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EXPERIENCE IN THE STORAGE OF LIQUID AMMONIA AT ATMOSPHERIC PRESSURE AND OF RECEIVING IT BY SEA AND RAIL .

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1. GENERAL:

With the increasing use of ammonia and the rise in stock levels, the storage of ammonia at atmospheric pressure has become more and more general during the last few years. Five or six years ago there were hardly any large fully refrigerated ammonia storage installations in Europe but by 1967 there were nearly 20. About a half of these installations were of above 5,000 tons, the largest being of 15,000 - 18,000 tons. At atmospheric pressure it is possible to store even very large quantities of ammonia in one tank. In the United States there are installations capable of storing as much as 30,000 short tons.

Concurrently with the increase in size of these installations, there has been an increase in the size of the tankers and waggons used for the transport of ammonia. Fully refrigerated tankers of 10,000 - 12,000 tons are currently in use for the sea transport of ammonia.

There are economic and, above all, safety factors which account for this trend towards the storage and transport of large quantities of ammonia at atmospheric pressure.

2. THE 15,000 TONS AMMONIA FACILITY OF RIKKIHAPPO Oy :

2.1. Operation of the facility:

The 15,000 tons of ammonia storage facility at Rikkihappo Oy's Uusikaupunki factory has now been in operation for more than 2½ years. The tank itself is a double walled structure, the inner tank being made of low temperature steel and the 60cm space between the inner and outer tank being filled with commercial grade perlite. Electrically driven two stage compressors are used for refrigeration. Operating experience has been encouraging. The fully automatic cooling system has proved reliable in operation and easy to maintain. The principal of the compression, liquefaction, evaporation cycle used for the removal of heat from the ammonia is well known and there is no need for me to go into details. Instead, I shall give some information about the operation costs of an ammonia storage facility of this type.

The amount of refrigeration needed in the tank varies over time in accordance with the prevailing barometric pressure. With rising atmospheric pressure, the need for refrigeration is small; it may be possible to stop the compressors for several hours. With falling atmospheric pressure, the compressors must be in operation frequently, sometimes even continuously. This is to ensure that the pressure in the tank is maintained in constant ratio to the atmospheric pressure.

However, the longer term refrigeration requirement is mainly dependent on ambient temperature and, to some extent, on the amount of liquid ammonia in the tank.

2.2 Costs of the installation:

Because of the factors mentioned above, the operating costs vary somewhat with circumstances; however, the average operating costs of the installation, without discharging and pumping costs, have been as follows:

1. Electricity - refrigeration 36 000 kWh/month	$ 235/month
2. Wages - 1 man per shift	$ 870/month
3. Water and heat - heating of the compressor building	$ 100/month
4. Maintenance	$ 350/month
5. Other	$ 45/month
Total	$1 600/month

It may be seen from the table that wage costs are an important consideration. There are unmanned and remote controlled ammonia storage installations for which the wage costs are small. In our experience, the pumping of ammonia to a number of plants and the emptying of railway waggons provide so much work that it is necessary to have one man continuously at the storage installation. In addition, we consider that for safety reasons it is preferable that the installation should be manned.

Amortisation of capital and interest are not shown in the above table. In this connection, however, it may be said that, depending on conditions, the cost of building a 15,000 tons ammonia storage facility is about $ 1 million.

3. THE UNLOADING OF SEA-GOING TANKERS:

3.1 The unloading procedure:

Most of the ammonia we use is now carried by tankers to Uusikaupunki. The first ships which were used were half-cooled vessels of 2,000 - 2,500 tons. The liquid ammonia was carried at the temperature of about - 12°C. The discharge rate of these ships was rather low-about 30 tons an hour - and this was unsatisfactory since the ship occupied a berth at the quay-side for 3 to 4 days.

The situation was considerably improved when larger fully-cooled tankers of 8,000 - 10,000 tons capacity were brought into service for ammonia transport.

Before the arrival of a ship the 10" discharge line must be cooled. This is done by circulating ammonia through a pipe alongside the discharge line to the end of the line, and through it, back to the tank. Cooling takes about 2 to 3 hours.

After the ship has berthed the quantities of ammonia both in the ship and in the storage tank are checked and readings taken of the ammonia flow-meters of the plants running during discharge.

The discharge pipe of the ship is joined by an 8" hose to the receiving pipe on the shore. At Uusikaupunki it has been our practice to use the ships hose, although it would be the inclination of the ship's authorities to leave the responsibility for possible hose damage to the receiver. We have, however, demanded that the ship should carry out a pressure test before discharge and have required a written certificate of test. In preparing for discharge, it is most important to ensure that the hose is fixed in a proper manner and to guide it with suitable supports. A high rate of discharge and lifting of the ship during discharge may damage the hose.

At the beginning of discharge the air inside the hose is blown into the sea. This is important - because air and other incondensable gases cause nothing but harm to the cooling system. The liquid is pumped into the storage installation by the ship's own pumps. This operation must be started slowly so that the refrigeration compressors and the pressure regulation of the storage tank have sufficient time to come into operation.

In our experience, the discharge rate has been about 600 tons per hour. This rate is mainly dependent on the discharge capacity of the ship. A ship of some 10,000 tons can be unloaded in less than 24 hours and the discharge costs remain low.

3.2 Unloading Costs for a Tanker:

The discharge costs for a fully refrigerated ship have been as follows:

1. Electricity 0.75 kWh/ton NH_3	\$ 0.005/ton
2. Wages (35 Working Hours/ship)	\$ 0.005/ton
Total	\$ 0.01 /ton NH_3

3.3 Safety precautions during discharge:

It is clearly very important to take the necessary safety precautions during discharge. Only the personnel actually involved should be allowed in the area and personal safety equipment - filter masks, compressed air respirators, rubber gloves and rubber suits - must be provided for them. Water hoses with sprinklers should be kept ready for small leakages. It does not seem feasible that enough water could be provided to take care of large leakages during discharge from a ship. To take care of a spillage of liquid ammonia, it is known that about 100 times as much water is necessary. As a result of this, it is hardly worthwhile to use water at all. It is not possible in practice to direct much water to the small discharge area. In discharge of a fully refrigerated ship, the only safety devices for hose breakage are the vessel's own emergency shut-off valves. At the end of the ship's discharge pipe there is a shut-off valve which can be remote controlled from many places on the ship's deck as well as from the bridge and from the ammonia control panel . The valve is kept open by air pressure in the control pipe net-work which can be let out from the remote control points, when spring power immediately closes the shut-off valve. During discharge, we take samples from the ammonia every two hours and an analysis is made for oil, copper and iron.

3.4 Checking the Cargo:

After discharge the checks which were made before discharge of the ship's storage tank, the storage installation and the plant are repeated.

Mainly at the request of the ammonia supplier, a representative of an international control office is always present during discharge. It is important that he should be present because the readings obtained in the ship and in the storage installation differ from discharge to discharge. It usually seems to be the case that 100 - 200 tons of ammonia remain in a ship of 10,000 tons which it is impossible to pump out because of vaporization. An impartial supervisor can arrange the situation both on the shore and on the ship and, in this way, it is easy to handle quickly any difference of opinion.

3.5 General:

Our experience to date of the procedure as a whole has shown that the discharge of a fully-refrigerated ammonia ship is very easy, convenient and safe. It is possible in a short space of time to discharge a large quantity of ammonia easily and very economically into the ammonia storage installation.

4. UNLOADING RAIL TANKERS:

4.1 Technical description:

We also receive ammonia by rail. The ammonia carried in railway waggons is warm - about $\pm$ 0°C. We use compressors to unload the waggons into a large common storage tank, cooling the ammonia during discharge. We have calculated that, in our conditions, it is not economic to build a separate sphere of, for example 2,000 m^3 in addition to the large tank which is already in use.

It takes a long time to discharge a railway waggon into the fully refrigerated tank; the discharge rate is about 20 tons/hour.

We are just completing the construction of a new discharge platform. A waggon is connected to the discharge pipes with loading arms. The loading arms are connected to the waggon by means of quick release couplings. The line of waggons is moved by a movable winch which can be steered from the discharge platform.

Because of numerous fastenings and unfastenings, the couplings between the waggon and the discharge pipes are the most dangerous part of the discharge equipment. It is therefore important to use couplings which are of the highest technical standard.

As a precaution against possible large leakages there are pipe breakage valves in the waggons. The valves are controlled by springs and stop the discharge of a waggon in the event of a bad leakage.

The personal safety equipment provided at the discharge platform for railway waggons is of the same kind as the equipment already mentioned in connection with the discharge of ships. The rails used by the ammonia waggons are closed to other traffic by special derailing devices. The derailing devices can be activated by remote control from the discharge platform. Signal lights on the discharge platform indicate the position of the derailing devices to the persons in charge of unloading. The waggon bridge cannot be drawn down before a "green light" is received and the derailing devices are in the correct position.

When unloading into a cold storage is carried out, the discharge of railway tank waggons takes a considerably longer time in comparison with that of a fully cooled tanker; it is also more difficult and more expensive. From the safety point of view, both the handling of the waggons in the railway yard and their discharge can cause trouble. With careful arrangements and extremely good technical equipment it is possible to attain sufficient safety.

4.2 Unloading costs for rail tankers:

Costs for discharge from a railway waggon into refrigerated storage have been as follows:

1. Electricity 23 kWh/ton NH_3		$ 0.15/ton
2. Wages		$ 0.01/ton
	Total	$ 0.16/ton

5. CONCLUSION:

Many of you will already have decided, or will have to decide, which type of ammonia storage to choose. If it becomes necessary, for one reason or another, to build a large ammonia storage installation, it is most important to consider which of the various type is most suitable and most economic. The following are the factors which have the greatest influence on the decision.

1. Building Costs;
2. Cost of Electricity;
3. The state in which the ammonia is delivered;
4. Safety precautions.

There is no need to take any technical risks in building a fully refrigerated ammonia facility; expert "know-how" is available if required.

On the basis of our own experience, we would say that storage and transport at atmospheric pressure is a convenient, safe and economic way of handling ammonia.

DISCUSSION

MR. RINKINEVA (Rikkihappo Oy, Finland): In my paper I have described the experience we have had in Uusikaupunki in the storage of liquid ammonia at atmospheric pressure and in receiving it by sea and rail.

In the next few minutes I should like to present slides taken of our 15,000 tons ammonia storage facility and tank vessels and railcars during unloading. In this way, the theme we are now speaking about will obtain more "colour".

Picture 1.

Our factories are built on an island 3 km outside the town. The 25,000 m^3 ammonia tank stands quite by the sea, 100 m away from the nearest factory. By the side of the tank there is the compressor building and the rest of the equipment which is indispensable for the cooling of ammonia. The discharging line from the quay to the tank is 280 m long and 10" in diameter.

Picture 2.

The open-type concrete foundation is grounded on the rock.

Picture 3.

The tank is equipped with two safety valves against over- and low-pressure. During $2\frac{1}{2}$ years the automatic function of the cooling system has been blameless so that we have had no difficulties with the tank pressure. The only troubles, but troubles great enough, have been the float type level gauges of the tank. There were two float type level gauges installed into the tank but in the first few weeks the tape of the first gauge broke. The other gauge has worked exactly until recently. But two weeks ago, because of a leak the float of this gauge sank to the bottom. Its repair is almost impossible as long as there is ammonia in the tank. Therefore we would say now that for this purpose only equipment of the highest possible standard should be used. After the first damage we have installed a differential pressure type level indicator as a third level gauge. However in the big tank the accuracy of this type of indicator is not always sufficient.

Picture 4.

For cooling we use double acting two stage piston compressors. The bigger one which we see in the picture is mainly used during unloading, and the smaller one for the normal cooling of the facility.

Picture 5.

We like the unloading of a fully refrigerated ammonia tanker. The discharge of an ammonia tankvessel is very pleasant, easy, economic and safe for the receiver of ammonia.

Picture 6.

The most important thing in preparing to discharge is to fix the hose in a proper manner and to guide it with suitable supports. A high discharge rate of about 600 tons per hour and the lifting of the ship during discharge may damage the hose.

Picture 7.

The only safety devices for hose breakage are the vessel's own emergency shut-off valves. There is at the end of the ship's discharge pipe a shut-off valve which can be remote-controlled from many places on the ship's deck as well as from the bridge and from the control panel of the ship's ammonia devices.

Picture 8.

We take samples from the ammonia during unloading, and analysis is made for oil, copper and iron.

Picture 9.

For railway transport of ammonia 77 m^3 railtankers are used in Finland. One railtanker carries about 40 tons of liquid ammonia. The discharge of tank waggons in comparison with that of a fully refrigerated tanker goes considerably slower and is more laborious. From the safety point of view it seems that both the handling of the waggons in the railway yard and their discharge in case of a greater daily number of railtankers can cause more trouble. But with careful arrangements and extremely good technical equipment it is possible to attain sufficient safety.

Picture 10.

We use about 5,000 tons per month of ammonia in Uusikaupunki. Main consumers are the nitric acid factory which you see in the foreground of this picture.

Picture 11.

Our two fertilizer factories which have a total capacity of 1,000 tons of concentrated granular compound fertilizers per day.

Ammonia is one of the most important raw-materials for our production. On the basis of our own experience, we would say that storage and transport at atmospheric pressure is a convenient, safe and economic way of handling ammonia.

MR. LE MENESTREL (Ugine Kuhlmann, France): On page 2 you indicate that an investment of about $1 million would be required for a storage facility of 15,000 tons. I suppose that, when you constructed this storage, you must have estimated what storage under pressure would have cost. Can you give any idea of the corresponding cost?

MR. RINKINEVA: I have no calculation for that, but ICI has written about these costs, and it seems that from about 5,000 tons upwards the cost for a pressure tank will be higher than the cost for a tank at atmospheric pressure.

MR. HEUGHEN (Mekog - Albatros): On page 3 mention is made of the discharge of air inside the hose which is blown into the sea. What is the opinion of the author on this procedure, because it seems there is a chance of creating a vacuum inside the tank, with the result that sea water is pulled back into it, which seems quite a harmful situation?

MR. RINKINEVA: When we blow the air from the hose away to the sea we put an extra connection, an extra pipe, to the hose and the main valve to the big tank is then closed. When the air blowing is finished, we take the pipe connection away so that it is not possible that the sea water could come into the ammonia discharge line.

ANONYMOUS: Can you give us any details of the types of special steel used in these kinds of tanks? Secondly, do you know of any studies of methods of protection against a possible serious leakage from such tanks other than spraying with water, which must be relatively ineffective in view of the large quantity of water that would be needed?

MR. RINKINEVA: For the inner tank we have used the so-called low temperature SM steel LE 36F. The outer tank is in normal carbon steel. This is mainly constructed only against the wind and the snow load we have in Finland. We assume that leaks in the big tank itself must be very rare, and as I mentioned already, our tanks stand quite by the sea. The ammonia would go direct to the water. For leaks in the piping system we naturally have water hoses and all possible safety devices which are normal for such cases. The cold ammonia stays in the pit for a very long time. With an amount of, say 10,000 t, about 25 t are used and then the rest of the ammonia can stay in the pit many weeks or many months until it is required to be pumped away to other tanks or to the railtankers.

MR. MERESSE (Péchiney-Saint-Gobain, France): I should like to know how many compressors there are, and, what are the average heat losses from storage installation in the summer and winter.

MR. RINKINEVA: We have two compressors. The bigger one has a capacity of about 2.3 t of ammonia vapour, and the smaller one about 500 kg of ammonia vapour per hour. In summer we must liquify about 100 kg of ammonia vapour per hour. In winter we liquify only about 50 kg per hour.