



## ACOUSTIC EMISSION AS A TOOL FACILITATING TECHNICAL CONDITION INSPECTIONS OF TANKERS CARGO TANKS

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*This article discusses several attempts at using AE as a diagnostic signal and a method facilitating technical condition inspections of tankers cargo tanks.*

**Keywords:** *acoustic emission, corrosion, cargo tanks, tankers.*

### **1. Introduction**

Anywhere in the world there is a large number of ships carrying crude oil. Tankers are ships especially designed for holding as much liquid cargo as possible. Despite regulations aimed at increasing the safety of crew and cargo, maritime disasters still occur. The currently used methods provide a relatively good overview on the diagnosed structure, however, they certainly can be improved.

#### **Tankers characteristics.**

*Crude carriers* are used solely for transporting crude oil. They are usually built with one or two longitudinal bulkheads and a relatively small number of cargo tanks – 15-20, no more than 36.

*Ore-oil carriers* are adapted to transporting ore in central bins. The main difference between them and conventional tankers is that central bins are located over the double bottom and are enclosed from the top with large and heavy hold covers. [1]

*Bulk-oil carriers.* The main difference between them and the above-described carriers is the fact that they do not carry oil in lateral tanks, which are used solely for ballast. Their central bins have a greater width, so their lateral tanks are narrower than in typical ships. Such vessels usually have between 50 000 and 250 000 DWT.[1]

*Product carriers* are built considering maximum operational flexibility in view of using their full capacity. They usually contain two longitudinal bulkheads and a separate ballast system. Their system of cargo pipelines is also more complex than in the case of crude carriers [1].

#### **Issues of hull and hold damages.**

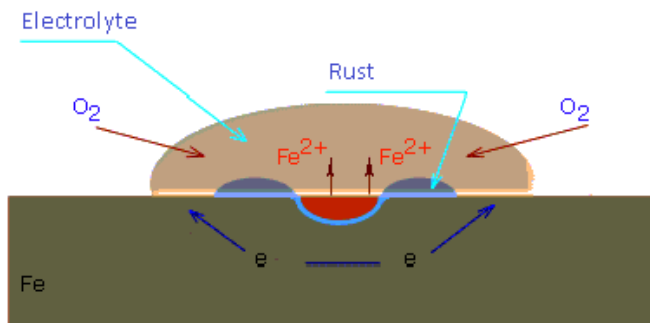
The four basic mechanisms leading to the damaging of the hull are:

- ship overload that causes deformations when the material of which the hull is made is subjected to stress exceeding its local strength,
- various cracks caused by material fragility, due to poor condition of the structure or severe corrosion,
- material fatigue, fatigue caused by corrosion, due to recurrent hull overloads resulting from operation,

### Corrosion damages

Metal corrosion may be generally classified into chemical and electrochemical corrosion. Chemical corrosion takes place when there is a direct chemical reaction of metal with its surroundings, while electrochemical corrosion occurs in electrolyte solutions and in the atmosphere. Most materials used in shipbuilding are subjected to electrochemical corrosion due to sea water and the atmosphere.

The course of a corrosion process may be represented schematically, as shown in Figure 1 below.



*Fig. 1 Course of electrochemical corrosion of iron in an electrolyte drop due to aeration [3]*

Typical areas especially exposed to corrosion in oil tankers are: [4]

- upper section of lateral and longitudinal bulkheads,
- upper section of lateral deck bracing,
- longitudinal deck bracing,
- longitudinal bracing on internal plating and longitudinal bulkheads,
- openings for bracing crossings,
- transverse girder web plate,
- longitudinal bracing shelves in bottom and floor structures.

Factors affecting the development of pitting corrosion are:

- adjacent, heated tanks,
- local loss of corrosion protection as a result of poor quality of hull construction,
- incorrect cargo distribution,
- excessive local load,
- areas with increasing flow, i.e. hatches and openings.

## 2. Acoustic emission (AE) as a supplementary method for diagnosing the technical condition of cargo tanks.

Strong AE signals occur most of all in the case of:[5]

- partition cracking at higher stresses and rapid spreading of cracking,
- non-uniform spreading of cracks due to loads,
- high pulsating loads close to the ultimate strength,
- cracking as a result of stress corrosion,

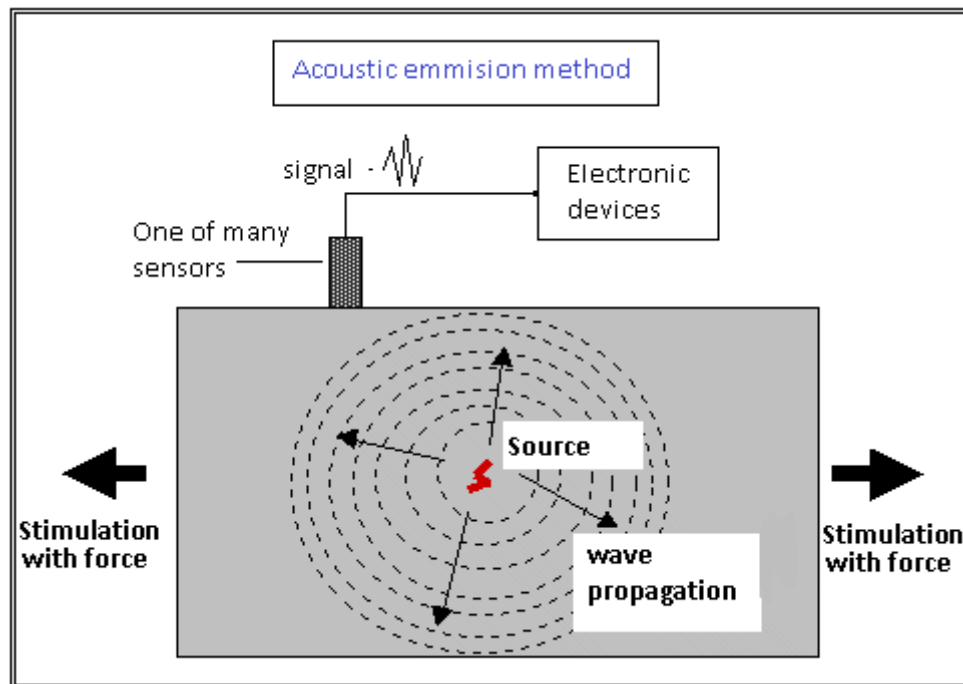


Figure 2 Graphic illustration of acoustic emission method [4]

### Instrumentation and software

Modern AE analysers comprise the following functional elements:

- converter of signals into an electrical signal,
- main amplifier with regulated gain,
- low- and high-pass filters system,
- noise cut-off system,
- signal energy or amplitude processing system,
- systems enabling the connection of AE measured signals loggers,

The AMSY5 system is a multi-sensor AE system comprising parallel measurement channels. Each channel is connected to an analogue measurement section, digital signal processing.

A complete AMSY5 system includes:

- main unit (MC2, MC6, MC15, etc.),
- one or more AE channels,
- basic software package – SWAT or SWBN. [6]

The components of an assembly used for analysing AE are listed below (fig. 4-9).

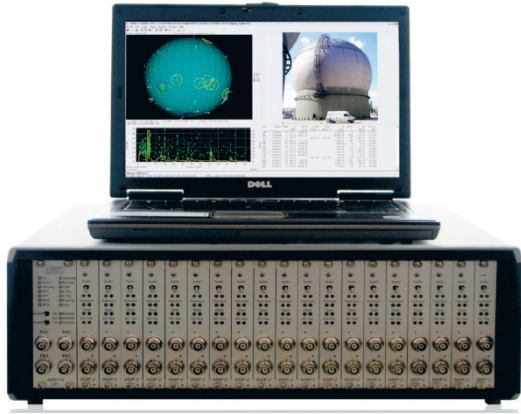


Fig. 4 AMSY5 equipment



Fig. 7 AEP4 preamplifier (gain up to 34dB).



Fig. 5 Sensors for tests



Fig. 8 MAGMA logger.



Fig. 6 Magnetic holders



Fig. 9 MAGMA PCMCIA processing unit.

## Tests

The AMSY-5 equipment, described in the previous section, was successfully used for diagnosing the technical condition of the following objects:

- "Icarus" tanker
- Polish navy fleet support ship – ORP "Bałtyk",
- tank for storing brine of the capacity of 3000 m<sup>3</sup>

The application of measurement instrumentation on board of "Icarus" in 2005 was the first case of the tests conducted in marine conditions. The aim of the tests was to measure the

acoustic background of MT IKARUS II at the anchorage by the "Baltic Beta" platform during manoeuvres involved in its first voyage to the port in Gdańsk. Preparation for the tests involved the construction of cable routes and a special seal for under the cover of the ballast tank hatch.

Large amounts of flammable and explosive gases are released from the tanks of M/T IKARUS II while extracting crude oil from the B-3 deposit.

#### Technical characteristics of M/T IKARUS II.

M/T IKARUS II was constructed in 1975 in Japan by KANASASHI SHIP-BUILDING. The ship is currently being used as a resource base for the production centre located on the "Baltic Beta" platform and as a carrier for oil extracted from the B-J deposit to the port in Gdańsk.

Capacity – GRT – 21 576;	Main engine type	- Kawasaki M.A.N K
Capacity – DWT – 36 194;	7SZ 70/125,	
Total length – Lc = 182.03 [m],	Main engine power	- M = 79 650 [kW],
Length on waterline – Lwp = 171 [m],	Speed	- 10 [Mm/h] at 145
Width	[RPM],	
Draught		
- B = 27 [m],		
- T = 17 [17],		



*Fig. 10 M/T IKARUS II at sea.*

Tests on board of M/T IKARUS II were conducted in the following manner. Selection of tanks filled with oil from the B-3 deposit for analysis.

Considering safety, the following tanks were selected for the tests:

- Tank No. 1 of the capacity of 6 710 m<sup>3</sup>, located in the centre between wing tanks, between frames 72 and 80;
- Wing tank No. 1 of the capacity of 2 767 m<sup>3</sup>, located on the port side, between frames 72 and 80.

The tanks were filled with oil from the B-3 deposit up to 98%

The figures below show the places and the method of AE sensors distribution.



*Fig.11 Marked and cleaned areas for fitting sensors at "C" measurement point and marking of sensor types and numbers on the surface of a wing tank bulkhead*

- VS 30-V and VS 150 RIC sensors with measurement cables at "D" measurement point on the surface of the ship sides plating
- VS 30-V and VS 75-V RIC sensors with measurement cables at "E" measurement point on the surface of the central tank bulkhead

An assembly by Vallen, type AMSY5, was used for the measurement of the acoustic background, containing:

- 16-channel measurement system;
- laptop docking station;
- laptop;
- 8 VS 30-V sensors with a preamplifier and magnetic holders;
- 4 VS 75-V sensors with a preamplifier and magnetic holders;
- 4 nagar magnetic holders;
- 16 BMC measurement cables of the length of 125 m.



*Fig. 12 16-channel measurement system and a docking station with a laptop in a bow room.*

Having connected measurement cables, sensors were calibrated and the preliminary value of discrimination on individual channels was determined.

- value of discrete emission, AE events count [HIT] – a basic parameter describing the source activity.
- Average intensity of continuous emission signals [RMS] – a basic parameter for specifying continuous emission.
- Amount of oscillations above the discrimination level, i.e. exceeding the discrimination level, and their rate in a unit of time,
- Amplitude of a discrete emission signal, the best parameter for specifying attenuation.
- Power (energy) of the discrete emission signal to various sensors,

With the recording of elevated parameters, the difference between the discrete emission signal travel times was also recorded (area under the AE signal breakdown).

Sample results of background tests are presented below.

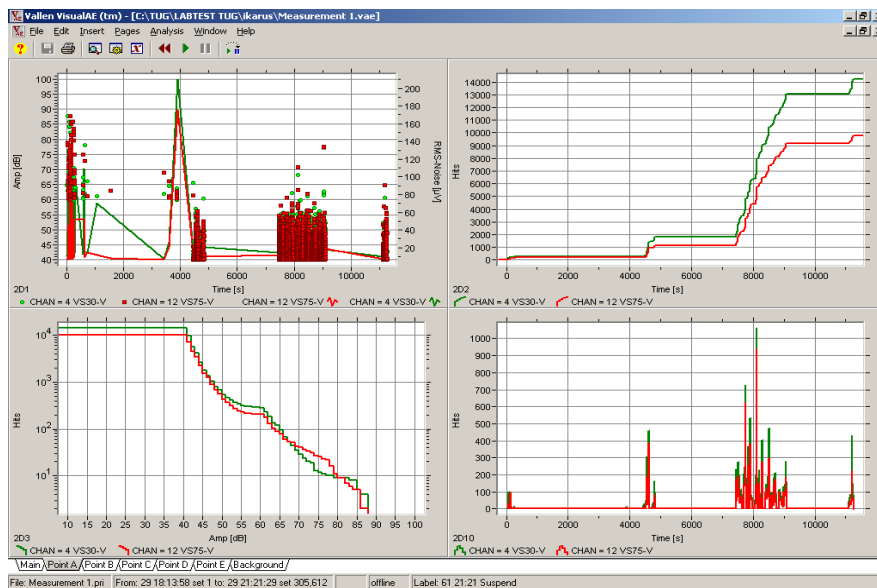
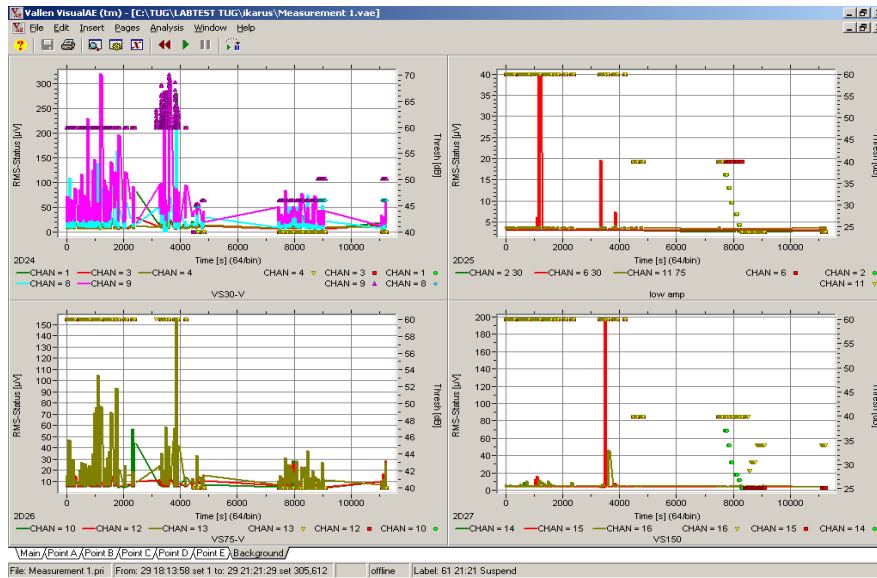


Fig. 13 Sample results of signals deriving from corrosion are presented below.

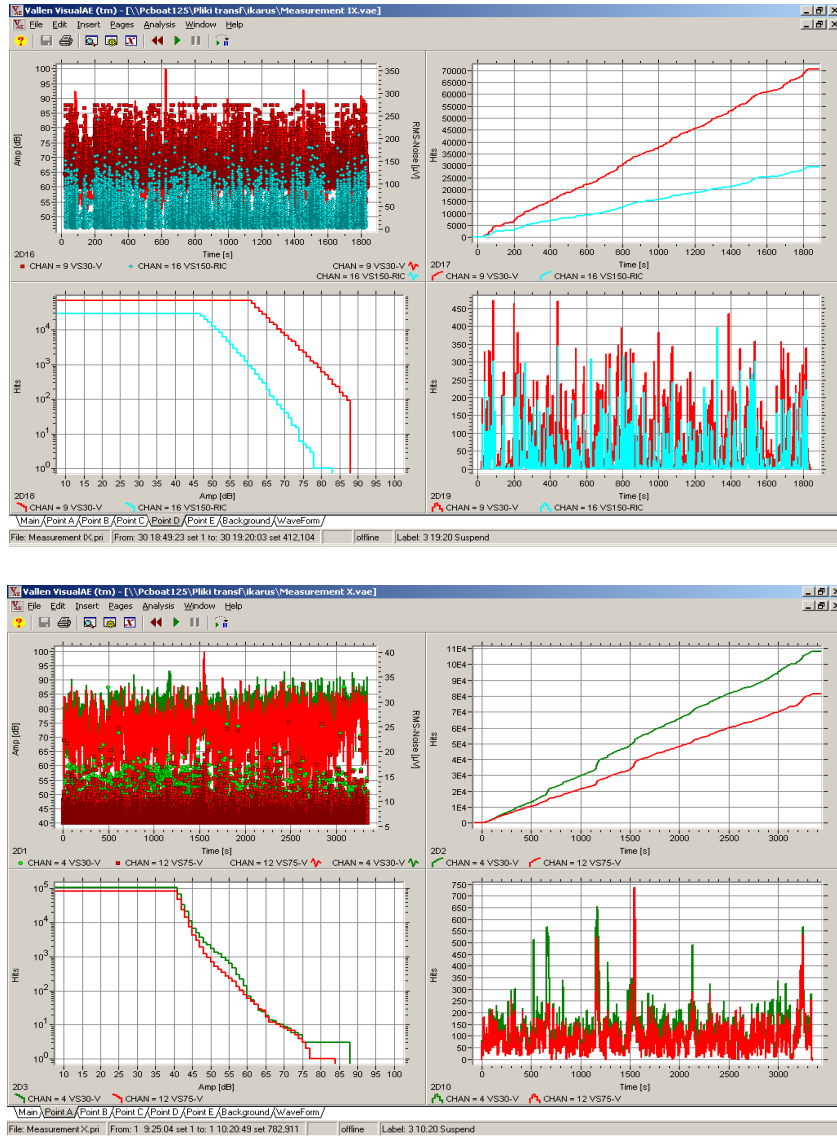


Fig. 14 The results of tests enabled the discovery and location of areas most covered with corrosion. Despite noise and many interferences, the results were unequivocal.

Another test object was a Polish navy fleet support ship – ORP "Bałtyk". The aim of the tests was to analyse below-deck corrosion, test the corrosion tester and the GUT fatigue tester on the ship.

Tests on board of ORP „Bałtyk” included AE measurements in V12 tank and cofferdams and their location with the interferences of the acoustic background from:

- operating auxiliary mechanisms, generators, main engine, screw propeller and others,
- commercial and navy ships travelling near the ship during its stoppage at the quay and anchorage in Gdańsk Bay,
- sea waves and wind during manoeuvres at sea and on the anchorage,

ORP "Bałtyk" was constructed in the shipyard of the Polish Navy in Gdynia Oksywie. Its task was to provide fuel, oils and fresh water, as well as collect fuel and waste.





Tab ORP Bałtyk's technical data

Displacement	D = 2984 t
Load carrying capacity	1276 t
Length	L = 84.75m
Width	B = 13.07 m
Draught	T = 4.80 m
Engines power	N = 2×1480 kW
Speed	V = 15 Mm/h

Fig. 15 ORP Bałtyk'at sea

Equipment used for the tests:

- Valen AMSY5 with ASIP2 filters
- New ISAS75 sensors,
- SE25-P sensors,
- Corrosion source – GUT TESTER, and fatigue GUT tester,
- Corrosion solution (2 L of water, 0.3 L of 65% HNO<sub>3</sub>, 0.25 L of 98% H<sub>2</sub>SO<sub>4</sub>, 0.07 kg of NaCl)



Fig. 16 Cargo deck of ORP Bałtyk'with sensors arranged for tests.

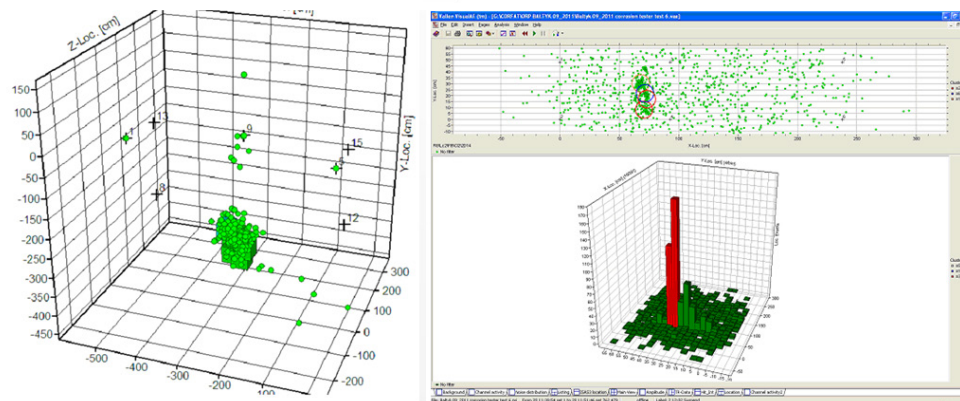


Fig. 17 Visualization of tests results. Visible signal of corrosion. [10].

## Tests results

The conducted tests were successful. Corrosion sources were recorded and located, without having to empty the tested tanks. The use of acoustic emission as a diagnostic signal supplements the currently used methods.

One of the overground objects covered by the tests was a brine tank in a lye facility in Kosakowo. The aim of the tests was to record AE signals in the tank structure side surface during its operation.



*Fig. 18 Brine tank ( $V = 2000 \text{ m}^3$ )*

Instruments by Vallen Systeme GmbH were used to measure AE signals:

- 16-channel AMSY5 system,
- VS75-V, VS30-V measurement sensors (7 + 7 pieces),
- AEP preamplifiers,
- magnetic holders and cabling

## AE SYSTEM ASSEMBLY AND PREPARATION FOR TESTS

Monitoring of the tank condition during the tests of its operation using acoustic emission (AE) was conducted using standard procedures.

Distribution of sensors on the tank plating was preliminarily calculated and the sensors were fitted onto the tank plating:

1. The first 7 VS30-V sensors were evenly distributed every  $L1 = 6.88 \text{ m}$  along the circumference, at the distance of  $h1 = 0.6 \text{ m}$  from the tank base. Sensors from 1 to 7 were numbered (clockwise).
2. Another 7 VS75-V sensors were evenly distributed every  $L1 = 6.88 \text{ m}$  along the circumference, at the distance of  $h2 = 4.1 \text{ m}$  from the tank base. Sensors from 8 to 14 were numbered (clockwise).
3. Sensors were installed with AEP4 preamplifiers in the designated places on the tank plating using magnetic holders. Then they were connected using cables with AMSY-5 instrumentation.

Arrangement of sensors on the first and second day of measurements

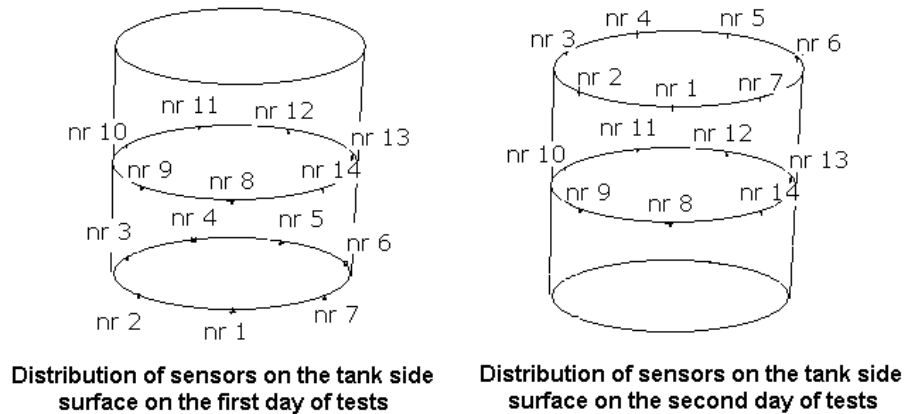


Fig. 19 Arrangement of sensors

Procedure for preparing the AE system for the tank tests was as follows for both days of tests:

1. Sensors calibration test and measurement system check.
2. Acoustic background level specification.
3. Acoustic background measurements during the tank operation for two variants – with water and brine inflow and drainage systems in on and off states.
4. AE signals measurement using a system of sensors.

## TESTS RESULTS

The level of acoustic background specified for the measurements on the first day of tests equalled 22 dB. This value remained unchanged for the second day of tests. Weather was changeable with rainfall spells during the preliminary works on the first day.

Representative results of the AE signals tests in the tank and on its side surface – during normal operation and with water and brine inflow and drainage systems in an off state – are presented below.

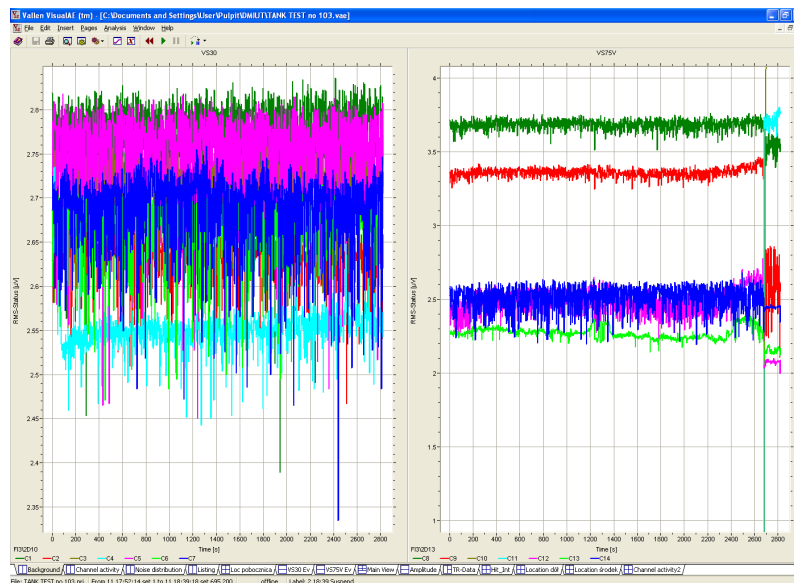


Fig. 20 Acoustic background

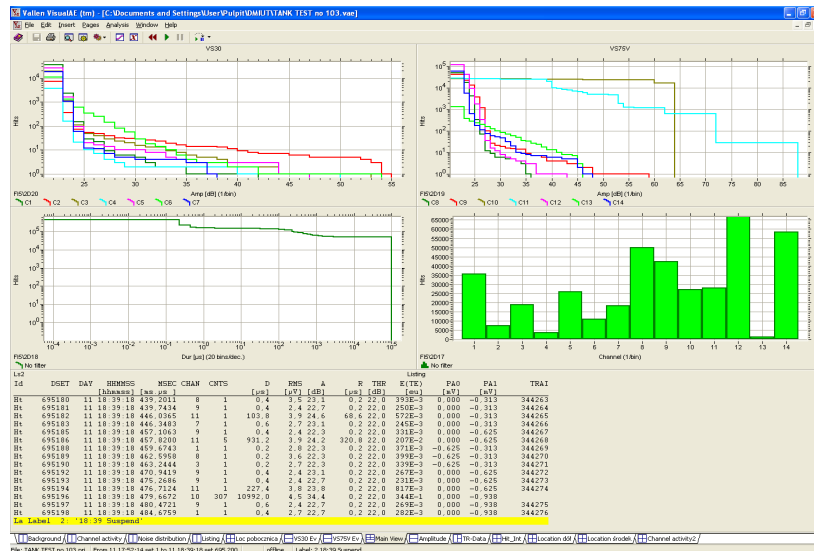


Fig. 21 Activity of individual channels

### 3. SUMMARY AND CONCLUSIONS

As part of preparations for the tests, measurement instrumentation and sensors were checked, measurement system was dimensioned, and the places of measurement sensors distribution were included in a coordinate system in the VISUAL AE system. Preliminary tests were conducted, and the THRESHOLD value was determined to be 22 dB. This enabled proper collection of measurement signals providing for the assessment of the tested phenomenon.

Several measurement tests were performed. The most representative ones were presented in this article. The tests commenced with the analysis of acoustic background, followed by a series of tests, analysing the quality and nature of the collected AE signals. Final conclusions drawn from the performed tests of the brine tank structure using the acoustic emission method are as follows:

- The tested brine tank is tight (no leaks), and its side walls (cylinder side walls) are devoid of active corrosion centres.
- Energy of the collected AE signals emitted during the tests is relatively low due to very strong attenuation by individual layers on the tank (paint, membrane).
- The obtained results of AE signals analysis (using the Visual AE module in the Vallen software) enable the correct assessment of the processes taking place and the proper verification of the condition of the tested tank structure.

The usefulness of a new generation of measurement sensors for tests was confirmed. Those new sensors may be installed even in poor weather conditions without the risk of damaging the measurement system or corrupting the tests results.

The tests were conducted as part of CORFAT project (Contract No. SCP7-GA-2008-218637 – Cost effective corrosion and fatigue monitoring for transport products) performed as part of the European Union FP7 framework program.

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