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# Results of acoustic emission tests of corrosion protection degree of ship steel tanks covered by means of protective coatings (Phase I)

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ABSTRACT

*This paper presents methods and results of the 1st series of tests of acoustic emission (AE) signals, aimed at assessing degree of corrosion protection of a tank made of hull structural steel, protected by means of a protective coating combined from polyurethane layer and concrete filler. The tests were carried out in compliance with a method specially elaborated for application to the work in question. In the method were used requirements of the standards in force, as well as experience gained during realization of the research project CORRSHIP, included in 5th Frame Program of European Union. The application of the AE method to detect and localize corrosion sources during exposure of specimens to corrosive mixture confirmed its high usefulness for the carried-out tests on corrosion protection effectiveness of new types of protective coatings.*

**Keywords**: protective coatings, ship tanks, corrosion, acoustic emission

## INTRODUCTION

The tests carried out in the laboratory of the Department of Ship Technology, Quality Systems and Materials Science, Gdańsk University of Technology, were aimed at effectiveness assessment of corrosion protection of a new protective coating based on polyurethanes, as well as at finding possible corrosion sources on steel specimen surface under the combined *polyurethane layer-concrete filler* coating. The tests were performed with the use of instruments and software of the firm Vallen Systeme GmbH [9]. During the tests AE signals generated by corrosion processes on specimen surface were recorded and analyzed. Experience gained during realization the CORRSHIP research project of 5th Frame Program of EU [8, 11] was also applied. As the tests of AE signals of specimens covered by the protective coatings constitute a new task hence specimens non-coated with the protective coating as well as those protected with standard paint coatings used to cover ship ballast tank surfaces (the reference coating), were tested in parallel for comparison. The test method which covered requirements of recognized norms, standards and rules [1, 2, 3, 5, 10] was elaborated specially for purposes of this work. The hull structural steel complying with the requirements of Ship Classification Societies [6] was used as the base for the tests.

## CHOICE OF DESCRIPTORS OF AE SIGNALS

All basic parameters of AE signals are defined in ASTM and PN-EN standards [13-15]. Among classical descriptors of AE signals the following can be numbered as the most important (Fig. 1) [8, 9, 13]:

1. Number of discrete emissions, counting the AE events ($\Sigma N$); this is a basic parameter informing about activity of sources
2. The mean intensity of AE signals ($U_{RMS}$); a basic parameter for determination of continuous emission:

$$U_{RMS} = \frac{1}{T} \cdot \sqrt{\int_0^T u^2(t)dt}$$

where:
$U_{RMS}$ – mean squares root
$u(t)$ – instantaneous value of electric signal transformed from acoustic one
$T$ – integration interval

3. Value, ($\Sigma AE$), and unit rate, ($\Sigma AE/\Delta t$), of oscillations above detectability threshold
4. Peak amplitude of discrete AE signal; the best parameter for determination of damping and mechanical failure characteristics
5. Rise, duration and decay time intervals of discrete AE signal, ($\tau_1$), ($\tau$), ($\tau_2$), respectively
6. AE signal energy (area under AE signal run diagram):

$$e = \frac{1}{T} \int_0^\infty u^2(t)dt$$

7. Source localization; determination of spatial location of AE source on the basis of return time measurement performed by means of a system of sensors.

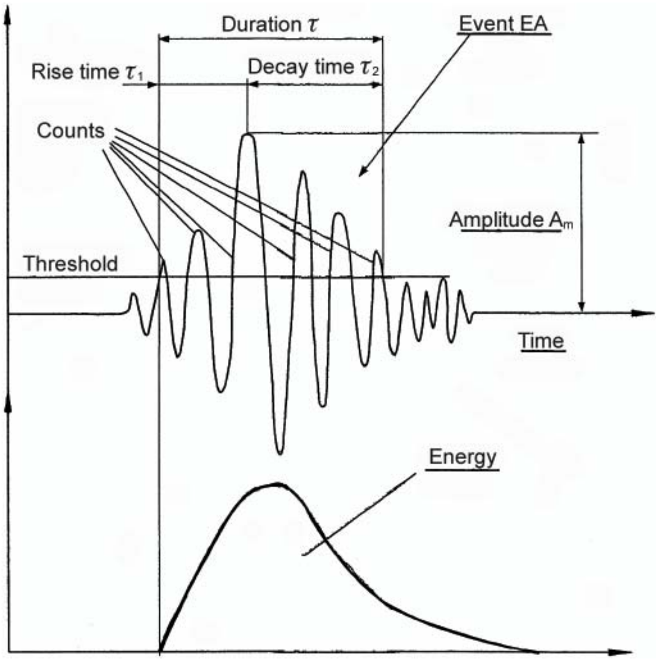



*Fig. 1. AE pulse signal parameters*

## TESTING METHOD

400 mm x 300 mm x 10 mm plates of hull structural steel were covered by two kinds of protective coatings:

- Paint coating commonly applied to protect ship ballast tanks against corrosion (the reference coating),
- *Polyurethane layer - concrete filler* protective coating system.

For the tests the following number of specimens was used altogether:

- One specimen in raw state (marked „S"),
- Two specimens covered with the reference coatings (numbered : 7 and 8),
- Six specimens covered with the *polyurethane layer - concrete filler* protective system (numbered: from 1 to 6).

In Fig. 2 the specimen covered with the *polyurethane layer - concrete filler* protective system is shown.

*Fig. 2. The specimen covered with the polyurethane layer - concrete filler protective system*

As a corrosive environment 5% NaCl water solution having 20°C (±2°C) temperature was used. The corrosive solution was aerated during the tests. For the paint coatings covering steel bases and the Im3 corrosivity category for immersion in water, a long durability life equal to 3000 h (abt. 125 days) was assumed. Accelerated corrosion tests were carried out in a tank made of austenitic steel, (Fig. 3) [8, 11]. The tank was placed on a special vibration - damping foundation (foamed polystyrene, rubber plate, fibre board). The specimens were placed on insulation plastic supports in the tank.

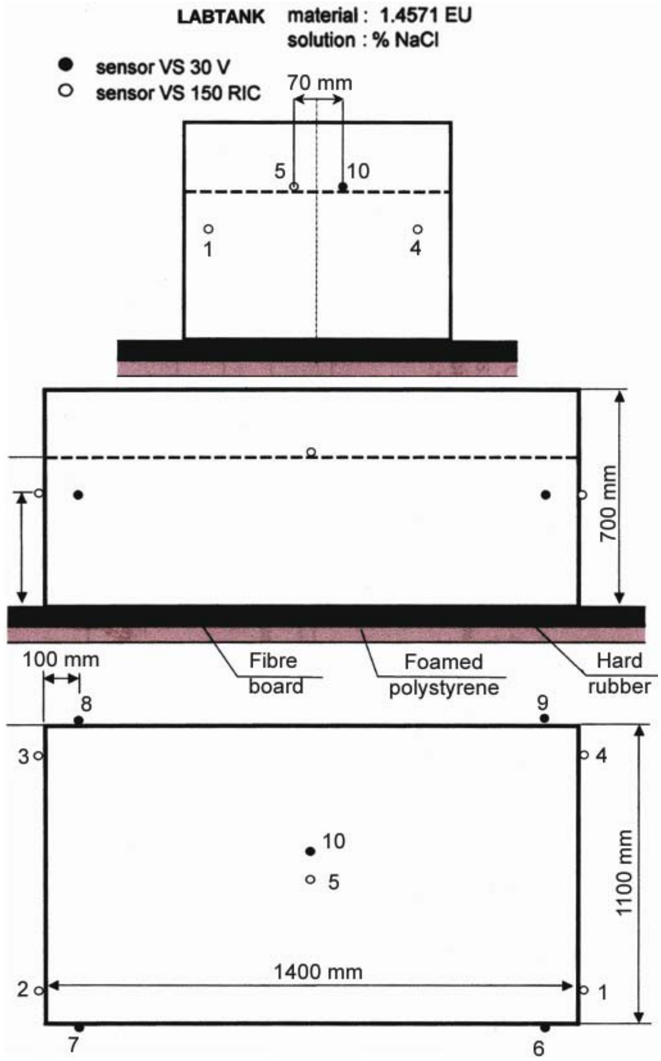



*Fig. 3. The tank for corrosion tests and arrangement of sensors*

For measurements the 16-channel set of AMSY5 system and VS30-V, VS75-V sensors of the firm Vallen Systeme GmbH (Fig. 4) were used.

*Fig. 4. AMSY5 system of the Vallen firm applicable to AE testing.*

To record AE signals and to analyze them a special software of the Vallen firm was used (Fig. 5) [8].

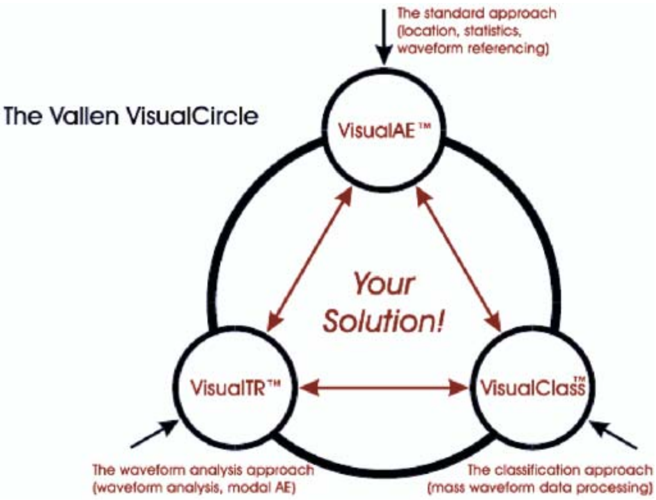



***Fig. 5.** The software for AE signal recording and analyzing, of the Vallen firm [8]*

## RESULTS OF THE TESTS

Into the current research program the following tests and investigations were included:

1. Localization tests and sensor sensitivity tests (graphite guide cracks –Hsu-Nilsen source); Test no. 0.
2. Background noise measurements of the tank filled with corrosive solution; Tests no. 1 through 3.
3. Localization test of the raw state specimen (the falling sphere test); Test no. 4.
4. Investigations of AE signals coming from the raw state specimen (S); Tests no. 5 through 8.
5. Investigations of AE signals coming from the raw state specimen (S) and two specimens covered with the reference paint coating (no. 7 and 8); Tests no. 9 and 10.
6. Investigations of AE signals coming from the whole set of specimens (no. 1 through 8); Tests no. 11 through 19.

Before commencing each of the tests the measurement system, setting of filters and background noise level was controlled. Assessment of localization was checked in compliance with the standard methods at the assumed values of acoustic wave propagation velocities in steel plating of the tank and corrosive solution, respectively. The obtained test-confirmed velocity values were put in the VISUAL AE program. The coordinates of the measurement sensors are presented in Tab. 1. The background noise detectability threshold was set (Tab. 2). In Fig. 6 the tank, measurement system and set of the tested specimens are presented.

***Tab. 1.** Coordinates of location points of AE measurement sensors*

| Type of sensor | Number | Coordinates | | Type of sensor | Number | Coordinates | |
|---|---|---|---|---|---|---|---|
| | | X | Y | | | X | Y |
| VS75 | 1 | -44 | -69 | VS30 | 6 | -54 | -59 |
| | 2 | -44 | +69 | | 7 | -54 | +59 |
| | 3 | +44 | +69 | | 8 | +54 | +59 |
| | 4 | +44 | -69 | | 9 | +54 | -59 |

***Tab. 2.** Results of measurements of background noise level (threshold) of the tank filled with corrosive solution [dB]*

| Type of sensor | Number | Background noise threshold | Type of sensor | Number | Background noise threshold |
|---|---|---|---|---|---|
| VS75 | 1 | 26.1 | VS30 | 6 | 25.3 |
| | 2 | 23.1 | | 7 | 25.7 |
| | 3 | 27.2 | | 8 | 26.1 |
| | 4 | 25.3 | | 9 | 28.4 |

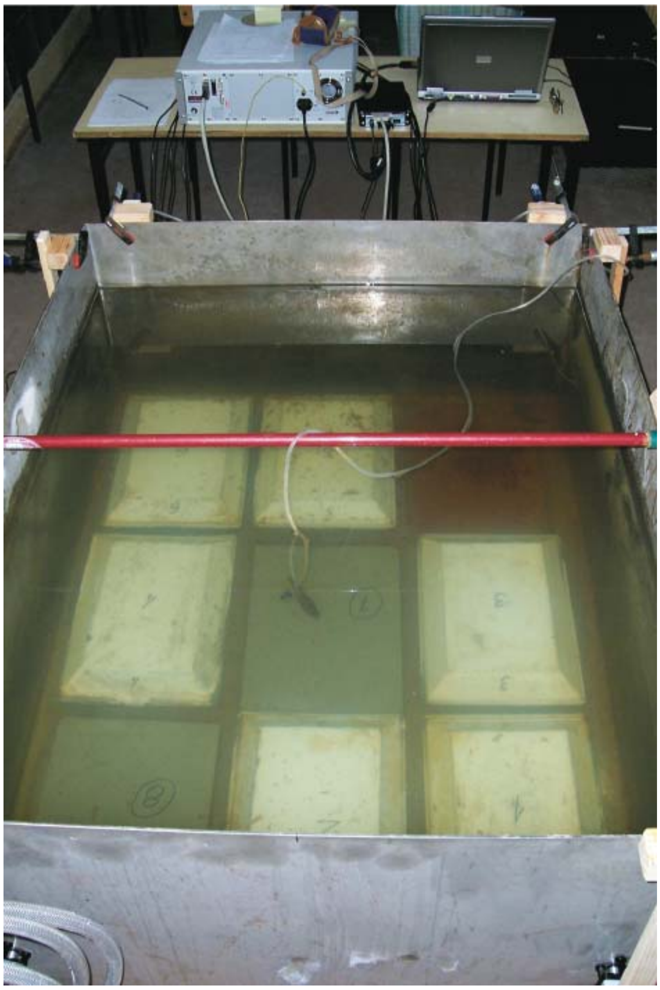
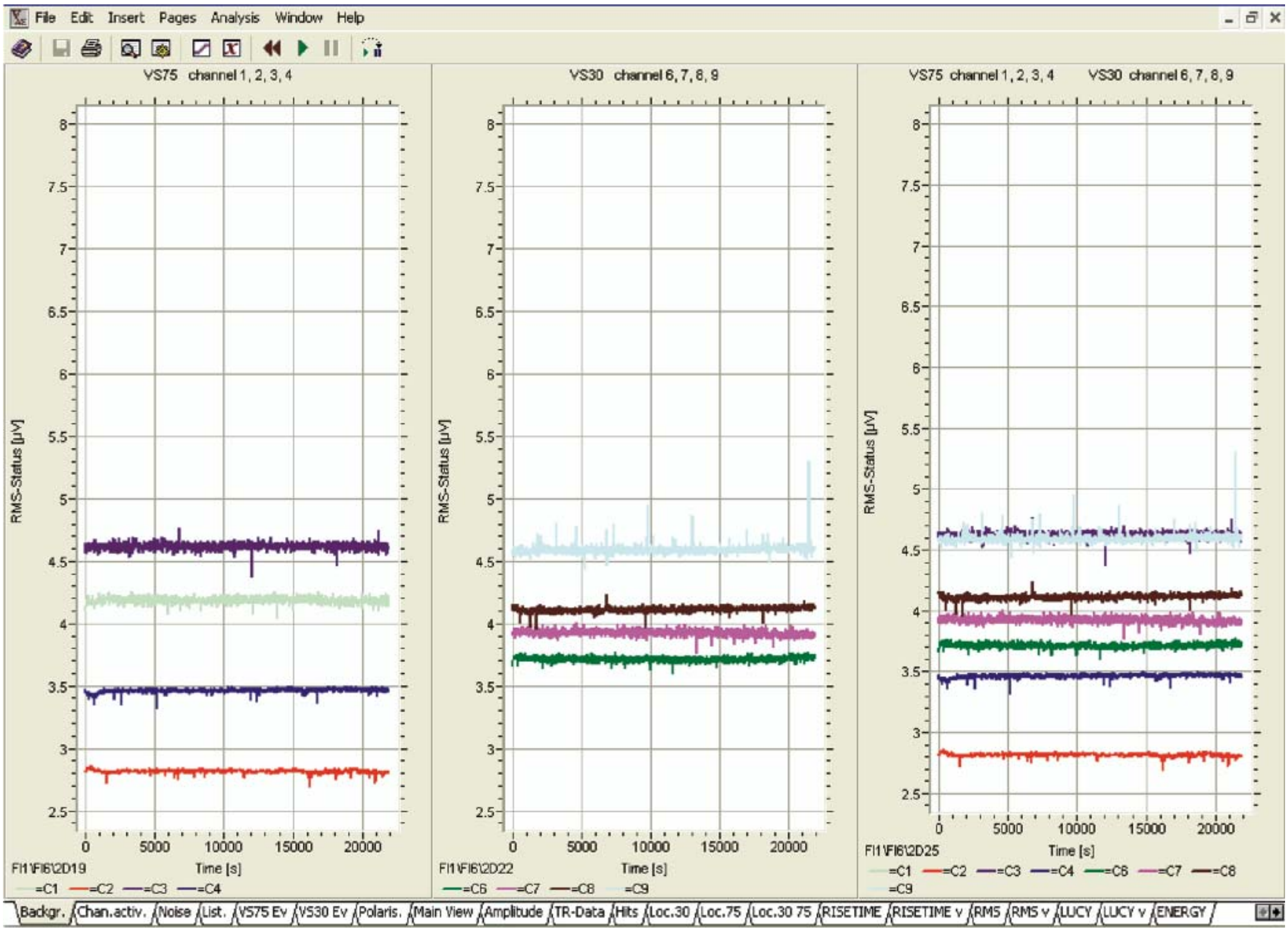
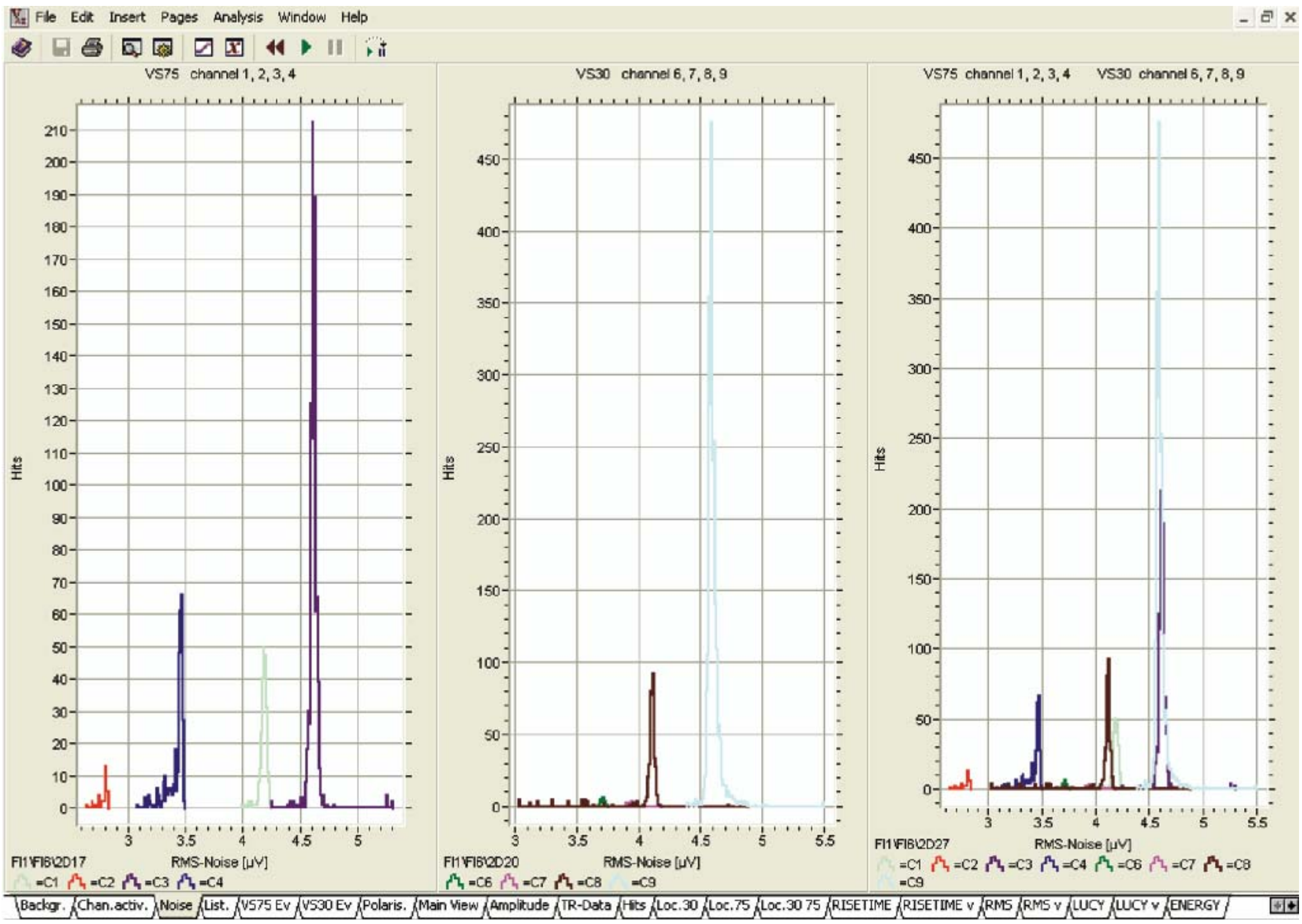


***Fig. 6.** The set of plate specimens : the raw plate specimen, two plate specimens covered with the reference coating (no. 7 and 8), six plate specimens covered with the polyurethane layer- concrete filler coatings (no. 1 through 6). The spout of aeration system is visible.*

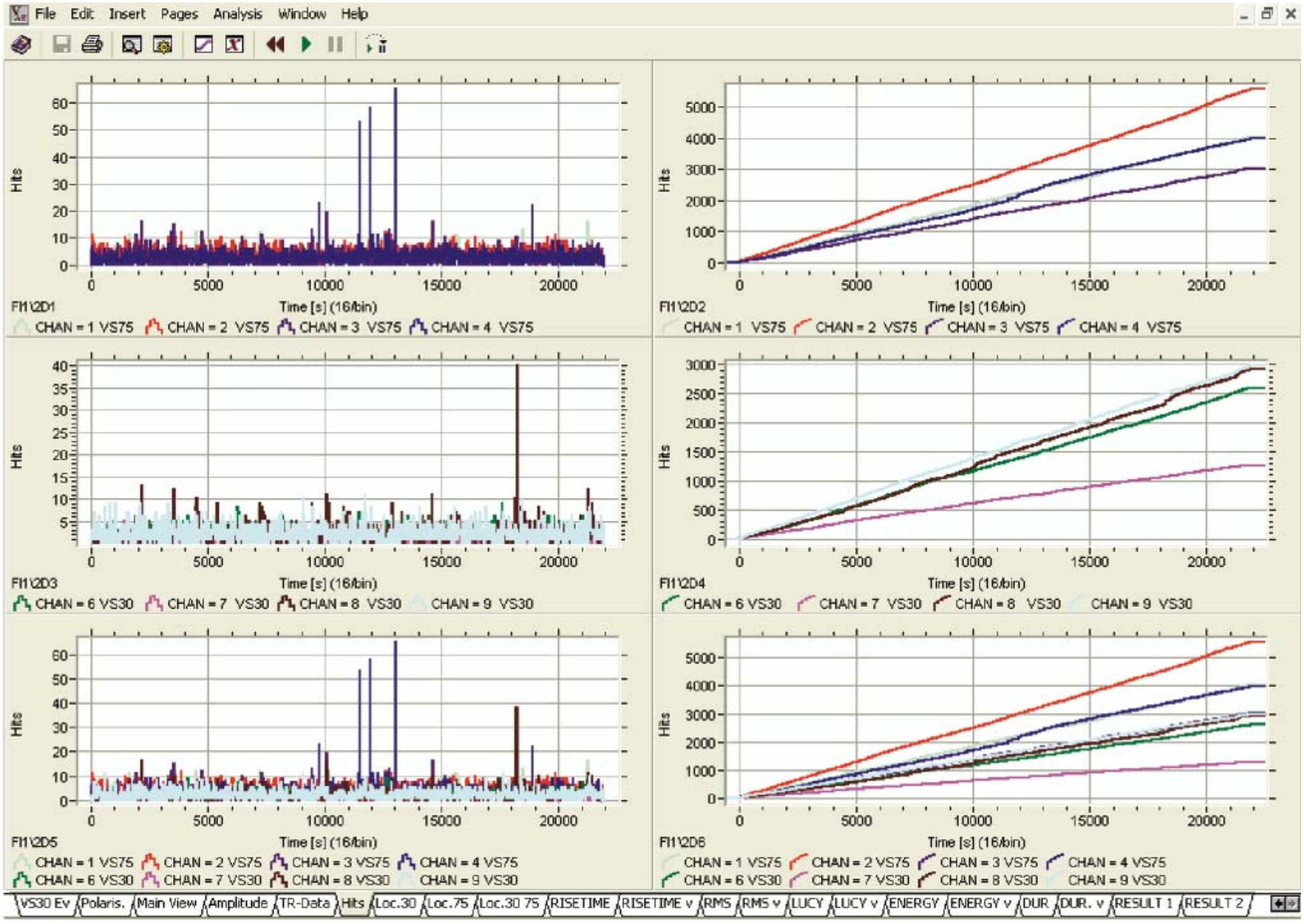
The example recorded AE signals and descriptors for the selected test no. 19 of the entire set of specimens, are presented in Fig. 7. The raw plate specimen (S) showing a significant level of AE signals has been correctly localized. The plate specimen no. 7 covered with the paint coating shows weak AE signals. Additional weak sources of AE signals, located on the plate specimen no. 6 covered with the *polyurethane layer-concrete filler* coating, were also found. As the AE signals localized in it are characterized by another quantity of energy and another rise time it can be deemed that the source of AE signals is of a different character than corrosive one. It can be e.g. processes which occur within internal structure of the concrete filler.

***a)*** *The mean intensity of AE signals (background) – the background* $U_{RMS}$

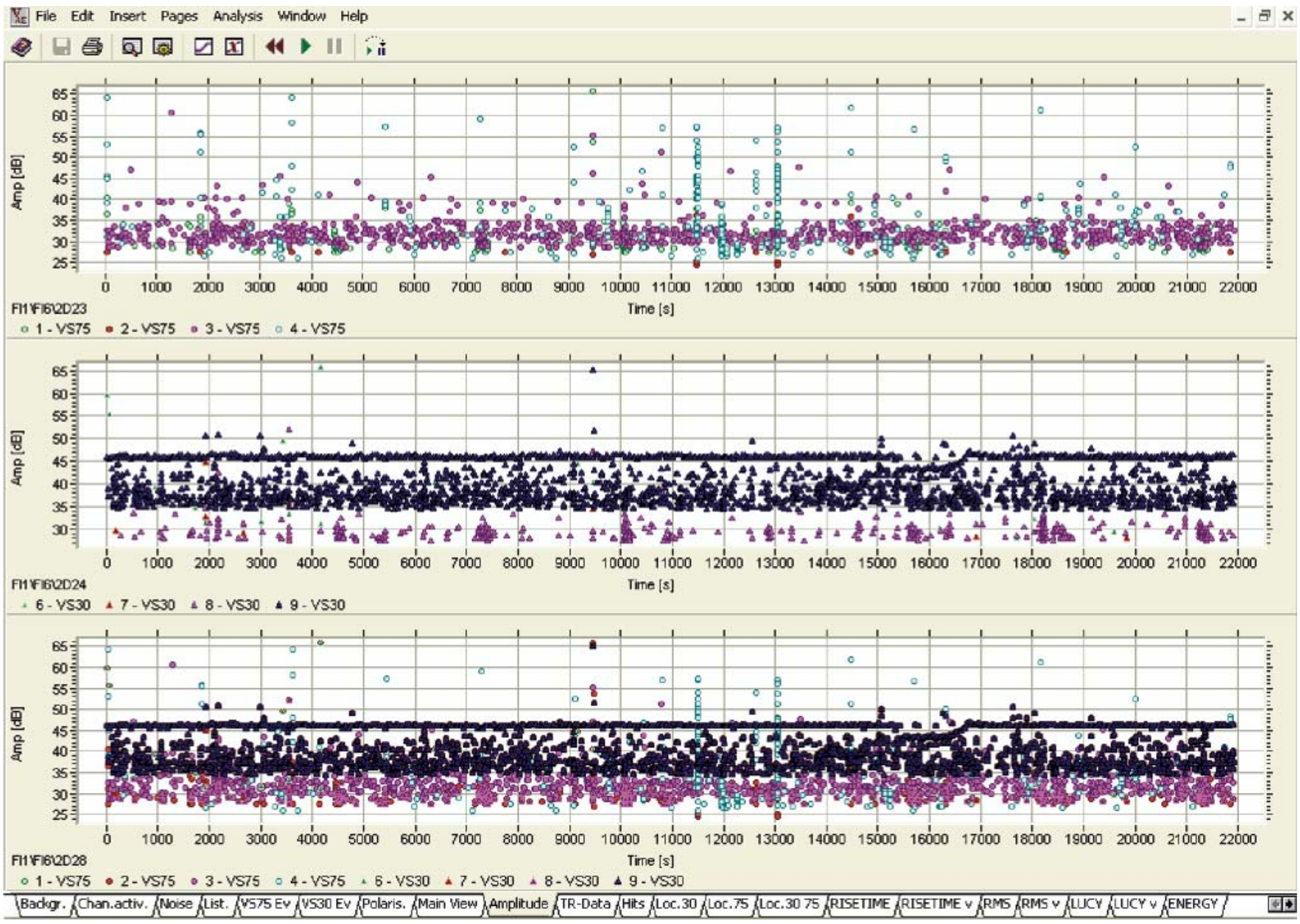


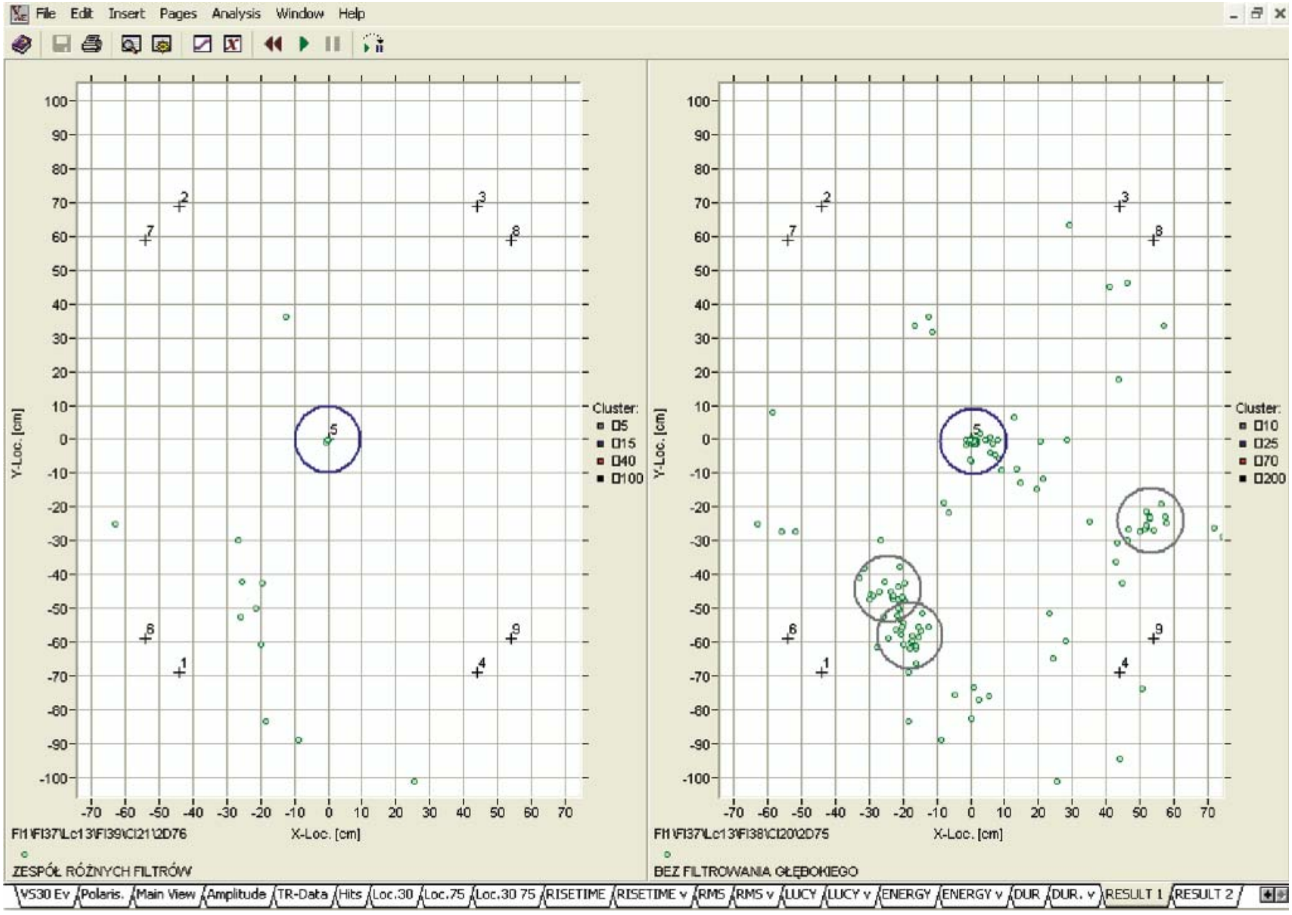
***b)*** *The response (detection of one pulse signal in the channel) - hits*




***c)*** *The peak amplitude* $A_m$



***d)*** *Localization without filtering*




***e)*** *Localization with filtering*

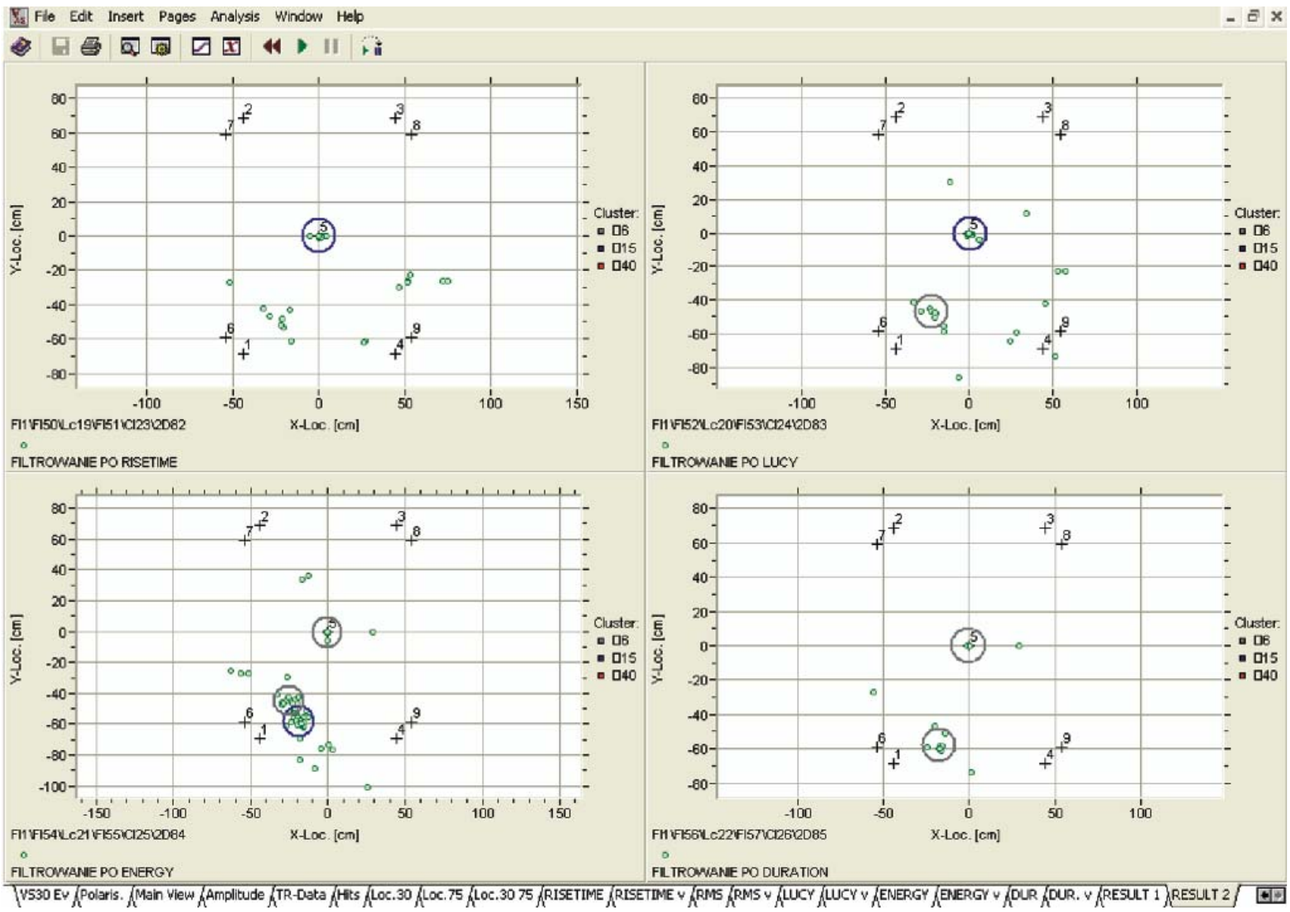



***Fig. 7.*** *Example AE signals and descriptors recorded for the selected test no. 19 performed for the whole set of plate specimens*

## SUMMARY

The application of the acoustic emission (AE) method to detect and localize corrosion sources during exposure of specimens to corrosive solution, confirmed its high usefulness during the performed tests on the assessment of corrosion protection effectiveness of new types of protective coatings.

The preliminary conclusions resulting from the 1st series of the tests are the following :

- The raw plate specimen is characterized by a significant level of acoustic emission and it was correctly localized in each case.
- The plate specimens covered with the reference coating did not show any corrosion acoustic emission during this phase of research. Small point sources of corrosion visible at the edges of the plates are characterized by a low level of acoustic emission, a few orders lower than that of the raw plate specimen.
- The plate specimens covered with the protective coating also did not show any corrosion acoustic emission during this phase of research. Small point sources of corrosion visible at the edges of the plates, are characterized by a low level of acoustic emission, a few orders lower than that of the raw plate specimen.
- Small additional acoustic emission sources localized on the plate specimen with the protective coating (no. 6) were found. The localized signals which are characterized by another energy quantity and another rise time, suggest that their origin character is different than that of corrosion processes, e.g. resulting from the cracking of internal concrete structure of coating layer.
- It is necessary to perform next series of the tests aimed at searching for corrosion processes on the plate specimens with the reference coating or *polyurethane layer-concrete filler* coating as well as to more thoroughly analyze signals coming from the plates (especially from the specimen no. 6) in order to find nature of origin of localized signals.

## NOMENCLATURE

$\Sigma N$ – number of discrete emission
$U_{RMS}$ – mean intensity of signals
$u(t)$ – instantaneous value of electric signal transformed form acoustic one
$T$ – integration interval
$\Sigma AE$ – number of oscillations above their detectability threshold
$A_m$ – peak amplitude of discrete emission signal
$\tau_1$ – rise time interval of pulse signal
$\tau$ – duration time interval of pulse signal
$\tau_2$ – decay time interval of pulse signal
$e$ – pulse signal energy.

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