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SYRIAN ARAB REPUBLIC

Technical report: Maintenance and operation of instruments and control systems in fertilizer plants*

(Trouble shooting and analysis of problems related to low production, failure of equipment, low capacity utilization and problems related to instrumentation and control systems)

Prepared for the Government of the Syrian Arab Republic
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

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ABSTRACT

An assignment as an expert in operation and maintenance of Instrument Control System in Fertilizer Plants under general establishment for Chemical industries in Syrian Arab Republic, was given by United Nations Industrial Development Organization, Vienna.

This assignment was for undertaking studies for low capacity utilization, frequent failures of main equipments and machineries, high energy consumption, inadequate Instruments and Controls and problems in operation and maintenance through them.

The duration of the study at the general Fertilizer Company was for 35 days at intervals. Most of the time was spent in the plant to assess for the problems during running and co-related the findings when the plant had faced an unscheduled shut down for Ammonia-Urea Plant due to failure of major high speed rotating centrifugal compressors for gas, Process air and CO2.

Various discussions were held with Chief of Operating Personnel Instrumentation and Mechanical Maintenance personnel, Technical and General Directors to find out the various problems relating maintenance and inspection procedures, responsibilities of personnel in the organization and general set up of the organization.

The General Fertilizer Company at HOMS in Syrian Arab Republic is the only Fertilizer unit in the country having a large integrated Complex. The plant started with its first unit for producing Calcium Ammonium Nitrate with concentration of 26% and for an annual production capacity of 140000 T.P.A. in 1972.

Thereafter, 2 big units were added. One for Triple Super Phosphate of 450000 T.P.A. capacity and Ammonia-Urea Complex of 330000 T.P.A. capacity in 1975.

Besides the above, it produces 130000 M.T. of Liquid Ammonia and 40000 M.T. of Sulfuric Acid along with 3000 M.T. of Aluminium Fluoride for export.

There are total of 3300 operators and technicians in various disciplines and specializations work in this Company.

1. GENERAL SECTIONS OF THE COMPANY

1.1 Ammonia-Urea Plant consists of :

Ammonia Section with a capacity to produce 1000 T.P.D. Liquid Ammonia - designed by Kellogg.

Urea Section with production capacity of 1050 TPD and of Stamicarbon Process.

The plant consumes 600 TPD Liquid Ammonia to produce 1050 TPD Urea Fertilizer. Remaining 400 TPD surplus Ammonia is used for other units in the Complex and also for export.

The Ammonia Plant was originally designed on base of Naptha as feed stock but subsequently modified and changed for use of natural gas as feed stock in 1988.

There is an old Ammonia Plant of 150 TPD capacity with Naptha as feed stock. This unit is not working since 1982 and kept idle.

The Ammonia-Urea plant has its own independent utilities section having Water Treatment Plant, Utility Boilers, Raw water and Cooling water system and Instrument Air Plant.

1.2 Triple Super-Phosphate Plant consists of

Sulfuric Acid Plant with capacity of 560000 TPA having two streams of 850 MT/day each capacity.

Phosphoric Acid plant with the capacity of 165000 TPA built by Rumania with their technology but never could achieve more than 40% of rated capacity since commissioning.

Super Phosphate Plant with capacity of 450000 TPA but cannot produce the rated capacity due to shortfall of Phosphoric Acid and frequent equipment failures.

Aluminium Fluoride Plant with capacity of 3000 TPA but closed down now due to high Silica problem in Fluorine.

Raw Phosphate rock is locally ensured by the General Phosphate Company at a rate of 80000 T.P.A.

Triple Super Phosphate unit has its own independent Utility Plant having Water Treatment facilities, raw and cooling water supply and Instrument Air system.

1.3 Nitrate Fertilizer Plant consists of
Nitric Acid production section with capacity of 87500 TPA at concentration of 100% Nitric Acid.

Calcium Ammonium Nitrate Fertilizer production unit with capacity of 140000 TPA.

This unit also have own independent Utility Section having integrated steam availability system with Sulfuric Acid plant where surplus generation of waste heat recoveries by way of steam is exported to this plant.

1.4 Each plant is headed by Plant Manager and there is a Central Directorate Organization for extending various supporting services.

1.5 Identification of problems through operations of the plant, equipments, high speed rotating machineries, process design shortcomings, improper design and selection of Metallurgy for Process equipments and machineries and finally the shortcomings in Instrument and Control systems both in system/application Engineering and Operation/Maintenance in running plant.

Observations were not only confined with Instrumentation and Controls' problems but with a wider perspective, the shortcomings in achieving rated capacities for the plants were scrutinized and identifications for the bottlenecks have been made. On the basis of personal experiences in Fertilizer Plant operation and System Engineering for Controls and Instrumentation, the wider observations and scrutinies were made for the greater interest of the Engineering profession which, may help further the plant to de-bottleneck the problems with the assessments.

1. AMMONIA AND UREA PLANT :

1.1 Problems in achieving rated capacity of Ammonia Plant and Urea Plant.

1.1.1 It was revealed that the Ammonia Plant is unable to produce at rated capacity since the changeover of the feed stock from Naptha to Natural Gas.

1.2 Arch Burners for Primary Reformer are not giving full capacity with Gas Burners' Header Pressure of gas at designed 4.2 kg/cm2g but requires a higher header pressure at 8.4 kg/cm2g for Flame Propagation and stability. Even though the system is for top firing, side . urners are also kept to support.

1.3 Higher temperature of flue gas at Primary and Secondary Reformer waste heat steam generator stack at 380°C.

1.4 High contamination of Silica and Rust particles in feed stock Natural Gas is taken for compression in Gas Compressor.

1.5 Insufficient Process Air availability in the Secondary Reformer even though the Compressor is at its full speed.

1.5 Insufficient Cooling water availability for condensers.

1.7 Inadequate on-line Analytical Instruments at various processing stages. All conductivity monitors and other Analytical Process Monitors are out of order.

1.8 No Instrumentation is provided for supervision of vibration, Axial Displacement and bearing temperature and major abnormality interlocks are not existing for predictive maintenance or precautionary measures.

1.9 Improper design of anti-surge control for air compressors and gas compressors.

1.2 <u>ANALYSIS OF PROBLEMS</u>

1.2.1 The problem starts with worst quality of polished water required to generate steam at 105 kg/cm2 and temperature at 515°C at Primary and Secondary Reformer Waste Heat Boiler. Similarly this quality of water is not even suitable for generating steam at Utility Boilers where the pressure is at 38 kg/cm2g and temperature 385°C.

Due to bad quality of water with high Calcium ions, Phosphate and Silica, high rate of scaling has occured in the Heat exchanger tubes. This is the beginning of the bottleneck.

1.2.2 There is a D.M. unit for name's sake but observation revealed that no Ion-exchanging taking place in the units but presently functioning as a filter. The capacity of the unit is not adequate and no back washing and proper regeneration facilities are incorporated. There are no monitoring instruments at the outlet of the Anion, Cation and Mixed Bed units. The final outlet conductivity is showing at its maximum value of 1000 microsiemens/cm. It was also revealed that the Mixed Bed Unit was out of service for some time.

It is dangerous to run an Ammonia Plant with such bad quality of polished water. The case is the same for the preparation of Cooling Water which contains high Spheroidal and Colloidal solids, which, in turn, affecting with large depositions on cooler and condenser tubes.

During a shut down of the Plant, all the above analysis were investigated. The Air Compressor Turbine unit was found with full of scalling on the bladings upto 4th stage. The scale deposition was with impingement and of 2 MM thick. The scaling is for the silicates of Calcium and Magnesium and has come along with the steam.

The nozzle valves' seat and plugs were found coated with scaling and similarly the main stop valve. Accordingly there were serious errosion found on the valve seat and plug. The errosion was so much that the compressor could achieve at its full speed with governor impulse to close fully. This operation is serious and due to non-existent of any trend instrument or flow measuring instruments for steam, predictive analysis and prior stoppage could not be undertaken. Vibration monitors also could help but they are non-existent.

The labyrinths are all scaled up and a costly repair is involved.

During this stoppage, the condenser coolers were observed and as anticipated, 60% of the tubes are scaled up fully with coatings of 1 mm thick Silicate. Obviously due to this, condenser vacuum was affected and the compressor was unable to give the full capacity. Unfortunately again, one condenser is connected with both CO2 centrifugal compressor and Process Air Compressor. All gas cooler tubes and air cooler heat exchanger tubes found scaled up.

The poor quality of polished water and cooling water, thus found as a major bottleneck in obtaining the rated production capacity.

1.2.3 The reasons for excessive flue gas outlet temperature is due to large scale internal scaling of the waste heat recovery system tubes - both in radiant zone and at flue path. Internal scaling has resulted in low recovery of heat thereby loss through stack. Due to low recovery of heat, steam generation is affected which is made up through use of gas supporting burners at

Waste Heat auxilliary Boiler. This is a colossal waste of energy. This also endangers the failure of tubes due to localised heating at much higher temperature near the stack.

1.2.4 The capacity of the gas header for the Primary Reformer burners is small and inadequate which causes to maintain a higher header pressure than burners designed. This gas header was originally for use of purge gas for burners when the Reformer was in Naptha feed stock. During that time, fuel oil was used for Burners and supporting was by purge gas availability.

This high pressure operation through burners, designed at 50% of the existing operating pressure, obviously affects the flame propagation throughout the length of the Reformer tubes and cold pockets canot be overruled. Moreover due to inadequate capacity in the header, volume of gas gets upset in other burners when a manual remote operation of flow of gas to a row of burner is made. The life of the Refractory linings would be affected due to high pressure operation. Already the linings are getting changed during the shut down, as they are damaged near the burners.

1.2.5 Natural Gas, as feed stock received from the Central Gas Agency is directly taken in the Reformer through Gas Compressor without any cross check for Sulfur content. There is no Sulfur on-line monitor to detect Sulfur content in the gas prior to entering Reformer tubes where costly catalyst may get poisoned by a minimum Sulfur content even for a short while when the Central Gas Agency's Desulfurizer Unit may not function properly and would not be known to the plant. There would be a heavy penalty to change the Reformer catalyst at an expenditure

taking a chance like this in a continuous operation without a Desulfurizer unit at this end and monitoring the Sulfur content continuously at Primary Reformer inlet. The interlock for automatic trip-off circuit must be connected with the preset unacceptable value of Sulfur in the feed gas(to be maintained at less than 0.02 ppm)

1.2.6 There is no strainer before the gas enters into the Compressor. The Gas is highly contaminated with dirt, rust and silica which is coming from external agency. This is detrimental not only for the Gas Compressor but also for Process stream.

During routine observation, abnormal rhythmic knocking sound was noticed at the Turbine Compressor. This was predicted to damage the mechanical part of the Governor Control Valve. This knocking is due to moisture carry over with the steam. There is no steam trap in the steam line before entering the valve nor there is any vibration monitoring instrument for this Compressor.

A week after, it was observed that the Gas Turbine is running at full speed even when the Governor input impulse is zero. It was feared that the Control Valve has sheared off and the plant was stopped. On checking, it was found that the prediction is correct and the valve had sheared off from valve stem. Manufacturing of such valve with high pressure drops during throttling operation calls for a one piece construction of stem and valve plug but the existing one was of two piece construction with threading and lock- Pin joint between stem and plug. Generally this is weak point as experiences have shown in similar failures till the valve plug was modified by a single piece unit.

1.2.7 Rear Baffles of the Burners for Primary Reformer have broken and channelling occurs frequently endangering Thermal cracking of the tubes and header. Consideration is being mooted to replace the Reformer tubes and planning is being made, but the root cause for the increase in size of the Gas Header has not yet been considered rather than operation of the burners at high pressure.

1.2.8 Raching rings in CO_2 regeneration system are damaged and capacity is affected. They are made of AISI 304L but suggest for AISI 316L for a longer life in the service. Pumps are also under capacity and there is a programme for changing them.

1.2.9 Activated Carbon for solution filtration in CO_2 removal section is not replaced for non-availability. Accordingly, frequent anti-foaming agent is used for the dirty solution which loads the system and capacity gets affected. Impure K_2CO_3 with high chloride Ion (more than 400 ppm) is badly affecting the CO_2 absorption which is also a contributory factor for reduction in capacity.

1.2.10 Re-Boiler tubes in this CO_2 regeneration system are partially blocked and some are cracked internally. This is also a bottleneck in capacity achievement.

1.2.11 The capacity of Process Air Compressor has decreased heavily due to :

Leakages in Inter-stage coolers

Heavy leakages through mechanical seal breathers

Leakages and venting out through the inter-stage cooler knock-out drums where Level Controllers are inoperative and no seal.

Anti-surge system is improper with vent to atmosphere.

The above has resulted to operate the plant at a lower capacity.

1.2.12 It was observed that all the three Utility Boiler Feed Pumps (normally two running and one standby) are working. On enquiry, it was revealed that two pumps cannot deliver the full requirement. Hence the third pump is also in operation.

The reason for decreased capacity was analysed. It was found that the minimum recirculation valve got fully erroded due to cavitation. High rate of recirculation caused for lower discharge capacity. The design of minimum recirculation loop is improper through a 3-way valve. This valve also requires hard facing to avoid cavitation due to excessive throttled flow and high pressure drop.

1.2.13 Inadequate Instrumentation and Controls for Process and Related Equipments have a serious bottleneck in achieving capacity production, safety and predictive diagnosis abilities and energy savings. Vital on-line monitors for process streams are not provided and most of the analytical instruments for return condensates are out of function.

1.3 Problems as observed in Urea Plant for achieving rated capacity.

1.3.1 Capacity of the Urea Plant was maintaining at 78-80% of rated capacity and gradually it dropped to 65% after which the plant was stopped during observation period, to safeguard the Evaporator-crystalliser unit.

1.3.2 The problem related mainly with the deteriorating capacity of CO2 Compressor and decrease of discharge pressure gradually.

1.3.3 Heavy leakages at Ammonia Plunger pump causing heavy Ammonia pollution in the area and making inaccessible for carrying out any timely repair and maintenances.

1.3.4 *Inadequate Instrumentation and non-existence of vital instruments to operate Urea Process Units. This blind operation is not only restricting the production capacity but also endangering equipment, machineries and quality of product. This is also contributing for high energy consumption.*

1.3.5 *Product continuous weigher is out of service and hence production rate of Prilled Urea is a guess.*

1.4 *Analysis of the problems in Urea Plant.*

1.4.1 *CO_2 Compressor has chronic problems and is the main factor for under capacity utilization and loss of production. Several failures have occured in CO_2 Compressor Turbie and Compressor unit.*

First relevant cause as identified for the failure of the CO_2 Compressor Turbine is for bad quality of steam as was the case in Ammonia Plant Air Compressor Turbine.

Second problem related to the manual operation of the interstage cooler moisture knock out drum level, as the level controllers are inoperative. This way of operation not only endangers moisture carry over with CO_2 Gas in the Compressor which causes failures of mechanical seals, labyrinth and 'O' rings but also loses CO_2 gas when the level is not existing. This operation has caused severe penalty by way of changing seals and 'O' rings. The root cause by providing "Auto" operation of level have not been made. It was revealed that these level controllers are inoperative for quite some time. The recent stoppage of the plant was also due to heavy loss of gas through the damaged mechanical seals and 'O' rings.

The knock out drum level controllers must be made operative and under no circumstances these should be operated manually. Self acting mechanical type level controller should be replaced by Displacer type pneumatic type level controller.

Moisture separator/demistors are recommended to meet the specification of maximum moisture of 0.5 ppm.

'O' rings used now in Compressor should be of [illegible] 'N' instead of Neoprene or Silicone rubber which is unsuitable for CO_2 with moisture.

1.4.2 Ammonia pumps are having problems with:

A. Non-Return valves leaking due to seat leakages for sticky depositions and springs frequently gets damaged.

B. Oil packings get frequently damaged

C. Safety valves on Discharge side leaks continuously due to rust formation around the seat. Independent safety valves have been blinded off to save the capacity loss keeping one common safety valve.

D. Suction/Discharge main valve 'O' rings getting damaged due to flushing with hot water.

E. No vibration switch is provided for plunger to acknowledge problems quickly before the entire pump requires stopping.

1.4.3 Carbamate recycle pump is having similar problems. There is no flow measurement system for the recycle Carbamate which is an utmost necessity to maintain proper mol. ratio. This is now being done arbitrarily with the value of the speed of the pump to maintain the mol. ratio at 5% rate.

1.4.4 Inadequate Instrumentation in Urea pLant affects greatly the production and quality. Some of the major shortcomings are:

I. There is no measurement of Ammonia and Carbon Dioxide Gas flow with mass flow concept and control provision for them to flow in the Reactor.

II. Density Monitor for proper adjustments of Ammonia and CO2 continuously on auto control is not provided to achieve efficiency, product quality with optimum loading and better performances for the downstream units.

III A flow meter for Ammonia on the suction side of the pump is not at all a true relevance of quantity when there are excessive leakages in Ammonia pump. Moreover, the flow meter is inoperative now.

IV. CO2 Recorder is not compensated for pressure and temperature, hence totally misleading, particularly, when the CO2 Compressor is losing pressure gradually due to seal leakages.

V There is no measurement for utilities used in the plant. Totalization of flow is necessary to calculate the efficiencies of equipments at regular intervals.

VI Return condensates are not monitored for their conductivities i.e. qualities before being sent to Utility Area.

VII Urea Reactor level monitor is of Gamma-Ray type and not calibrated for a long time. A life span of 5 years is quite adequate for recalibration.

VIII Stripper level controller is not functioning due to improper primary element.

IX The Cone Distributor of the melt is acknowledged by the speed of the motor which is misleading. Many a time jamming has occured. The motor speed is not relevant in this operation, as the distributor is belt driven. Any slippage and broken belt will not be acknowledged by motor speed. This is to be acknowledged by Motor load (amperage) at the Control room. (This has now been implemented immediately).

1.4.5 Crystalliser second Evaporator should be modified to get less pressure drop. Blow back system is advised.

1.4.6 High Burette in Prilled Ura is due to shortcomings of proper instrumentation in Evaporator and stripper section.

1.4.7 Cascade controls used in rectifying column is improper. No consideration has been taken to improve upon the measurement lag in temperature with accelerating relays or suppressed range temperature transmitter. Sluggish response was noticed. An anticipatory feed forward control with computing relay would have been a good design than a cascade loop.

1.4.8 Interlocks for pump operations for scrubber circulation pump and H.P. Carbamate pump are improper.

1.4.9 Urea Plant must be provided with vital trend recording instruments rather than indicating controllers which are insufficient in fault diagnosis and tell-tale of operation.

1.4.10 CO2 Compressor Steam Turbine speed control is by a simple volumetric flow controller without pressure and temperature correction of gas flow. The concept is wrong and mass flow of gas should control the speed.

1.5 Problems as observed in the Utilities Section of Ammonia and Urea Plant :

1.5.1 Water Treatment facilities for the area is inadequate by capacity, equipments, instruments and maintenance.

1.5.2 As observed in Ammonia and Urea Plant headings that a major bottleneck in achieving rated capacities for the plants are due to failure of equipments, using steam, boiler feed water, cooling water and raw water. Root causes of problems start with unacceptable quality of treated water which are being used for generating 105 kg/cm2g and 40 kg/cm2g steam. Treated Raw water quality for condensers, coolers etc. is also unacceptable.

1.5.3 This has further aggravated by way of Return condensates directly taken to the Deaerator without any monitoring of their qualities continuously through on-line monitors and automatic diversion, in case of bad contaminated condensate. On one side there is inadequate water treatment facility and other side contaminated condensates directly to Deaerators have multiplied the seriousness. There are no monitoring instruments provided for Return condensate quality.

1.5.4 Excessive steam leakages, approx. 15% of steam generation in the area was observed. These leakages are mainly from steam line joints, valve bonnets and glands and also from flanges of gauze glasses in Boilers.

Steam expansion loops are inadequate and similarly steam traps are minimum. Most of the leakages are for water hammering and poor maintenance of valves with packings.

2.0 Problems as observed in Phosphoric Acid Plant.

2.1 Rated capacity cannot be achieved. Operating at 40% of rated capacity.

2.2 The plant has inherited problems since it was commissioned with outdated technology and equipments, machineries etc.

2.3 Production team are fighting for a lost battle but nothing better can be achieved.

2.4 Failure of pumps are alarming due to excess of sulphate and solid matters. Corrosion and errosion failures or both are existing.

2.5 High P_2O_5 carryover in exit Fluorine from Evaporator.

2.6 High emission of Fluorine, SO3 fumes, and Phosphoric Acid fumes are causing sickness for operating personnel in the area.

2.7 Analysis of the Problems :

2.7.1 Obsolete and outdated technology with improper design of plant, machineries and metallurgy of equipments are the main hurdle to achieve rated production capacity right from the commissioning time.

2.7.2 Digester concept has not been considered in this process which is conventional in Phosphoric Acid making in Wet Process. A rubber line mixing tank was in early days which has been removed subsequently due to frequent damage of lining.

2.7.3 Extreme poor quality of raw water with high silica content associated withchloride and suspended solids have affected the filtration.

2.7.4 There is no Instrumentation and Controls provided in such an important plant.

2.7.5 The entire process requires revamping with modern technology, equipment, metallurgy and Instrumentation and Controls. Some recommendations can be made to improve upon the process as below :

Pulverized Phosphate Rock with proper weighment from Phosphate Rock hopper to mixing tank should be fed where digester underflow mixes via a slurry cooler. The slurry cooler should be under partial vacuum through barometric condenser.

Mixing Tank with an Agitator of low speed will continuously pre mix the rock and slurry which would work like washing of undesired errosive material from rock.

The overflow from the mixing tank should be ken to digester where the Sulfuric Acid in proportion with the concentration in Digester is added. The Sulfuric acid is fed from a mixing box where the recycle acid from Filtrate Receiver is taken. Accordingly the concentration of Sulfuric Acid is controlled by the Conductivity Analyser of the mixing tank outlet by the make up strong acid. The flow rate of Sulfuric Acid thereafter is controlled on the basis of concentration of filter feed tank outlet and this should be feed forward control.

The Digesters have Agitators and Fluorine can be scrubbed from the fumes with exhaust fans.

With above changes in the process, the plant can come out from the Primary problems.

Metallurgy should be upgrade with the use of Elasto-polymer rather than expensive Haste-Alloy 'C' indiscriminately. Precast Fibre pipelines are to be considered for Phosphoric Acid and Sulfuric Acid flow lines rather than rubber lined M.S. pipes.

Instrumentation are not existing, hence no comment can be made about their functioning.

3.0 Problems as observed in Sulfuric Acid Plant.

3.1 The plant has two streams, each having a capacity to produce 850 MT/Day Sulfuric Acid. The plant is at present running at 60% of capacity.

3.2 The Waste Heat Boiler is having a capacity of 40 MT/Hr at a pressure of 40 bar and at a temperature of 450°C.

3.3 The plant has its own Water Treatment Plant having excellent running method through Instrumentation. The water quality is highly polished at hardness of .008 ppm and Silica level at .02-.05 ppm, and pH betwen 7.5 to 8.2 for Boiler feed.

The steam quality thus at a hardness of zero and conductivity at 1-2 Micro-MHOS/cm.

3.4 <u>ANALYSIS</u>

3.4.1 Periodic maintenance and proper upkeeping of Process equipments and related instruments are carried out with proper check lists. Frequent breakdowns in the plant has thus minimised.

3.4.2 The plant is running at its 60% capacity due to problems in its off-take at Phosphoric Acid plant. Plant efficiency can go up if the plant runs at rated capacity. Suggesting for diversified product of Oleum at 25% for domestic use.

3.4.3 The inner baffles for the Waste Heat Boilers are in very bad shape due to high corrosion rate. This has now affected the refractory linings. Suggest to change the baffles by AISI 316 to combat against corrosion.

3.4.4 Steam leakages are due to high external corrosion due to Sulphurous mist and water vapour. Sufficient steam traps are not provided but the steam piping system is well laid with proper expansion loops.

3.4.5 Adequate judicious Instrumentation and Controls are provided in the plant and all are functioning well. With the help of Instrumentation, the plant could achieve a conversion of 99.2% and product concentration is maintained at 96-98% through controls. All the instruments in Waste Heat Boiler and Converters are working well.

The Water Treatment Plant is fully equipped with all necessary instruments and good vigilance is kept to maintain the quality of water.

4.0 Problems as observed in T.S.P. Granulation Plant.

4.1 Granulators have frequent problems due to mechanical breakdowns.

4.2 Electrical and Instrumentation problems in Material Handling systems.

4.3 Analysis of the problems.

4.3.1 Bearing failures are very frequent due to high vibration in Granulators.

4.3.2 Type of Instruments and interlocks are not suitable to work in such corrosive and highly conductive dirty areas. IP55 grade enclosure not specified in the area.

4.3.3 Granulators mounting pedastals should be checked for alignment and sealed bearings are recommended.

4.3.4 Granulator loadings should be monitored through microphone amplitude and should be located at three places along the span to monitor the loading and jamming.

4.4.5 Frequent checkings of vibration at bearings are recommended alongwith bearing surface temperatures with portable indicators.

5.0 Observation and suggestion in Nitrate Fertilizer Plant.

5.1 The Instrumentation in Nitric Acid Plant, after revamping through the use of Foxboro make instruments are working satisfactorily. It was noticed that mass flow concept for compressible fluid has not been adopted and Flow Control is misrepresented.

5.2 Oxidation reduction potential transmitter controllers are not used in the process, instead, pH controllers were put and not functioning. ORP method to be introduced with proper electrode specification and ultrasonic on-line electrode cleaner to repel the solid depositions. This is for reactor.

5.3 Conductivity monitors for controlling the concentration of Nitric Acid is not in use for ensuring product concentration.

5.4 A conventional orifice type flow measuring element has been used for Nitric Acid flow to the Reactor. This element has not been checked in the pipeline for years about the condition. This has been used in ratio form. A magnetic flow meter is suggested to take care of variations of fluid in flowing condition.

5.5 The concentration of the product from the reactor i.e. Ammonium Nitrate is not controlled as a master-slave cascade system for changing the ratio of Liquid Ammonia and Nitric Acid. Presently, this is in manual operation. This control is essential and highly recommended for achieving uniformity in product quality and conservation of raw material input.

5.6 Prill Tower has the problem of pressurization. Proper cooling of downcomer prills are getting affected. This pressurization has attributed to the damage of the tower structure. Caking is also occurring at the bottom.

Exhauster fans capacities are inadequate. Higher capacity blowers are to be put to maintain a draught of minus 3.0 MM W.S. in the tower.

It is also suggested to connect all the exhauster outlet at a common header and this should be vented through a Bag Filter. This would not only eliminate air pollution but also would help to recycle the collected dust through the mixer in the process. This is a saving. The draught in the tower would also help in cooling adequately and would avoid caking, as, sufficient air flow would keep the prill bed fluidic.

Elasto-polymer lining for the inner wall of the Prill Tower can be looked into to save guard the structure from corrosive fume.

6.0 Recommendations in the improvements of Instrumentation system with emphasis for safety and emergencies in Ammonia Plant and specification of equipments for standardization.

6.1 Comments on installed Instruments and System.

6.1.1 Oxygen and CH4 Analysers are inoperative due to their obsolency and non-availability of spares.

6.1.2 CO and CO2 Analysers at various stages are also inoperative.

6.1.3 Inadequate Process Control Instrumentation for Ammonia and Urea Plant for appropriate availability of guidances in operation and predictive action for any major breakdowns.

6.1.4 Vital requirements of on-line continuous conductivity monitors for Water Treatment facilities and Return Process condensates are all inoperative due to lack of spares and obsolency besides wrong specification for applications.

6.2 Suggestions and recommendations for Instrumentation and Controls in Ammonia Plant.

With modern plants built by reputed organisations of the world, special emphasis have been given to use sophisticated Instruments and Control systems for helping production/Process personnel to monitor the performances of reaction, efficiencies, malfunctioning and predictive actions thereby, besides to achieve optimum capacity utilization with optimum efficiencies. Though the use of Microprocessor based digital distributed control systems have been in use in Ammonia Plants since early 80's in many developing countries, but this recommendation will refrain from recommending the sophistication due to various preliminary shortcomings with the Process and Equipments besides the limitation of the availabilities of experienced staff to maintain them. This can only be recommended for any new plant, if the country thinks of.

Though this plant is equipped with conventional pneumatic analog instruments but the System Engineering is poor and totally inadequate for a plant of this size and nature, particularly when built by a reputed organisation like M/s Kellogg. It is evident also that the package offer was accepted without any technical scrutinies of the design and System Engineering of the Instrumentation and Control System including the type, model and make of reputation and reliability. The design of Control System was suitable for a plant of 60's but not for 80's.

6.2.1 Why better controls are recommended :

6.2.1.1 Ammonia production utilizing the direct synthesis of Nitrogen and Hydrogen, has over the past generation become the major source of Ammonia required in the production of Chemical Fertilizers. The single train Ammonia Plant requires a co-ordinated approach to safety instrumentation due to :

a) Greatly increased throughput
b) The utilization of Centrifugal Compressors
c) A highly integrated heat exchange system and
d) The High Pressure Reforming Reactor and Low Pressure Synthesis concept.

A large plant with 1000 TPD of Ammonia should have a good design with Instrumentation and Control system and the offer of this system should come generously from the designer to have initial lower investment cost and reduction of operating cost per tonne of production. These judicious control would help operators to maintain a high on-stream factor reliabilities as, a small outage can be serious in terms of loss of production.

6.2.1.2 Four Centrifugal Compressors are basic to the Ammonia Plant of high capacity single-train Ammonia unit. They are Gas Compressor and the Ammonia Refrigeration Compressor. Each is having their own characteristic of anti-surge (blow-back), speed control but totally of neglected supervisory and safety instruments. Similarly, there are no monitors to assess the condition of unit health to take predictive action.

6.2.1.3 Effective recoveries of all available heat is essential to this scale of Ammonia production. Accordingly, an integrated heat exchange system, effectively, should recover waste heat, utilizing process gas, process air, Boiler feed water preheat and superheat coils within the Primary Reformer.

This is at this point, where performance and quality monitoring of utilities available, play a major role and quality of both treated water and cooling water must be of high grade polished water to maintain the waste heat recoveries at maximum. This can only be achieved through proper design of utility plant with best reliable on-line continuous trend monitoring instruments and controls. Similarly, if the waste heat recoveries are affected in the main recovery areas like Primary and Second Reformers, the colossal loss of energy is attributed besides endangering the life of the equipments and loss of production.

A large quantity of steam is required as a process reactant and to power the numerous pumps' and compresssors' prime movers. Therefore 105 kg/cm2g steam is generated by heat exchanges between Boiler feed water and hot process gases at various points of the Ammonia unit. In addition many Boiler feed water preheat exchangers are provided throughout the process. The above facts thus cautions the operation to keep the related utilities at their best to play the best role of plant efficiencies at a high degree through their quality monitorings.

6.2.1.4 The objective of Ammonia Plant Instrumentation including the afety Instrumentation is to monitor the process condition and protection of personnel, mechanical equipment and catalyst inventories. Activation of plant shut downs systems with highly sophisticated interlocks in the plant thus is necessary.

With fired furnaces, Boilers, high pressure- high temperature reactors and a Complex High Pressure steam system, a potential safety hazards exist which must be adequately instrumented to assure man and machine protection. Modern control philosophy, thus provides continuous and alarm monitoring with emergency trips of all significant variables for operation inclusive of isolation, relieving and shut down for all critical variables. The high capacity equipment, utilized in single train Ammonia plant is expensive to replace and may require a lengthy shut downs with a loss of production during such replacements. The main factor with which the Ammonia Plant at HOMS is suffering is mainly due to the above shortcomings. The adequate Instrumentation is not provided for major high speed rotating machineries and nothing can be concluded till the equipment comes to a standstill with major damages.

6.2.1.5 Of the several catalysts in the plant reactors, the Primary Reformer catalysts are the most sensitive to damage. An interruption of reforming steam for very short period, while feed gas is flowing, can coke up the entire catalyst. Besides the high cost of catalyst, at least a week of downtime for unloading and reloading. Similar problem due to sulfur poisoning may occur in absence of sulfur monitoring, on-line type for feed gas to Primary Reformer, which automatically trips off the plant in case of unacceptable limit. This is not existing at all in HOMS factory particularly when the gas feed stock is desulferized by an external agency and the plant doesn't have independent desulfurizer unit. A continuous Sulfur Analyser thus is strongly recommended for Gas feed to Primary Reformer. This should be an on-line Analyser with remote recorder, alarm etc. with shut down interlock in the control room.

Another critical catalyst is in the Methanator where a short slippage of CO2 due to failure of the CO2 Absorber system, can result in a temperature run-away with damage to catalyst and possibly the Reactor. The low temperature shift converter is also subject to possible damage - of Catalyst.

Without a CO2 Analyser and on-line gas Chromatographs in the process stream, it is risky in operating such plant. These Analysers can provide a tell-tale of operation and predictive mal-operation can alert the operator to bring a safe shut down gradually.

6.2.1.6 The Instrumentation philosophy which are generally considered for an Ammonia plant, particularly by M/s Kellogg standard is described.

For Primary Reformer :

The existing Primary Reformer is a fired furnace containing catalyst-filled tubes through which feed gas and steam pass during reaction. As mentioned in earlier paragraph, the catalyst is very expensive and sensitive to coking if steam is interrupted while feed gas continues to flow. The furnace is long, large cabin type box with many burners, evenly spaced at the top of the box firing vertically downward. Besides the top burners, it has also supporting side burners. A slight negative pressure is held in the box by means of induced draft fan at the stack end of the furnace.

Reformer steam/feed gas ratio controller is not existing. This is a shortcoming of high magnitude in an Ammonia Plant designed and built in 80's. Steam to the Reformer must be supplied in excess of the quantity required for reaction, to minimize coking of the Reformer catalyst.

The feed gas and the steam flow are held constant by individual flow controllers. Depending on the variation in composition and pressure of the feed gas, it becomes necessary to compensate the pressure and density variations to achieve an accurate mass flow measurements. The feed gas flow is then ratioed to the steam flow which is also linearized, and pressure-temperature compensated, through a ratio comparator relay, which calculates the flowing ratio and compares to a present limit. If the ratio of steam flow to gas flow falls below the ratio setting an alarm is actuated to warn the operator of an impending emergency. If the ratio continues to fall, a low ratio switch actuates the feed gas shut down system. During this time, steam valve remains on flow "Automatic Control" to maintain a near normal Reformer tube temperature. This is a vital system to safeguard the catalyst.

For Secondary Reformer.

This is a large catalyst filled pressure reactor in which a partial combustion reaction occurs between the effluent gases from the Primary Reformer and combustion air from the process air compressor. This reaction provides the proper ratio of N2 for the synthesis reaction downstream and raises the gas temperature to 980°C to supply heat for the reaction occuring in the catalyst beds below. Because of the high temperature involved, the Reactor shell is protected by an internal refractory lining and an external water jacket. It is thus an utmost necessity that a) the internal reactor bed temperature are not allowed to become excessive and b) sufficient jacket water level is maintained with good quality of water not to scale inside.

Both the above two conditions are badly affected due to:

a) Non availability of adequate on-line stream analysers viz; O2, CO and H2 with gas chromatograph which are vital to control proper air flow in the Reactor.

b) Non functioning of the Analysers which are provided like CO2 and CH4.

c) Improper use of thermocouples without purged and sheathed to withstand high temperature and Hydrogen service.

d) Jacket cooling water level is maintained but no monitoring is done to acknowledge inlet and outlet temperatures of water for knowing the heat exchange. There is a serious doubt about the jacket internal scaling due to bad quality of water. Thus the quantity of water flow is restricted. This is established through the temperature recorder where some of the points are oscillating.

e) Heat exchanger tubes are suspected under high scaling which is evident by higher flue gas temperatures.

The above conditions would seriously hamper the operation of Secondary Reformer. The catalyst life is deteriorating fast and production of Ammonia would suffer.

The judicious control of mass air flow through pressure temperature compensation and by acknowledging the O2, CO and H2 would achieve the completion of reaction at an optimized mol. ratio which would help in subsequent unit operation without loading for maximising the production.

Safety interlock has not been provided sufficiently for the combustion air to the Secondary Reformer. The interlock must be looped with the eventuality of feed gas failure, when the combustion air flow must be interrupted to prevent damage to the catalyst and down stream equipments. Due to bad condition of Air Compressor, the capacity used to fall with a fall of pressure. Hence without the mass flow measurement of air, the flow value is misleading in operation and thus dangerous. Moreover, during the plant shut down, the amount of rust and dirt found in the compressor leads to belief that the catalyst space velocity has seriously affected and must be looked into.

6.2.1.7 CO2 Removal System

Problems are many fold in the area as described under 1.2.8 to 1.2.10. Inadequacy of safety devices have also been noticed.

The operation system calls for a clean carbon oxides free gas to enter in the synthesis loop. Accordingly the CO2 absorption system absorbs but a fractional percent of the carbon oxides using Vetrocoke Alkalyne solution. The remaining oxides are removed by the Methanator. Thus, it is essential to acknowledge CO and CO_2 percentage (in ppm) after the absorber. These are not available in operation.

Similarly, loss of absorber level in the high pressure absorber may allow a gas pulse ; "Blowing" to the atmospheric stripper causing the possibility of a serious damage to internals i.e. trays. This has occurred in the system and there is a doubt that the lo-level switches in the absorber have malfunctioned and the system was bypassed. There are sequences for lo-level alarm which alerts the operator of impending danger and to close a tight shut-off valve in case of such level failure. The valve normally operates with the lo-level switches via the Solenoid valves with latching system which can be reset manually by the operator after he clears the malfunction. On an overall observation it was noticed that such magnetic level switches are mostly inoperative due to supplies of unreliable make and internal metallurgy is unsuitable for the application.

6.2.1.8 Methanator Temperature

The Methanator utilizes a highly exothermic reaction to convert the remaining traces Carbon oxides into Methane. Thus Analysers and on-line Gas Chromatographs are essential both at inlet and at outlet of Methanator to monitor operation. None of such instruments are available in the plant. A large slippage of Carbon oxides from the Absorber would cause a very rapid and dangerous temperature rise.

A multipoint recorder for temperature is used but to acknowledge the temperature profile, trend monitoring recorder is suggested with in-built independent high temperature alarm to warn the operator for spot identification of zone and can take emergency measure by tripping through a quick closing Butterfly valve. There should be an overriding facility for the operator through a push-button for this. A pressure controller is included also to prevent over-pressurization of the upstream system during Methanator shut down and to allow operation of the CO_2 Absorber during malfunction operation and isolation of the Methanator.

6.2.1.9 *General Instrumentation.*

The plant has used all pneumatic instruments for Process Control purpose in open-loop concept. There are great ommissions of use of cascade control loops or anticipatory feed forward control loops. The mass flow concept and square-root linearization for flow controls are omitted. The range selections, judicious standardization of 'β' ratio for flow transmitters with minimum pressure drops have not been adopted. The vital temperature controls are not with derivative function in the controllers. No suppressed range has been adopted for temperature transmitter to achieve better span for control purpose.

Analytical Instruments are very few and most of them found inoperative due to lack of spares or due to poor maintenances. Latest concept of flow measurement systems like D.C. Magnetic flow meters, ultrasonic flow meters etc. have not been used in plant applications. Similerly volumetric sealed flow and level transmitters have also not been used. Ultrasonic cleaners for pH electrodes have not been considered and thus erratic readings and failures of electrodes in service are common.

No system has been adopted to monitor all return condensate quality through any reliable on-line conductivity monitors and automatic diversion loops are not existing for condensates. This is a serious shortcomings and the plant is suffering due to worst quality of water that an Ammonia Plant and Urea Plant associated with Utility Boilers can accept to generate high pressure and high temperature steam to run the vital prime movers of high speed centrifugal compressors and also where a batteries of heat exchangers are involved.

The main reason for under capacity utilization contributes to the factor for the failure of equipments and most of them are due to bad quality of steam and water and also for failure of instruments or inadequacies of them.

A final comment can also be made with the poor maintenance of instruments. It is now time that a well organised and well trained [redacted] competent Instrumentation Engineers are inducted with the job. The observation revealed that no *seriousness in the malfunctioning of instruments are taken and they are running manually the vital controls leading various equipment failures. It seemed that no serious considerations were given when the air cooler interstage knock out drum level controllers and CO2 Compressor interstage gas cooler level controllers were not functioning for months and lose of air and CO2 was attributed, thereby plant production capacity was curtailed without knowing as to why the capacity of compressors have reduced. Manual operation of level in knock out drums led to moisture carryover, resulted in damaging the mechanical seals, 'O' rings, labyrinths etc.*

There is no diagnostic approach for operating personnel. A round in the Compressor House could reveal the gradual deterioration of the performances of the equipments. Steam flow measurement to Turbine, the vacuum in the condenser can co-relate many information about the health of the Turbine. On first observation, it was revealed that the vacuum is hunting and knocking sound was coming from the Turbine end. Steady vacuum was not available due to condenser tube scaling fully with Calcium Silicate. Other side, the nozzle valves are erroded with Silica impingement and the Compressor could run with Governor impulse as minimum for full speed. There were no steam traps also for Turbine inlet steam to avoid water/moisture entry with steam causing internal hammering during a cold start or in running, particularly when the desuperheater temperature control in the Utility Section in manual operation.

The plant does not have standard make instrument which indicates that no scrutiny was made when any supplier supplied the package system. During recent shut down of the plant, it was noticed that the supplier's are calling external Technicians from their countries of origin to check the instruments. This job should be entrusted to the plant Instrument personnel and if necessary, the supplier can guide them. This is the only way by which the Instrument personnel would receive training and confidences.

6.2.1.10 Training of Personnel

The existing staff of Instrument Department has limitations with their knowledge and expertise. None of them are fully Graduate in Instrumentation and Control Engineering. They have no sufficient process experiences too.

It is recommended that some Instrument Specialist may be hired to impart training to the Instrumentation personnel, both in theory and also on the job training. Job instruction manuals are to be prepared for the Technicians for various types of instruments existing in the plant and periodic job training classes should be held for their upbringings. It is not necessary for sending the existing staff for any training outside the country.

If the Universities in the country do not have any course for Instrumentation and Controls Engineering, it is suggested to include in the curriculum. Similarly vocational training centres should have Instrumentation and Electronic Technicians training.

The Fertilizer Company also should take initiative to take up with the Universities and vocational training centres for the inclusion of this subject. This will also help for any future Fertilizer Complex of this country too.

6.2.1.11 Organization of General Fertilizer Company.

The present set up of the organization seem to be very much compartmentalized. Each unit is working independently and the Engineering is not common.

It is suggested that such huge set up should be brought under one umbrella. Technical, Engineering and Production units for the entire plant should be headed by three competent persons with high degree of Technocracy. The Engineers and Technicians should rotate to all the plants of the Complex so that they can get exposures to all types of emergencies and varied experiences.

Present structure of the organization at Managerial and Director level is not on a pyramid structure but more or less in a rectangular structure. The responsibilities, thus, are diluted and the sense of decision taking is getting delayed. Non-effective and non-utilization of manpower was observed.

The following suggestion may be considered in this regard.

A The entire General Fertilizer Complex at HOMS, in Syrian Arab Republic with all its units located here should be considered as one Complex with plants headed by respective Superintendents, responsible for production and operation. The maintenance of the entire Complex *be headed by a Central Maintenance Manager who would be assisted by Plant Maintenance Superintendents. A Technical Manager for the Central organization would be responsible for Research, Quality Control, spare parts monitoring and indigenization, Technological plant study and energy ana efficiencies including safety and house-keeping. The inspection wing can also report to him independently.*

All Managers would report to General Manager of the organization. He may be assisted by two Deputy General Managers - one for Operations and Maintenance and the other for Technical, Adminstration and Finance.

The Plant Superintendents would be assisted by Plant Engineers, Engineers, Trainee Engineers and skilled/unskilled workers. The maintenance organization should impart proper training to personnel to carry out maintenance for any of the plant machineries and they must rotate amongst plants for good exposure. Rotation should start with skilled workers and Trainee Engineers and then gradually for Engineers and Plant Engineers to handle maintenances of all/any production plants. An uniform pay scale should be arranged to avoid any discrepancies.

B. *There should be a practice to form committees with participation of Managers, Engineers and workers for undertaking various general work in the plant who should submit their observations to the General Managers. These teams would work as a Vigilance Committee for good house keeping and safety, Steam and Electrical Energy losses in the plant including potable water misuses.*

C. *Co-ordination meeting should be held for each branches of Engineering regularly to discuss about various problems and these meetings also should be conducted in higher levels.*

An organization chart, as is relevant in a Complex like General Fertilizer Company is atached for consideration which would help the Company to work in a better co-ordinated manner to achieve better productivity, efficiencies and flexible maintenance work in theplant with high manpower availability.

Designations may be altered according to country's prevailing system but the mention in the report is standard in developing countries. (Annex-1).

7. Conclusions

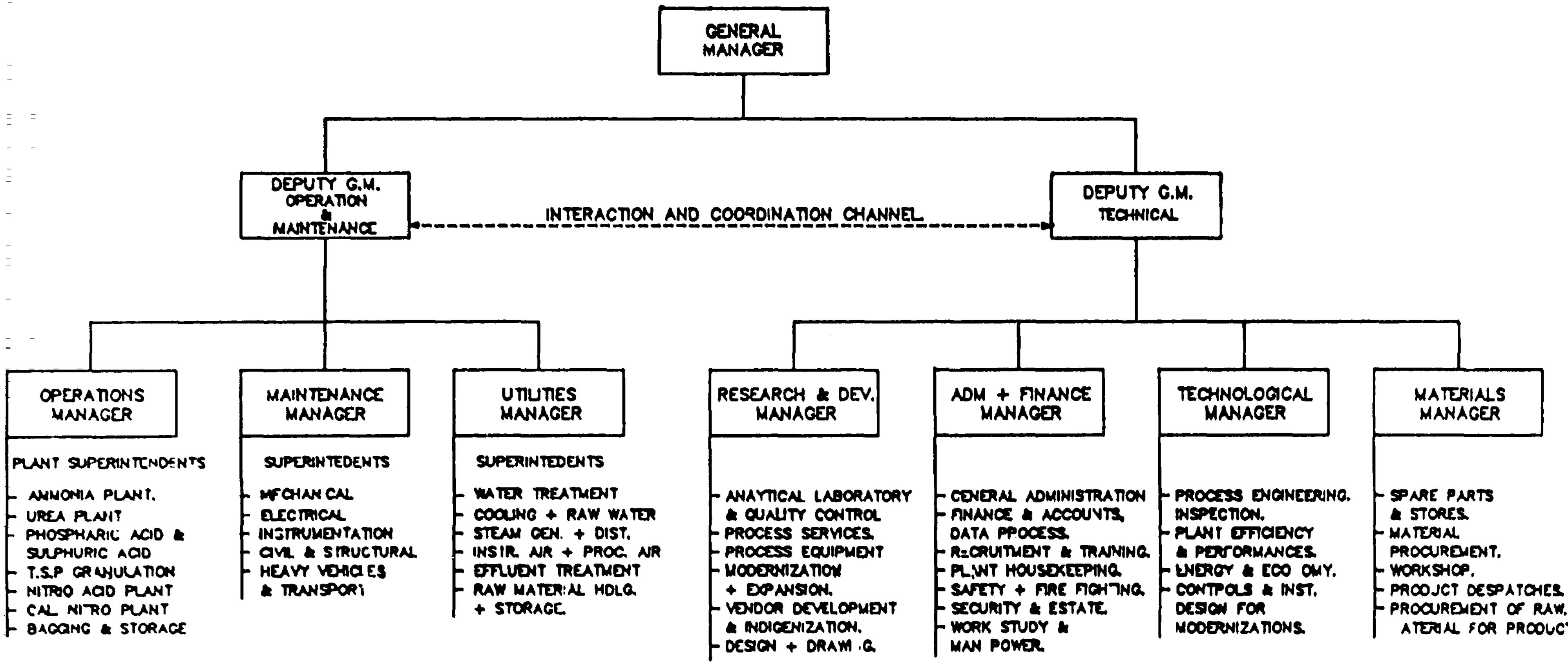
Extraordinary helps were extended by Plant Managers and Engineers of General Fertilizer Company to conduct the assignment and to assess the problems. People were receptive and they were indeed very good in responding the questions with most sincere answers without any prejudice. They are all interested to come out from the problems but are helpless due to frequent breakdowns, non-standardization of the equipments and instruments and most serious are shortages of spares.

Spare parts management is very poor and due to non-standardization, inventory requirement is very high. Involvement of Engineers, thus for attending problems are lukewarm.Root causes of the problems were not identified and timely actions were not taken.

General Director showed his keenness to implement the suggestions which UNIDO would pass on to him from this report.

This assignment, though was for Instrumentation and Controls, but on the basis of long process operation and design experiences in Fertilizer Industries and Utilities area, the observations have been unfolded in wider areas of problems in the greater interest of UNIDO to take a thorough view in all related problems leading to poor capacity utilization of the plant and Complex as a whole.

FOR ENTIRE COMPLEX INTEGRATION



CONCLUSION:

The Fertiliser Complex of General Fertiliser Company is suffering from the following :

A. *Improper operation of Water Treatment plant in the Utilities area for Ammonia Urea plant which is the root cause for the problems of under capacity utilisation.*

B. *Inadequate training and Analytical knowledge and experiences of the plant operating and maintenance personnel and improper co-ordination in the organisation is also the reason for frequent breakdowns.*

C. *Inadequate Instrumentation and Controls for predictive analysis for any breakdown or mal-operation of the unit. The unsafe operation without instrumentation for high speed rotating machinery and also operation of the Ammonia Urea plants without adequate analytical instruments at various stages are a serious bottleneck in achieving the capacity target.*

D. *Spare parts management is inadequate. Standardisation has not been made. Accordingly, inventory requirement for the spare parts become very high.*

E. *Frequent breakdowns, non-standard equipments and instruments and shortages of vital spares for various equipments are also contributory factor in the shortfall of capacity achievement. Old and obsolete technology viz. for Phosphoric Acid plant is a serious bottleneck for achieving of capacity more than 40% and highest breakdowns and failures of equipments have been observed.*

F. *Compartmentalised working and under-utilisation of skilled personnel in the plant are not conducive to the productivity thus a serious handicap in the availability of equipments for the production to minimise downtime.*

General Director of the General Fertilizer Company showed his keenness to implement suggestions which UNIDO would pass on to him from this report. Some of the problems have been discussed with him and he is aware of the problems.

This assignment from UNIDO though was meant for the analysis. of Instrumentation and Controls problems, but, on the *basis of my long process operation and design experiences in Fertilizer Industries and Utilities area, an opportunity was taken to unfold the problems in an Analytical manner to cover a wider area in the greater interest of UNIDO and to take an overall review for all related problems, leading to poor capacity utilisation of Ammonia and Urea plant in particular and entire Complex as a whole.*

I express my gratitude for the extraordinary helps which were extended by various Plant Managers and Engineers to study the problems in depth and for evaluating them to find out the root causes from my experiences.

It is also to mention that the operating and maintenance personnel were very receptive and they were responding well for various questions with most sincere and truthful answers without any prejudice. They were all interested to come out from the problems. They had their limitations in skill and expertise and had very limited experiences in Instrumentation and Controls Technology and had no exposure through trainings.

It is, at this point where I suggest and strongly recommend for undertaking a training programme by experts from UNIDO for various branches in operation, maintenance and Instrumentation and Controls. The experts should have adequate inplant training with analytical approaches for identifying the predictive problems in operation and maintenance including the breakdown of equipments. They should have sufficient theoretical knowledge to conduct the training at plant site and prepare a programme for the future continuous training for the organisation who will conduct them periodically according to their programme under a Training Manager.

UNIDO expert can impart the initial training to the identified senior people for a maximum period of two to four weeks. During which time, he can prepare the job instruction training procedures for the various branches of Engineering in the plant. By this way, the approach for the Engineers can be made upto date. Involvement for the Engineers in the job with anelytical approaches can be achieved.