UNIDO-FAI Inter-regional Meeting on Safety in the Design and Operation of Ammonia Plants 1976

PROCEEDINGS

THE FERTILISER ASSOCIATION OF INDIA, NEW DELHI-110057

UNIDO-FAI Inter-regional Meeting on Safety in the Design and Operation of Ammonia Plants

Proceedings of the Meeting
held at New Delhi from
January 20 to 23, 1976

THE FERTILISER ASSOCIATION OF INDIA
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FOREWORD

The Fertiliser Association of India in collaboration with the United Nations Industrial Development Organisation (UNIDO), Vienna had organised an inter-regional meeting on "Safety in the Design and Operation of Ammonia Plants" in New Delhi during January 20-23, 1976.

The objectives of this expert meeting were to identify and review the safety aspects for design and operation of ammonia plants in order to reduce the danger of explosions, production interruptions, etc., for both the existing and the new industrial complexes. To achieve these objectives, case histories and experience of ammonia producers were taken up as the basis for discussions.

Eighty experts from 15 countries participated in the meeting. Twenty-six papers were presented on five specific areas, namely, (i) design consideration, (2) operational and maintenance consideration, (3) testing and control procedures and welding techniques, (4) case histories and (5) general considerations. Emanating from the three-day discussions, several useful conclusions and recommendations were evolved.

The book contains all the papers presented at the expert meeting together with a resume of the discussions and conclusions and recommendations. We trust that all those interested in ammonia production technology will find this compendium a useful reference book.

SATYA NAND
Executive Director
The Fertiliser Association of India

New Delhi
July 5, 1976

RECOMMENDATIONS

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1. That a standard code for the identification of alloy pipe and bar stock be developed and that this code be used by all countries. All items marked for identification by this code will be marked either for this full length or at sufficiently close intervals to ensure the identification of the item from small samples.

2. That fabricators, contractors and sub-contractors avail themselves of direct reading spectrograph to be used for proper identification of metals to be employed in plant fabrication and construction.

3. That any fabricator of shop and field items be required to maintain the proper equipment for the testing of both incoming material and the final product and that his procedure for inspection and quality control must meet accepted industrial standards. That critical item of equipment space be tested and inspected by these procedures and the results of these tests made available to the client or his representative.

4. That a central data bank for corrosion and failures in fertiliser plants be started in each country and that access to this information be made available to all. The information to be collected will include first notifications of any failure followed by more complete data as the investigation procedure. The dissemination of this information will be by periodic circulars and annual or semi-annual seminars. It is suggested that such inter-country function be under the auspices of UNIDO.

5. That seminars and symposia be held on specific topics related to fertiliser plants' safety and that special attention be devoted to corrosion and failure.

6. That periodic review and Status Reports be published which will contain articles relevant to plant safety, corrosion and failure. Authors may be invited to submit appropriate papers dealing with these topics.

7. That specific agencies such as UNIDO and ILO provide to interested parties information relevant to safety in fertiliser plants. That this information be sent to a representative in each country who has direct and immediate access to all parties who will benefit from it.

8. That standards for environmental aspects including safe noise level developed by other countries be disseminated to all countries through a central agency.

9. That in the investigation of a plant accident, a person thoroughly familiar with plant operation, as well as selected specialists, be employed.

10. That each fertiliser plant in all countries should periodically carry out suitable non-destructive tests to determine the safety status of the plant.

11. That each country should have at its disposal equipment and apparatus for the appropriate testing of high speed rotating equipment.

12. That manufacturer of high speed rotating equipment should make available to the client for his future reference significant data which is characteristic of the machines.

13. That a central pool of long lead capital intensive item of plant equipment be maintained in each country.

RESUME OF THE MEETING

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The UNIDO-FAI Interregional Meeting on 'Safety in the Design and Operation of Ammonia Plants' was held at Vigyan Bhavan in New Delhi from January 20 to 23, 1976.

Inaugural Session

The Inaugural Session of the meeting was held on January 20, 1976. The UNIDO delegates, representatives of various countries, the participants and the invitees were welcomed by Shri Paul Pothen, Chairman, The Fertiliser Association of India, on behalf of FAI and by Shri M. C. Verghese, Chief of the Chemical Industry Section, Industrial Operation Division of the United Nations Industrial Development Organisation on behalf of UNIDO. The Inaugural Address was delivered by Shri K. C. Sharma, Chairman and Managing Director of The Fertilizer Corporation of India, New Delhi. The Welcome Address and the Inaugural Address are reproduced elsewhere in this book.

Shri Paul Pothen, Chairman of the FAI, was elected the Chairman of the meeting and Shri G. R. James, UNIDO Consultant, was elected a General Rapporteur. The meeting adopted the agenda drawn by the FAI and UNIDO.

Over 80 participants attended the Interregional Meeting from 19 countries, namely, Austria, Bangladesh, Brazil, Burma, Egypt, India, Indonesia, Iran, Italy, Japan, Korea, Kuwait, Malaysia, Pakistan, Poland, Saudi Arabia, Thailand, the UK and the USA.

The Chairman invited the representatives of various countries present at the meeting to make brief presentations of the status of fertiliser industry in their respective countries, highlighting the problems. The representatives of Bangladesh, Brazil, Egypt, India, Indonesia, Iran, Korea, Kuwait, Pakistan and Poland made brief presentations of the status of fertiliser industry in their respective countries.

Twenty-six papers were presented and discussed at the meeting. The presentations and discussions were held in five Technical Sessions, spread over four days. A resume of the Technical Sessions and the papers presented in each session are given below:

Session 1 : Design Considerations of Ammonia Plants

Shri K. S. Sarma, Officer on Special Duty, The Fertilizer Corporation of India Ltd., New Delhi, presided over this session. Shri T. R. Visvanathan of Madras Fertilisers Ltd., Madras, acted as the rapporteur.

In this session the following 10 papers were presented:

I. Safe Design and Operation of Ammonia Plants by M.VOS and A. C. Ludbrook, Kellogg International, U.K.

II. Safety in Design and Operation of IEL Ammonia Plant by K. Narayanan and R. B. Dutt, Indian Explosives, India.

III. Safety Consideration in the Design of Ammonia Synthesis Loops by A. Ward, ICI, UK, and A. Sunderland, Devy Powergas, UK.

IV. Design and Operation Problems of Turbine/Compressor Systems by L. Laboratore, Nuovo Pignone, Italy.

V. Centrifugal Compressors for Ammonia Plants—Design and Operation Considerations by W. A. Zech, Clark Dresser Industries, USA.

VI. Turbines and Compressors for Ammonia Synthesis Plants by A. N. Venkatesan, BHEL, India.

VII. Special Refractory Materials for Use in Gas Reforming by R. R. Miner, Carborundum Company, USA.

VIII. Safety Considerations for Design of Reformer Furnaces by R. N. Saran, G. Venugopal and S. N. Wazir, Mecon, India.

IX. Instrumentation and Computer Control for Safe Ammonia Plants by M. Nobue, Toyo Engineering & TOPACS, Japan.

X. Safety Audit in Ammonia Plant Design by P. M. Sales and E. W. Owen, Humphreys & Glasgow, U.K.

The presentation of the papers was followed by a lively discussion in which a majority of the delegates participated.

The difference in cost between energised and de-energised trip systems in an ammonia plant was indicated as about 30-40 per cent. However, both systems needed adequate backup power source and maximum circuit reliability. Though for general reliability, energised trip system was considered better, spurious trips were more likely in this resulting in loss of production. Some preferred de-energised system as being safer, but this should be constantly checked for continuity of power supply.

Regarding possibility of water freezing the secondary condenser during ammonia catalyst reduction, it was explained that this could happen because usually after startup the compressors were being kept in service and ammonia refrigeration system charged.

It was reported that gasket standardisation would be very helpful, but specific types of gaskets were required for different joints in the fertiliser plant. In order to conserve the more expensive gaskets, some preferred the use of temporary, readily available, non-specification gaskets, but this was not recommended though some of them might stand up to the hydrostatic tests.

About the problem of training of clients' personnel in similar plants, Pakistan indicated its readiness to give facilities for six trainees from this region at a time for 3 to 6 months in their modern ammonia plants. Pakistan has developtd schemes for the continuous training of its technical personnel through the joint efforts of the State and Dawood Hercules Chemicals. It was also mentioned that the production record in their fertiliser plants had been very good.

Kellogg ammonia plants were reported to have a very high degree of safe and trouble-free startup and operation. Only two cases of failures were known to have occurred—one due to wrong specification of piping in an ammonia loop, and the other due to use of non-specification blind at the outlet of a double block valve in the converter. It was, however, pointed out by some participants that in Kellogg plants, there were still a few areas where safety needed further improvement. These were absence of a flare stack in the front end of ammonia plant, use of carbon steel piping from the separator to CO_2 absorber which resulted in corrosion (there was mixed opinion on this as the pH of the condensate was reported to be 6 in some plants and 8 in some other plants), higher superheated steam temperature than design at startup conditions and absence of desuperheating facilities, and the need for more reliable vibration analysers and recorders for the centrifugal compressors. It was learnt that Bently Nevada system was being increasingly used in Kellogg plants. The correct location and proper installation of these probes were very important and should be done by experts.

The discrepancy noted in the vibration readings at the control room and the portable IRD analysers were discussed at some length. Keeping continuous track of all vibration readings would be found useful in such cases. Whenever the probes were damaged, wrong readings were likely especially of thrust bearings. Due to ageing, or change in position of the probe, readings would vary. Hence probe calibration had to be checked frequently. Interpretation of the vibration readings could vary from plant to plant based on one's experience of the machine characteristics and operating conditions. Abnormal or irregular readings needed checking for possible causes. Provision for automatic tripping of centrifugal compressors from the recorded readings at the control room might not always be necessary or desirable.

Regarding materials of construction for the fertiliser plants, it was brought out during the discussions that wrong materials supplied by oversight had led to many failures. Unfortunately, only the larger ones were usually reported. Use of coloured bands running the entire length of pipe at frequent intervals for identification might not always be infallible as purchaser, supplier and fabricator might have their own colour schemes and mix up was still possible. Hence a code of practice for colour identification of piping was being thought of in UK and other countries. A portable type of spectroscope was reported to be an inexpensive instrument that would be useful for identification of most metals and alloys. It could be handled by an operator with little training. Sometimes, valve internals got changed on reassembly during the construction phase of a project. An incorrect internal material with correct body material would lead to problems during operation.

Thorough inspection and rigid quality control at fabricators' shops for equipment and piping by a third party were necessary to avoid any differences arising between what was specified and what was fabricated. Some Middle East countries had considered even the black-listing of incompetent and unreliable inspection agencies. Due to inadequate checking, unmatched flange holes and bad piping welds were reported to have happened at fabricators' works.

On the use of high quality refractory in the reformers, alumina bubble castable was reported to be strong enough at 200 ft/second air blast even with modest particulate matter. If this refractory were to be cast with minimum amount of water and cured properly, it would be as good as brick work. However, if allowed to dry without proper curing, bad results would occur. For transfer lines in the reformer, internal metallic shrouds might not be necessary for additional protection if alumina castable alone was properly done. Alumina castable was resistant to hydrogen attack because of its low silica content. Regarding hot spots in transfer lines due to cracks in refractory, it was felt that though repair was not easy it could still be done. However, the best solution was to do a good job during installation so that the problem of hot spots could be avoided.

High alumina dense refractory could also be used in partial oxidation gas generators of Texaco or Shell design. There was no degradation of the refractory due to sulphur, but the steel shell might be attacked by the acid if there were cracks in the lining. About 3-4 years might be the life of the refractory in partial oxidation units but nobody would guarantee this life because of unknown conditions like improper installation, runaway temperature conditions and other operating factors which would affect the life of the refractory. Also, the life depended on the number of shutdowns, the way depressurising was done, and temperature variations. Some partial oxidation plants in Europe had reported a life of about 5 years, but experience in India showed an average life of only 2 years. The time required to completely rebuild the refractory work of a gas generator was about 3 weeks, including one week for curing.

The economics of computer installation in ammonia plants was difficult to calculate. With fully trained operators who could react to changes in operating conditions, there was no need for computer control. Even in the USA, very few ammonia plants had computers. Though better control of certain critical operating conditions was possible with a computer, not all types of operating variables could be tackled. The purpose of a computer was not to decrease manpower but to optimise operating conditions which could result in a 2-3 per cent additional ammonia production. The cost of a computer system was reported as 20-30 per cent of the total instrumentation cost of the ammonia plant, and this also depended on the extent of computerisation needed. The computer would be found economical if best operating conditions could not be ensured otherwise.

It was reported that bowing of reformer tubes was experienced more in staggered two-row construction than in single row furnaces, but this might be due to bad design also. Arch supported tubes were not expected to have this problem. Sometimes bowing was due to causes other than design like local overheating, non-uniform firing conditions in the furnace, catalyst deterioration, increased pressure drop, sudden and frequent shutdowns and start-ups. Bored catalyst tubes might have better life because of less thermal stress than the ordinary thicker tubes. Operating reformer tubes at lower than design temperatures would minimise hot spots and lead to longer life. It was suggested that to know more and to tackle the problems of hot spots, bowing and life of the catalyst tubes, the reformer designer, the catalyst supplier, the tube manufacturer and the plant operator should get together and share their experiences.

In order to repair cracks in incoloy pipes by welding, it was recommended that the old surface should be cleaned thoroughly by grinding or machining and then welded with inco wire by TIG weld. Regarding the frequency of checking the tensioning of the spring supports for the tubes in the furnace, it was indicated that more attention should be paid to this during installation as well as during turnarounds for their correct setting. A qualified piping engineer should preferably check this.

On the question of feedback information from plants, it was observed that most of the problems that came up during the commissioning stage in a well designed plant were being promptly attended to by their plant builders who were at site. Subsequently, feedback from clients' plants was also looked into and systems had been developed by most of the engineering firms to handle these informations as these were considered important and useful for plant designers. Seminars and meetings like the present one also furnished good feedback from plant operators, but it was essential that the talks and discussions were properly recorded and reviewed. Though engineering firms did not have a central computed system to handle and sort out reformer problems, published information on reformer failures and access to plant data of their clients were always being used to improve the design and performance. However, operating conditions and catalyst performance were considered major factors in reformer performance. Computer facilities that were available with ILO, Geneva, could be used if specific requests came from member countries for solving some of the problems.

Reverse rotation in centrifugal compressors on shutting down was normally prevented by ensuring proper closing of the delivery valves and provision of non-return valves on the piping. Optimum labyrinth clearances of just a few thousandth of an inch were provided based on experience of maximum vibration of shaft that was allowed. Regarding the balancing of rotors, normally, balancing was done at the shops after each impeller stage was fixed, at about 2000 rpm. If balancing was unsatisfactory, then higher speeds were tried. Balancing facilities were reported to be available at BHEL, Hyderabad, India, for compressor rotors. To avoid loose coupling between turbine and compressor shaft, it was necessary to ensure proper clearance before shrunk fit of the hub. Loosening might result from improper dimension checking during alignment, from unbalanced conditions and improper lubrication. The question of changing existing couplings in a compressor for better ones could always be taken up with the suppliers.

Session II : Operational and Maintenance Considerations

This session was chaired by Shri V. S. Pillai, Works Manager, Zuari Agro Chemicals Ltd., Goa. Dr. K. Narayanan of Indian Explosives Ltd., Kanpur, acted as the rapporteur.

The following six papers were presented in the Session:

XI. Stress Corrosion Cracking in Ammonia Plants by M. E. D. Turner, ICI, U.K.

XII. Catalysts in Ammonia Industry by T. S. Nagarajunan, Catalysts and Chemicals (West Asia) India Ltd., India.

XIII. Safety and Fire-Fighting in Refineries and Fertiliser Plants by S. Maruthappa, Madras Refineries Ltd., India.

XIV. Safety Consideration in the Operation and Maintenance of Ammonia Plants by T. M. Das, Fertilizer Corporation of India Ltd., Trombay Unit, India.

XV. Corrosion Problem in Air Separation Plant by A. S. Chatha, Fertilizer Corporation of India Ltd., Gorakhpur Unit, India.

XVI. Corrosion Control in Ammonia Plants by V. S. Pillai, Zuari Agro Chemicals, India.

After the presentation of the papers, the session was thrown open for discussion during which the following points were brought out.

Stress corrosion cracking (SCC), defined as a non-ductible fracture resulting from the simultaneous application of a tensile stress and a specific corrodent is responsible for failure of plant equipment resulting in consequential hazards. The non-availability of any specific relationship between the corrodent and the material in question, has resulted in the inability in predicting SCC. For example, until pure titanium was produced, there was no method of predicting its immunity to SCC with fuming red nitric acid. The general factors responsible for SCC, along with specific SCC systems, are known. However, although the average stress levels and corrodent concentrations may be low in the system, highly localised stresses and/or local corrodent concentrations could result in SCC. Photographic analysis is also difficult since the crack morphology can vary considerably. While SCC rarely leads to catastrophic failures, the importance of SCC, particularly when leading to fatigue failure, should be appreciated.

The only positive method of avoiding SCC is to use non-susceptible metals/alloys but often economic considerations prevent this approach.

In ammonia plants, apart from process material, environment also acts as a corrodent for many systems. The SCC behaviour of brass is well known, and in most ammonia plants, copper alloys containing greater than 15 per cent zinc are not used. In smaller equipment like oil coolers, etc., failure can lead to contamination or starvation of lubricant and often cupro-nickel or stainless steel tubes are resorted to. Use of Benzotriazole coating coupled with lanolised tape wrap has been found satisfactory for air fittings on instrument lines.

Though stress relieving of large vessels is difficult, this must be done wherever possible since there is evidence to show that SCC occurs even at very low stress levels.

Although SCC is attributed to presence of localised stresses, no means of measuring such stresses was readily available, making the problem more complex. It was, therefore, essential that all *care* is taken during fabrication stage and stress relieving operation to ensure that minimum residual stresses are left in the equipments.

Mechanical design often plays an important part in preventing SCC.

Use of non-metallics for fabrication/lining of equipment for preventing corrosion, is coming into vogue with the development of new materials. However, insufficient data on the properties required of the non-metallics for the duty in question, has resulted in non-usage of such materials. Often, temperature limitations and fabrication problems have hindered the use of these materials. Austenitic stainless steels are susceptible to chloride SCC. In fertiliser plants this is often experienced in cooling water systems and, due to rain water on pipeline/equipment with lagging. Incoloy 825, though very satisfactory for chloride SCC duty, is rather expensive. Two families of alloys with properties similar to stainless steel with better SCC immunity to chloride, have been developed, e.g., mixed austenitic/ferritic stainless steels and fully ferritic stainless steels. The former are higher chromium and nickel alloys, but are difficult to fabricate. The latter contains extremely low carbon content and are also easy to fabricate.

SCC of carbon steel tubes with caustic results from a very high stress level being present. With most equipment stress relieved, the problem no longer exists in modern plants.

Vetrocoke solution is a specific SCC agent for carbon steel. The variable SCC rates experienced in the various Vetrocoke plants lead ICI to investigate the properties of Vetrocoke solution with respect to carbon steel. Results showed that Vetrocoke solution contains passivating ions (As^{+3-}) and activating ions (HCO_3^-). The SCC properties of Vetrocoke solution is maximum at the point when the activating ions are more or less in equal proportion. Presence of Sb and Fe^{+3} ions shift the solution to the passive region and render it harmless. Most cases of corrosion have been identified to be due to depletion of Fe^{+3} ions because of lack of air sparging. Apart from the above, temperature, Cl and other ions present, also affect the SCC behaviour of Vetrocoke solution. ICI's method of continuous monitoring of electro potential has been used successfully in this area to prevent SCC in Vetrocoke systems.

ICI's investigation and experience on SCC of carbon steel with Vetrocoke solutions has led to a method of preventing the corrosion of carbon steel by passivating the solution through timely air sparging. Some seven plants have operated with this system of corrosion control—five in the UK and two abroad—some of them since 1966. No new cracks or extension of old cracks have been observed in these plants.

Benfield/Catacarb systems, using vanadium, do not suffer from stress corrosion cracking. Experience has shown that, even when Vetrocoke plants are converted to Benfield/Catacarb type units through modifications, the adsorbed arsenic in the vessel wall reduces the vanadium in service initially and hence there is high consumption of vanadium on changeover which must be borne in mind. A range of organic inhibitors is also available for vanadium/arsenic system.

The experience of Neyveli Lignite Corporation, having had no SCC failure of their Vetrocoke system operational since 1961/62, was attributed to the air regeneration of Vetrocoke solution, and hence eliminating the possibility of Fe^{+2}.

ZACL presented the results of a systematic study carried out on the Vetrocoke system indicating the velocities and materials of constructions in the various sections.

The SCC has been observed in atmospheric temperature ammonia storage vessels. In this case, oxygen and/or nitrogen acts as activator and water as the passivator. Work in this area is still being carried out in the UK and USA.

According to research carried out at Fulmar Laboratories and the University of Newcastle, both nitrogen and oxygen seem to have an effect on SCC of carbon steel in ammonia storage tanks. For commercial storage, 0.2 per cent of water is generally adequate to prevent SCC. The exact figure would, however, depend upon the oxygen concentration and such correlations are available with Fulmar Laboratories. Although laboratory experimentation has shown that SCC can be produced at —33°C, there is no practical evidence of such a corrosion in storage tanks.

The experience of ZACL on sulphuric acid corrosion of the cold and of the waste heat recovery train, when using high sulphur fuel oil, was described. The sulphuric acid dew point was lowered by ammonia injection into the flue gas duct to prevent corrosion. Ammonium sulphate and bisulphite formed had no corrosive effect. Use of fuel oil containing vanadium and sodium often resulted in the formation of a hard corrosive scale leading to damage. Addition of barium or magnesium containing material resulted in the formation of metavanadates which have high melting point and hence do not affect tube performance.

Cooling water is responsible for large amount of corrosion in a fertiliser plant. Chromate dosing has been used with success, but suffers from the ecological disadvantage of effluent disposal. Dosing with SHMP/STPP leads to problem of calcium phosphate precipitation if not operated very carefully. The emergence of zinc organo phosphates is likely to provide a satisfactory answer in the long term.

For cooling water service, chromate dosing was considered the most satisfactory treatment although accompanying environmental problem may impede its usage. MFL reported satisfactory operation in systems containing upto 600 ppm chloride. ICI's experience with synergized chromate system has been complete inhibition of corrosion even at 800 ppm chloride level. However, chromate based systems have to be operated with clean cooling surfaces and there must always be flow in the system. However, environmental restrictions may swing the balance in favour of organo phosphates which have been used with success in many plants.

Fatigue failure, particularly in suction and discharge of ammonia and recycle solution lines, is a common occurrence. Recent use of centrifugal machines has eliminated such failures to a substantial extent.

In air separation plants having copper internals in the cold box, the presence of ammonia in atmosphere poses serious corrosion problem. Apart from selecting suitable material of construction, proper location of air intake points, preferably two, would offer an optimum solution.

In air separation plants, while proper location of air intake towers coupled with having two towers for operation, depending upon wind direction, may provide the solution to corrosion of cold box internals, it might be worthwhile looking at atmosphere inversion phenomenon as well. Experience has shown that minor traces of ammonia cannot be economically removed by water or acid scrubbing, although some plants have reported success, using air scrubbing before the turbo compressor. The main reason for using air was, however, to remove dust particles rather than any ammonia.

MFL's experience on the use of brass in ammonia plant steam turbine condensers has been satisfactory with annealed brass tubes.

Petroleum refineries and fertiliser plants, by virtue of their large scale operation and large columns of explosives, hazardous and toxic material pose major problems from safety considerations. Research programmes undertaken worldwide have resulted in evolving codes of safe practices. Apart from loss of production and equipment time, accidents result in economic and social loss to the community. Safety is, therefore, one of the prime responsibilities of the management with the active cooperation of the employees. Managements of most large refineries and fertiliser plants have accepted this responsibility and have adopted a variety of training and educational programmes for personnel to ensure safer operation of the plants.

According to a survey carried out by ILO, 80 per cent of accidents arise out of human factors in one form or another, with the balance 20 per cent due to faulty design and random accidents. The use of techniques such as "safety audit", "safety sampling of unsafe acts" and "ergonomic checklists for equipment operation in industries" has resulted in eliminating several unsafe designs and acts. While safety committees, compaigns and posters do improve awareness of the workforce to the various aspects of safety, the single contributory factor which results in poor safety record, is the management's lack of awareness and commitment towards safety. Unless safety is given at least an equal status with production activity, it would not be possible to make radical improvements in safety performance. Joint inspection by worker/management team in safety audits and assessments of the work environment along with giving weightage to aspects of safety in the annual assessment of the various managers, would facilitate achievement of safer operation. In Singapore, advanced legislations of safety have been brought out which involve the participation of external bodies like Factories Inspector on a regular basis on subject of safety in any establishment.

For safety in large ammonia storages, bunding was felt desirable except for the cost aspect. This was felt more necessary when the factory