The Acoustic Emission Monitoring System of Aboveground Storage Tanks

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Abstract. The paper present the research carried out as part of construction a new monitoring system using the AE method, in the aspect of the adaptation to the requirements of the storage tanks of the Polish Minister of Economy of 21.11. 2005, and to the provisions and conditions of maintenance.

Leaks are structural failures especially in old construction of the single-bottom aboveground storage tanks that are mainly caused by corrosion or by weld defects. These damages from the degradation of material and structure are the subject of investigations carried out within the framework of the Research and Development Project of The Polish National Centre for Research and Development entitled "Design, implementation and use of a control system for monitoring activity and leakage of corrosive processes by acoustic emission (AE) of storage tanks for liquid media" - NR15 011410.

Researches of corrosion processes and leakage with use of AE were made under laboratory conditions, as well as under operating conditions of the storage tank. The main aim of the tests was to record the reference data, with correspondingly wide range of the frequency spectrum for the various stages of corrosion processes and different kinds of leaks. The long-time AE background monitoring tests on storage tanks in the different monitored conditions and additionally tests with the leaks simulator were performed. The environmental conditions were monitored by the weather station and collected data were synchronized with the AE measurement data - weather data were included to the analysis and visualisation of AE data stream. Data collected during all measurements are used in frequency and AE parameters analysis in order to develop the conditions and criteria of conducting AE monitoring on operating storage tanks regarding condition of the tank bottom. The measurement data are undergo pattern recognition analysis to separate the AE signals due to corrosion and leaks from background noise for different conditions measurements. The collected database is also the basis of building the classifier, which aimed the identification and reporting of failure events (e.g. leakage, corrosion) during the on-line AE monitoring. The idea of the new AE monitoring system of aboveground storage tanks will be presented.

Introduction

The article shows a further part of the work presented during EWGAE 2012 in paper entitled "Analysis of Corrosion Processes and Leaks in Aboveground Storage Tanks with AE Monitoring".

Environmental protection and the need to meet the requirements of law concerning the supervision of aboveground tanks intended for storage dangerous media, causing search for ever more efficient ways to anticipate and detect critical defects in the material of tanks. This applies particularly to non-pressure or low pressure tanks for hazardous liquid (toxic, corrosive or flammable) stored in the bases of fuel. For this type of tanks the primary threat is influences of the corrosion on the material, substantially dependent on the aggressiveness of the stored medium and the type of material used and the structural stress levels.

This issue is valid especially for large-capacity tanks with danger of explosion or leakage of aggressive media. Existing methods for surveillance of these type tanks usually allow to take react after the occurring damage not previously informed of the approach and the investigation into its critical state. One of the responses to an existing problem may be the protection of the tank leak into liquid fuels by building a second bottom. The solution is very costly especially in the case of tanks already in service, often technically risky because of the stress relaxation resulting in cracking of structural material structure outside the protected zone.

Based on above facts, the Research and Development Project of The Polish National Centre for Research and Development was established. The project entitled "Design, implementation and use of a control system for monitoring activity and leakage of corrosive processes by acoustic emission (AE) of storage tanks for liquid media" - NR15 011410/2010.

In the project is proposed to solve this difficult problem through the application of AE method to monitor continuously the technical condition of the structure of tank during service. It is proposed that the general solution of the problem through research conducted in the laboratory and research on single real structures and afterwards organization and testing of storage tanks operated in the selected base fuels. During tests on real storage tanks the leaks simulator was used. In long-time AE background monitoring tests on storage tanks in the different monitored conditions were performed with use the prototype of new monitoring system. The idea of the new AE monitoring system of aboveground storage tanks is presented.

Laboratory tests

AE enables us to monitor the activity of corrosion processes as well as leaks detection. Based on this knowledge the corrosion and leak laboratory tests were conducted. The main purpose of the lab measurements was to record data with appropriate wide spectrum of frequency domain for different stages of corrosion processes and different kind of leaks.

During laboratory tests were used AMSY6 system with ASIP 2 dual channel AE boards made by Vallen Systeme GmbH. The following types of sensors were used: VS30-SIC, SE45-H, VS75-V and VS75-SIC.

Laboratory testing for leaks using the AE method were conducted for different types of leakages and the rate of the flow. It was used the leakage simulator for comparison and verification of leak in the laboratory and in real conditions on the storage tank.

Laboratory leak tests were intended to record AE waves typical for leakage at different rates (0,01 ÷ 0,10 m^3/h) and different shapes of holes. All tests were performed in order to collect the measurement data for the widest range for different parameters of leaks.

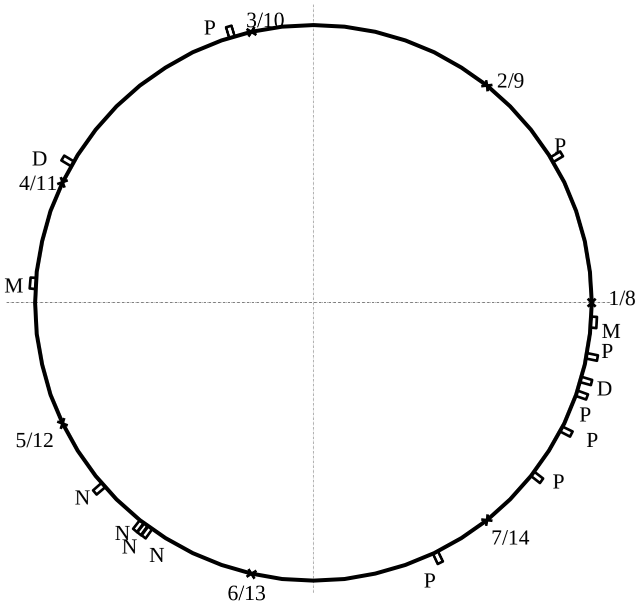
Laboratory tests of corrosion using the AE method were conducted on the specimens in different stages of material degradation. The specimens were obtained from real storage tanks – material made from carbon steel of normal quality.

AE measurements of corrosion processes are intended to acquire AE signals typical for various stages of degradation of the specimens, and for different rates of progress of corrosion (0,20 ÷ 5,00 mm/year). Laboratory tests are performed on the test stand, where in special corrosive environmental conditions (3% NaCl aqueous solution) specimens were undergo corrosion processes. Also here, all tests were performed in order to collect the measurement data for the widest range for different parameters and stages of corrosion.

Measurement data collected during the tests were used to parameters and frequency analysis in order to develop guidelines and criteria of conduct by AE measurement and monitoring of bottoms of storage tanks.

Tests on a storage tank

For AE testing it was selected one of storage tanks of a refinery (PKN Orlen S.A.), which cooperates with this project. The storage tank is in service and stores diesel oil. In figure 1 is presented the layout of AE sensors together with the accessories of tank. AE monitoring of this storage tank was conducted in order to detect corrosion and/or leak sources. In the next step, AE background monitoring measurements were made on the storage tank for various operating conditions and under different weather conditions.



Legends: P – pipelines in/out; M – manholes; N – nozzles; D - drainage

Fig. 1. Layout of sensors together with the accessories of storage tank

The measurements were performed in a variety of operating conditions (e.g., for different levels of stored product) and the environmental conditions. During AE monitoring on the storage tank, it was used AMSY6 system with ASIP-2 dual channel AE boards made by Vallen Systeme GmbH. At the beginning the same types of AE sensors as in lab tests were used but in subsequent tests used the new intrinsically safe AE sensors model ISAS3-030 (the resonant frequencies of 30 kHz).

Also the leak tests were performed on the storage tank using a leak simulator. In figure 2 showed the scheme of such tests with leak simulator immersed in the liquid inside storage tank. The main part of the tests were made in the same way as in laboratory leak tests with leak simulator in the basin. The aim was to comparison and verification of leak tests in the laboratory and in real conditions on the storage tank. The leak tests were made during different operating condition and different weather condition.

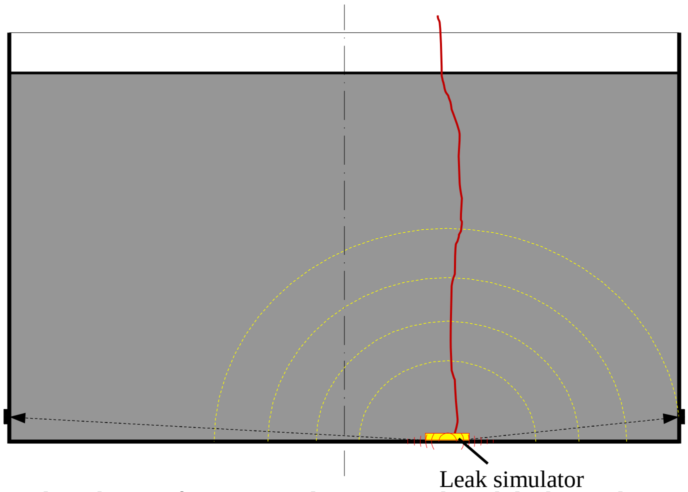


Fig. 2. The scheme of tests on real storage tank with leak simulator inside

Long-term AE monitoring tests on a storage tank

Based on the results of the subsequent stages of the project the prototype of the new AE monitoring system was developed. In long-time AE background monitoring tests on storage tanks in the different monitored conditions were performed with use the prototype of new monitoring system. The general scheme of prototype new AE monitoring system is presented in fig.3.

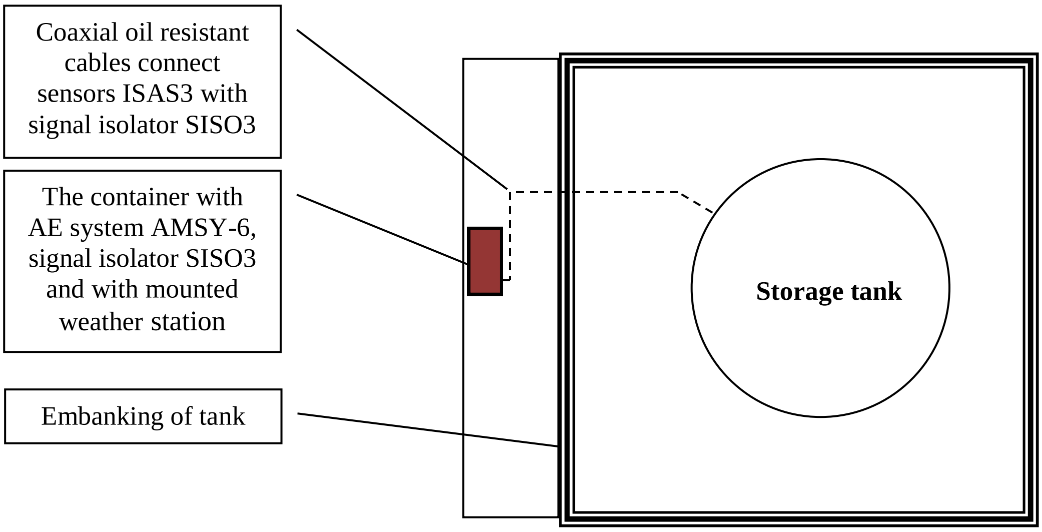


Fig. 3. The scheme of tests on real storage tank with leak simulator inside

Long-term tests for safety reasons as well as the relevant provisions require unconditionally use in tank zone (hazardous area) the intrinsically safe apparatus (ATEX certified for that zone).

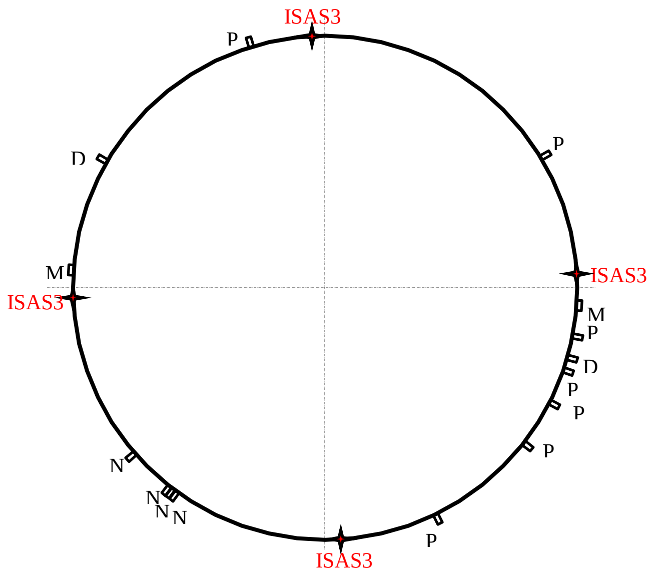
In order to address the safety aspect of installing electrical equipment in an explosion hazardous area, intrinsically safe AE sensors ISAS3 and signal isolators model SISO3 are used. The SISO3 signal isolator is necessary to achieve galvanic isolation of the electronic circuit in the explosion hazardous area and to limit the electrical power, voltage, current and pulse energy delivered to the sensor in the hazardous area. The SISO3 units are located in the non-hazardous area nearby the AMSY-6 in container.

The prototype AE monitoring system consisted of the following elements (fig.3):

- AE sensors intrinsically safe ISAS3-030,

- Coaxial oil resistant cables,
- The signal isolator SISO3 mounted in the casing HISO3,
- The AE measurement system AMSY-6,
- The computer with new prototype software,
- Weather station type MK-III-LR,
- The container where were placed most of above elements.

ISAS3 sensors have been arranged according to the scheme shown in Figure 4. The necessary number of sensors was determined based on a range of research studies on the storage tank.



Legends: P – pipelines in/out; M – manholes; N – nozzles; D – drainage

Fig. 4. Layout of ISAS3 sensors on storage tank during long-term monitoring tests

The system worked automatically with the possibility of remote control via the internet. The computer was connected to the internet via GSM modem. This allowed the remote control and supervision over the work of the monitoring system. Especially for the new prototype system has been developed and built the new software "Automation Manager" by Vallen Systeme. The new software was developed based on the results of the project. Vallen Automation Manager is a separate software module for continuous monitoring and automation using Vallen acoustic emission equipment.

The prototype AE monitoring system had been running for almost one year.

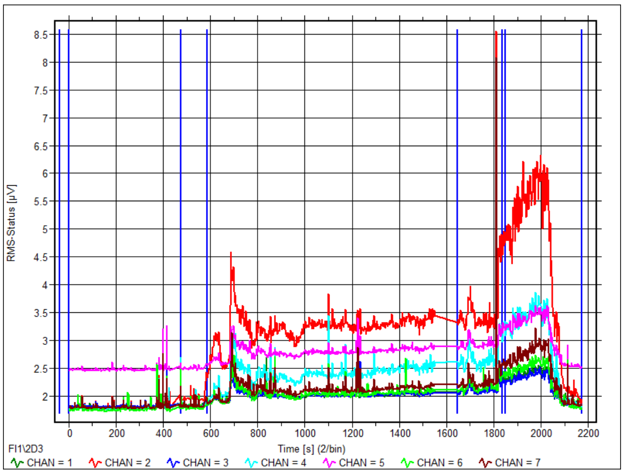
Results

AE measurements during leak tests enables us the detection of leakage and monitoring of their states for different conditions. The most sensitive parameter of AE regarding leak is Root Mean Square voltage or RMS. The RMS value of the signal between two hits (the time period from end of hit detection to next start of hit detection) is continuously evaluated and stored with the next hit as the RMS result. It provides information about the continuous AE signal level below the threshold. Most practical is use RMSS parameter, which is the time driven Status Data Sets. RMSS can be used to monitor the background noise, even when there are no hits at all.

AE measurements during corrosion tests enabled us the detection and monitoring of active corrosion processes. These are long-term tests due to the duration of corrosion processes. All measured data were recorded at several measurement sequences at different stages of the corrosion degradation of the specimens.

All collected data were used in numerical analysis. Numerical analysis was performed using the VisualClass to verify and compare the data from the tests of corrosion and leak. The AE waves generated by leak and by corrosion process sources as recorded AE signals were compared. For the analysis the selected data from all tests were used.

In figure 5 is presented the RMSS value for active leak during tests with leak simulator inside the storage tank. The sensor number 2 was closest the place where was put on the bottom the leak simulator. So, due to leak activity the RMSS value was doubled.



0 ÷ 480s -> AE background; 480 ÷ 2100s -> active leak on leak simulator

Fig. 5. RMSS value during leak tests with leak simulator inside storage tank

Below, in the figure 6 is shown the use of the built classifier to identify signals from leak, as well as shown an analysis of the influence of the number of sensors for such identification and localization. Classifier working well and identifies AE signals originate from leak source, as well as from corrosion processes. The minimum number of sensors in this case is four (6b) because in case of use three sensors the number of detected, localized and identified AE signals are not enough.

In figure 7 are presented collected data during long-term AE monitoring by new prototype AE monitoring system. The horizontal axis shows the time in hours whereby the time refers to the measurement time. In this case the measurement started on Friday, 18th of October at 14:57. At this point of time there was probably a switch of data files because the old file reached a predefined limit. When this happened a new data file was started automatically. The measurement finished approximately 115h later. Whenever there is an increase rain has fallen and was measured in mm (what corresponding with litre per square meter).

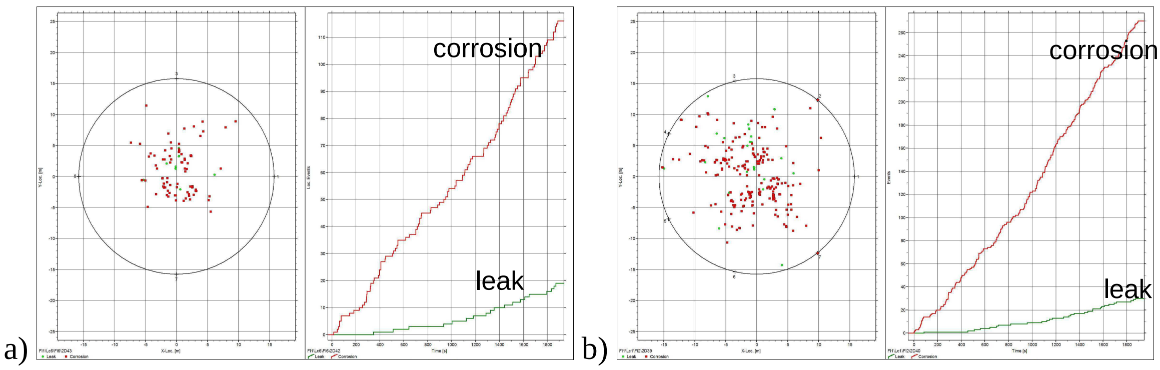


Fig. 6. Location of AE events and their identification by use classifier - 7 sensors in row (a) and 4 sensors in row (b)

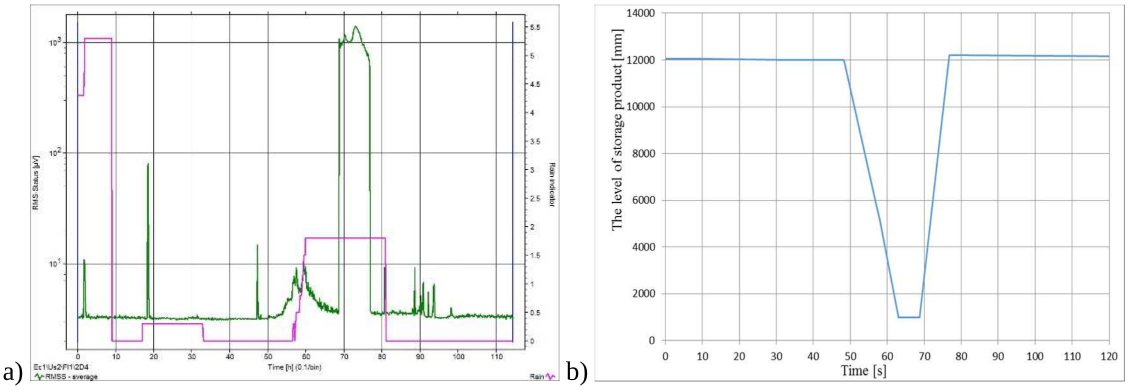


Fig. 7. RMSS vs time and rainfall indicator (a) and the level of storage product in time in storage tank (b) – long-term AE monitoring

When the indicator is constant, e.g. a horizontal line, then no rain has fallen, which is interpreted as good weather condition for acoustic emission data analysis. Every 24 hours (at midnight) the rain indicator is resetting, what is visible as decline in the value to zero. In figure 7a is shown how weather station data was combined with acoustic emission data. There are presented the average value of RMSS and rain indicator over time measured in hours. While in figure 7b is shown the level of storaged product in storage tank - change of level in time corresponding with filling or emptying of the tank. The RMSS value increasing during rain (~2 h and 56 h) and drastically increases during filling of product (68 ÷ 76 h) the storage tank.

The new prototype AE monitoring system

Based on the obtained results of the project developed prototype of a new AE monitoring system. Results of long-term monitoring tests conducted on the storage tank allowed to develop preliminary criteria for the new system work. The collected data are huge and currently results and findings are evaluated and requirements for hardware and software as well as analysis are revised.

In figure 8 is presented the scheme of new prototype AE monitoring system of aboveground storage tanks. The principles of operation of system are described below.

The monitoring measurements based on the fact that the waves generated by the source AE from the bottom of the storage tank, is processed by the AE sensors mounted on the tank walls into electrical signals. AE signals are transmitted via coaxial cables by the protective barrier, and further using coaxial cables to channels of AE measurement system. Successively are recorded and archived of AE measurement data for further processing, analysis, classification and visualization. Simultaneously the environmental and operating conditions are monitored, leading to the detection of AE signals that indicate a leak and / or the presence of an elevated activity of corrosion processes in the bottom material and alerting operating personnel of the occurrence of such events.

Conclusion

Based on the obtained results and on their analysis, the following conclusions can be drawn:

- It was obtained very good result during tests of leaks using the leak simulator on the storage tank in real conditions,

- It is possible to simulate leaks in the laboratory and on real storage tank in order to collect database for further numerical analysis,
- Acquired during laboratory tests and during tests on real storage tank, AE signals are very good basis of project database,
- VisualClass analysis of data and built classifier enables us to identify AE sources well as leak and corrosion,
- Running the prototype AE monitoring system for one year showed that the goals set at the beginning of the project can be achieved,
- It is possible the correlation of weather status and operating status with AE measurement data. Monitoring weather and operating conditions allowing to find good conditions for optimal AE measurement.

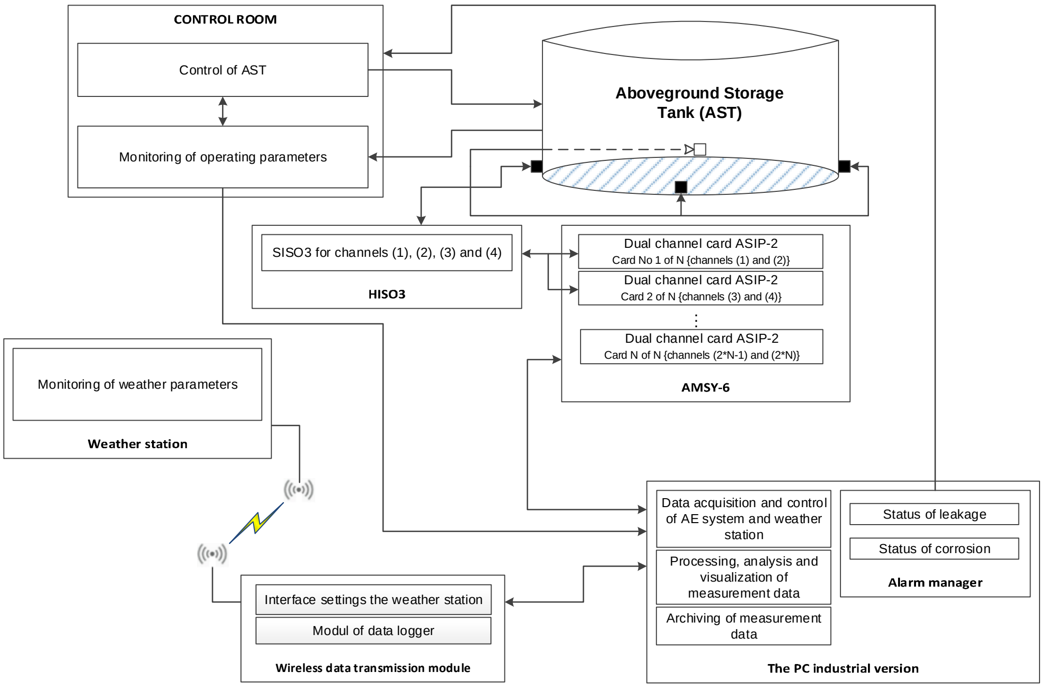


Fig. 8. The scheme of prototype AE monitoring system of aboveground storage tanks

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