The COMPACS® computer monitoring system for machinery health control and accidents prevention

The stationary equipment monitoring system COMPACS® serves for safe ecological resource-saving operation of fire explosion production facilities, accidents prevention, production failures and units health control by means of stationary computer monitoring. The COMPACS® system automatically provides vibration analysis extrapersonal diagnostics, monitoring and health forecast of the units, issuing recommendations for operators and chief executives on the nearest urgent actions to be taken by means of the diagnostic network.

Condition (Health) Monitoring – is diagnostics of the main equipment and its assemblies failures with a probability close to 1, on continuously adjoining such time intervals when the machinery condition does not change significantly. The machinery condition monitoring allows to detect timely the destructive loads, defects and malfunctions and to take effective actions on the restoration of the acceptable condition and to stop the malfunctions developing.

The COMPACS® system is an all-purpose comprehensive machinery condition monitoring system which possesses a flexible distributed parallel-serial architecture, providing a high speed and accuracy of the information processing (scanning rates for rotating equipment are less than 0.02 sec per channel, for stationary equipment - on a real-time basis), which allows to carry out the following main principles:

1. **Information Completeness Principal** provides a diagnostic criteria choice, which reduces the failure omission probability.
2. **Sufficiency Principal** determines a choice of the minimal sensors number, which provides observability of the machinery health.
3. **Invariance and Collective Identification Principal** regulates selection of collective diagnostic principles, invariant to the machine construction and connection with its health parameters.
4. **Structural Flexibility and Programmability Principal** provides realization of an optimal parallel-serial system structure.
5. **Measuring Path Faultiness Correction Principal** carried out through computational methods (correction of sensors nonlinear effect, gain-phase characteristics, match-converting links, etc.) allows to provide high metrological characteristics of diagnostic and monitoring systems with small equipment costs.
6. **Principal of Self-diagnostics and Automatic Check-up** of the measuring and controlling system channels provides an easy launch, maintenance and repair of separate channels, metrological and functional system reliability, its survival rate and adjustability to the constant changing real production conditions.
7. **User-friendly Interface with Maximal Information Capacity of the Display Principal** allows an operator to identify the technological system general health, at mere sight of the display and to get a designation instructions on the nearest urgent actions.
8. **Multilevel Structure Principal** allows specialists with different qualification and responsibility levels to operate the system.

The COMPACS® comprehensive monitoring system uses such non-destructive control methods, as vibration, acoustic emission, thermal, electric, vortex-current, acoustic, optical and other. The complex usage of this methods allows to control both rotating (pumps, compressors, etc.) and static equipment (columns, reactors, tanks, pipelines) on the single soft-hardware platform and in the common information environment, which constitutes the COMPACS®-AE system.

Vibration sensors allow to measure 3 vibration parameters simultaneously: vibration acceleration, velocity and vibration displacement. Joint analysis of vibration acceleration, velocity, vibration displacement and their growth rates, stochastic and spectral-correlation characteristics of vibration parameters allows to detect the defects at the formation stage, which has been proved by the 20-years operating experience of the COMPACS® system, implemented at hundreds of factories of 12 Industries.

The comprehensive stationary equipment monitoring system COMPACS® belongs to the first class systems (according to the RF GOST R 53564-2009) and can be used for the comprehensive processing station monitoring, including objects of the first, second and third categories with the dangerous units automatic blockage function, and provides the safe resource-saving machinery operation according to the actual health.


The COMPACS® system advantages

The COMPACS® Health Monitoring System automatically and in real-time carries out the following actions:

1. diagnostics and forecast of the main failures (>95-98%) with early detection, full usage of the resource and saving of maintainability;
2. personnel warning on the nearest urgent actions connected with the machinery health control;
3. control of the diagnostic instructions fulfillment and the personnel actions via Internet technologies;
4. formation of the goal-orientated repairs schedules on the basis of the actual machinery condition;
5. diagnostics, operation, replacement and equipment recourses database maintenance, reports on all levels of the plant management;
6. detection and elimination of fundamental reasons of the machinery failures;
7. elimination of assemble and design errors;
8. optimization of technological schemes and configuration.

The COMPACS® systems are certified with the most strict requirements of explosion safety (0ExiaIICT6).

The COMPACS® systems are registered in the State Register of Instrumentation under No 20269-07 (Certificate of approval of instrumentation type RU.C.28.004.A No 27641).

The COMPACS® system has an open architecture, and the number of measuring channels can be increased to 8192, depending on a client's demands and whether is possible or not to integrate with an Automatic Process Control System by means of the COMPACS®-OPC Server Software.

The COMPACS® system has a built-in self-diagnostic system, substantial mean time between failures, which provides an unattended operation during run-to-failure, and makes low demands to the personnel.

The COMPACS® system structure

The Static Vibration Analysis and Health Monitoring System COMPACS® includes:

![Diagnostic station of the COMPACS® system](image1)

Console diagnostic station

![COMPACS® system controls different equipment states using one soft-hardware platform](image2)
- **distributed sensors system**, controlling the main equipment parameters;
- **distributed remote modules system**, carrying out primary transfer of sensors signals and their transmission in diagnostic controller, as well as integrity control providing sensors and communication lines;
- **diagnostic station**, responsible for collection, storage, data processing and issuing of monitoring results;
- **enterprise diagnostic network Compacs-Net®**, providing full and timely information on the machinery health for all users (from chief executives to shop personnel).

**SCADA - The CORNET® Distributed Fieldbus**

Appeared in 1991, the CORNET® has become the first Russian distributed fieldbus of measuring and control modules that provides data collection from various sensors (vibration, temperature, pressure, flow rate, current, acoustic emission, discrete signals, etc.) and control signal output. Being produced in 1996 in the USA, the fieldbus consists of 2 cables (coaxial or twisted pair). Data transmission is carried out in Manchester-2 format.

Sensors construction provides efficiency and metrological characteristics of the Vibration Analysis System Compacs® in the conditions of the real-time machinery operation in the continuous health monitoring mode. The Compacs® system sensors mounting does not presuppose violation of the machinery safe functioning; all sensors are mounted without violation of the unit design, thus, coordination with a manufacturer is not required.

The CORNET® fieldbus includes 2 basic peripheral modules:
- universal programmable PIH™ module, that has 8 analogue inputs and a feature for programming the type of connected sensor and the parameters of measuring channel;
- discrete I/O module 4428, that has 16 programmable channels of discrete block I/O with galvanic decoupling.

The COMPACS® system remote modules are mounted in a close proximity to the measuring object, where measuring sensors are placed. The modules are placed in protective ducts or metal boxes. There are special explosion-proof modules of 0ExiaIICt5 class, and sensors of 0ExiaIICt6 class, which can be used in all fire explosive class areas, they also possess dust and water protection IP-54. Working temperature range of the modules varies from -40 to +60 °C. One of the main distinctive features of the COMPACS® systems is a low power consumption (does not exceed 50 mW per channel) of remote modules distributed fieldbus at a broad transmission band (0.25 kHz) of the measuring channels.

The modules can be connected to the diagnostic station through two connection lines, one of which is the power supply and control line, and the other is the signal line. The length of communication lines is more than 500 meters. The power and control line (PCL) is used for transmission of control signals and powering the module. The signal line (SL) is used for transmission of analogue and digital signals to the diagnostic station.

The wireless fieldbus Compacs-Radio-Net®, based on Ethernet-intelligent modules 4440, can be built.
The main advantage of the Vibration Analysis System COMPACS® is the automatic expert system for decision-making support.

The COMPACS® Expert System (ES) is designed for automatic diagnostics and predicting the equipment health. The COMPACS® ES uses vibro-acoustic, acoustic emission, current, ultrasonic, thermal, and parametric (pressure, level, flow rate, temperature) diagnostic methods. The COMPACS® ES belongs to the class of decision-making support expert systems, which means that the ES aims at helping the operators to take the necessary grounded decisions regarding the machinery operation and maintenance.

The COMPACS® ES inferencing Principal

The automatic expert system for decision-making support uses such current values of diagnostic features as input data, their time trends, spectral and cepstral signal characteristics. The expert system is invariant to the diagnosed equipment parameters, which makes the diagnostics possible even without full data on the machinery design features. Automatically, without specialists (diagnosticians) assistance, the expert system detects defects and malfunctions and issues the task list that should be followed in order to make the machinery operational.

Receiving signals from the sensors located on the diagnosed equipment the COMPACS® system generates a vector of diagnostic indicators consisting of 3 groups:
- general type parameters by signals from sensors;
- rate of parameters change;
- indicators calculated as a result of processing trends, spectra and cepstra.

The diagnostic indicators vector then enters a processing unit of the Expert System logic predicates. The conclusion made by the expert system is based on the results received from the latter.

As a result, the automatic diagnostic expert system generates diagnostic instructions, displayed on the main screen in the form of text messages, and also generates commands to the voice warnings output module. The expert system allows to diagnose rolling bearings, valves, reducers, electric motors, centrifugal pumps, centrifugal and piston compressors. The system can evaluate the rate of a parameter change by any parameter, and this is one of the diagnostic indicators which is invariant to the machinery type.

Independence from the diagnosed machinery allows users to configure and distribute the system easily. Due to availability of the built-in programming language - CDPL, it is easy to implement new rules based on the personnel experience of the system operation.

### Defects automatically indicated by the COMPACS® Expert System

<table>
<thead>
<tr>
<th>Centrifugal machines</th>
<th>Reciprocators</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bearing:</strong></td>
<td><strong>Valve:</strong></td>
</tr>
<tr>
<td>- poor lubrication;</td>
<td>- springs, plates breakdown;</td>
</tr>
<tr>
<td>- deformation;</td>
<td>- lack of hermeticity (oission);</td>
</tr>
<tr>
<td>- weakening;</td>
<td>- condensate ingress (hydraulic impact);</td>
</tr>
<tr>
<td>- outer ring defect;</td>
<td>- technological mode violation.</td>
</tr>
<tr>
<td>- error of an outer ring form (out-of-roundness, facets, roughness);</td>
<td></td>
</tr>
<tr>
<td>- internal ring defect;</td>
<td></td>
</tr>
<tr>
<td>- error of an inner ring form (out-of-roundness, facets, roughness);</td>
<td></td>
</tr>
<tr>
<td>- roller defects;</td>
<td>- wear of a babbitt layer;</td>
</tr>
<tr>
<td>- separator defect;</td>
<td>- weakening of fastening;</td>
</tr>
<tr>
<td>- breach of oil wedge in a plain bearing.</td>
<td>- poor lubrication.</td>
</tr>
<tr>
<td><strong>Gear:</strong></td>
<td><strong>Crankshaft bearing:</strong></td>
</tr>
<tr>
<td>- coupling defects;</td>
<td>- wear of a babbitt layer;</td>
</tr>
<tr>
<td>- gears defects.</td>
<td>- weakening of fastening;</td>
</tr>
<tr>
<td><strong>Machine:</strong></td>
<td>- poor lubrication;</td>
</tr>
<tr>
<td>- fastening problems;</td>
<td>- gap increase in a finger-slider interface.</td>
</tr>
<tr>
<td>- rotor disbalance;</td>
<td><strong>Slider crank mechanism:</strong></td>
</tr>
<tr>
<td>- wheel rotor defect;</td>
<td>- wear of a babbitt layer;</td>
</tr>
<tr>
<td>- shaft cut: shaft displacement;</td>
<td></td>
</tr>
<tr>
<td>- inadmissible beating of a rotor;</td>
<td></td>
</tr>
<tr>
<td>- inadmissible axial shift.</td>
<td>- weakening of fastening;</td>
</tr>
<tr>
<td><strong>Unit:</strong></td>
<td>- poor lubrication;</td>
</tr>
<tr>
<td>- violation of shaft centering;</td>
<td></td>
</tr>
<tr>
<td>- disbalance of rotating masses;</td>
<td></td>
</tr>
<tr>
<td>- violation of lubrication system operation;</td>
<td></td>
</tr>
<tr>
<td>- violation of basing and attached constructions.</td>
<td>- gap increase in a finger-slider interface.</td>
</tr>
<tr>
<td><strong>Gas-and-hydrodynamic:</strong></td>
<td><strong>Cylinder-piston group:</strong></td>
</tr>
<tr>
<td>- cavitation;</td>
<td>- wear of rings;</td>
</tr>
<tr>
<td>- hydraulic impact;</td>
<td>- wear of a sleeve;</td>
</tr>
<tr>
<td>- air-lock.</td>
<td>- weakening of details fastening;</td>
</tr>
<tr>
<td><strong>Temperature:</strong></td>
<td>- poor lubrication;</td>
</tr>
<tr>
<td>- overheating;</td>
<td>- condensate ingress (hydraulic impact);</td>
</tr>
<tr>
<td>- irregularity of heating;</td>
<td></td>
</tr>
<tr>
<td>- prohibitive gradients.</td>
<td>- technological mode violation.</td>
</tr>
<tr>
<td><strong>Electric:</strong></td>
<td><strong>Unit:</strong></td>
</tr>
<tr>
<td>- current overload;</td>
<td>- weakening of casing components fastening;</td>
</tr>
<tr>
<td>- phase mismatch;</td>
<td>- disbalance of rotating masses;</td>
</tr>
<tr>
<td>- defects of the stator;</td>
<td></td>
</tr>
<tr>
<td>- distortion of the relative position of the rotor and stator axes;</td>
<td>- violation of lubrication system operation.</td>
</tr>
</tbody>
</table>
The COMPACS® Software

The system software comprises of a module for measuring and calculation of the initial parameters, calculation-diagnostic module for analysis of received data (expert system), modules for displaying the information on the diagnostic station screen, voice output, signals analyser with automatic generation of colour matrix, log-book of the mechanical/electric engineer, report printing, a communication through switched Ethernet channels under TCP/IP protocol.

The monitoring system software has a modular structure with the core that makes the following functions available:

- multitasking of the connected application modules and controlling the information exchange among them;
- protection against unauthorized access to the system data and differentiation of a user’s authorization by using a password system;
- control of the software unauthorized use by dint of registration information;
- UPS and WatchDog timer compatibility.

The COMPACS® System Basic Modules

1. **Channels Manager** is used for measuring the signals received from the sensors and transmission of control commands to an execution module of the COMPACS® system. It allows:
   - servicing of more than 20000 channels of the field network CoRNet® modules;
   - synchronised multichannel measurements up to 32 channels;
   - the system scaling depending on the necessary number of different field modules which are capable to transmit not only ready numerical data, but also analogue signals directly to the main controller;
   - ensuring a prompt measurement by one controller: up to 100 measurements of analogue signals per second and up to 1000 measurements of digital ones.

2. **Valuator of diagnostic indicators** is based on the built-in programming language CDPL operation that ensures easy and flexible input of new indicators into the system and is designed for:
   - signal processing and calculation of static and dynamic parameters (temporal realization, spectra, cepstra, envelopes) using the signal processing functions (filtration, synchronic filtration, integration, FFT, etc);
   - calculation of diagnostic parameters: vibration acceleration, velocity and vibration displacement, temperature, current, rotation speed, radial motion, axial motion, pressure, level, voltage at field module input, surface temperature gradient, linear motion, discrete parameters, peak factor, parameters change rate, indicators of synchronous measurements, characteristics of acoustic emission and location, characteristics that take on different values depending on the CDPL-application results;
   - machinery condition assessment and selection of the most hazardous object and a further placing of a cursor on it.

3. **Expert system**, which is invariant to the diagnosed equipment in accordance with the diagnostic rules based on the values of diagnostic indicators:
   - displays expert messages on the screen in the form of a task-setting instructions for the personnel to take actions immediately;
   - controls the emergency units blockage depending on their health through interaction with the operator;
   - automatically saves the temporal realizations of the vibration signals by following a set algorithm (periodically and/or in case of machinery health change).

4. **Data base module** functions are:
   - keeping real-time recording of diagnostic indicators values;
   - automatic saving of the signals time realizations on the expert system commands;
   - automatic saving of trends in case of unacceptable state of measured parameters;
   - saving trends, signals and configuration on external medium (Compact-Flash disc) for laboratory analysis.

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5. **Voice output module** is designed for generating the voice messages that are repeated periodically until the information is acknowledged by the operator.

6. **Interface of the diagnostic network Compacs-Net®** is designed for monitoring of the whole enterprise machinery by:
   - servicing of the network server requests which come through a modem, connected to the telephone network and through an infranetary network using TCP/IP and HTTP protocols;
   - exchange of data on the diagnosed equipment health with the personal systems Compacs®-micro;
   - sending test reports to the Compacs-Net® network server if it is used as a stand system.

7. **Interface with an external metering** instrument allows:
   - scaling the system using the necessary number of measuring controllers (up to 32) connected to the main controller;
   - reduction of interrogation time for the most important and fast-changing parameters by parallelization of the measuring process.

8. **Interface with terminals** shows the unit condition at personnel working places (mechanical, electrical engineers, etc.) in real time.

9. **The Built-in WEB-server** allows accessing remote users information on the diagnosed machinery health from any place on the Earth by using standard browsers, e.g. Microsoft® Internet Explorer.

10. **"MONITOR" mode** is used for issuing the information on all equipment data as light-signal pictograms (green light - acceptable, yellow - measures required, red - unacceptable) and text messages of automatic expert system. The system automatically detects the most hazardous object with the worst condition and marks it with a cursor, issues a verbal warning through a loudspeaker and visual a warning via showing expert messages in the right top of the screen and all measured parameters values and their thresholds in the left top of the screen.

11. **"TREND" mode** allows to look through trends of the parameters controlled by the COMPACS® system. The COMPACS® system carries out trend data analysis by means of the cursor and the information board. The system saves trends and signals when set events appear (inappropriate value of diagnostic feature or object condition). The COMPACS® vibration analysis system displays at least 2 trends for any parameters chosen from the measured ones, using the following time intervals (at the time operator accessed):
   - Real time;
   - 12 hours in increments of 1.5 min;
   - 4 days in increments of 12 min;
   - 40 days in increments of 2 hours;
   - 1 year in increments of 1 day;
   - 9 years in increments of 7 days.

12. **"ANALYSIS" mode** serves for analysis of the temporary realization of signals, spectra, cepstra, etc., in order to control the machinery health in real time, which allows diagnostics to reveal the fundamental reasons of failures, such as operating, projecting and assembly errors. It is possible to process multi-channel signals with different digitization frequencies up to 1 MHz, an accuracy of harmonious components frequency measurement reaches 0.2 Hz. There are spectral matrix options which carry out signal division into periodic and noise components.

13. **"SYSTEM" mode** is used for automatic diagnostics of sensors, modules, measuring lines and diagnostic station, issues the verbal warning through the loudspeaker and the visual warning via showing the expert messages in the right top of the screen (more than 20 automatic expert messages), such as: “check_modules”, “check_line”, “check_sensors”, “place_sensor_on_the_unit”, etc.

14. **"OSCILLOGRAPHY" mode** is used for automation of the metrological system check on the control unit and commissioning and maintenance of the COMPACS® system.

15. **"REAL-TIME OSCILLOGRAPHY" mode** displays the measured signals in accordance with the interrogation mode.

16. **"AFC TESTING" module** is used for testing the system on-site without disassembling within the amplitude and frequency range using Calibrator 8003.

17. **Graphic user interface module (GUI)** ensures:
   - friendliness of graphic interface combined with a maximal information content of the data representation screens;
   - easy perception of the information on the process system health, displayed on the screen;
   - easy control due to the minimum number of buttons;
   - automatic screen switching.

18. **"MECHANICAL ENGINEER LOG-BOOK"** automates documentation and repair-works planning, i.e. has a built-in automated blockage of the equipment operation and repair. The system automatically calculates the values of the units and their assemblies operation between repairs and transfers this data to the company's diagnostic network. The system automatically creates the units repair and maintenance schedules, a list of the units under repair, which contains reasons and defects, allows to create databases on the equipment and its parts replacement works which have been made. Repair planning protocols are of most importance. One can operate the system via the web-server.
19. "EVENTS LOG-BOOK" registers the events not only connected with the diagnosed unit operation, but with the COMPACS® system functioning. EVENTS LOG-BOOK and MECHANICAL ENGINEER LOG-BOOK carry out a reliable feedback between the monitoring system instructions and the personnel activities. After every action taken on the unit or its operation mode the personnel must input an acknowledge message, or state the reason of the unit shutdown, as well as state the types of repairs, works and replacements made. The technology ensures a reliable control of the personnel actions: if a person in charge of the unit has not carried out the required acknowledge through the diagnostic network, it becomes automatically known to all of the higher levels heads. That is how the system provides a rigorous delivery of the diagnostic instructions to the personnel and their fulfillment irrespective of the personnel wishes and other subjective factors.

**The COMPACS® system network features**

The monitoring system's objective information on the machinery health is combined in the one base via the diagnostic network Compacs-Net® and is provided to the users' workplaces for the repair planning and arrangement processes automatization, timely service parts provision, personnel implementation standard control and evaluation of its efficiency.

All the information concerning the machinery health, provided by the COMPACS® systems via Compacs-Net® diagnostic network, is transmitted to the departments heads, responsible for the machinery operation safety. A specialist can see the whole picture of the machinery and technological equipment health without visiting the unit.

This allows not only to see the technological complex state, but control and correct the personnel actions on the system instructions fulfillment, as well as control the technological process.

The network features are provided with the built-in support of switched (telephone) networks, using modems for transferring data and supporting HTTP and TCP/IP protocols. The data can be published on the built-in Web-server, thus giving access to the data on other users' computers that are equipped with a standard internet software.

Implementation of Internet technologies in the COMPACS® software has helped to imply the built-in WEB-server which processes Compacs-Net® network users' requests and allows to receive the diagnostic information using common browsers.

Information on the diagnosed machinery is displayed on the screens of the personnel work-stations (mechanical, electric engineers, etc.) with no addition adjustment of the user software. The screens information layout repeats the screens of the COMPACS® stationary system.

In case when the analysis of parameters trends or signals temporal realizations is needed, all one has to do is to put on Compacs-Net® network software modules - "TREND" and "ANALYSIS".

Due to the Internet-technology support it is possible to exchange diagnostic information by using OPC protocols with the help of the COMPACS®-OPC-Server software installed on the integration station of Automatic Process Control System (APCS). The COMPACS®-OPC Server software is installed on the APCS integration station or network server and works under OS Windows® 9x/NT 4/2000/XP/2003/ Server. Data exchange over OPC protocols allows both transmitting diagnosed parameters and expert messages to APCS or ERP-system of the enterprise as well as receiving parameters from them in order to perform consolidated processing within the COMPACS® system and get instructions generated by the expert system.

**The COMPACS®-OPC-Server software**

The COMPACS®-OPC-Server software is developed to ensure the connection and data exchange between the COMPACS® and APCS/ERP systems. It has the following advantages:

- easy installation and set-up;
- automatic tag-tree building for the COMPACS® configurations;
- two-way transmission of controlled parameter values;
- provision of the COMPACS® system expert messages in the form of individual tags;
- automatic update of the tag tree in case the COMPACS® system configuration is changed.

OPC-client presence in APCS is necessary for functioning of the COMPACS®-OPC-Server software and an additional software, which provides data copying (OPC gateway) is necessary for exchange between APCS server and the COMPACS®-OPC-Server.
Minimal system requirements:
- processor Intel® Celeron 400;
- RAM 64 Mb;
- free disc space 40 Mb;
- network card Ethernet 10/100.

Basic delivery set:
- The COMPACS®-OPC-Server 1.0 software CD;
- user manual;
- registration card;
- license agreement.

The COMPACS®-OPC-Client software
The COMPACS®-OPC-Server software is developed to ensure the connection and data exchange between the COMPACS® and APCS systems, in case, when APCS acts as OPC-server. The software has the following functions:
- The COMPACS® system configurations reception;
- The COMPACS® system diagnostic feature values reception;
- The COMPACS® system expert messages reception;
- transmission of the diagnostic feature values to the local and network OPC-Servers;
- transmission of the expert messages to the local and network OPC-Servers;
- transmission of the tag values, gathered from OPC-Servers to the proper COMPACS® systems;
- visual configuration of the connections between diagnostic features of the COMPACS® systems and OPC-Servers tags.

Operating System Requirements:

Minimal hardware requirements:
- processor Intel® Pentium 4 1.6 GHz;
- RAM - 1 GB;
- free disc space 100 MB;
- network card Ethernet 10/100.

The software universality allows to use it on stationary and stand systems for different purposes. The developed programs novelty and currentness are confirmed by Patents and Computer Programs Incorporation Certificates.

The COMPACS® system economic benefits
Adoption of the safe money-saving operation management technology, based on the COMPACS® monitoring systems, has several goals:
- elimination of accidents and downtime due to the machinery failures;
- maximal increase of the technological complex and its machinery run-to-failure;
- decrease of duration and complexity of processing units shutdown repairs;
- operational expenditures and losses by means of inefficient unplanned and scheduled-preventive repairs elimination.

Emergencies or sudden failures of the machinery can happen when the actual operation time between the unit failures exceeds the regulatory schedule-based preventive repair period. In order the malfunctions development become observable, it is obligatory to carry out continuous diagnostics with an automatic objective results delivery to the departments heads and specialists, responsible for the machinery operation. Machinery real-time health monitoring allows to transfer the biggest part of failures from the sudden failure category to the gradual and preventable ones.

Economy due to reduction of repair expenses is possible by dint of the regulatory schedule-based preventive repair and off-schedule repair elimination because of the machinery operation according to its actual health. Due to timely maintenance, intentional repairs, liquidating fundamental causes of the machinery failures (technology LIFC™), the equipment operation and repair expenses reduce in 6-8 times.

Economy due to reduction of raw stock and the equipment losses from accidents can be calculated due to the lower probability of the accidents occurrence, given by the COMPACS® systems. Conditional time periods between accidents before and after the machinery is commissioned to the operation according to its actual health, can be calculated by the total probability of the unit failure omission by all reasons, which counts less than 2% for the COMPACS® systems.

Economy due to the unit downtime losses caused by the machinery failures, can be defined as extra charges loss reduction, not obtained in the time unit due to the technological complex downtime.

Economy due to the regulatory schedule-based preventive repair period reduction and acceleration of commissioning is connected with timely and purposeful maintenance, repair and elimination of the fundamental reasons of poor efficiency and equipment downtime.

Today economy effect from the COMPACS® systems implementation in Russia and abroad is more them 100 billion rubles.

Industries, succesfully using the COMPACS® systems are the following:

<table>
<thead>
<tr>
<th>Basic Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of measuring channels</td>
</tr>
<tr>
<td>Measured parameters*</td>
</tr>
<tr>
<td>Frequency range*, Hz</td>
</tr>
<tr>
<td>Major metrological specifications</td>
</tr>
<tr>
<td>Measuring range** of vibration parameters</td>
</tr>
<tr>
<td>------------------------------------------</td>
</tr>
<tr>
<td>vibration acceleration, m/sec²</td>
</tr>
<tr>
<td>velocity, mm/sec</td>
</tr>
<tr>
<td>vibration displacement, μm</td>
</tr>
<tr>
<td>Temperature measuring range**, °C</td>
</tr>
<tr>
<td>Pressure measuring range**, kg/cm²</td>
</tr>
<tr>
<td>Level measuring range**, mm</td>
</tr>
<tr>
<td>Axial shift and radial clearance measuring range**, μm</td>
</tr>
<tr>
<td>Measuring range** of alternating current 50 Hz, A</td>
</tr>
<tr>
<td>Shaft rotation speed measuring range**, rpm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>AE channel parameters</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency range, kHz</td>
<td>80 ... 150</td>
</tr>
<tr>
<td>amplitude, dBuV</td>
<td>≤110</td>
</tr>
<tr>
<td>duration, ms</td>
<td>0,02...320</td>
</tr>
<tr>
<td>energy parameter, mV²</td>
<td>10⁻⁴...10⁻⁵</td>
</tr>
<tr>
<td>Sampling frequency of measuring channels, channel/sec</td>
<td>≤100</td>
</tr>
</tbody>
</table>

**Operational Characteristics**

**Characteristics of supply mains:**
- Voltage, V: 220±10%
- Frequency, Hz: 50±0,4
- Power input, W, not exceeding: 160

**Operation-temperature range, °C:**
- diagnostic station: +10...+40
- remote modules: -40...+60
- vibration transducers: -60...+100

**Maximum cable length between components, not less, m:**
- 500

**Time to failure of sensors and remote modules, h:**
- ≥100000

**Service life, years:**
- 10

* The system measures any parameters within frequency range from 0 to 25 kHz, represented as current or voltage in compliance with GOST 26.011-80.
** Measuring range can be programmed for the concrete system configuration.
*** Measuring range depends on the capabilities of the used sensors.
Specifications can be changed without notification.