CRACK FORMATION IN STORAGE TANKS

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Anhydrous ammonia is widely used as fertilizer in Denmark. The quantity in 1970 is expected to be approximately 128,000 metric tons. Essentially all of the anhydrous ammonia used in Denmark is distributed by A/S Ammonia. Denmark is geographically a country of one peninsula and many islands. A widespread system of storage facilities for anhydrous ammonia is therefore required to serve the Danish farmers.

Until recently it was the common opinion in Denmark that the storage of liquid ammonia in mild steel tanks under pressure and at normal temperatures should give no difficulties of stress corrosion cracking, and, consequently, very little attention was given to the problem before 1964. At that time, however, an almost new 230 m³ cylinderical tank started to leak through a 50 mm long crack, running along a circumferential seam in the middle of the shell. The seam had been locally repaired over a length of 500 mm and the crack was situated at one end of this repair. The leak was observed 3 months after the repair was made and 3 weeks after the tank had been filled up with ammonia.

A number of independent investigations were carried out in order to find the possible cause of this and other similar cracks on the tank, and all results pointed to stress corrosion cracking.

The tank was eventually repaired by renewing all welds completely and stress relieving the complete tank before putting it back into operation.

As a consequence of this incident it was decided to carry out crack detection checks at regular intervals on all bigger storage tanks for liquid ammonia. The inspection should mainly cover the inside surface of the welded seams of the tanks.

During the period since 1964 an extensive inspection program by means of the magnetic particle method and also to some extent by ultrasound has been carried out. The ultrasound investigation has particularly been used to look for defects and cracks which do not propagate to the interior surface of the tanks.

The tanks included in this program comprise a total of 8 spherical tanks out of which 4 are 5,250 m³ spheres, a large number of cylindrical tanks of different sizes, a few selected transport tanks of small dimensions, and 2 atmospheric storage tanks, one of 25,000 m³ size, and the other of 38,000 m³ size.

Development of testing technique

The technique normally applied, as mentioned above, has been the magnetic particle method also called the magnetoflux method.

The sensitivity of the magnetic particle method varies within wide limits and according to the experience gained only a method giving a high sensitivity should be relied upon for this inspection.

However, for all inspections performed before 1968 the following simple technique was used, giving relatively low sensitivity: the surface under test was cleaned by a wire brush and a thin coat of white paint applied. The magentizing was done by sending 400-500 Amps AC directly through the material from contact electrodes spaced 150-200 mm apart. Black test ink was applied and the surface inspected under white light. A tangential field strength of 15-20 Oersted was achieved by this system.

This technique was improved in 1968 when the testing of a spherical tank with numerous very fine cracks had shown the need of higher sensitivity.

By diminishing the distance between the electrodes to 100 mm, a field strength of about 35 Oersted was obtained. At the same time the surface was cleaned more carefully by machine brushing or by grinding, and the use of ultraviolet light and fluorescent magnetic powder was taken into use.

A considerable amount of testing was done using this technique, but although many cracks were detected and ground out, the most recent experience has shown the sensitivity to be still insufficient. This became obvious when a repeated inspection of two tanks, where cracks had been removed and later liquid ammonia had been stored over a period of 4 months, showed new cracks at the bottom of old grinding marks. A few test pieces containing such cracks were cut out and a microscopic examination showed all cracks to be following the deformation of the surface layers, caused by the grinding operation carried out 4 months earlier. Apparently the grinding must have been stopped before the cracks were completely removed. As this was controlled by magnetic particle testting, the testing method must have been unable to indicate the cracks at that instant. However, the influence of ammonia over a period of 4 months must have widened the cracks so much that magnetic detection again became possible. This theory was supported by an experiment carried out on a few cracks on one tank. The cracks were ground out to the extent that all magnetic indications disappeared. Following this, the surface was etched until the deformed surface layers were dissolved and finally a repeated magnetic testing was made. Hereby the crack indication appeared again.

This led to the use of an even more sensitive method in which the tangential field strength was doubled to reach about 75 Oersted. This was done by use of 600-700 Amps through contact points not more than 70 mm apart. Only fluorescent ink was used and all grinding out of cracks was done by a sharp and fast running grinding stone only slightly pressed against the surface. This method has until now given satisfactory results and it has been checked on cut out pieces on several occasions. A microscopic examination of such sample pieces has not disclosed any more cracks than those found by the magnetoflux method. A further improvement of the sensitivity of the magnetoflux is possible and has been tested in the laboratory. Such further increase in sensitivity has proven not to be desirable since it gave evidence of apparent cracks on a sample which by microscopic examination showed not to contain any cracks but only small structural differences in the weld metal without any consequences for the strength of the weld.

Case history

5,250 m^3 spherical tank manufactured 1964/65.

Material Si, Mn, Al-fine grain steel with a yield strength of 33 Kp/mm^2 and tensile strength 50-58 Kp/mm^2 (1 Kp/mm^2 = 1400 psi).

Working pressure: 7 Kp/cm^2

Tank dimensions: 21.6 m^0/22-28 mm

When the tank was manufactured in 1964/65 it was X-rayed and all cracks and other defects in the welds were repaired. Supplementary ultrasound investigations were carried out of the complete lower horizontal seam, and of 2,000 mm seam on each of the two middle horizontal seams. No defects were found during this inspection.

The first magnetoflux investigation was carried out in 1968 and comprised all weld seams. Prior to the investigation the weld seams were ground flush with base material; then controlled for cracks. The investigation disclosed quite a large number of fairly superficial cracks of which few penetrated more than 5 mm but there were also a few cracks which penetrated up to 18 mm below the surface of the base material.

The investigation was repeated after the tank had been in service for 4 months during which period the ammonia had been added 0.3% of water as a protection against further stress corrosion. At the new inspection a further large number of cracks was discovered but it was ascertained by microscopic examination of test specimens that most of these had resulted from cracks which had not been completely removed during the earlier repair.

In January/February 1970 the tank was investigated 100% by ultrasound. A total of 120 cracks and other defects were disclosed, all positioned in the weld metal. About 80% of the cracks were positioned at the crossing of weld seams and some of the cracks were quite deep.

Since it is not definitely known to which extent these cracks may have originated before adding water to the ammonia it is still too early to draw any conclusion as to the effect of water addition.

Appearance of stress corrosion cracks

The stress corrosion cracks appear in the inner surface of the welds and run in all directions, often as a branched net of cracks. They do not penetrate into the adjoining plate. The depth of the stress corrosion cracks do not normally penetrate more than 5 mm measured from the inner surface of the base metal except in cases where they may connect to weld defects.

Thermal stress relief is considered a most effective means against stress corrosion.

The 38,000 m^3 atmospheric storage tank was investigated for stress corrosion cracks in 1969 after the tank had been in service for about 5 months. The inspection concerned a large number of welds, particularly in the lower part of the tank which is exposed to the largest tensions and where the heaviest plate is found. No cracks were found during this inspection. Since plate dimensions and weld electrodes correspond quite closely to those used for the spherical tanks one would assume that a certain possibility should exist that cracks might develop slowly. However, stress corrosion cracking like any other chemical processes depends strongly on temperature and at a temperature of -33°C the process is likely to go on so slowly that no stress corrosion cracking is to be expected even after years use of the atmospheric tanks.

It is also worth mentioning that all of the thin walled small transport tanks investigated proved to be free of stress corrosion cracking. This may indicate the importance of residual stresses in heavy plate tanks.

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