ACOUSTIC EMISSION TESTING ON LPG TANKS - DEFECT DETECTION CASE STUDIES

Gerald LACKNER 1, Peter TSCHELIESNIG 2

1 TÜV AUSTRIA, Deutschstrasse 10, 1230 Vienna, Austria; e-mail: gerald.lackner@tuv.at
2 AT – Consult e.U., Planckhgasse 21, 3400 Klosterneuburg, Austria; e-mail: office@at-consult.at

Abstract

One main practical application of acoustic emission is testing of metallic pressure vessels at site of installation in the field. Beginning with the qualification of the employed testing technique and then throughout the whole period of field testing, people want to know what the intervention on the test object is good for. It is in the very interest of the stakeholders (manufacturers, owners, operators, authorities as well as testing and inspection organisations) to verify its capabilities. Practical examples of detected defects taken from qualification tests as well as from routine tests are able to demonstrate the main advantages and thus support the acceptance of the testing technique by all parties concerned. This contribution describes by means of case studies a few tests on LPG tanks where severe defects were found.

Keywords: liquefied petroleum gas (LPG) tank, pressure vessel, field testing, integrity testing, corrosion detection, leakage detection, crack detection

1. Introduction

The requalification of a pressure equipment after a certain period of service requires usually a set of inspections/tests in order to assess the structural integrity. Depending on the legal environment given in the country of installation, the set of inspections/tests to be performed may consist of external inspection, pressure test, leak test, internal inspection and the like. Acoustic emission testing (AT) may be employed in the course of the requalification either alone or in combinations with other tests. It provides information regarding the structural integrity of the item under test at the same level of safety achieved by conventional inspections/tests. The following list highlights the most important drivers for its application:

- Internal inspection is considered to be a high risk activity. Entry into a confined space needs thorough preparation and execution. Serious situations in the course of internal inspections are reported every year. Acoustic emission testing on LPG tanks makes internal inspection unnecessary.
- Water used for hydrostatic testing is considered to be a hazardous waste and has to be disposed at specialised facilities. Furthermore, residual humidity may induce or promote internal corrosion. Acoustic emission testing does not require to empty or to clean the tank. In most cases it is performed with the LPG of the tank under test. After completion of the test, the tank is immediately available for the consumer.
- In the event of an already severely damaged tank, monitoring of the pressurisation with acoustic emission provides on-line information regarding the actual condition of the tank and thus enables the test operator to suspend or even to terminate the test in a safe way in order to prevent a serious situation to evolve.

Starting from 1993, when the first testing campaign in Austria with more than 1000 tank tests had been completed, TÜV AUSTRIA and its cooperation partners have been testing successfully several thousands of LPG tanks in Austria and other European countries till
today. The core part of the developed procedure consists of the testing technique including the Cluster Evaluation Factor (CEF) based on measuring equipment from Vallen Systeme and the mobile testing laboratory. The on-board pressurisation unit utilizes for evaporation some part of the liquid phase of the LPG tank under test and feeds back the resulting gas phase at a higher pressure, thus being independent from other pressurisation media like nitrogen. The applied testing technique is described in detail in several publications [1, 2]. This contribution focuses on the discussion of test results obtained from different qualification, demonstration or testing activities at different sites.

2. Case study for crack detection on an above ground tank

A serious incident occurred in Austria in 2009, where a LPG tank failed during a filling operation inside a gas facility. One head of the tank detached from the cylinder and it was sent about 100 m away where it hit the ground luckily without causing major damage, neither at the gas facility nor at the neighbouring facility as shown in figure 1. However, this incident triggered a follow-up investigation and it was found that both circumferential welds (joggle joints) were affected by stress corrosion cracking (SCC) due to unspecified maintenance works performed on the tank using a corrosive medium. At the other joggle joint a crack with a length of approximately 1 m centred at the 6 o'clock position had been detected. It had to be shown to the authority that in case of further tanks with similar history, such kind of defect will be detected by AT while performing the pressurisation. For this purpose a new head was welded onto the tank. It was intended to pressurise the tank till to burst for obtaining the burst pressure of the already severely damaged tank. The pressurisation was monitored with AT during the pressure test section and the results were analysed and described in reference [3]. It could be shown that the degradation was indicated by AT well before the failure of the tank. The sensor positions and the measuring results are given in figure 1 and figure 2 respectively.

On the other hand side, the tank passed the hydrostatic test (test pressure equal to 1,5 times the design pressure) without any finding of plastic deformation or leakage.

![Figure 1](image1.jpg)

*Figure 1.* Set-up of an above ground LPG tank (2700 litre) for crack detection, photo on the top left shows the tested tank with new head welded onto the tank near sensor XD 1, photo on top right shows the affected circumferential weld near to the tank leg after the previous failure of the tank head, graph below indicates the incident with the head sent about 100 m away, over the neighbouring road right into another facility.
Figure 2. Qualification test on an above ground LPG tank (2700 litre), tank was loaded up to 1 MPa (10 bar) before the test, graphs show CEF and pressure vs. time (1st row left), CEF of located events vs. position along the cylinder lengths (1st row right), maximum amplitude and energy accumulation of located events vs. time (2nd row left), waveform and frequency content of an event located near to sensor XD 2 (2nd row right)

One may easily take from figure 2 that the activated degradation process lead to rather high values of CEF at an early stage. The test operator had to be alarmed already at about 1,1 MPa (11 bar with value of CEF equal to 2,6) and the test was to stop at the latest at 1,3 MPa (13 bar with value of CEF equal to 2,9). And it is obvious that the obtained location results based on the linear location using sensors XD 1 and XD 2 (both VS150-RIC, Vallen Systeme) near to the circumferential welds are in good agreement with the location of the SCC affected weld near to sensor XD 2. The performed test and the gained results were another proof of competence towards the Austrian Accreditation Body, where TÜV AUSTRIA SERVICES GMBH is accredited as ISO 17025 testing laboratory with the scope of accreditation comprising the European standards EN 12817 and EN 12819 (requalification of LPG tanks up to 13 m$^3$ and greater than 13 m$^3$, respectively).

3. Case study for corrosion detection on an underground tank

LPG companies usually perform a service provider assessment prior to awarding a long term frame contract for performing AT on their tank population. The purpose of this measure is to demonstrate the quality and the effectiveness of the proposed testing service. In many cases this includes a demonstration on real structures, where tanks with or without defects are to be tested and evaluated.

At the site of a gas storage facility we were invited to test an underground tank, which was buried according to figure 3. The linear sensor setup consisted of sensors XD 1 at the circumferential weld near to the valve chamber, XD 3 in the area of the valve chamber and XD 4 at the other circumferential head of the tank. All three sensors were of type VS75-SIC. The pressurisation was done by a nitrogen blanket on top of a liquid product. The only information we received from the tank owner regarding the tank condition was, that the tank
had been tested previously by another testing organisation. Therefore we asked to pressurise the tank up to 1.1 times the design pressure, which was near to 2 MPa (20 bar). In this way we obtained the maximum amount of information still achievable by AT and at the same time we kept rather close to the design limits due to risk considerations. All three sensors were mounted on the 12 o’clock position after removing the soil at their defined location.

Figure 3. Set-up of an underground LPG tank (5000 litre) for detection of degradation, photo on the top shows the buried tank with the valve chamber box in green and sensors XD 1, XD 3 and XD 4 (VS75-SIC) used for linear location, photo on bottom right shows some corrosion effects in the area below the valve chamber, photo on the bottom left shows the close-up of the maximum affected area.

Figure 4 indicates that the given active sources lead to a value of CEF above 2.4 at about 1.7 MPa (17 bar) and then increased at about 1.9 MPa (19 bar) to a value of CEF above 2.8. The tank owner was satisfied with this result and after a final presentation no further information regarding the technical background was requested. All questions were answered in sufficient detail and finally we won a frame contract for a three years duration. In order to fulfill the required number of tested tanks per year we had to produce additional mobile testing laboratories and we had to train local test operators. Both tasks were handled for the subsidiary TÜV AUSTRIA TURK by the acoustic emission unit of TÜV AUSTRIA based in Vienna.
4. Case study for leak detection on an above ground tank

During a regular field testing route on the Iberian Peninsula, the test operator of QTEC – the Portuguese subsidiary of TÜV AUSTRIA group - came to an above ground tank as shown in figure 5. He applied the usual test set-up procedure and then started with the pressurisation by feeding LPG liquid phase from the tank under test to the mobile laboratory, where it was evaporated in the heat exchanger and fed through the filling valve back to the gas phase.
He saw that the value of CEF increased rather quickly as shown in figure 6 and was alarmed. Additionally he realised that the background noise (given by the measuring parameter RMS-status) was rising with increasing load (see figure 7). This led him to the conclusion that there might be a leakage at the tank fittings. A leakage was confirmed at the first pressure hold where after closing the gas flow to the tank the RMS-status did not reduce, as it is supposed to do in case the increase of noise is caused by the gas flow to the tank from the pressurisation unit.

**Figure 6.** Evaluation of a field test on an above ground LPG tank (2300 litre), graphs show CEF and pressure vs. time (1st row left), CEF of located events vs. position along the cylinder lengths (1st row right), maximum amplitude and energy accumulation of located events vs. time (2nd row left), waveform and frequency content of an event located near to sensor XD 1 (2nd row right)

He continued the test till to 1,75 MPa (17,5 bar) and performed the final pressure hold phase. The tank was graded preliminary by class C (value of CEF greater 2,8 $\rightarrow$ red light, the tank will finally most likely fail the test). Then the follow-up was done to clarify the found indications. For this reason soapy water was applied to check the fittings for leakage. Unexpectedly the nozzles and valves did not show any indication for loss of gas phase. Suddenly the test operator saw that bubbles indicating a leak showed up not at the tank fittings but below at some vertical distance. The photos given in figure 7 document these findings. The owner/operator was informed immediately.

**Figure 7.** Leak indication at an above ground LPG tank (2300 litre), graph left shows RMS-status (red for XD 1 and green for XD 2) and pressure (blue) vs. time, photo on the right shows two leak indications (bubbles of soapy water) within parent metal of LPG tank
The tank was taken out of service and replaced by a new one. It was the first time that such kind of defect has been seen in the field and the test result prevented an unsafe situation, which most likely would have evolved in time.

5. Conclusion and Outlook

The described case studies for crack detection, corrosion detection and leak detection strongly support to use AT in the course of the LPG tank requalification process. It is evident that the level of safety is at least the same compared to the conventional approach consisting of, as applicable and as required, a hydrostatic test and other tests connected to the internal or the external inspections. The experience gained by TÜV AUSTRIA group within a period of time exceeding 20 years and after testing more than 100000 tanks installed all over Europe highlight the contribution of AT to raise the level of safety in LPG tank operation. It proofs that AT is the standard test method in many European countries.

The testing technology is applicable to very large tanks with several hundred cubic meters. In this regard a reference has been set by TÜV AUSTRIA in Italy. The largest cylindrical LPG tank tested in 2014 was a mounded cylindrical tank with a capacity of 2000 m³ using an innovative methodology to access the tank shell developed by Blu Solutions [4].

Enquiries from all over the world indicate that our testing service is considered to be beneficial for our clients of the LPG industry.

References
