

Application of acoustic emission method for the diagnosis of underground gas pipeline without taking it out of operation

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ABSTRACT: The study of the acoustic properties of a pipeline section was conducted in accordance with standards regulating acoustic emission testing of pressure vessels and related activities. To achieve this objective, an experiment was performed to emit acoustic signals on the surface of the pipeline section. Based on the test results and assessment, corrective measures were prescribed to restore the pipeline to optimal operational condition. A multi-channel acoustic system was utilized to carry out the tests on the pipeline section.

KEYWORDS: ACOUSTIC SYSTEM, PIPELINE INSPECTION, LEAK TESTING, PIPELINE INTEGRITY

1. Introduction

The Acoustic Emission (AE) method is based on the occurrence and propagation of elastic oscillations (AE waves) during the formation and development of defects in the material of monitored objects. These elastic oscillations are recorded and converted into electrical signals by piezoelectric sensors, which are placed on the surface of the objects according to a specific sensor placement scheme (sensor layout plan). Based on the parameters of the recorded AE signals (amplitude, duration, energy, etc.), conclusions are drawn about the hazard level of the signal sources. The location of AE sources is determined by calculating the time difference of signal arrival at various sensors.

Pipelines are a vital part of industrial infrastructure, as they play a crucial role in the transportation of liquids and gases in various industries. They are also one of the most popular modes of transport globally due to their accessibility, safety, and economic benefits. However, pipeline leaks can occur due to factors such as fatigue cracks, material corrosion, material defects, and environmental influences. A leak can result in economic losses and pose potential environmental contamination risks. Therefore, early detection of leak conditions is extremely important for ensuring the stability and reliability of pipeline systems. It should be emphasized that detection of a leak condition refers to the task of identifying the presence of a leak in the pipeline, without considering its location. Thus, detecting leak condition does not involve localization, which is inherently complex and labour-intensive to perform [1].

Acoustic Emission (AE) is an excellent tool for detecting and localizing developing defects in buried pipelines. Access to the pipeline is required only locally for the installation of AE sensors. The pipeline remains pressurized, and AE testing can be conducted on sections up to 1000 meters in length at a time. AE sensors detect turbulent flow at the leak site, and with the use of digital AE systems and specialized software, the leak location is determined. This paper provides a technical description of the AE method, outlines the necessary features of AE equipment for performing such tasks, and reports examples of successful applications of the method on an operational underground gas pipeline [2,3].

2. General provisions and brief description of acoustic emission testing (AET) and its application methodology

The study of the acoustic properties of a pipeline section was conducted in accordance with the requirements of European Standard EN 14584:2013, which regulates acoustic emission testing (AET) of pressure vessels and other related activities.

To address the task, an experiment was conducted to emit acoustic signals on the surface of an 800-metre pipeline section with a diameter of $\phi 150$ mm, wall thickness of 10 mm, and burial depth of 800 mm. Based on the test results and assessment, corrective measures (if necessary) are to be prescribed to restore the pipeline to optimal operational condition.

For conducting tests on the pipeline section, a Vallen Systeme GmbH (Germany) 8-channel acoustic emission (AE) system was used.

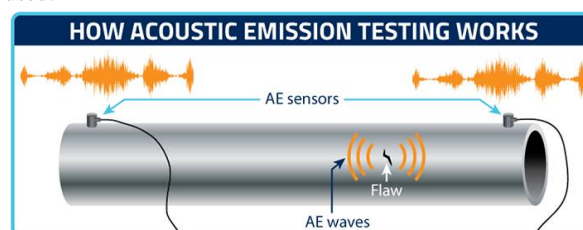


Fig. 2.1. Principle of AET

AE, or Acoustic Emission, is the emission of acoustic waves by the monitored object.

AET, or Acoustic Emission Testing (method), is a testing method based on the analysis of elastic waves of acoustic emission.

An AE source is an acoustic emission source, which is the area of the monitored object where a particular type of energy is converted into the mechanical energy of acoustic emission.

An AE signal is an acoustic emission signal, which is a changing stochastic value that reflects information about acoustic emission.

Continuous AE is acoustic emission whose mechanical signals represent a continuous wave field or are recorded as a continuous signal.[4]

AET is an acoustic emission transducer, which is a device that converts the mechanical AE signal into an electrical signal.

3. Equipment (devices)

AE registration system made by Vallen Systeme GmbH, Germany, is an 8-channel AE signal registration and record system AMSY-6 model MB6 by Vallen Systeme GmbH. It conforms to the EN13477-1 "Non-destructive testing - Acoustic emission.

This is a multi-channel modular system for collecting and processing AE information, featuring a high-speed digital data transmission channel.

It ensures continuous real-time acquisition of all test data, explosion-proof design, and the ability to automatically control the testing process.

All processing of the obtained information and calculation of AE parameters occurs directly in the module located on the monitored object, with the transmission of processed data carried out in digital form, ensuring galvanic isolation of each module.

The design principle of the system and its capabilities allow the Vallen System to be used for both mobile periodic monitoring and stationary continuous monitoring, with the ability to control the monitored object.

The cable segments connecting the modules can vary in length depending on the characteristics of the monitored objects, and the use of standard adapters allows for the extension of segment length if necessary. Furthermore, it becomes possible to position the

system and maintenance personnel at the maximum possible distance from the monitored object.

The Vallen System offers the following features: adjustable gain, software-switchable filters, pulse emission mode, a digital oscilloscope with the ability to set an independent threshold and adjustable sweep, three parametric channels with the option to reconfigure as control outputs, a temperature sensor, and a bi-colour status indicator for the AE module, all of which are available for each channel.



Fig.3.1. Vallen System AE processor unit (below) with the recording PC (on top) AE sensor VS-150-RSC

4. The object of testing

The object of testing is a section of a natural gas pipeline system (gas-methane-CH₄) consisting of 800 metres of steel pipe with dimensions $\varnothing 150 \times 10$ mm, located as part of a gas distribution installation at a burial depth of 800 mm.

A section of 800 metres of steel pipeline is between the line valves and the gas distribution station.



Fig.4.1. The object of AE testing

Conditions for AE testing

Sensors were installed in the pits on the pipe, with the working medium being compressed methane gas (CH₄); the level of acoustic noise is no more than 57 dBA; vibration level - there was no vibration detected during the registration of AE signals; electromagnetic interference - no interference present; frequency of pulsed electromagnetic interference - less than 0.01 Hz; ambient temperature - plus 19°C; No abnormal phenomena affecting the results of AE testing were recorded.

5. Preparation for AE testing

During the preparation for AE testing, safety measures were taken in accordance with the requirements of the current regulations (Operator of the monitored object - a 800-meter pipeline section).

Excavation work was carried out to enable the technical inspection and access to the pipe.

The insulation coating of the pipe and the condition of the shut-off valves were inspected and found to be satisfactory.

The main pressure gauge indicating the operating pressure was also checked.

The insulation layer on the pipe at the sensor attachment points was removed, and the surface (40x40 mm) was cleaned to a shiny metal finish using a grinding disc.

To reduce the level of interference, the following measures were implemented:

- a reliable alternating current source with a voltage of 220 V (50 Hz) was provided, along with secure grounding;
- all activities unrelated to the AET were halted during the AET (silent mode at the site).



4.1



4.2

Fig.5.1. Standard processing

Fig.5.2. Sensor installation locations

AE transducers of type VC-150RSC were installed to ensure reliable ultrasonic contact with the bare metal of the pipe using CIATIM-221 lubricant, and secured at the top of the pipe with rubber bands and powerful permanent magnets as holders.

The AE system was located near the midpoint of the pipe to ensure the safety of the AE testing specialists and maintain operational contact with the pipeline personnel for monitoring the stages of work. The registration of AE signal parameters was carried out by connecting the AE measurement channels in a parallel configuration on the pipe.[5]

To ensure the reliability of the AE measurements, a trial measurement of the AE signal was conducted by the AE device in the first pit, 40 meters from the gas pumping station.

The AE testing of the steel gas pipe was conducted in seven stages: first, the pressure was reduced to the accessible minimum of 20 bar, followed by an increase back to 27 bar and holding, as well as an increase to the maximum accessible pressure of 34 bar and holding, during which the gas (methane) was retained in the internal cavity for approximately 10 minutes at each holding stage.

- 1st stage - pressure - 34 bar (with subsequent reduction);
- 2nd stage - pressure - 20 bar (with subsequent increase);
- 3rd stage - pressure - 27 bar (with subsequent increase);
- 4th stage - pressure - 34 bar.

During the AE testing, preparatory measures were carried out. No electromagnetic interference or abnormal phenomena affecting the results of the inspection were observed during the AE testing.[6]

The pressure loading programme for the object of testing was coordinated based on the technological capabilities of the customer

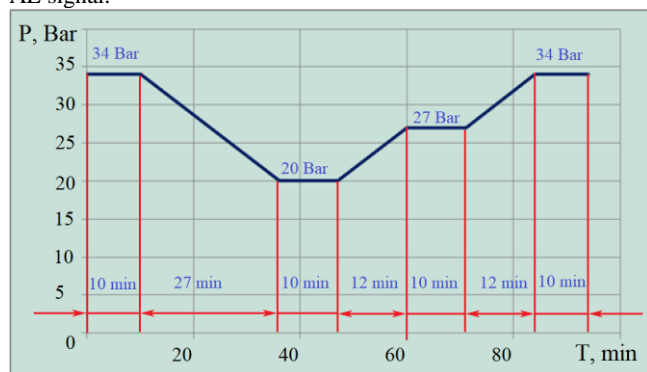
to prevent any interruption in gas supply to consumers, without taking the tested object out of operation.

Table 1 presents the operating gas pressure at the time of testing.

Testing stage	Time, min	Operating gas pressure, bar	
		Initial	Final
1	10	34	34
2	27	34	20
3	10	20	20
4	12	20	27
5	10	27	27
6	12	27	34
7	10	34	34

Table.1 Operating gas pressure at the time of testing

Operating gas pressure at the time of the experiment - 34 bar. T/minute - the time required to reduce the pressure by 14 bar, to increase the pressure by 7 bar, and the time required to register the AE signal.



AE diagnostics (10 min)

Fig. 5.3. Load chart of the AE testing object, with pressure holding time of 10 minutes (600 seconds).

6. Processing and presentation of AE testing results

AE signal registration was carried out during the pressure holding stage, with AE signals during pressure release and increase being filtered out.

Id	DAY	HMMSS	MSEC	CHAN	THR	A	D	R	CNTS	E	SS
		[hhmmss]	[ms_μs]		[dB]	[dB]	[μs]	[μs]		[eu]	[nVs]
La Label 1:		16:02									
Dt	Tuesday, May 21, 2024,										
La Label 2:		16:06	12 605.8159	3	36.1	38.1	8.2	0.3	2	755E-2	352E-2
Ht		21 16:06:12									
La Label 3:		16:12									
Dt	Tuesday, May 21, 2024,										
La Label 5:		16:43	11 542.0959	1	36.1	44.6	1573.1	32.1	53	244E00	521E-1
Ht		21 16:43:11									
La Label 6:		16:46	49 952.9406	1	36.1	37.8	204.7	204.2	1	365E-1	121E-1
Ht		21 16:46:49									
La Label 8:		17:03	05 207.9426	1	36.1	41.3	613.7	204.5	21	105E00	263E-1
Ht		21 17:03:05									
La Label 9:		17:13	14 816.7661	4	36.1	37.5	49.0	0.4	0	967E-2	474E-2
Ht		21 17:13:14									
La Label 11:		17:27	50 935.6118	3	36.1	42.2	1236.7	339.6	40	199E00	445E-1
Ht		21 17:27:50									
La Label 12:		17:36									

Fig. 6.1. Table of AE test data by channels: channels No. 1 - 8

During the first holding period, two instantaneous signals were recorded on AE sensor No. 3 (at 2338.025117 seconds) and No. 4 (at 2355.18251 seconds).

AE signals did not recur during the subsequent holding stage. All other AE signals were obtained during transitional phases and can be disregarded. The acceptable source is corrosion delamination on the inner wall of the pipe.

During the testing, the detected AE activity indicated a minor signal and is classified as “non-critical”. At the time of the AE testing, the pipe showed no risk of significant defects, despite a sufficiently long period (35 years) of regular operation.[7]

It is recommended to conduct monitoring and testing at established regular intervals in accordance with the quality documentation approved by the operator.

At the time of the AE testing, the detected AE activity indicates the possible presence of minor corrosion on the inner walls of the pipe.

7. Conclusion

Based on the results of the pipeline section testing, it should be noted that the most optimal non-destructive testing method, which allows for the establishment of monitoring systems, is the integral acoustic emission method. Its application is possible for monitoring a wide range of technical devices, and its existing advantages enable the determination not only of the location but also of the hazard class of AE sources (fatigue and corrosion damage). The AE method does not require scanning the surface of the object (to assess the condition of the object, it is only necessary to install several sensors stationary on its surface), allowing for real-time monitoring of the object (On-Line). The detection of AE sources will play an even more critical role in the future, achieving its objectives while conserving valuable resources and protecting the environment. The use of scanning non-destructive testing methods is necessary as a tool to confirm registered damages.

Monitoring is effective if it is strategic in nature, aimed at achieving specific results, timely, responsive, accurate, and cost-efficient.

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