STORAGE OF LIQUEFIED AMMONIA IN LARGE TANKS AT ATMOSPHERIC PRESSURE

G. O. Morgan and J. D. Reed
Agricultural Division
Imperial Chemical Industries Ltd.
Billingham, Durham, England

A liquefied ammonia tank of 13,500 short ton capacity is being built in the U.K. for the Billingham Works of Imperial Chemical Industries Ltd. This tank differs from others presently in operation in that an unusual form of diking has been adopted.

The tank is sited on a river bank near a deep water jetty to facilitate sea transportation. An additional advantage of the site is that it is remote from large gatherings of people, e.g., the nearest public roads and private residences are 8,000-ft. distant.

Description of a tank

The tank itself is of vertical cylindrical form 110-ft. diameter by 68-ft. high on the straight shell, and the roof is a self-supporting dome 88 ft. radius. Every possible design and manufacturing precaution has been taken to make the tank safe.

The tank, which is fully insulated, sits on a circular concrete raft which is raised 4 ft. from the ground to allow free circulation of air underneath. The nature of the ground required piling in any case and it was considered easier to elevate the tank than take other precautions to prevent frost heave.

The raft which supports the tank has been extended to support the circular dike wall which is the novel feature of the installation. This wall is of prestressed concrete construction and is designed to withstand the full hydraulic load of the full contents of the inner tank. The 5-ft. annular space between the inner tank and the wall is bridged with a cover, and the space itself purged with dry air, Figure 1.

Why a concrete protection wall?

An examination of incidents which have occurred over the last few years involving the escape of liquid ammonia has shown that they are all characterized by a formation of dense lethal fogs which make isolation of the incidents very difficult. Although ammonia gas itself has a density appreciably less than air, considerable concentrations of ammonia are experienced at low levels.

It can be shown that although mixtures of ammonia gas and air have a density less than air, when liquid ammonia is mixed with air or when evaporation of liquid ammonia takes place in such a way that the latent heat of vaporization is removed from the air, then ammonia-air mixtures are produced which are denser than the surrounding air.

Following a study of the behavior of large liquid ammonia spills, it was decided, therefore, that should a failure of the main tank occur, the liquid ammonia should be contained in a manner which would expose as little surface area as possible to the atmosphere. This can be achieved by building a dike wall as described.

Three stages of evaporation

If large quantities of liquid ammonia are released, for example, into a compound surrounded by a conventional low earthen dike from a tank where the initial pressure and temperature conditions are 0.5 lb./sq. in. gauge and −27°F (typical conditions for an atmospheric storage tank), there will be evaporation from the pool in three stages.

Initially there will be spontaneous flashing as the thermodynamic state of the ammonia adjusts itself to the diminished pressure. The quantity evaporated in this first stage will, however, be quite small and for a 10,000-ton pool initially at 0.5 lb./sq. in. gauge and −27°F will only amount to about 17 ton. The heat of vaporization will be drawn from the pool which will fall in temperature to −28°F. Further evaporation during this first stage will take place due to heat being absorbed from the ground and dike wall and will increase the quantity by possibly another 5 ton. This quantity will, however, be dependent to a large extent on the shape of the pool and the nature of the ground.

Buoyancy causes convection

The pool will not however remain at −28°F as this infers a partial pressure of 1 atm. of ammonia above the liquid for a gas which is appreciably lighter than the surrounding air. In this second stage the buoyancy of the ammonia vapor will cause strong convection currents which in turn will cause rapid evaporation and cooling of the pool. In the case considered of a 10,000-ton pool, up to 500 ton of vapor could be liberated in this stage, during which time the temperature will drop to about −60°F.

The rate of evaporation will, of course, depend

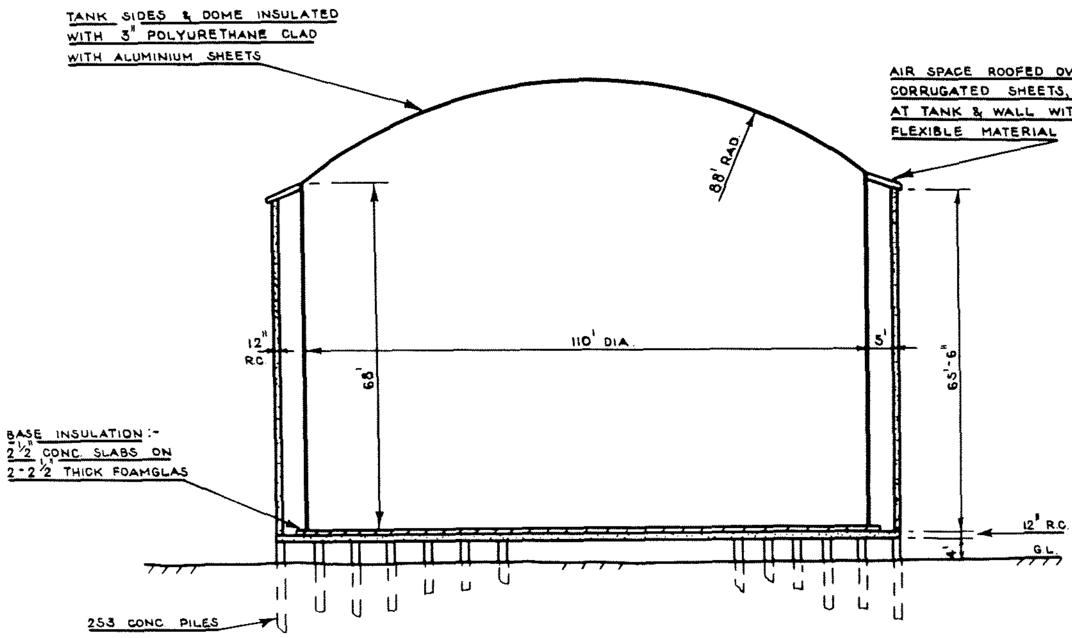

Figure 1. The 12,000 ton/day refrigerated ammonia storage tank.

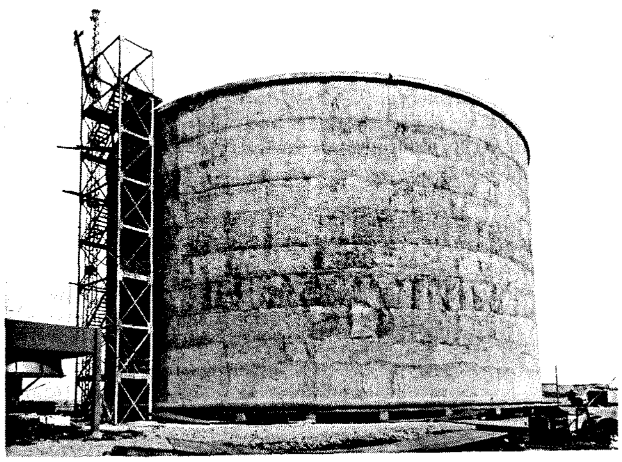

Figure 2. The ammonia storage tank under construction.

upon the size and configuration of the pool. The rolling cloud of vapor which would ensue would tend to rise but because of air turbulence the air at ground level could become heavily contaminated for considerable distances.

At a temperature of about $-60°F$ the ammonia will not produce a buoyant vapor and evaporation in the third stage will take place by the wind blowing ammonia off the surface of the pool. The heat of evaporation will be drawn partly from the pool, causing a further fall in temperature to, say $-70°F$, and partly from the air. This will produce a mixture of cold air and ammonia which is denser than the surrounding air. This cold heavily contaminated mixture would remain close to the ground and could drift for considerable distances.

Characteristic thick white fog

During all stages of evaporation the surrounding air will be cooled below its dew point producing the thick white fog which is characteristic of these incidents.

These considerations led to the conclusion that the most important factor was to contain in as small an area as possible any liquid spillage. The concrete tank, therefore, serves a twofold purpose. It acts as a secondary container which prevents liquid ammonia spillage, and even if there is a failure of the roof the liquid ammonia level will be appreciably below the wall height in a relatively small area and access of air to form lethal heavy mixtures will be very much restricted. The second purpose the concrete tank serves is to protect the inner tank from rupture by external forces such as flying objects.

Draining the concrete tank

Provision has been made for draining the concrete tank of any ammonia spill so that it can be removed safely by either pumping or by road tanker. The normal pumps, of course, will be able to remove the bulk of the liquid.

There are difficulties, in this form of construction, in bringing the export pipes out of the tank through the concrete wall. Some allowance has to be made for the thermal movement of these pipes. In this case one has arranged for the pipes to pass through openings in the base slab. These openings are sealed with a double bellows, one inside, and one outside the tank.

It is believed that these elaborate precautions are necessary in view of the potentially disastrous consequences which would follow a major failure of the inner tank.

DISCUSSION

LAWRENCE—Central Nitrogen: Do you feel that a dike is worthless as a protection against tank failure in a congested area?

REED: We think that a low earthen dike is inadequate for the previous reasons that I stated. If you get a large open pool, as you would get with the large tanks that are being built today, you would get a vast amount of ammonia being released which could produce disastrous results. The reason for this is that the buoyancy of the ammonia gas above a large pool will produce a considerable driving force, which, in turn, will cause the evaporation of the large quantities I was referring to.

MILLER—DuPont: With the precautions that you've taken, are you not rather vulnerable at the transfer lines or do you have isolation valves?

REED: We have good isolation valves inside the tank.