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Safe Ammonia Storage

presented by

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About the IFA Technical Committee

The IFA Technical Committee encourages the development and adoption of technology improvements that can lead to greater production efficiencies and reduced emissions, as well as better health and safety standards throughout the fertilizer industry. Our mission is to actively promote the sustainable development of efficient and responsible production, storage and transportation of all plant nutrients. The Technical Committee accomplishes these objectives through a variety of channels, including:

- Technical and policy-oriented information materials. The committee regularly conducts surveys and produces reports on key industry metrics, including the IFA Energy Efficiency and CO₂ Emissions Report, the IFA Safety Report, and the IFA Emissions Report. This work enables member companies to assess their operations over time, make comparisons with similar facilities on an established level of performance, determine the need for technology improvements and identify good industrial and management practices.
- Regular exchange of information on technology developments and industrial practices. A key role of the IFA Technical Committee is to encourage ongoing technical innovation in the fertilizer industry through the development, compilation and exchange of technical information between members, researchers, engineers, equipment suppliers and other industry associations. To this end, the committee organizes a Technical Symposium every other year to examine progress in the production technology of fertilizers. Each Symposium traditionally features the presentation of 30-40 new technical papers from member companies worldwide, providing members with information on the latest technological developments. In the intervening years, the committee holds a variety of meetings to assess current industrial practices and standards, with an eye toward identifying key developments of interest to members.
- Technical and educational workshops and special events. The IFA Technical Committee provides workshops designed for engineers working in the fertilizer industry, particularly those who have recently assumed new responsibilities, and for new engineers to increase their technical knowledge. These workshops (e.g. concentrating on nitrogen and/or phosphate fertilizer production) are designed to improve the participants' skills and broaden their vision and understanding of the entire industry, including technology, economics, energy use, safety and environmental stewardship. Workshops also provide engineers with an opportunity to exchange ideas, solve specific problems and improve plant operations and profitability.
- Education and advocacy. The IFA Technical Committee recognizes that customers, markets and regulatory environments are best served by clear and concise information on the fertilizer industry and its practices and products. Because the knowledge and expertise found within the fertilizer industry is the best source for this information, the Technical Committee endeavours to educate policymakers, standardization bodies, customers and the public on industry achievements, technological advances, voluntary initiatives and best practices. The committee also encourages universities and development centres to conduct research on fertilizer product development and production processes.

Safe Ammonia Storage

Abstract (1/2)

Ammonia is fundamental in production of fertilizer and the fertilizer business is handling huge amounts of it. As ammonia is a highly toxic chemical the treatment must have the highest attention. The ammonia is stored in large tanks, usually at atmospheric pressure and at a temperature of ca. -33°C. However, we also see that ammonia is stored under pressure at ambient temperature.

When an ammonia tank is designed and constructed, this is done according to relevant codes. The type of construction has to be chosen as well as the correct material. The location is also important. Risk analyzes and HAZOP have to be carried out.

When the tank is erected, proper attention shall be given to quality control /assurance. Detailed procedures are needed for commissioning and the operators have to be adequately trained. Procedures for education and safe operation are based on a HAZOP or other studies of safety.

When a tank is put into daily operation there will be a need for maintenance. Inspection and NDT is important to bring to light issues (corrosion, SCC) that may reduce the structural integrity of the tank.

Abstract (2/2)

The presentation will focus on an inspection philosophy for atmospheric storage tanks based on NDT from the outside and without the need to empty and open the tank. A big advantage will be that the tanks will not have to be filled with air, hence heavily reducing the risk of stress corrosion cracking (SCC). For double integrity tanks, the inspection will be carried out from the outside of the outer tank, requiring that the outer tank has the structural integrity to withstand a sudden rupture of the inner tank from bottom to top. This approach is supported by coupled flow and structural calculations of atmospheric double integrity tanks within Yara, documenting that the outer tank will withstand a rupture of the inner tank. Results from such calculations will be presented.

Yara has also carried out a project together with TNO in Delft, Holland regarding detection of cracks from outside by use of ultrasonic methods. The result from this project will be presented.

Based on experience, we have seen that accidents related to ammonia tanks have occurred due to erroneous operations and inappropriate pipe arrangements for filling and emptying. Yara has developed questionnaires and performed audits based on these questionnaires at our own sites where ammonia is stored. The intention of this survey has been to improve the operation with respect to safety and also to focus on filling/draining arrangements etc. Results from these audits will be presented.

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All papers and presentations prepared for the IFA Technical Symposium in Vilnius will be compiled on a cd-rom to be released in June 2006.

Safe Ammonia Storage

1. Introduction

Yara owns 24 refrigerated ammonia storage tanks altogether. The best of these tanks are located in Europe, but we also have tanks in Trinidad, Brazil and USA. The tanks vary in size from 7.500 m³ to 60.000 m³. The maximum capacity is not utilized for all the tanks. Altogether, Yara has a total ammonia storage capacity of 478.000 m³. In addition to these tanks, Yara is part owner of other sites around the world where ammonia tanks are found.

This paper deals with refrigerated ammonia storage tanks and how Yara believes that these tanks can be operated in the safest way.

According to the EFMA recommendations, all the refrigerated tanks within Yara now have a requirement for internal inspection.

We are presenting an inspection philosophy based on ultrasonic testing from outside and what we believe shall be the requirements for doing inspection in such a way.

Yara Rostock experienced a fatal accident in January 2005. One double integrity ammonia storage tank inflated and consequently ruptured all along the circumference where the outer tank is welded to the bottom. The rupture came into being in the annular space between the inner and the outer tank, close to the weld. The inflation was due to the reaction between ammonia water and liquid ammonia during commissioning after an outage.

As a consequence of this accident, Yara decided to examine the safety of all the refrigerated ammonia storage tanks within the company.

2. Inspection

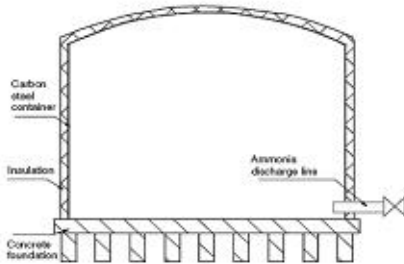
The atmospheric ammonia storage tanks in Yara can basically be split into 2 different designs:

- Single wall tanks:
 - Single wall with external insulation;
 - Single wall with external insulation and external concrete wall.
- Double wall tanks:
 - Double wall, double integrity tanks;
 - Double wall tank with common roof.

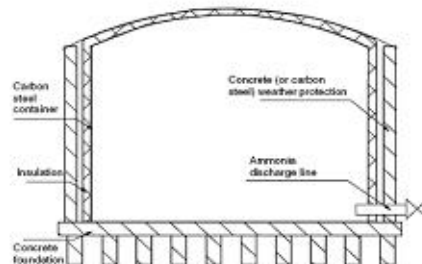
Figure 1. Types of ammonia tanks.

(from "RECOMMENDATIONS FOR THE SAFE AND RELIABLE INSPECTION OF ATMOSPHERIC , REFRIGERATED AMMONIA STORAGE TANKS 2002", EFMA).

A. Single wall tanks

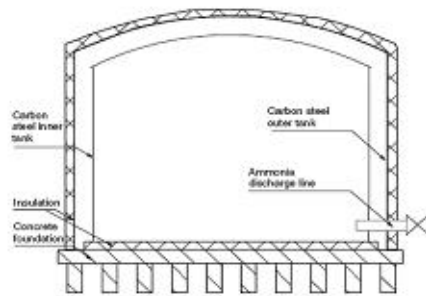


A1. Single wall with external insulation.

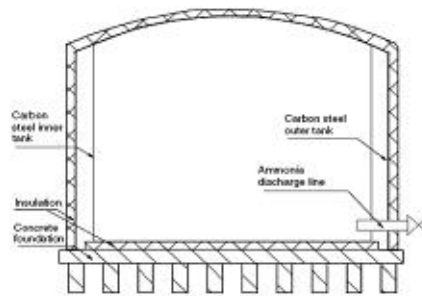


A2. Single wall with external wall.

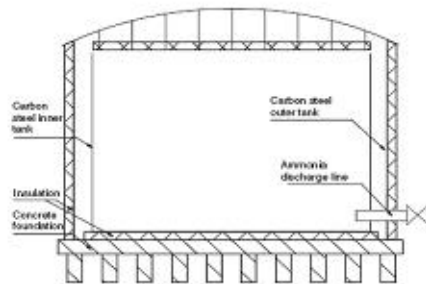
B. Double wall tanks



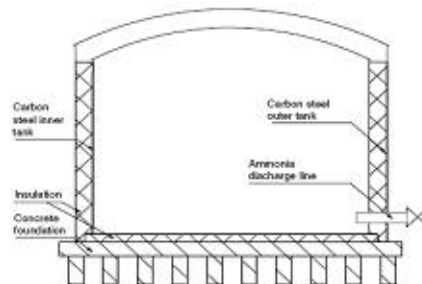
B1. Double wall tank.



B2. Double wall tank with common roof.



B3. Double integrity tank.



B4. Double wall tank with perlite insulation.

Atmospheric ammonia storage tanks are very often huge tanks containing thousands of m³ of ammonia. A collapse of an ammonia tank with subsequent emission of ammonia to the environment will cause a very serious situation and has to be avoided.

There may be at least two reasons for an ammonia tank to rupture. One reason may be degradation due to SCC (Stress Corrosion Cracking). Another is inflation to an extent that causes rupture.

SCC is a degradation mechanism that is predominant in higher strength carbon steels.

SCC is contingent on the presence of liquid ammonia and oxygen and is usually associated with welds where higher hardness occurs and residual stresses provide a source of tensile stresses. The susceptibility to SCC cracking increase with increasing oxygen content. Water acts as an inhibitor.

As the susceptibility to SCC cracking increases with increased oxygen content, Yara believes that any access to the ammonia tanks that also requires ingress of oxygen should be avoided if not absolutely necessary. This includes also access for inspection from the inside.

To avoid opening the tanks, it is necessary to do the NDT inspection from the outside. To do this, there are certain requirements that we believe have to be satisfied:

- The tank has to be subjected to an extended testing during construction to bring to light any manufacturing defects;
- Or: An internal inspection shall be carried out after a certain period of operation to bring to light any defects;
- It will be evaluated if an extended external inspection based on the UT technique described later in this paper can substitute the 2 points above;
- A fracture mechanical calculation shall be made to define the size of a critical crack for each individual tank;
- Inspection methods have to be defined and it has to be verified that the chosen method is able to detect cracks smaller than the critical cracks;
- A complete inspection program has to be defined;
- For double integrity tanks, it shall be verified by calculations that the outer tank can withstand a sudden rupture of the inner tank;
- An evaluation of criticality shall be made based on EFMA recommendations. These criticality evaluations shall form the base for the extent and frequency of the inspections.

3. Ultrasonic testing

Yara has, together with TNO in Delft, Holland, carried out a project where numerical methods are utilized to simulate various defects (cracks) and system set-ups to detect the defects. System set-ups include type of UT methods, frequency, angle of incident, wave type etc. A special focus has been on detecting cracks filled with liquid.

The conclusions of the numerical studies are that a narrow beam transmission method can be used for screening for SCC defects. In general, reflection techniques show to be very sensitive to defect orientation, shape and size and hence are regarded to be unreliable for sizing purpose.

The TOFD (Time Of Flight Diffraction) method can be used to size the defects accurately, however, proper inspection procedures are required.

When this paper is written, the theoretical study has just been finished. Theoretical simulations to develop inspection procedures and practical experiments will follow in the near future.

4. Structural integrity

Outside inspection of the outer tank of a double integrity tank and no inspection of the inner tank requires that we have to rely on the outer tank and that this has the structural integrity to withstand a rupture of the inner tank. To make sure that the outer tank has the structural integrity, we are doing coupled analyses between flow and structure, i.e. the interaction between flow and structure is calculated. Dynamic effects are allowed for as well as non-linear material properties and large deflections.

The scenario that forms the basis for the analyses is that the inner tank is exposed to a sudden rupture from bottom to top due to SCC when the tank is filled to design level. As the inner tanks opens up, the ammonia flows out and hit the outer tank wall as well as the crack edges of the inner tank will hit the outer wall. The calculations determine the outer tank response in terms of displacements, stresses and strains.

The important issue is to make sure that the outer tank can withstand the forces from the flowing ammonia and crack edges hitting it. It really does not matter if the outer tank gets heavily deformed as long as it keeps the ammonia. Based on this, the acceptance criteria should be remaining plastic strain in the outer tank.

Norsk Hydro Research Centre in Porsgrunn did a study, which concluded that the materials, TStE285 and 355, are documented to withstand strains exceeding 10%. A reasonable acceptance criteria is therefore set to 5% (SF=2)

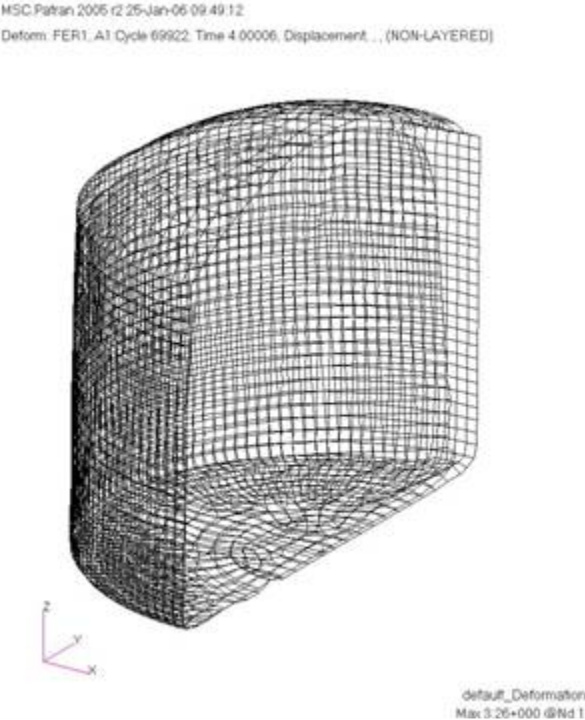
Generally, the best part of our atmospheric double integrity ammonia tanks has shown to be able to withstand a rupture of the inner tank without collapsing. However, for a very few tanks it has been necessary to reduce the allowed filling height to satisfy the requirements for strain in the outer tank.

We have also seen that some of the tanks will be heavily deformed due to a rupture of the inner tank while it will hardly show on the outer tank for others. Figure 1 shows the deformed shape of one of the tanks while ammonia is flowing out.

The calculation is carried out for all the double integrity tanks within Yara. A Norwegian specialist company, Seaflex, carries out the calculations, which are nearly finished. The code MSC.Dytran is utilized.

Force Technology is doing a 3rd party verification of one of the tank calculations. This work is carried out with another code and has just started. We expect it to be finish late spring.

Figure 1. Plot showing the deformed shape of an ammonia tank.



5. Organizing inspection

A PM (Preventive Maintenance) inspection program for the ammonia tanks has to be developed taking this new approach into consideration. As of today, this will be a RBI (Risk Based Inspection) based program where the criticality evaluations will be based on the EFMA recommendations. We will also develop a "Best Practice" and implement this in our steering documents.

The management of the ammonia tank inspection will be a central responsibility in Yara. The central organisation will also be responsible for establishing contracts with one or some few inspection companies.

We believe that it is important to use one or just a few contractors as they will do the job more frequently and hence develop more experience in scanning, analysing and sizing. It will also make it more feasible to develop special equipment for doing this kind of inspection.

This way of doing inspection described in the previous section has been discussed with German, French and Norwegian authorities as well as having been presented to EFMA. We have not received any objections so far. We are also working to have this approach adapted to the EFMA recommendations.

In contrast to other forms of stress corrosion cracking, ammonia SCC develops relatively slow. Propagation can be monitored and followed by using TOFD. Based on findings during inspection, development in known defects and critical crack size, it will be decided if there is a need for opening the tank and do repair work.

6. Safety survey

The accident that Yara experienced in Rostock made us decide to do a safety survey of all atmospheric ammonia tanks within Yara. The main purpose is to avoid similar accidents. The survey includes an audit to the sites where the ammonia tanks are located and the opportunity is utilized to evaluate the general condition of the tanks, the documentation and the PM program.

The audit consist of four half- day parts:

- A risk evaluation based on predefined, internally developed forms.
- Evaluation of instrument based safety function.
- Review of status of:
 - HAZOPs (performed analyses and follow up),
 - Non-conformities to internal procedure for safe operating practice;
 - Non-conformities from earlier safety surveys.
- Mechanical review including a plant and control room tour.

The risk evaluation consists of three elements:

1. Evaluation of containment- operation and preventive barriers.

Questions deal with issues like stratification, if ammonia can be fed to the bottom of the tank, water leaks into the tank, lack of cooling, overpressure, external impact, etc.

2. Evaluation of migration barriers.

Questions deal with issues like double integrity or concrete outer wall, bund wall, emergency plans, safety distances, etc.

3. General safety in operation.

Questions deal with issues like maintenance, inspection programs, operation, training of operators, work permit system, etc.

The evaluation of instrument-based safety deals with issues like safety integrity of instrument-based safety functions, documentation and temporary overriding of safety functions.

The mechanical review includes design drawings (piping/wall penetrations and valves location), relevant documentation and a plant tour where we also look at the standard of housekeeping.

To make the audit as effective as possible it is important that both auditors and the plant are well prepared. All relevant documentation must be taken out and all relevant persons must allocate time.

The audit teams are put together of people with broad experience from the special fields, but also overall knowledge. To safeguard consistency, we have chosen to let one person participate in all the audit teams.