IMPROVING RELIABILITY OF FERTILIZER PLANTS

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ABSTRACT

A Nitrogenous Fertilizer complex consisting of Ammonia and Urea plants with related Utilities and Offsite facilities require a host of Instrumentation and Safety Systems for trouble free operation. Improving the Reliability of operation of these plants is a constant endeavor of the designer as well as of the Plant Management. This paper highlights some of the modern techniques adopted by the designers during the design / engineering stage of these plants. The paper also discusses the methodologies to be adopted by plant management in improving the reliability of operation and the plant life.

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A Fertilizer plant, specially a Nitrogenous fertilizer complex consisting of Ammonia & Urea plants and related utility facilities is very complex in nature. It involves many unit operations spanning a wide range of operating temperatures and pressures. Since these plants operate in high pressure and temperature zones and also handle explosive gases and toxic chemicals, maintaining safety and reliability of operation is of utmost importance to avoid any operational disaster. Various methodologies have been adopted to improve the reliability of chemical plants.

There is a marked improvement in the reliability of operation of present day Ammonia / Urea plants as compared to those of 60's and 70's vintage. Improvement in reliability of operation of Ammonia & Urea plants have become possible because of methodologies adopted during the design / engineering stage as well as during plant maintenance and inspection.

A. Methodologies Adopted in Design / Engineering to Improve Plant Reliability

Modern Ammonia / Urea Plants adopt measures during the design engineering stage to maximize reliability in plant operation. These are described below:

1. HAZOP Study of the Plant Sections

HAZOP study is a review of the Piping & Instrumentation Diagram (P&IDs) of the system / plant and ensures that adequate protection is provided by way of instrumentation, interlocks & others to mitigate any operational hazard that may get generated by any process upset conditions.

A HAZOP analysis comprises of a structured technique in which a multi-discipline team performs a systematic study of a process using guide words to discover how deviations from the design intent can occur in equipment, actions, or materials, and whether the consequences of these deviations can result in a hazard.

The results of the HAZOP analysis are the team's recommendations, which include identification of hazards and the recommendations for changes in design, procedures, etc. to improve the safety of the system. Deviations during normal, startup, shutdown, and maintenance operations are discussed by the team, and improvements thereon are included in the study report.

The following terms are used in the HAZOP process:

- *Design Intent* - the way a process is intended to function.

- *Deviation* - a departure from the design intent discovered by systematically applying guide words to process parameters.

- *Guide Word* - simple words such as "high" pressure, "high" temperature, "leak" etc. that are used to modify the design intent and to guide and stimulate the brainstorming process for identifying process hazards.

- *Cause* - the reason why a deviation might occur.

- *Consequence* - the results of a deviation.

- *Safeguard* - engineered systems or administrative controls that prevent the causes or mitigate the consequences of deviations.

- *Hazard Category* - an assessment of the hazard risk of the operation.

- *Recommendations* - recommendations for design changes, procedural changes, or for further study.

Section wise HAZOP Study is carried out in two Phases. Initial HAZOP study is done with first issue of P&I drawings. Final HAZOP study is done when P&I drawings have been finalized with information from different equipment vendors.

2. Safety Integrity Level (SIL) Study of the Control System.

Objective of the SIL Study:

- To classify critical loops in the chemical plant in terms of a SIL in conformity with the International Safety Standards IEC 61508 & IEC 61511
- To verify whether the plant's safety functions meet the SIL requirements.
- To recommend possible mitigations if the safety functions do not meet the SIL requirements.

Basis of a SIL Study

The SIL review consists of two parts:

- The SIL classification phase
- The SIL verification phase

During SIL classification phase, potential hazards resulting from failure of shutdown loops are assessed. The SIL verification phase verifies whether the classified SIFs (Safety Instrument Functions) in the present architecture meet the required SILs.

A SIF is a function implemented by means of instruments and is provided to reduce the likely hood or magnitude of an accident which affects the safety to plant personnel, impacts the environment and the facility in terms of asset damage and loss of production.

If the verified SIL is less than the classified SIL for a given SIF then either the SIF architecture needs to be rectified or its maintenance region needs to be improved to increase its SIL to meet the classified SIL as a minimum.

A key document in SIL classification phase is the Cause and Effects Matrix, which presents information regarding the Shutdown / Trip actions of the facility.

The SIL assigned to a particular SIF is a measure of the safety of a given process.

Mitigation measures are considered in the assessment in the form of Layers of Protection (LOP) available. With consideration of LOP, the classified SIL for a particular SIF could be brought down.

Numerical Definition of SIL

SIL	Probability of Failure on Demand (PFD avg.)	1/PFD
X	A change to safer design shall be provided .	
4	$10^{-5} – 10^{-4}$	10000-100000
3	$10^{-4} – 10^{-3}$	1000-10000
2	$10^{-3} – 10^{-2}$	100-1000
1	$10^{-2} – 10^{-1}$	10-100
a	Moving the shutdown function from ESD to DCS can be allowed	
Unclassified	No action needed, hence may be removed by consensus of the SIL team.	

In a SIL Study, Risk Matrix is used to classify SIL for protection of people, environment and property. Severity of consequences is denoted by parameter "S" using S_0 to S_5 i.e. six classes.

A SIL Study and review ensures that the facilities' safety shut down loops meet the specified safety requirements. Both the HAZOP and SIL studies during the design / engineering stage, improve the reliability of modern Ammonia / Urea plants to a great extent compared to those of the seventies.

3. Emergency Shutdown (ESD) System of the Fertilizer Plant

Reliability of plant improves by proper design of the ESD system.

Process dynamics of Ammonia / Urea complex are fast and during any upset the plant may be tripped in a few seconds if there is a delay in operator intervention. ESD system design consists of:

- Field Input Measurements
- Interlock Logic Solver
- Field Activation Elements

In the course of years of development, vendors have improved and updated the ESD system of Ammonia plant to use latest Programmable Logic Controller.

The reliability of a modern Ammonia / Urea complex has improved due to consideration of the following during the design of the ESD system.

- Sensing element redundancy (voting logic)
- Use of analogue devices
- Utilization of high integrity reliable logic solver
- Separating the ESD system from the process Control layer
- Design of effective alarm systems
- Understanding of the Failure Modes
- Use of known and proven technology
- Test Safety System periodically
- Ensure Management Control of Changes & System by passes / Understanding human errors.

4. Advanced Process Control System (APC)

Modern Process Plants, specially fertilizer plants are designed for flexible production and maximum recovery of energy. They become complex in nature and demand a suitable control system for reliable operation. Provision of a Distributed Control System (DCS) along with an Advanced Process Control (APC) philosophy can serve this purpose. The objectives of APC implementation in a Gas based Ammonia Plant are as follows:

- Minimization of specific energy consumption.

- Stabilization of plant load even during fluctuations in variables such as Natural gas pressure, flow or quality.

- Precise control of “Steam to Carbon” ratio in the Primary Reformer for steam economy.

- Optimum control of Oxygen in the Flue Gas.

- Control of Synthesis gas quality i.e. the Hydrogen to Nitrogen Ratio.

- Accurate control of Methane slippage from the Primary and Secondary Reformers.

During 2003 M/s RCF implemented a robust Multivariable Predictive Controller to achieve these goals of an APC in their Thal Ammonia Plant. Similarly many other plants also implemented the APC system to increase reliability of operation and to optimize production and consumption.

5. Selection of Vendors

This factor has a very important role in new projects as well as in subsequent operational stages. Selection of experienced and reputed vendors for critical equipments improves the reliability of the plant operation. Similarly there is a marked improvement in operational reliability if the catalysts for Catalytic reactors are selected from reputed vendors.

Moreover during initial selection of vendors, a proper evaluation needs to be done. For the already registered vendors, regular feedback needs to be taken regarding their performance. A technical team is sent to the vendor’s workplace to assess his overall capability in delivering the goods. Some of the areas in which the vendor is assessed are:

- Production planning system.

- Quality Assurance system with in house inspection and testing

- Production Machinery and computer software and hardware possessed.

- Design development activities

- Quantity and qualification of personnel employed.

- Quality of sub-vendors.

- Standards / codes followed

- Certifications possessed

- Adequate Safety, Sanitary and Environmental facilities

- Reference list of Clients and feedback on performance from Clients.

- Financial Status.

6. Selection of Material of Construction

Corrosion is a serious problem in chemical process plants specially fertilizer plants. Improper selection of material of construction can lead to equipment failures and unexpected shut downs. With improvement in material technology and proper selection of M.O.C. in critical areas, there is marked improvement in reliability of modern fertilizer plants.

A very good example is the changes in tube metallurgy of the Primary Reformer. Over the last 30 years the changes in metal of construction from HK-40 to Microalloys like Manurite 36M, Paralloy H39W etc. have improved the reliability of the Primary Reformer operation.

Similarly the material of construction of the Urea Stripper has undergone upgradation from Titanium tubes to Zirconium tubes and later to Sandvik 2RE69 (Cr 25 – Ni 22 – Mo 2) to improve the reliability and economics of the operation of the Urea Plant.

B. Methodologies Adopted in Plant Maintenance & Inspection to Improve Reliability

a. Risk Based Inspection (RBI) Programme

The main aim of the Risk Based Inspection programme is to;

- Maximize safety by evaluating risks for individual equipments/accessories and recommend methods to reduce risks.
- Optimize productivity by optimizing plant shut down timings
- Optimize inspections, testing and maintenance to improve plant reliability.
- Improve the understanding of the condition of plant hardware and its management for long term plant operation.
- Make optimal use of resources through a risk based approach.

Equipment that should be covered in the RBI programme are;

- Furnaces
- Reaction vessels
- Heat exchangers
- Boilers
- Storage tanks/Vessels
- Piping and Pressure Relief valves

The following approach is generally adopted in a RBI Study :

- Preparation of comprehensive lists of pressure equipment based on criticality in terms of services and set up inspection programme accordingly

- Prioritize the pressure equipment so that the assessments to be carried out enable the major outcomes from the critical plant to be reported as early as possible.

- Develop process loops for piping such that each process loop has the same environment and similar risk exposure.

- Complete a risk-based assessment so that meaningful profiles of failure risk, failure likelihood and failure consequence can be established for each “nominated” pressure item or process loop in the ammonia plant.

- Prepare inspection programmes for pressure equipment and piping to ensure these items of plant are effectively operated, maintained and their condition assessed.

- Recommend actions, which will be needed to be carried out to ensure safe & reliable operation of the plant prior to and after planned shutdown.

- Use of a proprietary Reliability Management System (RMS) software of the Vendor who will be entrusted to carryout the study.

- Recommend preliminary scope of work and period of the planned upcoming shutdown.

A Risk based Inspection study helps to standardize the inspection procedures to optimize production and time span for planned shutdown.

b. Improving Plant Reliability through Corrosion Monitoring

Corrosion attacks can reduce equipment performance and lead to unexpected failures and plant shut downs. Corrosion attack of process equipments may be external or internal. External attack is by ambient environment whereas internal attack is caused by process fluid handled inside.

Corrosion monitoring is an essential input in Residual Life Assessment and Aging Management Programme.

Corrosion monitoring techniques are;

- Methods that indirectly measure parameters related to corrosion and inter corrosion behavior from some model of corrosion process, e.g. electrochemical potential, pH and temperature.

- Methods that directly measure corrosion behavior, e.g., Non-destructive Inspection, Material Test Coupons, Galvanic Currents etc.

Corrosion Monitoring Techniques:

Direct Measurements

- Non Destructive Inspection (NDI)
- Electrical Resistance (ER) Probes
- Material Test Coupons
- Galvanic Currents
- Cyclic Potentiodynamic Polarization (CPP)
- Linear Polarization Resistance
- Electro Chemical Noise (EN)
- Electrochemical Impedance Spectroscopy (EIS)

Indirect Measurements

- Potential
- Biological Count
- Hydrogen
- pH
- Temperature
- Conductivity
- Specific Ions

Periodic assessment is the most common method of corrosion monitoring and can help to:

- Evaluate materials performance under specific service conditions
- Aid in proper material selection
- Evaluate and control the production process
- Provide necessary data for Residential Life Assessment

c. Improving Plant Reliability by Conducting Regular Safety Audits

Plant reliability is further increased by conducting regular and comprehensive Safety Audits through in house resources as well through specialized external agencies, and implementing the recommendations. Organizations such as the British Safety Council and DNV which conduct their specialized Five Star Health and Safety Management System Audit and International Safety Rating System respectively, can be engaged to carry out such audits and give ratings to the Plant.

It is recommended that these audits be conducted at regular intervals of 3 to 6 months for internal audits and 1 to 2 years for external audits. The plants management should ensure that the recommendations arising out of the audits are studied and implemented at the earliest.

d. Installing CCTV and P&A Systems in the Plant

By installing a Closed Circuit Television system, with signal to the central control room / DCS, the operational reliability is further ensured by enabling a close monitoring of the critical areas and large areas of the entire plant from the Central control room by the operators and the senior managers. Additionally it is recommended to install a Public Address system for proper and timely communication between managers and operators.

e. Obtaining ISO Certification.

All plants should implement the management and safety systems to obtain Certification of the ISO 9001 Quality Management System, the ISO 14001 Environmental Management System and the OHSAS 18001 Occupational Health and Safety Management System. .

An ISO 9001 Certification leads to plant reliability through improved product and service quality, improved management and operational processes, resulting in less waste in terms of both time and materials, increased productivity, efficiency and cost savings.

An environmental management system (EMS) based on the ISO 14001 standards is a management tool enabling an organization of any size or type to control the impact of its activities, products or services on the environment. This certification ensures a commitment to achieving legal and regulatory compliance to regulators and the government.

The OHSAS 18001 certification establishes an Occupational Health and Safety (OH&S) management system to eliminate or minimize risk to employees and other interested parties who may be exposed to OH&S risks associated with its activities.

f. Disaster Management Plan.

Each fertilizer producing facility is required to have a Disaster Management Plan in place. It consists of an “Onsite Plan” and an “Offsite Plan”.

Disaster Management forms an integral part of any Industrial Activity Management in dealing with the hazards and risks which may have impact on environment, human lives, health and safety and business interests. It is the means by which an industry manages itself in order to mitigate these risks

Disaster Management planning is done for : the Total Prevention or Safe Management of Disaster; Safety of men at work and in the vicinity of Disaster; Effective rescue and treatment of casualties; Mitigating the severity of Disaster first and ultimately to control the whole situation; Causality identification, classification and safe transportation to Trauma Centre / Hospital; and Providing factual information to authorities coordinating the operations to avoid contradiction and confusion

The primary step in any Disaster Management planning is the identification and assessment of the principal hazards. The hazard can be fire, explosion, toxic release, failure of structure or vessel holding hazardous substances, sudden heavy toxic emissions from exhausts/ vents/ chimneys etc. Identification of vulnerable points likely to result in Disaster are essential through Operational experience and Past history.

The "Off-Site Emergency / Disaster Management plan" begins beyond the premises of the plant. The following are the important features of the "Off Site Plan". The off site emergency plan will be under the control of local administration. The plant authorities need to extend their cooperation to the local administration. The Plant authorities should make available their 'on site emergency plan' so that the nature of risks and hazards involved in the plant will be known to all the concerned people.

The copies of emergency plans should be with the government authorities (e.g. Administrator / Fire station officer/ Factory Inspectorate/ Environment Authorities etc). The people living in the immediate vicinity of the plant should be made fully aware of the plant activities and the possible risks associated with the processes.

g. Other Recommendations.

After any modification is carried out in the plant as a result of implementing a new scheme, the Operating manual, P&I Diagrams and other documents should be updated accordingly to reflect these changes.

Moreover all such new schemes should again be reviewed by conducting a Hazop study to ensure that proper safety aspects are covered, and the recommendations if any should be implemented.

C. Conclusion

Improvement in reliability of Chemical Plants, specifically the nitrogenous fertilizer plant is an on going process. Process and technological improvement along with improvement in quality of operation, maintenance and inspection has improved the period of continuous operation of the Ammonia / Urea plants. Taking annual routine shutdowns is no longer seen in a modern day plant.

Continuous operation at rated capacity for a longer period has led to an improvement in the globalised specific energy consumption in many plants, leading to savings in precious energy and a reduction in atmospheric pollution.

Projects & Development India Limited being a design and engineering consultancy organization, has always worked with the primary objective of improving the reliability of the plant it has undertaken to engineer and commission.

D. References

1. Improving Plant Reliability through Corrosion Monitoring – Carl E. Jaske, J. A. Beavers & Neil G. Thompson.

2. Various HAZOP and SIL Study Reports of Fertilizer Plants.

3. Published Reports of various Fertilizer Plants

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