The COMPACS®-AE Static Equipment Monitoring System

The COMPACS®-AE system is a part of the comprehensive COMPACS® computer-aided monitoring system that can be used independently. It is designed for continuous monitoring and evaluation of hazardous production facilities health, such as coke drums, reactors, pipelines and other static equipment without decommissioning. Monitoring is carried out according to parameters of vibration, acoustic emission (AE), temperature, pressure, stress-strain state and others, with detection of cracking and deviations in the technological process.

Recently an acoustic-emission testing has been recognized one of the most efficient health monitoring techniques.

The advantages of NDT Acoustic Emission techniques are:

- **Integrity**, which means you can monitor the facility in whole;
- **Flexibility**, which means you can monitor any structures and materials under any conditions, including in service;
- **Remoteness**, which means you do not need to prepare the whole surface of the facility, for example to remove the insulation, except for the sensor locations.

The techniques allow not only to detect and record emerging defects, but to classify them by hazard at minimum tool and manpower costs. An acoustic emission signal from each sensor gives the parameters describing the equipment health. In addition to the acoustic emission sensors, the system can use unique fiber-optic transducers that measure the surface temperature of vessels and pipelines, and X-Y axes deformation.

The COMPACS®-AE system monitors the condition of materials, detects the presence, location and category of acoustic emission sources in real time. The system displays the health state of column and vessel equipment and pipelines as a surface development. If any defect, the system indicates its location, type, growth rate and hazard rate. The personnel can take timely measures, plan repair works and prevent accidents. To carry out repairs the personnel do not inspect the entire surface of vessels or pipelines. They just repair the places automatically indicated by the system.

**The COMPACS®-AE System Advantages**

- Display of the readings as **coloured pictograms**, where green is acceptable, yellow is actions required, red is unacceptable, and user-friendly diagrams with numeric parameter values.
- Reliable signal detection in high level industrial noise conditions, integral in-service equipment health estimation, localization of acoustic emission sources that are the areas of origin and/or growth of defects.
- Use of the data obtained from the system to calculate the equipment resource that prolongs its operation time without decommissioning.
- Multistage signal processing including pre-filtering, signal processing and detection of acoustic emission pulses at the hardware level. Pulse filtering during the discrimination of events.

- Creation of diagnostic features vector for each signal channel.

- Location of AE sources under a priori uncertainty of material performance, facility wall constructions and acoustic wave propagation. It is based on a facility 3D model using statistical data for a specified monitoring interval, depending on both the facility operation mode and its process cycle.

- Automatic detection of AE sources by plotting the clusters with increased activity on the event location map using adaptive criteria based on probabilistic models.

- Monitoring of AE sources state, evaluation of their hazard by the activity dynamics based on the exponential model of defects development, the built-in expert system with automatic personnel instructions.
- Full system self-test from the check of the signal channel, the sensor's cable integrity, the sensor fault, the sensor-to-facility acoustic contact, the
sensor installation that is geometrical sensor arrangement on the facility, to the estimation of location accuracy and the system dead time.

**Multichannel Digital Hardware Platform**

The hardware of the COMPACS®-AE system is placed next to the monitoring facility. The AE sensors are mounted on the facility and connected to the acoustic signal modules with a coaxial cable. All the modules are connected in a single chain or ring topology network with a standard UTP-cable. The synchronization of the modules is carried out using the same cable.

The explosion-proof media converters transmit the diagnostic data through fiber-optic lines to the diagnostic station. The hardware is powered from the nearest 220 V substation.

The system has **1ExibIIBT4 explosion protection**.

**Key Benefits:**

- The smart AE sensor with a current loop output provides high dynamic range (over 80 dB) and selection of proper gain.
- The sensor switches by the system command in the AE transmitter mode. It maintains control for the acoustic connection to the monitoring facility and sensor locations.
- The 8-channel acoustic signal modules provide parallel signal recording, filtering and processing, including amplitude-time selection.
- The modules inter-synchronization ensures the system scalability. Several modules act as a single multi-channel module (up to 64 channels).
- The line and inroute check functions provided in the module ensure full system self-test.
- All system components have high-class explosion protection, anti-vandal protection and industry design for a wide range of climatic conditions. It allows place the hardware next to the monitoring facility.
- The fiber-optical lines provide reliable high-speed connection of the fieldbus with the diagnostic station.
- The detailed design of the system components provides fast and high-quality installation of the system.

**The COMPACS®-AE Software**

The software is divided into two parts: the server part that performs processing and storage of diagnostic data, and the client part or the terminal that displays the data and implements the user interface.

The multi-platform implementation allows you to use the server part under Linux that provides continuity and stability, and the client part under Windows that provides users with a familiar interface.

The distributed modular architecture allows to combine in one system the various techniques of static and dynamic equipment diagnosis, and to connect multiple terminals.

The multi-threaded signal processing ensures high system performance.

The implementation of the software interface using the 3D graphics based on OpenGL provides high-quality presentation of diagnostics and monitoring results.

The software supports a wide scalability from embedded systems, personal and industrial computers (including panel) to multi-processor server platforms.

The **MONITOR** mode displays the equipment location map, which allows you to determine the location of acoustic emission signal source.

The section field shows the general condition of all facilities monitored by the system. If you set the cursor on the selected facility, its detailed health state according to the acoustic emission parameters displays on the right part of the screen. The facility state is displayed as a conditional facility image divided into zones with indication of the sensor places (on the left of the screen) and location zone (on the right).

The location zone represents a surface development of the facility (columns, reactors, tanks, pipelines) that is divided into location zones and indicates the zone acoustic activity level. The numeric symbols on the location map denote the number of AE pulses in the location zone.

The upper part of the screen displays the diagnostic features of acoustic emission used to monitor the facility health, namely instantaneous and accumulated values of energy, number of AE pulses, the amplitude of AE pulses, the AE pulses rate and etc.

The cursor automatically sets on the most dangerous zone and, in case of danger the system issues a diagnostic message in text, graphical and verbal form.
The COMPACS®-AE Software - MONITOR Mode

The **MACHINE-MAN-ELECTRICIAN LOG** mode automatically forms the following protocols:

- General Equipment Condition;
- Detailed Equipment Condition;
- Equipment Repair History;
- Repairs Scheduling;
- Unit Equipment in a Certain State;
- Events Recorded in the System Event Log;
- Table of Possible Repair Causes, Repair Works and Replacements.

The **TREND PLOT** mode displays the trends of total pulses, the total pulse energy, temperature and its rate of change, linear expansion and its rate of change, local deformation and its location temperature.

The trends of local deformation at various points allow us to estimate the magnitude of the stress-strain state of the vessel or pipeline material. The trends of temperature and linear strain, and their rates of growth characterize the operating modes. The absolute values of parameters do often not exceed the levels specified by the vessel or pipeline operating regulations, while the gradients of the controlled parameters quite often exceed preset thresholds, which indicates high destructive loads on the equipment.

The total AE signal energy parameter is an adequate indicator of the correctness of the technological process. Even peaks show that the process is steady. Uneven peaks show violations of the technological mode in certain cycle.

The **expert system** analyzes information on current parameter values, their time trends and spectral signal characteristics, and automatically interpreters the analysis results in terms of the equipment health.

The **system network opportunities** are provided with the built-in support for dial-up (telephone) networks that use modems for data transmission, and network protocol support. It is a possible to publish the data on the built-in Web-server that provides an access to the system data for all users equipped with standard software for the Internet work.

The **engineering solutions**, implemented in the system are protected by patents of the Russian Federation on various intellectual property and the certificates on official registration of computer programs.

The COMPACS®-AE System Application Examples

**Integrated Monitoring of Delayed Coking Unit Drums**

Automatic diagnostics of a coke drum is normally carried out through the channels of:

- acoustic emission that online monitor the processes of defects development;
• linear displacements that monitor linear extension and the vector of reactors slope;
• deformations;
• temperature that show the temperature field of the reactor walls and its gradient.

The experience in application of the systems involves the regenerators within the FCC reactor-regenerator section block and the liquefied hydrocarbons storage tanks.

![Total AE pulses showing an unsteady coking process](image)

![Total energy of AE pulses showing uneven load of the drum in different cycles](image)

![Local deformation along X and Y axes showing change in the stress-strain state of the drum walls in different cycles](image)

![Temperature in the local deformation measuring point showing change in thermal stress of drum wall local areas](image)

**The COMPACS®-AE System Economic Effect**

We have analyzed the COMPACS®-AE system introduction and operation costs through the example of four coke drums of the 21/10-3M unit. The analysis revealed that during a two-year operating cycle the overhauls and standard downtime took 64 days. The COMPACS®-AE system had reduced the downtime for repairs to half through targeted repairs and real-state operation, which in turn made possible to annually get additional products worth over 1.2 million dollars. The system implementation paid back by reducing the unit repair downtime for just three days and allowed increase four times the run between repairs.

The implementation of the COMPACS® monitoring system at hazardous production facilities allows significantly improve the safety of equipment operation and operate all processing facility equipment according to its real condition due to health monitoring of dynamic equipment (pumps, motors,
compressors, etc.) and static equipment (reactors, furnaces, pipelines, etc.), which substantially increases its capitalization.

<table>
<thead>
<tr>
<th>Specifications</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic Signs Vector Correspondence According to ED 03-299-99</td>
<td>yes, exceeds 80...120</td>
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<tr>
<td>Frequency Range, kHz</td>
<td>35...5x10^3</td>
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<tr>
<td>Amplitude Range, µV</td>
<td>80</td>
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<tr>
<td>Dynamic Range of AE-signal Amplitude Measurement, dB, not less</td>
<td>165</td>
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<tr>
<td>Dynamic Range of AE-signal Energy Measurement, dB, not less</td>
<td>3</td>
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<tr>
<td>Flatness, dB, not more</td>
<td>± 2</td>
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<tr>
<td>Maximum Relative Error of AE Amplitude Measurement, dB, not more</td>
<td>3.1x10^6</td>
</tr>
<tr>
<td>AE Pulse Duration Measurement Range, µs</td>
<td>3</td>
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<tr>
<td>Time Parameters Measurement Error, µs, not more</td>
<td>20</td>
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<tr>
<td>Hardware Dead Time, µs, not exceeding</td>
<td>10000</td>
</tr>
<tr>
<td>Maximum AE Pulse Processing Speed for a Channel, s^-1, not less</td>
<td>10</td>
</tr>
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</table>

Specifications subject to change without notice.