Hazard Operability Study (HAZOP) in a Fertiliser Plant

K. Muthukumar, M. Suman Mohan

Abstract: ***Hazard Operability (HAZOP) study is especially valuable for recognizing shortcomings in frameworks (existing or proposed) including the stream of materials, individuals or information, or various occasions or exercises in an arranged grouping or the methodology controlling such a succession. The HAZOP study was carried out in one of the fertiliser industries in India. The investigation was done for five unique tasks having 17 hubs, unusual working conditions and bothersome exercises which may happen are recognized and considered amid the examination utilizing suitable guide words like No, More, Less, As well as and so on. More stream, more temperature, more weight and additionally in the hubs are having unfavourable impact and prompt consideration is required. 101 reasons for deviation were distinguished. The causes are as given: disappointments in the dimension estimation instrument, non direction of the siphon, execution of creation process physically, erosion of the caustic way, obstruction of the passages, blemished check valves, mechanical issues of check valves, spillage of the channels, and blending of water in the framework. 35.7 % of all dangers were inadmissible, 37% risky, 19.8 % satisfactory yet required re examination, and 7.5% worthy with no requirement for any restorative activity. To keep any calamitous*** results, we prescribe to do HAZOP think about.

Keywords: ***HAZOP, Analysis, Guide words, Nodes, Abnormal, Consequences.***

I. INTRODUCTION

The process industry is an industry with innovations. It produces a continual stream of new processes and products, which sometimes involve working at extremes of temperatures, pressures, and scale of operations or toxicity. There is a great and growing awareness of the necessity to apply more systematic approaches to safety and ease of operations particularly in design within the industry. Human variables and subjective assessment of a scope of the conceivable security and wellbeing impacts of Process disappointment of controls. A Process Hazard Analysis Hazard Analysis (PHA) is a careful, deliberate, and methodical methodology for recognizing, assessing, and controlling the perils of procedures. The procedure risk examination approach chosen must be fitting to the unpredictability of the procedure and must recognize, assess, and control the dangers associated with the procedure. The procedure danger investigation will address the risks of the procedure, distinguishing proof of any past occurrence that had a presumable potential for calamitous outcomes, designing and managerial controls pertinent to the perils and their between connections, results of disappointment of building and authoritative controls, (PHA) group incorporates process wellbeing pro, engineers, administrators, bosses and different specialists who know about the models, codes, particulars and controls which apply to the procedure being examined.

A part of the Process danger examination are HAZard Operability (HAZOP) Study[1], Hazard Identification (HAZID) ponder, bow tie investigation, What if investigation and Quantitative hazard appraisal. Among these HAZOP investigation is for the most part utilized in process works. There is, an extraordinary and developing attention to the need to apply increasingly efficient ways to deal with wellbeing and simplicity of activities especially in plan inside the works. The investigation of these dangers focuses to components, for example, human mistakes, an excessive amount of dependence on the wellbeing of hardware, issues in structure of the plant, ill-equipped to face and adapt to basic circumstances and absence of HSE Rules [2]. Different components, normal or man-made, can likewise contribute or heighten the issue. [3]. Generally, wellbeing joined in the structure of compound plants dependent on the use of codes of practices and in addition agendas arranged by experienced and proficient experts and masters in this industry [4]. With regularly expanding of multifaceted nature in present day concoction plants, these extra methodologies are probably going to miss some real issues which should be considered at the structure phase of an undertaking [5]. As to recognisable proof of compound wellbeing dangers, end was that the HAZOP guideline appeared to be appropriate, expecting that satisfactory guidewords could be built up [6]. A HAZOP is an organized and precise examination of an arranged or existing procedure or task so as to distinguish and assess issues that may speak to dangers to faculty or gear, or anticipate productive activity [7]. The HAZOP strategy was at first created to break down synthetic process frameworks, however has later been stretched out to different sorts of frameworks and furthermore to complex tasks and to programming frameworks [8]. The examination is performed utilizing a lot of guidewords and characteristics. The method is amazingly adaptable and can be connected to a wide range of plants. It is a survey by the consolidated expertise of a gathering of specialists, group comprising of four to eight people with a adequate information of the framework to be broke down. The HAZOP pioneer of the gathering will typically be a word related security and wellbeing engineer with broad preparing in the utilisation of HAZOP and other danger examination techniques. The examination itself is finished by going deliberately through all framework parts distinguishing conceivable deviations from expected conduct and researching the conceivable impacts of these deviations.

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Dr. Muthukumar K, Professor (Industrial Safety Engineering),Department of Mechanical Engineering, Bannari Amman Institute of Technology, Sathyamangalam-638401 ,Erode District, Tamil Nadu, India,

M. Suman Mohan, Safety Officer, Elite Air Technique Pvt. Ltd ,C/o.M/s. MRF Tyres Pvt. Ltd, Perambalur, Tamil Nadu, India

For every deviation the group embarks indicate a progression of inquiries to choose regardless of the deviation could occur, and assuming this is the case, regardless of it could resulted in a danger. Where potential perils are distinguished, further inquiries are requested to choose when it may happen and what should be possible to diminish the hazard related with the risk [9]. At the point when the group confirms that insufficient shields exist for a dependable deviation, it for the most part prescribes the move be made to diminish the hazard.

The hazard prioritisation and estimation of the subjective dangers, chance administration as hazard appraisal grid were additionally investigated [10]. The hazard factors were additionally arranged in three stages and after that outcomes are to be marked in the HAZOP data book:: Probability of results of variation from benchmark in 5 bunches were resolved as "visit" to "uncommon" [11]. Seriousness of mishaps was ordered into 4 bunches as "cataclysmic" to "minimal." Severity and likelihood in every circumstance is joined to decide the hazard levels to set need of control measures [12, 13]. The operational issues were the fundamental concentration by colleagues, however more consideration was given to the distractions with antagonistic effect on the budgetary misfortune and individual wounds [14].

There might be a few deviations with possible causes and having conceivably perilous outcomes. They are to be noted down for healing activity. All in all, planning and actualizing a preventive program is extremely powerful in distinguishing and controlling these sorts of hazard [15]. Check all parts of the procedure and guarantee every conceivable deviation from the manner in which the plan is relied upon to work and note down all the risky circumstance that is evident and not prone to cause unfriendly consequences for alternate parts of the structure. It might be chosen to change plan on the spot. HAZOP is more proper than Energy Trace and Barrier Analysis (ETBA) to foresee and distinguish dangers yet applying ETBA is less demanding than HAZOP [16]. The way toward utilizing HAZOP is contributing fundamentally to the improvement of the organization working procedures and better maintainable condition proposals [17].

II. DESCRIPTION OF HAZOP PROCESS

IEC 61882 [1] states, "A precise and finish structure portrayal of the framework under investigation is an essential to the examination errand" This infers at any rate:

- a Logical (schematic) Description, typically dependent on Piping and Instrumentation Diagrams (P&IDs) – in some cases called Engineering Line Diagrams (ELDs); and
- a physical design of the Equipment, typically General Arrangement scale illustrations (GAs)

which, together with some other reports required, characterize the fashioner's "structure expectation" for the framework. The HAZOP contemplate then looks at "deviations" from the plan purpose.

The concept of HAZOP is to systematically question every part of the process, discover how the deviations from design intention can be caused and decide whether such a deviation can cause any hazard. The above questioning is done by a set of guidewords, which are derived from method study techniques. These guidewords are used to test the integrity of each part of design and to explore how it deviates from the original design intention of the conceptual stage. If the consequences are seemingly unrealistic, ignore it and if they are trivial need not be considered further. There may be some deviations with conceivable causes and having potentially hazardous consequences.

To decide the deviation of parameters from the primary point of process configuration, control words including temperature, weight, conductivity, water stream, administrations disappointment, usage of instruments and others are likewise connected (18, 19, 20). The subjective lattice techniques, as an instrument for receiving a consistent choice, have likewise been utilised for deciding of any relative hazard level (21, 22). There have been couple of logical examinations in the field of risk distinguishing proof utilising HAZOP. It gives extraordinary affirmation of cause and bewildering conspicuous evidence of essential assortments, it is a brilliant very much exhibited methodology for pack far reaching plant in a certain manner[23].

A. Guide Words

None - No Flow- No Level, Complete negation of design intentions, Cessation of flow, No activity. More Flow-Temperature, Pressure Level, Quantitative Increase Parameters above design limits. Less Flow-Temperature, Pressure Level, Quantitative Decrease Parameters below design limits. As well as - Flow Level Quantitative Increase, Different level Along with the intended activity something more happen. Part of- Flow Quantitative Decrease Incomplete activity, Reverse Flow- Opposite of design intention , Other than- Flow Complete substitution Something totally different happens.

B. B. Hazop Methodology

The current and recently arranged workplaces were separated into legitimate units and pursue the HAZOP procedure. The methodology for HAZOP procedure is given underneath. The procedure framework is assessed as structured and taking note of the potential for deviations. Every single potential reason for disappointment are recognized. Existing shields and security frameworks are recognised and their ability to deal with the deviations assessed. At the point when a peril condition is recognised, suggestions may be made for process or structure changes.

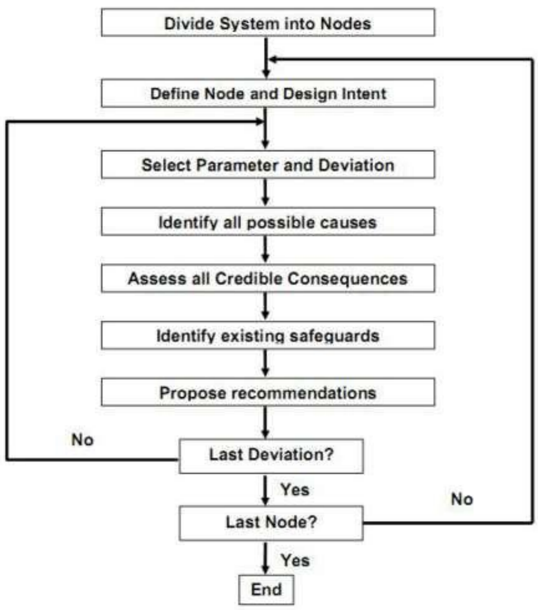

Fig .1 HAZOP Methodology

The HAZOP study team member shall not be more or less in size. In general the observation is made out by the member of 4 to 6 persons a service provider and scribe. The group shall consist of members as indicated, Design executive in-charge for the concerned facility, Project executive (for fresh establishments), Plant executive in-control, Maintenance executive, HSE executive, Facilitator and scribe.

C. Process Description Of The Fertiliser Industries

The HAZOP study was carried out in one of the fertiliser industries in India. The manufacturing process of complex fertilizer involves direct neutralisation of sulphuric acid and phosphoric acid with ammonia. The chemical reactions are carried out in a series arrangement of 2 Continuous Stirred Tank Reactors (CSTR). Mono ammonium Phosphate MAP and ammonium sulphate are the main products of these reaction. The resulting acidic reaction mixture is drained to blunger where it is mixed with recycle material and further ammoniated to such an extent that mole ratio of NH4/ H3PO4 remains 1.8. Some of the MAP is converted to Di-ammonium Phosphate (DAP).

The granules hence formed are discharged to a Rotary dryer where the material is heated by means of concurrently flowing hot air so as to dry the material without causing the decomposition of DAP. The dryer discharge is then size classified by sets of vibrating screens to separate the product from the remaining oversize and fines. Fines and the ground oversize are returned to the blunger for granulation and product is weighted and bagged into units of 50kg each.

Due to vigorous exothermic nature of reaction, the contents of the reactor boils violently and lot of vapour is produced. This is drawn to Ammonia Scrubbing System by fume fan and discharged to Fluorine Recovery Scrubbing System before venting it to atmosphere. The dryer and dust fans draws dust and fumes from dry material handling equipment and discharge them to respective scrubbing systems. These gases are also vented to atmosphere by stack after scrubbing.

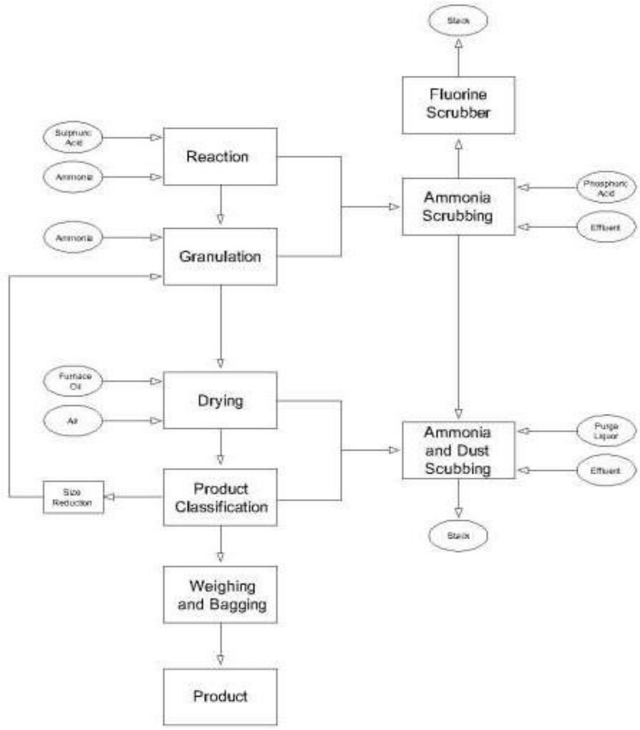

Fig. 2 Process flow of the fertiliser industries

III. CHEMISTRY OF THE PROCESS

Chemical reactions in the process are as follows:

$$H_2SO_4 + 2NH_3 \longrightarrow (NH_4)_2SO_4 + 65.99\ \text{KCal/gmol} \quad \text{------ } 1$$

$$H_3PO_4 + NH_3 \longrightarrow NH_4H_2PO_4 + 32.19\ \text{KCal/gmol} \quad \text{------ } 2$$

$$NH_4H_2PO_4 + NH_3 \longrightarrow (NH_4)_2HPO_4 + 22.5\ \text{KCal/gmol} \quad \text{------ } 3$$

Reaction 1 & 2 and part of reaction 3 is completed in reactors. Reaction of sulphuric acid (H2SO4) with liquid ammonia (NH3) to from ammonium sulphate ((NH4)2SO4) is spontaneous is completed immediately at feed.

Reaction of phosphoric acid (H3PO4) with NH3 is also rapid but starts only after the H2SO4 is completely neutralised.

Conversion of MAP (NH4H2PO4) to DAP ((NH4)2HPO4) starts only after completion of reaction 1 and 2. The reaction is rapid at the beginning. As the proportion of the MAP to DAP decreases, the rate of reaction falls down. To complete the reaction, excess ammonia will have to be supplied to the reactor.

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IV. HAZOP STUDY IN THE FERTILISER INDUSTRIES

The reactions are carried out in series arrangement of reactors R1 and R2 (provided with agitators AG1 and AG2). Sulphuric acid for the process is added to R1 in controlled basis. Phosphoric acid is directly added to scrubber solution from the fume scrubber C1. This feed of scrubber solution is then feed to the reactor by reactor feed sump pump P3 A/B. Anhydrous liquid ammonia from ammonia handling section is fed to R1 at a controlled rate. Liquid ammonia temperature and pressure are indicated by TI 7 and PI 7 respectively. HAZOP study carried out for the following 9 nodes in the five operations.

Charging of Phosphoric acid, Charging of Phosphoric acid to Storage tank, Charging of Sulphuric acid to Service tank, Charging of Effluent tank, Charging of Reactor and reaction Charging of dryer and drying process, Charging vibrator and screening, Recycling fine product, Incoming to drier cyclone and separation of fines. For example the HAZOP study of Charging of Reactor and reaction is reproduced below in the table.

Table. 1 Study Title: Charging of Reactor and reaction

Parameter	Guide Words	Possible causes	Direct consequences	Action required
Flow	No	H_2SO_4: 1.FCV 6 fails to close 2.Inlet line rupture 3.Inlet plug valve closed 4. No material	No ammonium sulphate formation Excess ammonia concentration in the reactor	1.Periodic maintenance of control valves 2.Visual inspection of pipelines 3.Ammonia detectors to be installed in work area
		Ammonia: 1. FCV 7 fails to close 2. Manual valves in upstream line closed 4. Line rupture 5. Sparger choking	No reaction takes place inside the reactor	1.Breather valve to be installed in the reactors to prevent vacuum formation 2.Periodic maintenance of control valves
		Scrubbed liquor: 1. P 3 failure 2. FPV 3 fails to close 3. Line rupture or clogging	2[nd] and 3[rd] reaction does not takes place (No MAP and DAP formation)	1. Ammonia monitors to be installed in work area 2.Periodic maintenance of control valves
	Less	H_2SO_4: 1. FCV 6 malfunctions 2. Isolation valve closed partially or malfunction 3. Line clogging or leakage	Process gets disturbed and ammonia does not converted to ammonium sulphate	1.Periodic maintenance and of valves 2. Direction indications on valves
		Ammonia: 1. FCV 7malfunction 2.Chocking in sparger 3.Gate valves partially closed 4.Low delivery pressure 5. Line leakage	Reaction rate gets reduced Leakage causes ammonia accumulation in work area	1. Direction indication on gate valves 3. Visual inspection of pipelines daily 4. Ammonia monitors to be installed 5. Breather valve to break vacuum
		Scrubbed liquor: 1. FPV 3malfunction 2. Line clogging or leakage due to gypsum formation	Reaction gets disturbed	1.Control valve maintenance 2.Pipeline visual inspection
	More	H_2SO_4: 1. FCV 6 fails to open 2. Wrong setting of valve	Reactor temperature increases due to more 1[st] reaction	1. Proper maintenance of control valves and flow indicators 2.Breather valve to be installed to release pressure
		Ammonia: FCV 6307 fails open	Excess ammonia in the reactor	1. Proper maintenance of control valves and flow indicators 2. Ammonia detectors to be installed in work area

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		Scrubbed liquor: FPV 3 fails open	Reactor level rises	
	As well as	LP steam: 1. Steam line valve failure 2. Steam line valve opened unknowingly	Reaction gets disturbed	1. Proper maintenance of valves 2. Direction indications on valves 3. Breather valve to be installed
	Part of	Scrubbed Liquor: Scrubbed liquor with less phosphoric acid concentration	Product composition changes	
Pressure	More	1. While charging, air above creates pressure 2. When steam line opens to reactor 3. When fume fan K6 fails 4. When more H_2SO_4 flows to reactor	Acts pressure on tank walls	1. Standby fan should be provided 2. A breather valve with outside vent to be installed
Vacuum	More	1. When the reactor level reduces and fume fan runs 2. When ammonia flow gets interrupted	Vacuum generation inside the reactor tanks	1. Vacuum relief valve or breather valve to be installed 2. FIC in ammonia line and fume fan should be interlocked
	Different	Faulty reading shown by TT 1	Product composition varies	Calibrate level transmitter during maintenance
Drain	Too long	Drain pipe clogging	Takes too much time to empty tank	Cleaning of drainpipe
	Too short	1. Drain valve failure 2. Drain valve opened fully	Sudden level decrease	Drain by taking intervals
	Wrong timing	Miscommunication	Process disruption	Follow procedure systematically
Agitation	No mixing	1. Agitator motor failure 2. Shaft seal failure	Slurry gets thicken inside the reactor	Motor to be checked Proper lubrication of motor
	Slow mixing	1. Corrosion in the impeller 2. Wear or tear on motor 3. Gear reducer, belt or shaft damage	Proper mixing does not takes place	Proper lubrication of motor
	More mixing	Gear reducer failure	Impeller runs with high rpm	Proper inspection and maintenance

V. RESULTS AND DISCUSSION

As shown in the table the study was carried out for five different operations and 17 nodes the results are tabulated, recommendations are given for each node based on the discussion.

A. Charging of Phosphoric acid to tank and transferring to Reactor

Mixing of water and acid in pipeline- Water gets boiled and pressure in pipeline increases. Pipeline may rupture.
More Temperature - Production of hydrogen gas on reaction with metals (tank walls).
More Pressure - Formation of hydrogen gas inside increases pressure - Chance for explosion

- When the valves in the downstream is closed suddenly, pressure gets developed in the pipeline leading to pipeline rupture or pump damage. To avoid this a circulation line at the pump discharge end to the storage tank to be provided.
- A Non Return Valve (NRV) or check valve to be installed in the pump discharge line to avoid reverse flow of acid.

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B. Charging of Sulphuric acid to Service tank and transferring to Reactor

More Temperature - At high temperature SO2 and SO3 gas generated inside tank which escapes out through overflow pipe- on exposure 1. SO2 can cause asphyxiation, and respiratory problems in workers 2. Above 100 ppm, it is extremely dangerous to health.3. Inhalation of SO3 can cause burns inside respiratory tract. More Pressure - Formation of hydrogen gas inside increases pressure - Chance for explosion

- An online pH meter to be installed in the tank, so that technicians can monitor pH in the tank continuously.
- Vent pipe should be installed in the tank to avoid build-up of pressure or vacuum inside the tank.

C. Charging of Effluent tank and transferring to process

More Pressure - Pressure acts on tank walls- Tank may rupture

- When the valves in the downstream is closed suddenly, pressure gets developed in the pipeline leading to pipeline rupture or pump damage, a circulation line at the pump discharge end to the storage tank to be provided to avoid this To avoid this.

D. Charging of Reactor and reaction

Less H2SO4: Process gets disturbed and ammonia does not converted to ammonium sulphate
More H2SO4: Reactor temperature increases
More Pressure - Pressure acts on tank walls - Chance for explosion
More Vacuum - Vacuum generation inside the reactor tanks-Chance for implosion
More Temperature - 1st reaction takes place in excess and more heat generated- 1. Excess heat generated may damage reactor walls 2. Chance for explosion

- Draining of reactor should be carried out step by step by taking intervals. Sudden draining of slurry may generate vacuum inside the reactor.
- During start-up, checklist procedure should be followed to avoid missing or doing in wrong sequence.

E. Ammonia scrubbing

No/Less (Scrubbed liquor)- Scrubbing action gets affected-Exhaust fumes going out from scrubber will contains more ammonia than permissible limit (360 mg/m^3)
Reverse (Circulating liquor)-Reverse flow of liquor by gravity- Pump may damage

- Ammonia monitor to be installed in outlet line from Ammonia scrubber column.
- Draining of ammonia scrubber venturi should be done step by step taking intervals to avoid vacuum formation inside.

Scrubber nozzles should be cleaned periodically to avoid clogging due to gypsum presence in phosphoric acid.
The work related obstructions were the important look out by HAZOP investigation group. Totally 308 deviations were identified; of those208(67.32%) were related to un safe activity of the worker and 101(32.68%) improper functioning of the machines. 20% of the machine faults can be caused due to improper maintenance of the machines and remaining 12.68% is due to ageing of the machines. 101 reasons for deviation were recognised. A part of the reasons are as given: disappointments in the dimension estimation instrument, non direction of the siphon, execution of generation process physically, consumption of the corrosive way, blockage of the passages, deficient check valves, mechanical issues of check valves, spillage of the channels, and blending of water in the framework. 35.7 % of all dangers were unsuitable, 37% hazardous, 19.8 % satisfactory however required re examination, and 7.5% worthy with no requirement for any remedial activity.

VI. CONCLUSION

It is concluded that the HAZOP study carried out in a fertiliser industry revealed that the plan prerequisites comprise of subjective and quantitative necessities which the framework needs to fulfil. All sensible use and abuse conditions which are normal by the client is identified. However arrangements for strange working conditions and unfortunate exercises which may exact recognized and considered amid the examination utilizing suitable guide words. The crumbling instruments, for example, maturing, consumption and disintegration and different components which cause weakening in material properties are not explicitly expressed. Expected life, dependability, practicality and upkeep bolster is recognized and considered together with risks which might be experienced amid support exercises. The above data gives the premise to recognising the structure goal for the parts were examined. Conducting HAZOP study will support to prevent any catastrophic consequences.

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