

Process Hazards in Fertilizer Industry and Their Safety Measures

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This paper discusses the process hazards associated with the fertilizer industry highlighting the operational conditions of the processes as well as the physical and chemical properties of the materials involved. The process hazards are classified into three categories namely (i) health, (ii) flammability, and (iii) reactivity. The hazard prevention and protection measures to be incorporated at each unit of a hazardous process plant in order to minimize the degree of severity of hazards are also discussed in the paper.

INTRODUCTION

To keep pace with the evergrowing requirements of fertilizers in the agricultural sector, a wide variety of fertilizers using raw materials like coal, liquid fuels, natural gas, sulphur and rock phosphate are being produced. These compounds have varying degrees of health, flammability and reactivity hazards. The fertilizer and allied chemical industries are characterized by: fast changing technologies; the development of large so-called world-scale plants, a huge capital investment base; and large earning potentials associated with single train of process cycles or compact facilities. The plant and equipment are exposed to large quantities of process materials involving moderate to severe flammability, toxicity, reactivity, explosibility and incompatibility of hazards.

Through better understanding of the risk inherent in facilities in the chemical classes or materials being used in the manufacture of fertilizers, one can gain a better appreciation of the benefits of protective systems, procedures, equipment design, training, safety instrumentation, etc. Every year many fires/explosions or toxic releases are reported from the fertilizer industries world wide. Taking into account the hazard potential involved in the fertilizer industry, all process hazards should firstly be identified, assessed, categorized and then managed in accordance with the lessons learnt from the previous accidents and as per prevailing safety standards by making provisions for adequate prevention and protection measures.

CASE STUDY²⁻⁹

This case study highlights the salient features of the anhydrous ammonia release incident which occurred at a fertilizer manufacturing unit in California, USA, and lessons learned from this mishap.

The incident began at 0430 h when the shift supervisor smelt a strong odour of ammonia in the storage tank area. Upon investigation, a small leak of ammonia vapour was noticed in

the north shell of a 6500 t anhydrous ammonia storage tank (33.5 m in diameter and 11 m in height). The tank was in operation since 1958 for the storage of liquid anhydrous ammonia at an atmospheric pressure and at a constant temperature of -33°C . This tank was built as per ASME code, section VIII, paragraph UW-52.

Emergency notification procedures were put into effect upon detection of the leak. Based on the evaluation, immediate action was taken to control the fugitive vapours with water spray and to make arrangements for transfer of anhydrous ammonia from the tank. The incident ceased on Thursday when all of the ammonia had been taken out from the tank. The standby evacuation alert was called off, and workers began a two-week process of cleaning and airing out the tank to allow for safe entry.

CAUSE OF INCIDENT

After the incident, examination of the tank interior showed a large crack 28 cm long, approximately 60 cm from the tank wall, oriented perpendicular to a weld and extending into the parent plates on both sides of the weld. A smaller crack approximately 60 cm from a weld in the parent plate was also observed on one side only. Laboratory inspection of the backside of both plates revealed a 3 mm - 6 mm gap between adjacent backup bars on both the large crack and small crack plates. Also, there was a gap between the plate and backup bar on the small crack section. Examination of the fracture surface of both plates showed fatigue striations that originated at the centre of the weld and propagated to the root. Microscopic examination of the weld did not reveal any defect. The chemical composition indicated that the samples did meet the chemical requirements of ASTM A212 Grade B low temperature service. A mechanical analysis revealed that the samples did not meet the tensile requirements of ASTM A212 Grade B and the specified impact strength requirements. The examination of the plate sections indicated that a fatigue crack developed and propagated in both welds until the applied stress was sufficient to cause brittle failure of the parent metal adjacent to the welds. Both cracks were perpendicular to the weld and did not have the backup bar support underneath them. It is most likely that the cyclic loading on the tank bottom from changing levels of product initiated

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stresses, locally intensified at the crack locations. The cracks may not have happened if continuous backup support existed under the weld. Also, the deficient mechanical strength and impact resistance of the parent metal contributed to the initiation and propagation of the cracks. Improved impact resistance of the parent metal may have increased the life span of the tank. The condition of the tank foundation was not investigated. It may be possible that some deterioration and subsidence of the foam glass insulation must have occurred, which could have contributed to buckling of the tank floor.

Leak Control

At the beginning of the incident, the tank contained 2000 t of liquid anhydrous ammonia. The cold liquid was leaking at an estimated rate of less than 3 l/min and was quickly vapourizing upon contact with the underlying soil. To control the vapours, two options were discussed. The first option was to fill the dike areas around the tank with water to absorb the leaking ammonia. This action could have caused thermal stress on the tank bottom and was considered too risky. The second option was to use water spray. Because of the small rate of leakage, the water spray was applied with fog nozzles directly to the outside periphery of the tank at the point of vapour emissions in order to completely dissolve the ammonia.

Immediately after detection of the leak, a round-the-clock operation began to transfer the contents of the tank into trucks for transportation off the site. The transfer operation started at 0600 h on Tuesday and ended at 2200 h on Thursday.

Problems were encountered while using the fog nozzles due to shifting winds which necessitated repositioning of the fog lines several times. To solve the problem, the fog nozzles were replaced by lawn sprinklers. Canvas tarps and burlap bags were laid on the ground around the tank to help trap and restrict the movement of the ammonia vapours. The soaker hoses placed strategically around the tank were successful in removing most vapours and generated much less water than the fog nozzles.

Actions were taken to prepare for a potential catastrophic failure of the tank. In this worst-case scenario, to control the rate of vapourization from a pool of liquid ammonia, ways were investigated to insulate the pool from the air and the sun using F413 foam. To find an alternative to the foam, polyurethane foam was tested. In case the tank had failed, the polyurethane foam sheets would have been placed on top of the ammonia pool to reduce the amount of exposed surface area and to insulate the ammonia until it could be properly removed.

Public Perceptions

Public perceptions of the incident were shaped by statements from company and public officials through the local media. The media received information from the Company.

Comments and reactions from the general public varied from the uninterested to the paranoid. But overall, the leak tarnished the good reputation of the company within the local community and created disagreement between public juris-

dictions. Even after three years, the ammonia leak is still mentioned as a footnote in many local newspaper articles dealing with chemical releases.

EVALUATION AND CONCLUSION

In the wake of the incident, the company needed to ask some hard questions :

Could the incident have been prevented? How well was the chemical release controlled? How well did the company communicate with emergency officials? Could the company have minimized the negative impact of the event? The answer to these questions may perhaps prevent a similar incident from happening again.

Although containment dikes were constructed around the tank to contain a major spill, a small secondary containment wall constructed close to the tank wall, like a tank within an open tank design could have significantly eliminated the vapour release from the leak and made it easier to control. Because of errors during fabrication tank, failure was destined to happen and probably could not have been avoided. To avoid future leak incidents, periodic inspections of the floor welds could be done, but this procedure would put restrictions on tank operations. Another option would be to store ammonia in smaller quantities at the facility. This would reduce operation flexibility and require daily movement of ammonia. However, it would minimize the impact of a tank failure on the local community.

The methods used in managing the ammonia fumes were successful in keeping the fumes within or close to the facility fence line. The ammonia vapours were captured by water spray and contained within a dike system, from where it was pumped to a process pond for eventual recovery of the ammonia in the fertilizer granulation plant.

The fire department knew how to respond to an ammonia accident and acted appropriately. The company had a poor relationship with the city of Manteca. The Manteca Fire Department had a little or no experience with ammonia, and there was no line of communication between city officials and company managers.

To help minimize the impact of any similar incident, the following steps may be taken. First, the facility should have a good working relationship with all local agencies and jurisdictions and a strong line of communication must exist between them. During an emergency situation, the facility and the various agencies should feel comfortable contacting each other. This will help to minimize the impact of an incident by allowing for the flow of information and by preventing misunderstandings.

Second, provide information quickly. Immediately after an incident begins, the company should supply as much information as possible to the agencies and to the public. If the information needed by the agencies and desired by the media is not provided, they may gravitate towards other sources outside the company. It is better for information to come from qualified sources than to let bystanders speculate. However, the information and recommendations given should be relevant and well thought out, and should not be misleading

and not speculative. Wrong information or the lack of information may create distrust and cause overreaction or disappointing judgment.

Third, the company must present itself as a team. Immediately after an incident begins, the company should be prepared to give strong, solid recommendation on how to handle the incident, what precautions need to be taken, and how much area will be affected. This information should be presented to the agencies and media by the facility team so that any question presented can be properly and competently answered. The team ought to include people who can answer technical questions dealing with plant operations and maintenance chemistry, the environment, public health and safety. The team also should have people who can answer questions dealing with legal issues and public relations. The ability of a team to answer questions in a solid, confident manner is important, for any hesitation or nervousness can be interpreted as incompetence.

A company cannot have total control in an emergency incident, but by preparing for potential incidents, communicating with emergency agencies, and by gaining the trust of the agencies and the public, the company can have a hand in controlling the situation and minimizing adverse effects.

PROCESS HAZARDS¹⁰

Because of variations in the type and quantity of chemicals present in different fertilizer manufacturing process streams, the hazards posed by them due to accidental release or other mishaps vary from stream to stream within the process-stream cycle. In general, a high-volume stream is more hazardous than a low-volume stream; a gas is considered to be more of a toxic hazard than a liquid because inhalation is more likely to be the shortest route of exposure to toxic substances in the plant; a gas is more easily ignited than a liquid and, therefore, is considered to be more of a flammable hazard; high-temperature liquid streams are considered to be more of a hazard than low-temperature streams because of their greater volatility; high pressure liquid streams are also more of a hazard than low-pressure streams because they evaporate rapidly if suddenly released into a lower pressure environment. Although not considered in the hazard analysis, some streams of the fertilizer manufacturing processes may pose a lesser hazard than is indicated by their physical and chemical properties because they are remotely located. Distillation columns or cracking columns, overhead vapour streams and vent streams, for example, are usually placed above ground levels and do not pose a hazard to persons at the ground level. The flammable hazard of the vapour streams of hydrocarbons downstream of the reactors would be reduced if little or not excess carbon monoxide is used in the reaction. On the other hand, the flammability hazard of these vapour streams would be higher than indicated or calculated if hydrogen is present as an impurity in CO fed to the reactor. The gasification of hydrocarbon or coal to hydrogen and CO, being the first step in ammonia manufacturing process, involves potential hazards of fire, explosion and toxicity at every stage from storage through handling to reaction with O₂ and steam. The reactivity hazard of the high-pressure liquid stream of acids, such as H₂SO₄, HNO₃,

HCl and wet-process H₃PO₄ used for the manufacture of NH₄NO₃, (NH₄)₂SO₄, NH₄Cl, (NH₄)₃PO₄, K₂SO₄, etc may be considerably higher if they are accidentally released in the sections of the process equipment and machineries not resistant to their corrosive effects. Flammability hazards of gaseous hydrocarbon feed-stocks and dust-exposibility hazards of coal dust are of high potential danger to other plant processes.

The main categories of process hazards prevailing in the fertilizer and allied chemical industries are discussed hereunder.

Health Hazards

The health hazards arise from two sources: (i) the inherent toxic properties of the materials being handled or processed,

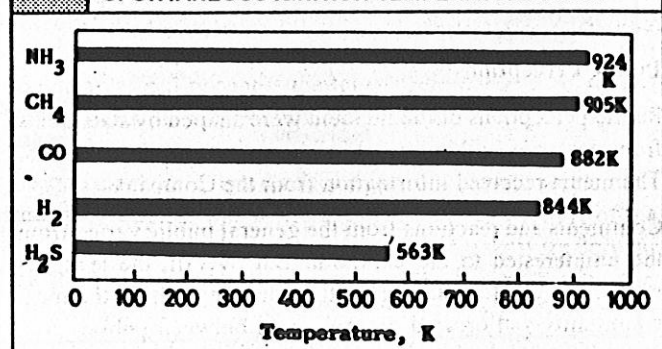
TABLE 1
THRESHOLD LIMIT VALUES OF SHORT EXPOSURE OF HEALTH HAZARDOUS GASES

Material	Threshold Limit ³ Values of Exposure in Air, ppm
NH ₃	50
CO	50
CO ₂	5000
H ₂ S	10

TABLE 2
FLAMMABILITY HAZARD RATING OF MATERIALS AS PER NFPA

Material	Flammability Hazard Rating ¹¹	Susceptibility of Material to Burning
NH ₃	1	Must be preheated before ignition starts
CO	4	will rapidly or completely vapourize at NTP or will readily disperse in air and burn easily
H ₂	4	
H ₂ S	4	
Ethylene	4	
Methane	4	
Natural gas	4	
Naphtha	4	
HNO ₃	0	will not burn
H ₂ SO ₄	0	
NO ₂	0	
HCl	0	
NH ₄ NO ₃	0	

FIGURE 1
SPONTANEOUS IGNITION TEMPERATURE IN AIR



and (ii) from the toxic products of combustion or decomposition of the material (common hazards of ordinary combustible materials are not included). In fertilizer industry, the materials like NH_3 , CO , CH_4 , H_2S , hydrocarbon vapours, NO_2 , P_2O_5 , CO_2 , Cl_2 , and coal dust by virtue of their inherent health hazardous properties, pose threat of potential danger to the health of working personnel. Therefore, it is essential to know their threshold limit values of short exposure, as shown in Table 1, from the view point of better health safety considerations.

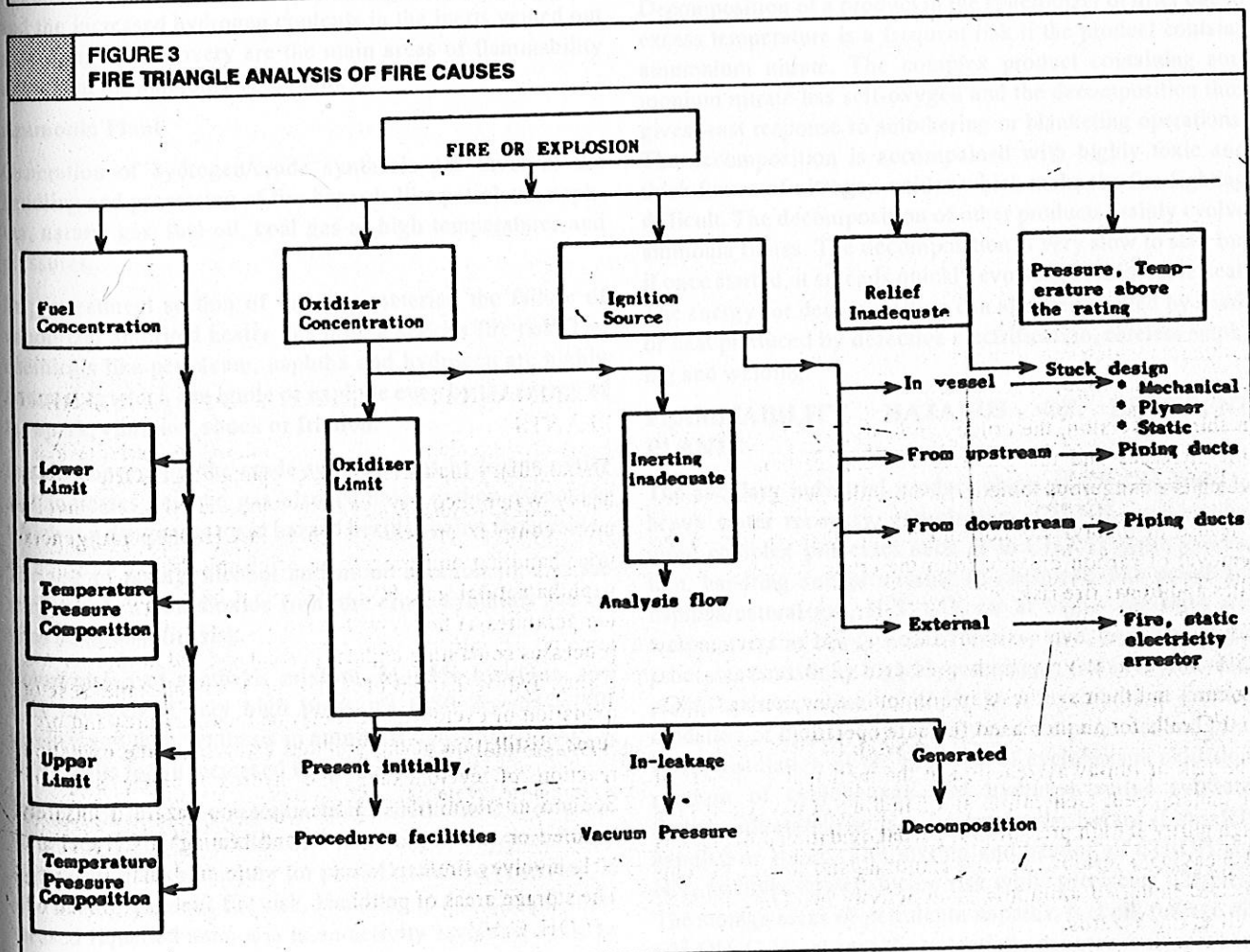
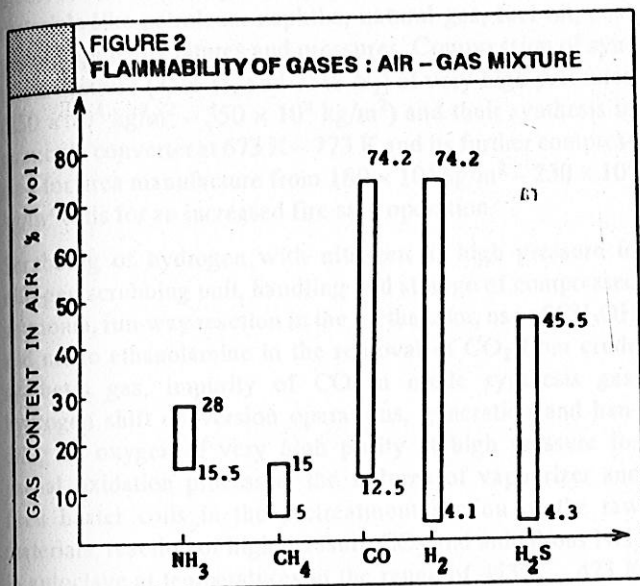
The degree of hazard should indicate (i) that people can work safely only with specialized protective equipment, (ii) that they can work safely with suitable respiratory protective equipment, and (iii) that they can work safely in the area with ordinary clothing. In general, the health hazard in the plant is that of a single exposure which may vary from a few seconds to an hour.

Flammability Hazards

Flammability hazards deal with the degree of susceptibility of flammable materials to burning, even though some materials that burn under one set of conditions will not burn under others. The form or condition of material as well as its properties affect the hazard. The degree of flammability hazard is ranked according to the susceptibility of materials to burning. Table 2 gives the flammability hazard rating of the materials being handled or processed in the fertilizer industry.

Spontaneous ignition temperature in air^{11,12} (Fig 1) and flammability of gases : air-gas mixture¹¹⁻¹² (Fig 2) show the degree of flammability hazards associated with ammonia, methane, carbon monoxide, hydrogen and hydrogen sulphide in the fertilizer industry.

The fire triangle analysis of fire causes¹ (Fig 3) being observed to be most prominently present in almost all process streams of the fertilizer and allied chemical industries, shows briefly the sequence of cause removal analysis of the flammability hazards.



FIRE HAZARD AREAS AND FIRE POTENTIALS

Taking into account the various units installed in fertilizer plants, the following fire dangerous areas with fire potentials mentioned therein can be listed.

Ammonia-Urea Plant

In the fertilizer industry, ammonia-urea plant has a high hazard potential. Generation of hydrogen/crude synthesis gas involves the handling and processing of fire hazardous materials like petroleum naphtha, natural gas, fuel oil, coal gas at high temperatures and pressures. Compression of synthesis mixture (75% H₂ and 25% N₂) at very high pressures (250 × 10⁴ kg/m² – 350 × 10⁴ kg/m²) and their synthesis in ammonia converter at 673 K – 773 K and its further compression for urea manufacture from 180 × 10⁴ kg/m² – 230 × 10⁴ kg/m² calls for an increased fire safe operation.

Scrubbing of hydrogen with nitrogen at high pressure in nitrogen scrubbing unit, handling and storage of compressed ammonia, run-way reaction in the methanator, use of CH₃OH and mono ethanolamine in the removal of CO₂ from crude synthesis gas, impurity of CO in crude synthesis gas, hydrogen shift conversion operations, generation and handling of oxygen of very high purity at high pressure for partial oxidation processes, the failures of vapourizer and fired heater coils in the pretreatment section of the raw materials, reaction of high pressure CO₂ and anhydrous NH₃ in autoclave at temperatures in the range of 453 K – 473 K and the increased hydrogen contents in the inerts vented out after ammonia recovery are the main areas of flammability hazards in the ammonia-urea plant.

Ammonia Plant

Generation of hydrogen/crude synthesis gas involves the handling and processing of fire hazards like petroleum naphtha, natural gas, fuel oil, coal gas at high temperatures and pressures.

In pretreatment section of the raw material, the failure of vapourizer and fired heater oils pose a serious fire risk. The chemicals like petroleum, naphtha and hydrogen are highly flammable which can ignite or explode even by the energy of the spark, vibration, shock or friction.

In shift conversion, the crude synthesis gas-hydrogen purity still increases and the gas also contains carbon monoxide which is a dangerous toxic hazard besides being flammable.

The use of methyl alcohol and mono ethanolamine in the removal of carbon dioxide from the crude synthesis gas invites additional fire risk.

Compression of synthesis mixture, *ie*, 75% hydrogen and 25% nitrogen at very high pressures (250 kg/cm² – 350 kg/cm²) and their synthesis in ammonia converter at 400°C–500°C calls for an increased fire safe operation.

The risk of run-away reaction in the methanator should not be undermined. Generation and handling of oxygen of very high purity at high pressure for partial oxidation processes, is also having a serious fire risk. Handling and storage of compressed liquefied ammonia is an activity involving toxic as well as fire hazards.

Urea Plant

Reaction of high pressure carbon dioxide and anhydrous ammonia in autoclave in the temperature range of 180°C – 200°C is a process having potential hazards like equipment failure due to corrosion and high pressures, presence of free hydrogen or free oxygen due to contaminated CO₂ and more anticorrosion air fed to reactor, failure of pressure reducing valve after the reactor, etc.

Increased hydrogen contents in the inerts vented out after ammonia recovery.

COMPLEX FERTILIZER PLANT

Complex fertilizer plants involve a very wide range of chemical inputs which possess a greater degree of flammability hazards by virtue of their flammable nature in different operational conditions. Decomposition of a product in the spherodizer or drier due to excess temperature is a frequent risk, if the product contains NH₄NO₃. The solidified NH₄NO₃ being heated followed by confinement and/or compression can disastrously explode to the extent of complete damage. Failure of water seal of slurry pump and/or choking/blocking of slurry discharge lines can cause entry of the slurry in the seal, or nearby where the slurry upon getting heated may explode.

Pumping and vapourization of anhydrous ammonia involves fire and toxic hazards.

Decomposition of a product in the spherodizer or drier due to excess temperature is a frequent risk if the product contains ammonium nitrate. The complex product containing ammonium nitrate has self-oxygen and the decomposition thus gives least response to smothering or blanketing operations. The decomposition is accompanied with highly toxic and thick fumes of nitrogen oxides which make the fire fighting difficult. The decomposition of other products mainly evolve ammonia fumes. The decomposition is very slow to start but if once started, it spreads quickly evolving considerable heat. The energy for decomposition can also be supplied by spark or heat produced by defective electrification, careless smoking and welding.

FLAMMABILITY HAZARDS OF DIFFERENT PLANTS

The ancillary industrial product plants of CH₃OH, NaNO₃, heavy water recovery, caprolactum, CH₃NH₂, etc involve more complex processes such as in CH₃OH plant, generation, handling and processing of chemicals like petroleum naphtha/natural gas, H₂S, CO, etc at higher pressures and temperatures at heavy water recovery unit, handling of the processes containing high H₂ percentage; and in caprolactum plant, hydrogenation of C₆H₆ in a cyclohexane reactor, oxidation of cyclohexane at elevated temperatures and pressures, distillation of the products of cyclohexane oxidation, reaction of cyclohexane and hydroxyl amine sulphate. Sodium nitrate/nitrite is a fire/explosion hazard if unsafely handled or stored. The mixing and heating of CH₃OH and NH₃ involves fire/explosion risk while producing CH₃NH₂. The storage areas of petroleum naphtha, fuel oil, furnace oil, CH₃OH, C₆H₆, etc are the potentially dangerous areas where

bulk fuel for a fire is available to cause disasters. In power plant, the boiler house, especially the boiler furnace and its firing mechanism, superheated steamlines and steam-turbines, the diesel/gas driven generators, electrical installations such as transformers, switch gears, substations, motor control centres possess an inherent risk of fire and/or explosion. The compression and distribution unit of natural/fuel gas possesses a high degree of fire and/or explosion hazard due to varying pressurization/depressurization and compression processes.

NATURAL GAS/FUEL GAS COMPRESSION AND DISTRIBUTION UNIT

The leakages from the piping, flanges or valve glands form a very serious fire risk.

Operational failures such as sudden draining, venting or sudden pressurizing and depressurizing invite dangerous fire risks.

The incoming piping for this unit is lengthy as it comes from refinery/oil fields. Unnoticed fire at any point can cause a serious hazard.

INDUSTRIAL PRODUCTS PLANTS/OTHER PLANTS

Sodium nitrate/nitrite is a fire/explosion hazard if unsafe storage or shipping practices are adopted.

Methanol plant is a serious fire and explosion area due to generation, handling and processing of chemicals like petroleum naphtha/natural gas, hydrogen sulphide and carbon monoxide at high pressures and temperatures. The synthesis unit of methanol is a very critical area from fire and explosion point of view. In the distillation unit, the gaseous effluents containing dimethyl ether pose a serious fire risk.

The storage of methanol of various purities requires a large tank farm. The despatch unit of the product includes pumping station and loading platform. All these areas are dangerous fire zones.

Heavy water recovery unit involves handling/processing of a gas containing high hydrogen percentage. Serious fire/explosion has been experienced during commissioning of this plant in one of the fertilizer factories.

Methyl amine production is also associated with fire risks. The mixing and heating of the methyl alcohol and ammonia involves fire/explosion risk. The heaters – especially their failures – pose a critical fire hazard. The handling, storage and despatch of the anhydrous product call for an increased fire safe operation.

Caprolactum plant – the caprolactum process involves the following stages which are self-explanatory about the extreme fire and explosion risks.

- (i) Hydrogenation of benzene in a cyclohexane reactor,
- (ii) Oxidation of cyclohexane at elevated temperatures and pressures,
- (iii) Distillation of products of cyclohexane oxidation, and
- (iv) Reaction of cyclohexane one and hydroxylamine sulphate. The raw material, the intermediate and the

product have a potential fire risk. The product is used in the manufacture of Nylon-6 yarn.

STORAGE AREAS

The storage tank farm of petroleum naphtha, fuel oil, furnace oil, methanol and benzene is an area where bulk fuel for a fire is available to cause disasters.

The storage tanks of anhydrous ammonia which range from 1 500 t to 20 000 t are the installations containing toxic as well as fire hazard like ammonia. The heavy release of ammonia presents very critical rescue and leakage control problem for fire fighters.

The dilute sulphuric acid storage tank is a source of hydrogen besides containing a toxic liquid.

The complex fertilizer silos and empty bags godown are the places where fires can take even a couple of days to put out.

The LPG or fuel gas bullets and hydrogen holders in the fertilizer plant have an inherent fire risk.

Chemical stores godown where catalyst, chemicals, laboratory reagents, grease, gas cylinders, lubrication drums, etc are stored, also present a fire risk.

The huge store yards of coal and sulphur have a risk of fire and dust explosions.

POWER PLANT

The boiler house especially the boiler furnace and its firing mechanism is an area of greater fire risk.

Superheated steam lines and steam turbines provide ignition energy for fire if combustibles come in contact with uninsulated portions.

The fire risk arising out of high pressure piping or boiler failure cannot be undermined.

The fire chances in power generators (diesel driven, steam driven, gas turbine driven) cannot be ruled out.

Electrical installations such as switch gears, transformers, sub stations, motor control centres, etc have an inherent risk from flash explosions.

DRAINAGE SYSTEM, YARD PIPING AND ELEVATED LOCATIONS

The factory drainage due to presence of flammable/combustible substances such as naphtha, oil, grease, etc has been considered to be the fire dangerous area. Poor housekeeping around the drains invites serious fires which may involve manufacturing units. Poor housekeeping and leakages from yard piping can also contribute to fire incidents. The places like prilling towers, chimneys, flare stacks, reaction towers, etc are challenging ones for the rescue operation.

REACTIVITY HAZARDS

In fertilizer industry, the important reactivity hazardous areas exist in acid plants. The reactivity hazards deal with the degree of susceptibility of materials to release energy. Some materials are capable of rapid release of energy (as by self-reaction or polymerization), or they can undergo violent eruptive or explosive reaction if they come in contact with

water or other extinguishing agents or with certain other materials. The violence of reaction or decomposition of materials may be increased by heat or pressure, by mixture with certain other materials to form fuel-oxidizer combinations, or by contact with incompatible substances, sensitizing contaminants or catalysts. Because of the wide variations of accidental combinations possible in fire emergencies, these extraneous hazard factors (except for the effect of water) cannot be applied in a general numerical scaling of hazards. Such extraneous factors must be considered individually in order to establish appropriate safety factors such as separation or segregation. Such individual consideration is particularly important where significant amount of materials are to be stored or handled.

ACID PLANTS

Acid plants of the fertilizer industry involve high degree of reactivity hazards. Compression and vapourization of liquid NH_3 in the HNO_3 plant and further burning it in the presence of air is a process of involving a greater amount of fire risk. The pilot firing system of HNO_3 reactor (NH_3 - burner) involving the use of pure hydrogen or a fuel gas, is again a fire hazard. Sulphuric acid sludge in storage tanks contain considerable hydrogen potentials. The storage vessels used for dilute H_2SO_4 , which are either found in HNO_3 concentration unit or in H_3PO_4 plant, positively contain considerable amount of hydrogen. Storage and handling of solid sulphur, melting of sulphur, burning of molten sulphur, concentrated high pressure liquid streams of H_2SO_4 , HNO_3 , HCl and H_3PO_4 may have an endangering potential to other process plant equipment and machineries which are not resistant to their reactivity hazards.

Compression and vapourization of liquid ammonia in the nitric acid plant and further burning it in presence of air is a process involving fire risk. The pilot firing system of the nitric acid reactor (ammonia burner) involves the use of pure hydrogen or fuel gas which is again a fire hazard.

There is a risk of sulphur dust explosion in tank silos made for receiving solid sulphur from ships.

Storage and handling of solid sulphur, melting of sulphur and burning of molten sulphur in furnace to get sulphur dioxide in the sulphuric acid manufacture, is a hazardous activity. Fires in sulphur yard - though small and controllable, take place due to friction of handling machinery or careless smoking. Fires in molten sulphur pit are very frequent, which usually take place due to poor quality of sulphur, operational failure or welding sparks. Fires in sulphur furnace take place during preheating when fuel gas is used in burners.

Sulphuric acid sludge in storage tanks contains considerable hydrogen potential. The storage vessels used for dilute sulphuric acid (these vessels are either in nitric acid concentration unit or in-phosphoric acid plant) positively contains hydrogen. Also, the acid handling equipment and piping evolve hydrogen when washed with water. The addition of water in sulphuric acid evolves a lot heat to initiate fires.

Repairs or providing rubber lining to the vessels involve fire risk.

SAFETY MEASURES

In general, prevention and protection measures constitute either (i) passive prevention and protection measures and/or (ii) active protection measures.

Passive prevention and protection measures consist of those ones which are taken in order to prevent the occurrence of hazard and to limit its spread. These measures are built into the basic plant layout and design. They include:

- (i) Elimination of hazards
 - (a) leaks and spillage,
 - (b) sources of ignition
- (ii) Emergency materials transfer
 - (a) pressure relief and flaring
 - (b) blowdown
 - (c) dumping
- (iii) Hazard-resisting such as fire-resisting, reactivity-resisting, toxicity control, etc.
- (iv) Hazard spread limitation
- (v) Storage tank layout
- (vi) Cleanliness, routine maintenance and good housekeeping

Active hazard protection measures are also provided in the basic plant design, but are only effective when activated in response to hazard. These measures are the arrangements to be made to take care of any hazardous eventuality. They include:

- (a) hazard warning system,
- (b) hazard detection system,
- (c) fire fighting agents,
- (d) water supply arrangements and distribution system,
- (e) sprinkler system,
- (f) fixed foam system installation,
- (g) fixed CO_2 system installation,
- (h) fixed halogenated system installation - likely to be phased out in the immediate future,
- (i) fire hydrants,
- (j) fixed water/foam monitors,
- (k) water spray system,
- (l) first-aid fire fighting equipment,
- (m) mobile fire appliances,
- (n) refuge areas, etc.

CONCLUSION

Identification, assessment and evaluation of process hazards in chemical industries are of paramount importance and utmost priority as far as life and property safety are concerned. Process hazards in all hazardous plant areas of the fertilizer industry broadly comprise: (i) health, (ii) flam-

mability, and (iii) reactivity. Ammonia-urea plant is a core of high flammability and toxicity hazards since it handles large volumes of high energy compounds of a combustible, and explosive nature. Acid plants involve high degree of reactivity hazards due to compression and vapourization of liquid ammonia. Other industrial product plants such as CH_3OH , NaNO_3 , heavy water recovery, caprolactum, CH_3NH_2 , etc involve highly complexed hazardous processes such as generation, hydrogenation, distillation, oxidation, handling, storing and processing. Storage areas are undoubtedly more hazardous ones by virtue of high capacity holdings. These hazardous plant areas and the manufacturing processes need extra thrust though R&D for the enhancement of fire safety standards from the viewpoint of better fire safety not only for those who are within the working system of the industry but also for those who are in the immediate surroundings of the industry. Therefore, it is essentially required to have, within the reasonable cost and expenditures, the provision of adequate hazard prevention and protection measures to check each unit level of the plant processes constituting the hazards, right from the plant design to the complete commissioning and in the subsequent stages.

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