day operations are in conformance with EFMA's Product Stewardship Program. The inspection check lists cover the areas in the Product Life Cycle which we believe are most vulnerable as regards to possible accidents:

- 1) Inspection of storages.
- 2) Transportation
- 3) Inspection of contractor management at manufacturing sites. This list can be changed and/or extended to other areas in the Product Life Cycle in the coming years.

3. Reviewing

The result of the assessment of each member company will be displayed against minimum EFMA requirements. Those companies that do not meet the minimum requirements have to comply with it in the next round (2004). The minimum requirements, the scope of the self-assessment and inspection, as well as the compliance system itself, are subject to review.

EFMA's Product Stewardship Program Launch

The EFMA's Product Stewardship Program was officially launched on the 23rd September, 2003 for a broad audience of Press, Members of the Parliament, Commission, Non-Governmental Organizations, EFMA members etc. this to show to the general public that the Industry is serious with this initiative.

Examples of EFMA's Product Stewardship Program

I would like to address four EFMA initiatives as examples of EFMA's Product Stewardship Program. The first two examples are related to partnership with the authorities.

1. Partnership with the Authorities

Be proactive and participate in discussions with international agencies, national competent authorities and local regulatory bodies on Product Stewardship seeking to promote a balanced judgment between the HS&E, scientific, economic and practical arguments. EFMA regularly discusses with the European

Commission, members of the Council and members of the Parliament proposals for new EU legislation. EFMA seeks well balanced legislation where community interest such as environment and safety have an equal place as the economic interest of the fertilizer industry.

Amendment of the Seveso II Directive

Council Directive 96/82/EC of 9 December 1996 on the control of major accident hazards involving dangerous substances (Seveso II or COMAH Directive) regulates risk assessment of storage of dangerous substances.

Ammonium nitrate being one of the dangerous substances is part of that regulation and appears in the following two entries:

Dangerous substances	Qualifying quantity (tones) for the application of	
	Article 6 and 7	Article 9
Ammonium nitrate	350	2500
Ammonium nitrate	1250	5000

Immediately after the Toulouse accident, the EU Commission proposed to amend the existing Seveso Directive. Though ammonium nitrate fertilizer conforming with E.U. and French national legislation was NOT involved and the explosion rather involved material classified as off-spec., consisting of off-spec. low density/high porosity ammonium nitrate (technical grade), together with off-spec. high density/stabilised ammonium nitrate (fertilizer grade), the commission proposed to add in their proposal additional entries including one on off-spec material .

Column 1	Column 2	Column 3
Dangerous substances	Qualifying quantity (tonnes) for the application of	
	Articles 6 and 7	Article 9
Ammonium nitrate (Compound, NPK)	5000	10000
Ammonium nitrate (Fertilizer grade)	1250	5000
Ammonium nitrate (Technical grade)	350	2500
Ammonium nitrate (Off-spec).	50	200

Ever since, EFMA has started a discussion with National Authorities, Commission, Council and Parliament with the purpose to have a safe and reasonable amendment for Ammonium nitrate. Although EFMA was not successful at the end in convincing the legislators to consider EFMA's proposal as a better alternative we are sure that we by our actions have prevented a much worse legislation or even a ban.

Commission proposal for a regulation on Cadmium in fertilizers.

More recent the EU Commission proposed a new legislation on Cadmium Fertilizers for consultation by stakeholders. The results is claimed by the Commission to be based on the outcome of the Risk Assessment studies done by the Member States. "Seeking to promote a balanced judgment between the HS&E, scientific, economic and practical arguments" is what I mentioned earlier. These scientific and

economic arguments however, are lacking in this proposal and EFMA continues to discuss with Commission and National Authorities to achieve a much more realistic piece of legislation.

Examples 3 and 4 are related to safe storage loading and filling

2. Establish Best Practice for Safe Loading and Filling

Guidance for safe handling and use of non-conforming fertilizers and related material

Also as a consequence of the Toulouse accident, the West European Fertilizer Industry recognizing that handling of non-conforming material was not part of EFMA's 1992 Handbook Safe Storage of Ammonium Nitrate Based fertilizers. EFMA promised the EU Commission to develop such document a task which recently has been completed.

This guidance identifies sources of such materials, brings out relevant aspects of their properties and outlines various methods available for their safe utilization or disposal. It focuses on solid Ammonium Nitrate (AN) based fertilizers and typical solid fertilizer process raw materials, in packaged or loose bulk form. It also covers urea and urea-based fertilizers, potassium nitrate, potassium sulphate, ammonium sulphate and other common fertilizer raw materials.

This guidance is not prescriptive in nature; it offers alternative options, which operators should evaluate in relation to their own particular situation and select the most suitable one having carried out a risk assessment. As a follow up EFMA now has started a similar guidance document form distributors.

Recommendation for safe storage and reliable inspection of atmospheric, refrigerated ammonia tanks.

As a last example of good Product Stewardship I would like to present EFMA's Recommendations for safe and reliable inspection of atmospheric, refrigerated ammonia storage tanks. A full presentation was given by me in the Joint meeting of the Technical sub-committee and committee Thessaloniki Greece 10 October, 2001.

This document, produced by EFMA and issued in 2002, provides guidance and an optimum basis for the periodic inspection of fully refrigerated anhydrous liquid ammonia storage tanks, operated in Europe. The recommendations and guidelines provided are applicable to those tanks, which operate at or near atmospheric pressure and -33°C. The guidance uses a risk based inspection approach requiring the evaluation of the probability and consequences of failure for each individual tank. Tanks are positioned according to their scores on probability and consequences of failure the need for the frequency of an internal inspection can be determined. EFMA has conducted a survey, covering 37 tanks in Europe, to validate the recommendations. The underlying intention is to maximise operational safety and reliability of these tanks.

With this I would like to end my presentation. Hopefully was able to show you that EFMA is a proactive association, willing to learn and seriously willing, not only to secure today's safe and environmentally responsible production, storage, transport and application of our fertilizers but surely wants to lift our SHE performance up to higher level. EFMA is convinced that the EFMA Product Stewardship Program is a very good tool in achieving this and will be happy to give a helping hand should you wish to accomplish such a program.

