amc

TECH
VIBRO
WORKS

amc

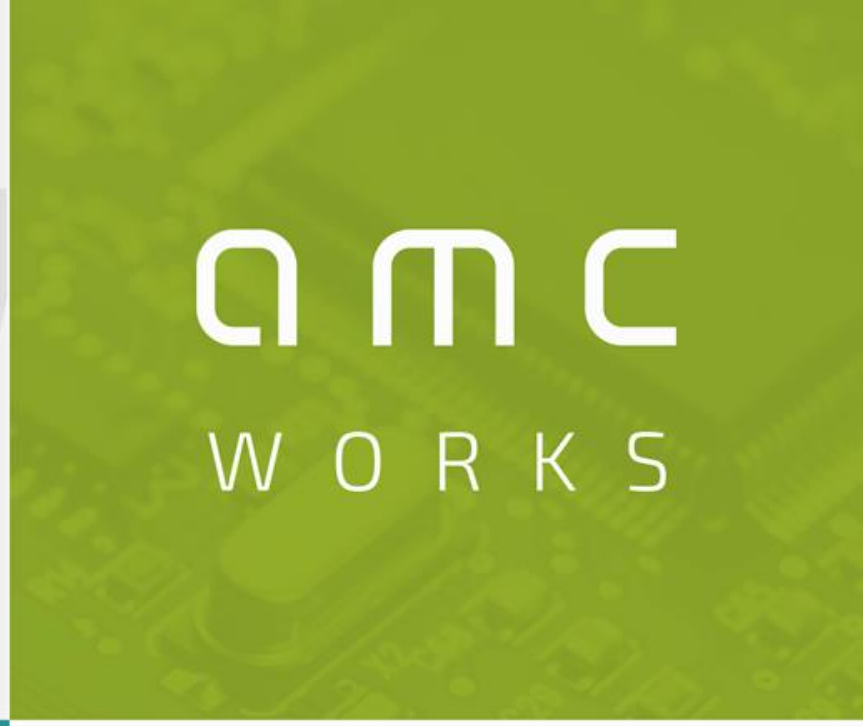
Independent expert in advanced software and electronic solutions for home and industry.

Specialization: **condition monitoring, diagnostics, testing and control.**

www.amctech.pl
www.amcvibro.pl
www.amcworks.pl

02.
AMC WORKS

electronics, mechanics,
and automatics contract **assembly**



01.
AMC TECH

electronics, mechanics and software
design for industry

03.
AMC VIBRO

sales of machinery maintenance
products and services (vibro, laser,
ultrasound, oil, current, infrared)

AMC’s clients

+300
CLIENTS

+20
COUNTRIES

+15
INDUSTRIES

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R&D cooperation

CLOSE COOPERATION

with technical universities from around the world (especially with AGH University of Science and Technology).

AGH
INSA LYON
utc Université de Technologie Compiègne
UNSW AUSTRALIA
The University Of Sheffield.
INP TOULOUSE
cetim
Grenoble INP
DTU
IMP PAN GDAŃSK

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AMC team

>100 engineers

>20 years of experience

electronic, diagnostic, automation, and software engineers

technical and management certificates

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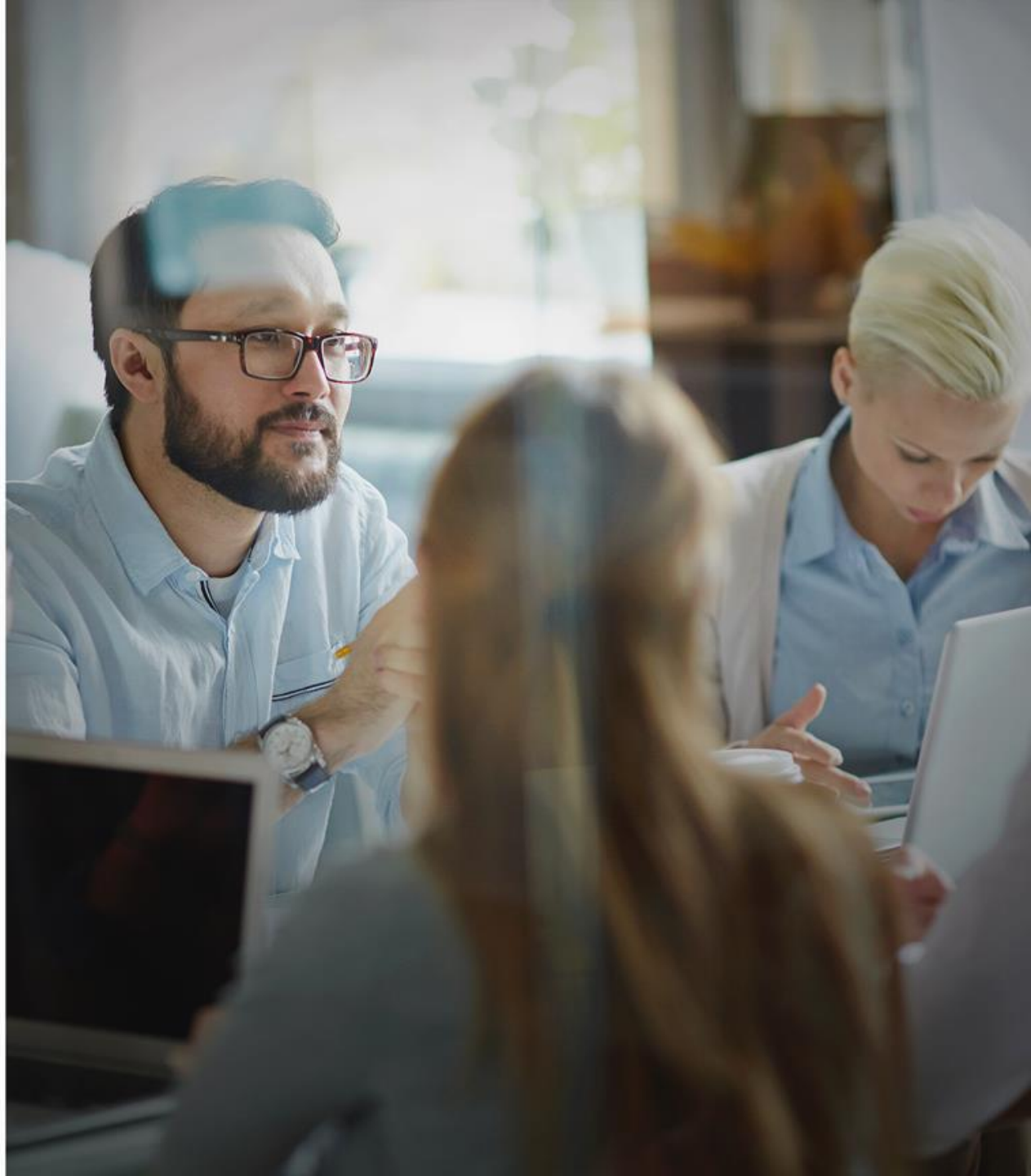

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THE COSTS, RISKS AND RETURN OF INVESTMENT IN MACHINERY DIAGNOSTICS

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What is machinery diagnostics?

Assessment of the technical condition of the machines without dissassambly, by examining the properties of their operation's processes or by examining the properties of the machine's products.

Determines the condition of the machine indirectly, without dismantling, based on the measurement of diagnostic signals and comparing them with the nominal values.

Is it worth it?

- **23%** of business owners confirm that they are suffering losses due to machine faults
- **90%** of those who monitor the condition of machines confirm that they reduced their lack of availability at least twice
- **14%** believe that thanks to diagnostics they avoided a critical failure

The most common causes of machinery failures

operator errors	22%
wear of machine components (including overexploitation)	21%
no inspections, incorrect service	20%
design flaws	14%
bad consumables	12%
environment	5%
unidentified	6%

in 80% of cases

the failure is progressive

Machinery diagnostics – is it worth it?

MODERN DIAGNOSTICS MEANS:

up to **70%**

less breakdowns and downtime

up to **20%**

lower maintenance and maintenance costs

up to **30%**

longer lifetime of the monitored machines

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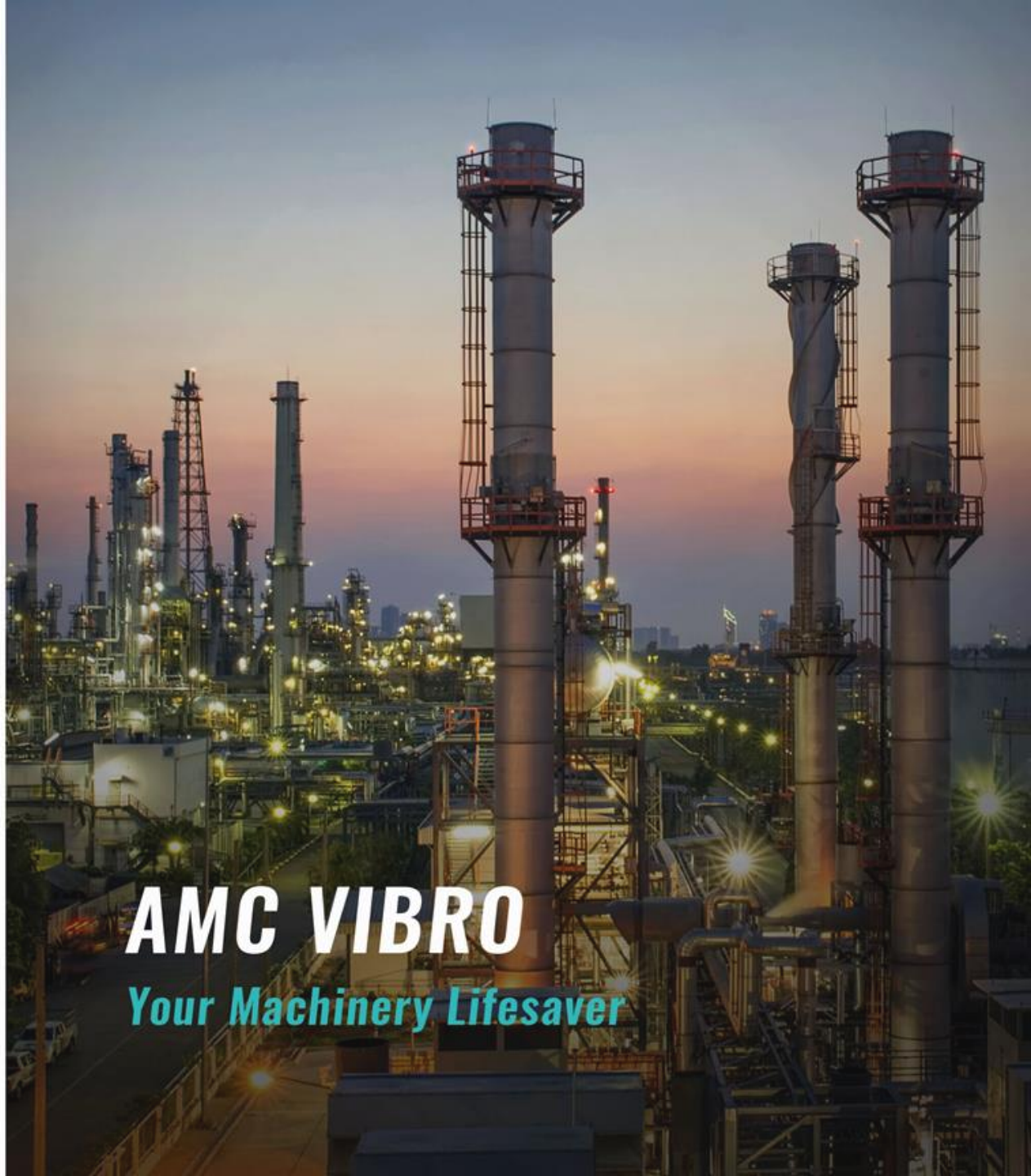
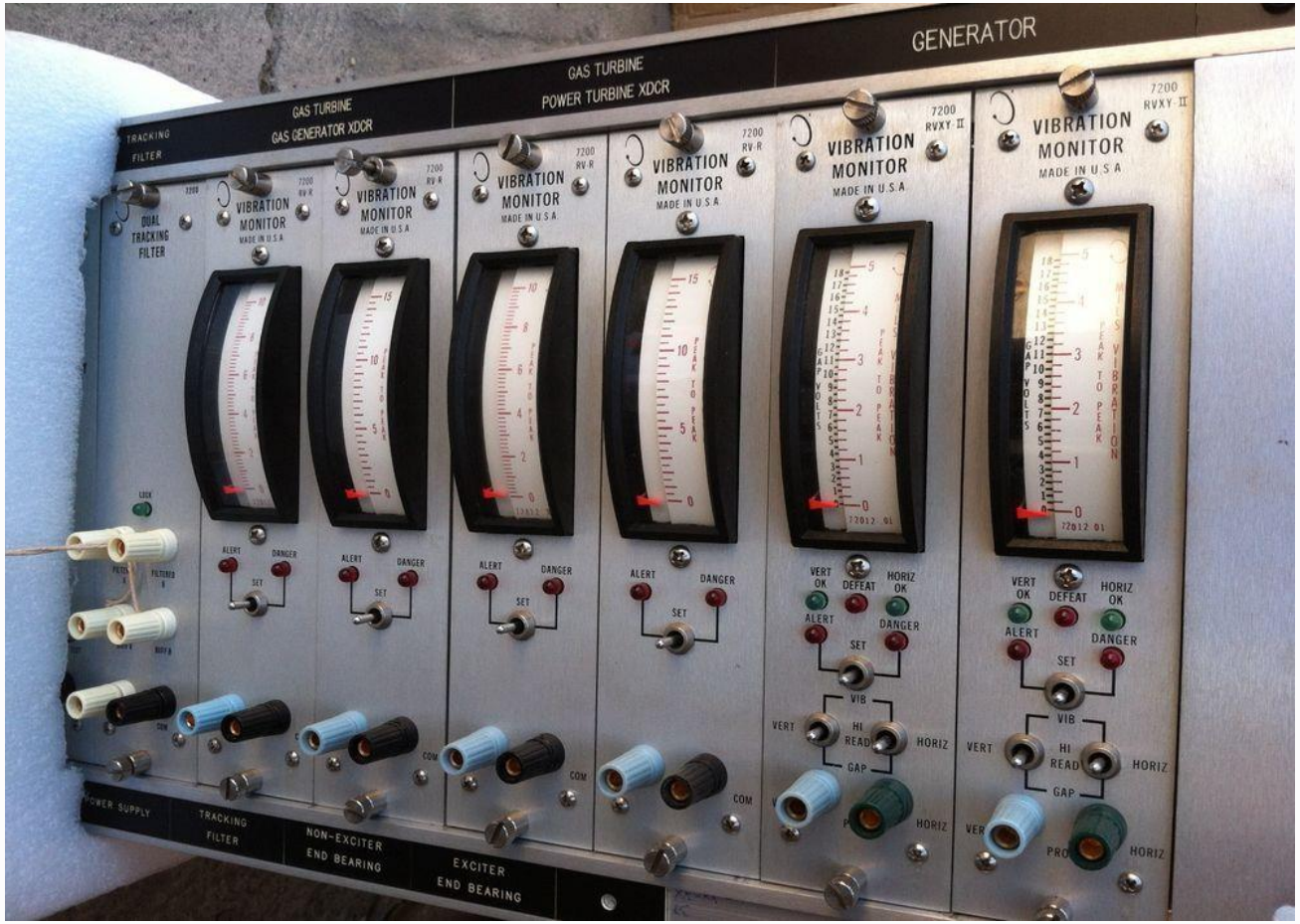


The Past, Present & Future of Diagnostics

1960s-1970s:

Analog systems, paper tape recorders

- overall values
- no data recording



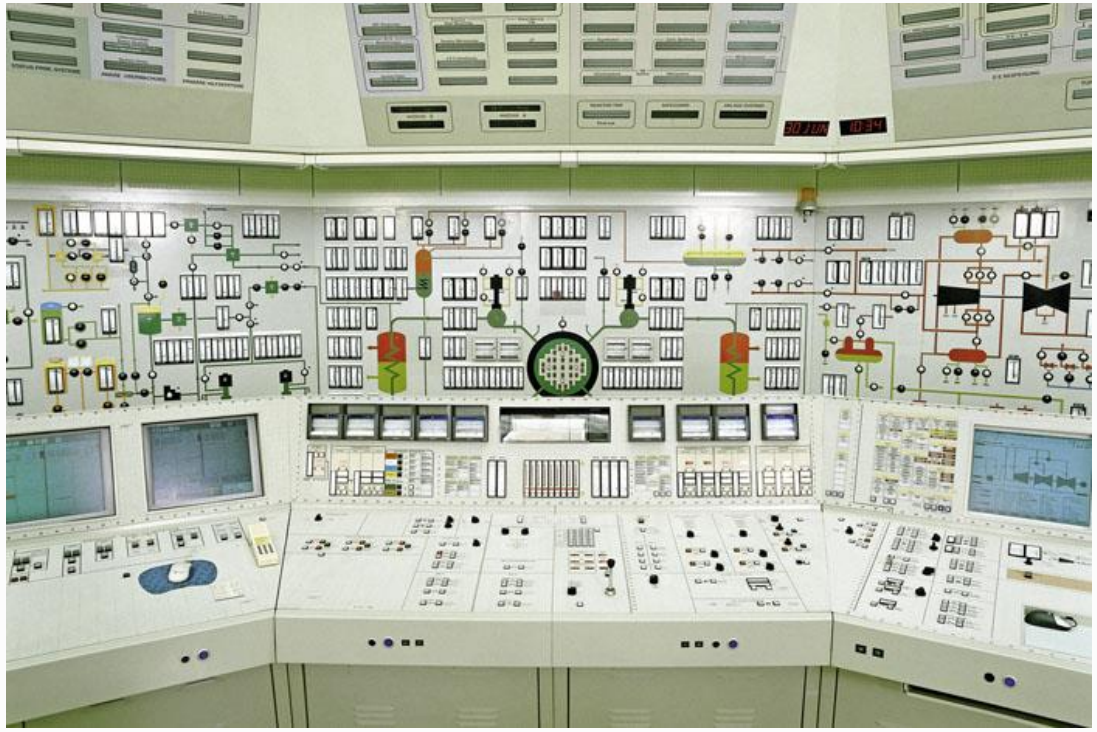
The Past, Present & Future of Diagnostics

The 1980s and 1990s: Rapid development - growth of data processing, digital technologies, improvement of data quality

- vibration velocity measurements - ISO 10816 standard
- portable analyzers
- on-line systems - very expensive - nuclear power plants

The Past, Present & Future of Diagnostics

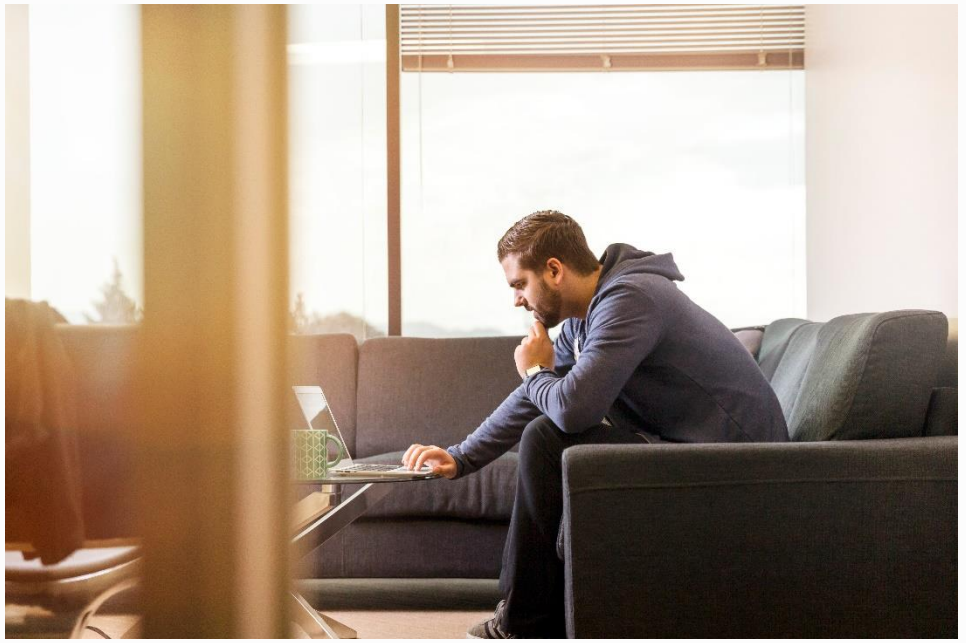
The first decade of the 21st century:
increasing automation, lower installation costs, first wireless systems, remote diagnostics



The Past, Present & Future of Diagnostics

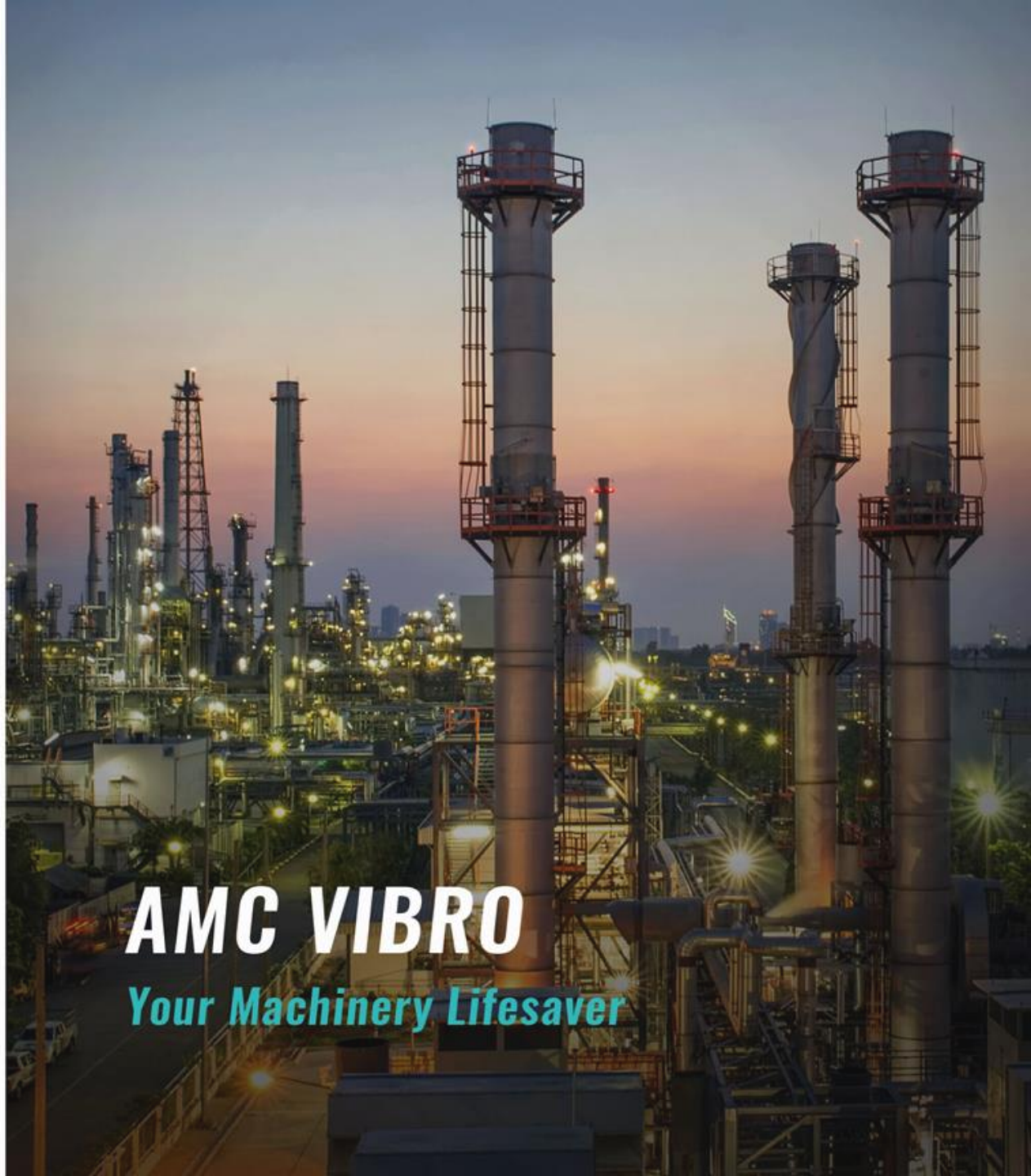
The present – minimizing the involvement of service personnel, development of intelligent systems, miniaturization

The Past, Present & Future of Diagnostics



Maintenance strategies

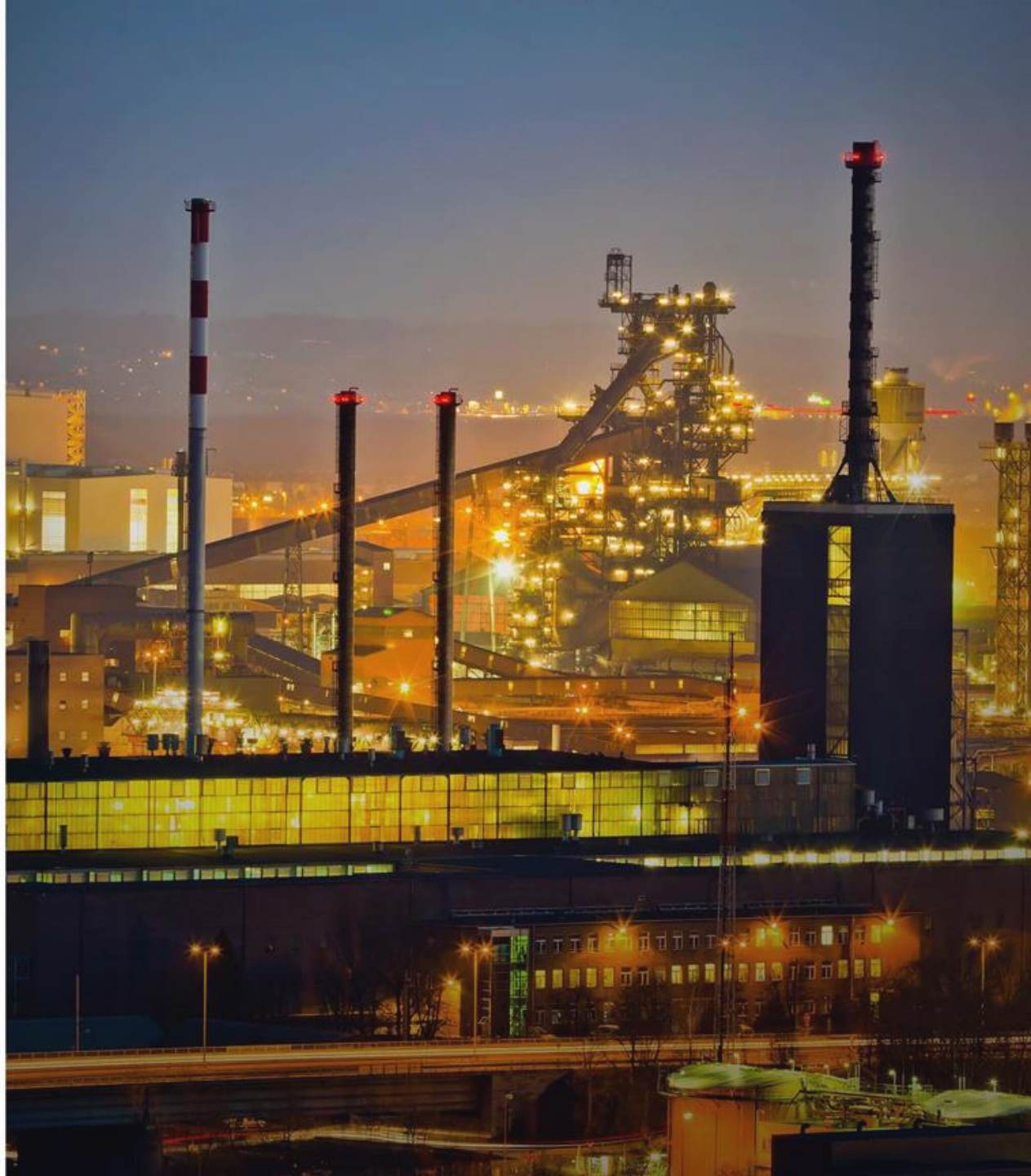
- Reactive
- Preventive
- Proactive



Maintenance strategies

Reactive

In this model repairs are performed when the machine has already broken down in order to restore it to normal condition.



Maintenance strategies

Preventive

Maintenance activities related to a given machine are carried out on a regular basis in order to reduce the probability of a failure. Repairs and replacements of elements are performed while they are still operational, preventing their unexpected failure.

Maintenance strategies

Proactive

The aim of proactive diagnostics is, firstly: to *predict* when a failure may occur and what will be its cause, and secondly: to *prevent* it from happening by the means of maintenance activities. Monitoring of future failures allows you to plan repairs and downtimes before problems arise. Predictive diagnostics allows you to reduce the number of repairs and the costs of too frequent repairs and downtime.

Maintenance strategies

76%	16%	8%
reactive	preventive	proactive

▼42%	▲34%	▲24%
reactive	preventive	proactive

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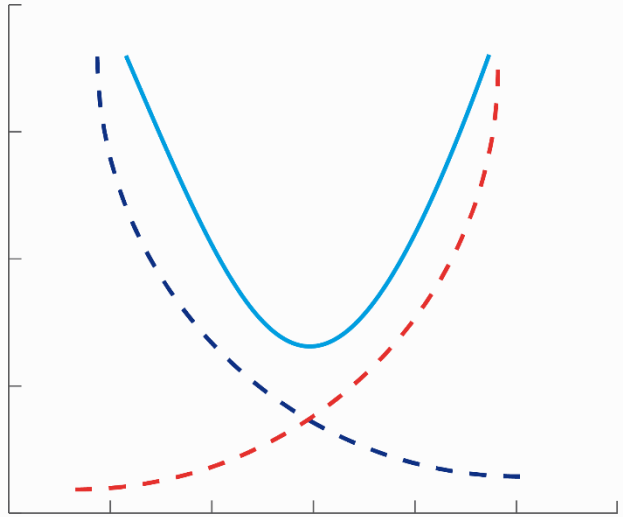
How much should diagnostics cost?



maintenance costs

diagnostic equipment costs

total cost

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How to Plan an Investment In Diagnostics

Investment planning is the most important time in any project. A properly planned project will allow for:

- Adjusting the scope to expectations
- Defining the budget
- Proper scheduling
- Appropriate preparation of the plant for implementation

Planning Investments In Diagnostics / Step I

On-site inspection

- The Client presents the problem and their expectations for a solution
- An inspection of the machine(s) is performed
- General features of the proposed solution are defined
- Reference measurements are performed

Planning Investments In Diagnostics / Step II

Technical assessment

Based on the information gathered, the AMC team outlines the architecture of the system

- Individual elements of the system are selected
- The solution is proposed to the client, verification with expectations

Planning Investments In Diagnostics / Step III

Implementation

- Installation dates are defined
- Criteria are established on the basis of which the project will be approved
- The plant is preparing for implementation (machine stoppage, line shutdown)
- A customer representative must be present at the time of installation

Case studies

Lotos Energobaltic

Reciprocating compressor diagnostic system

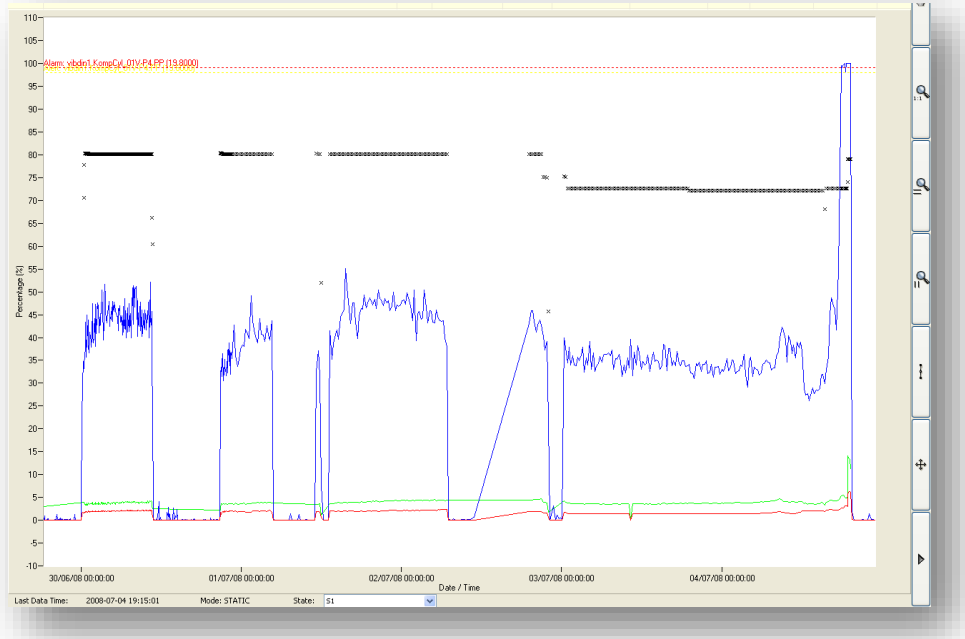
Remote, on-line diagnostic support

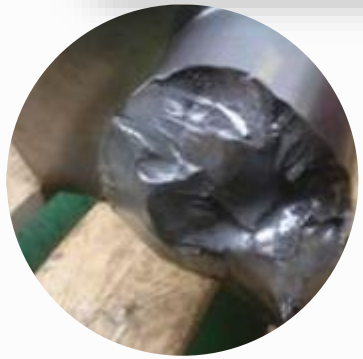
Lotos Energobaltic

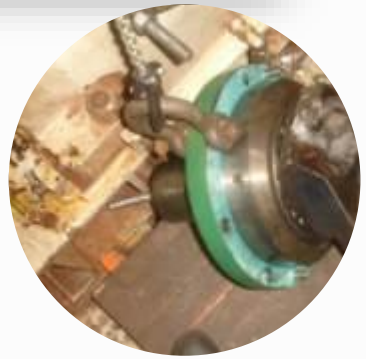
- 2007 – diagnostic system installed on Dresser-Rand reciprocating compressor
- The system consists of 20 vibration channels mounted on:
  - Cylinder
  - Intermediate chamber
  - Crankshaft bearings
  - Drive motor bearings

Major Accident Prevention

- The diagnostic system generated warning signal
- An increase in the vibration level was detected, and more detailed analyses were performed
- The compressor was stopped
- Serious shaft fractures were detected
- **Until the machine was stopped, the fault had no effect on its operation**
- The damaged shaft was replaced







Costs comparison

- Cost of the diagnostic system: approx. **EUR 100,000**
- Repair costs with early failure detection :
  - Shaft replacement : **30,000 EUR (parts + services)**
  - Machine unavailability: **6 weeks**
- Potential costs (no knowledge of the actual machine condition):
  - New housing and shaft : **400,000 EUR**
  - Transport and installation: **200,000 EUR**
  - Delivery: **6 months**
  - Machine unavailability: **8 months**

Grupa Azoty ZA Puławy nitrogen fertilizer factory

- Cooperation since 2008
- Over 20 compressors covered by vibration monitoring systemsPonad
- **Over 200 vibration channels**
- Successive covering of new machines with the vibration monitoring system
- **Over 40 failures detected**

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ZA Puławy:
Failures deteced

- A significant increase in the vibration level was detected on one of the cylinders
- Additional analyzes were performed with a portable instrument
- A failure was detected related to the work of the pistons
- It was recommended to inspect the cylinder as soon as possible
- During the inspection, the diagnosis was confirmed - the surface of the cylinder was damaged

ZA Puławy:
Costs comparison

- The cost of the basic diagnostic system for one compressor

  EUR 80,000 (incl. implementation)

- Actual repair cost:

  EUR 8,000

- Estimated cost of compressor failure due to cylinder damage

  EUR 300,000 – 500,000

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MONITORING VS DIAGNOSTICS

- how not to mistake apples for oranges?

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What is monitoring? What is diagnostics?

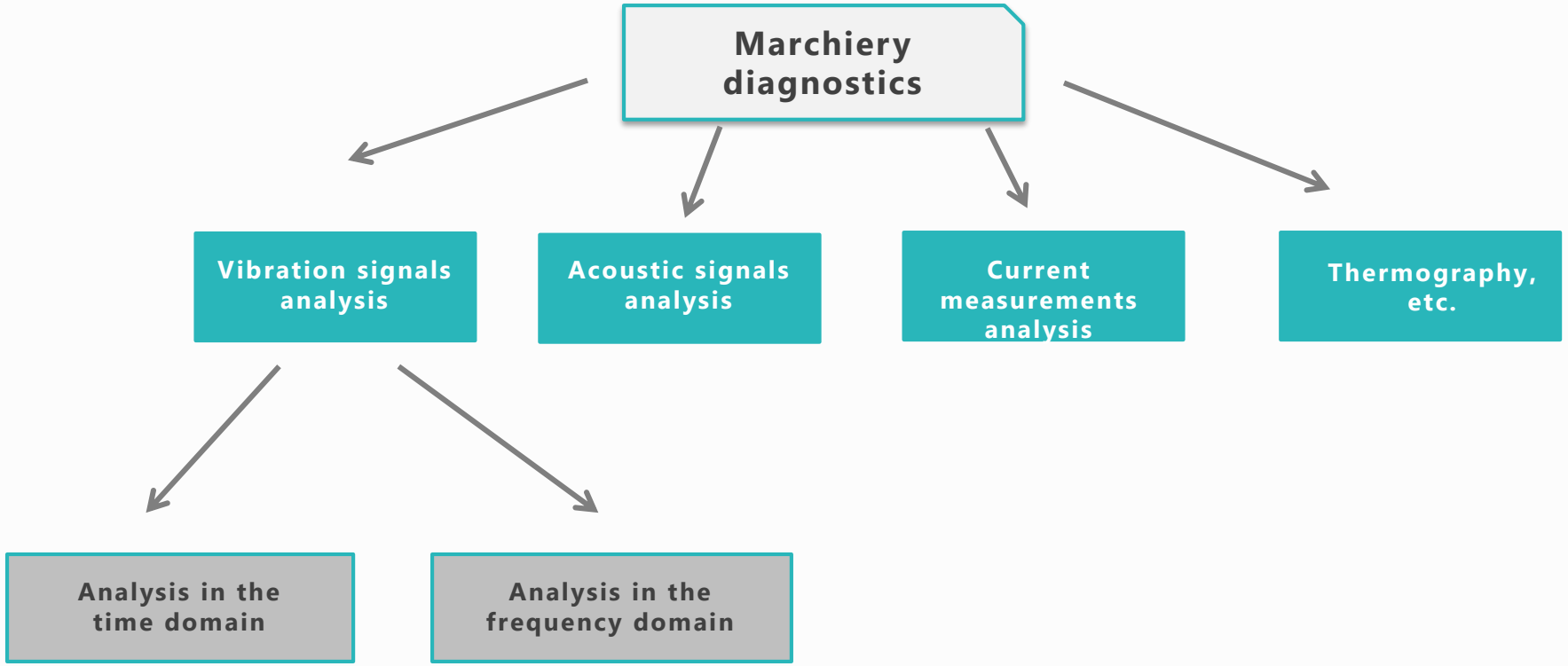
Monitoring – observation, supervision, registration

Diagnostics

– distinguishing, recognizing, evaluating

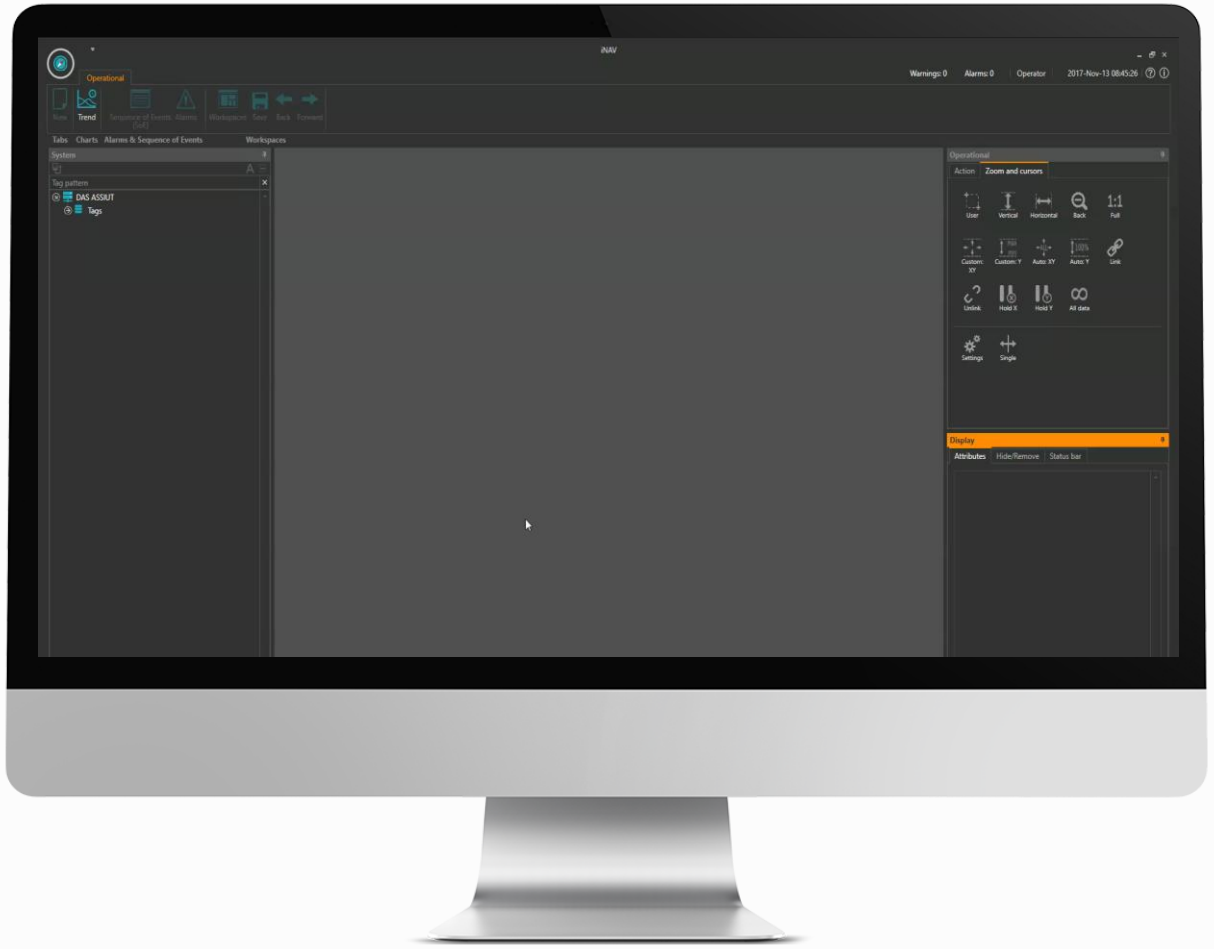
Industrial health service

methods of machinery diagnostics



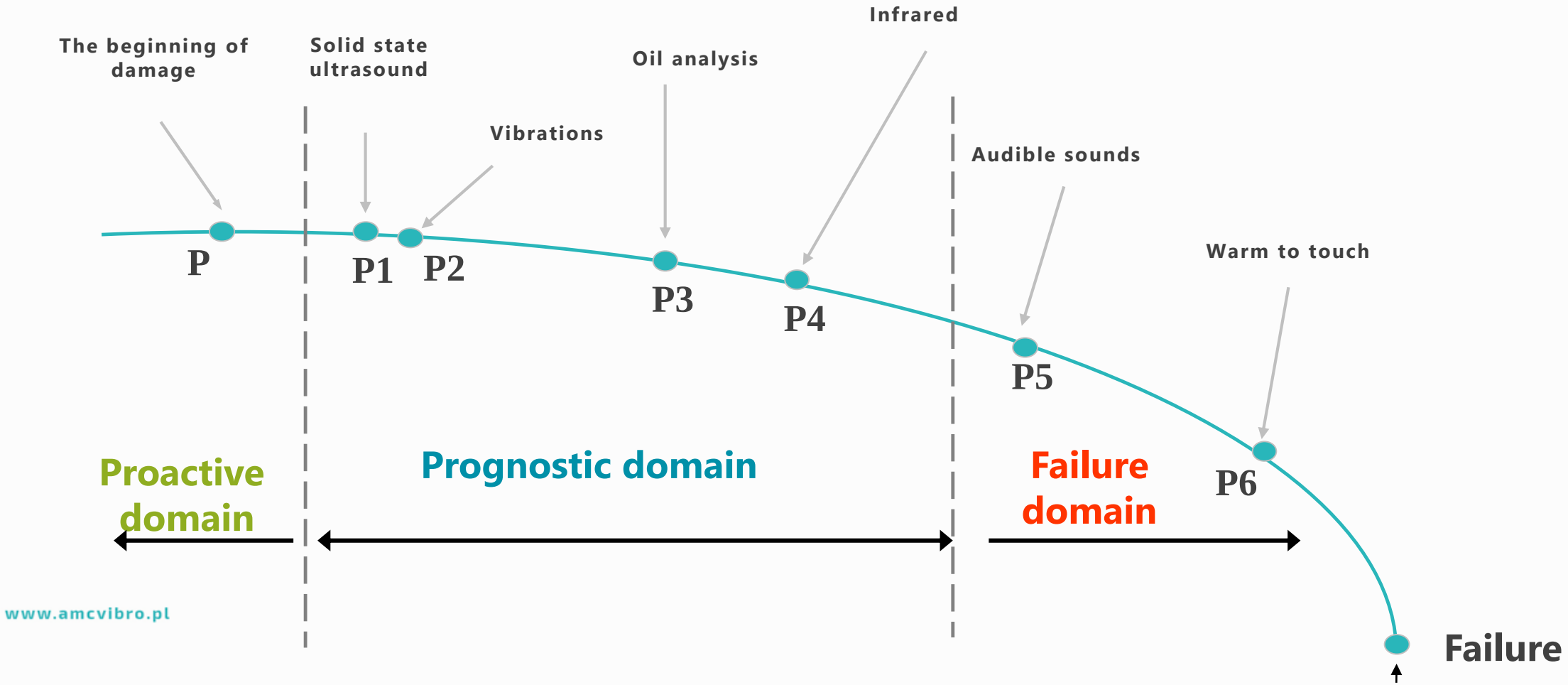
What is vibrodiagnostics?

A proven, effective method of **assessing the technical condition of industrial machines** on the basis of measurement and analysis of generated **vibrations**.



Industrial health service

methods of machinery diagnostics



Theory of vibrations

For rotating machines, **vibrations** always result from forces acting on the machine elements and **are an undesirable phenomenon.**

Machines speak to us through the generated vibrations and it is a language worth learning!!!

Theory of vibrations

- **Level 1 – detection:**
  the system tells you that something is wrong
- **Level 2 – identification:**
  which component is damaged?
- **Level 3 – evaluation:**
  how serious is the defect?
- **Level 4 – forecasting:**
  how long can the component work safely?

AMC VIBRO offer

- sensors
- wireless sensors
- monitoring systems
- portable systems
- protection systems
- accessories
- services

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Data acquisition

Source

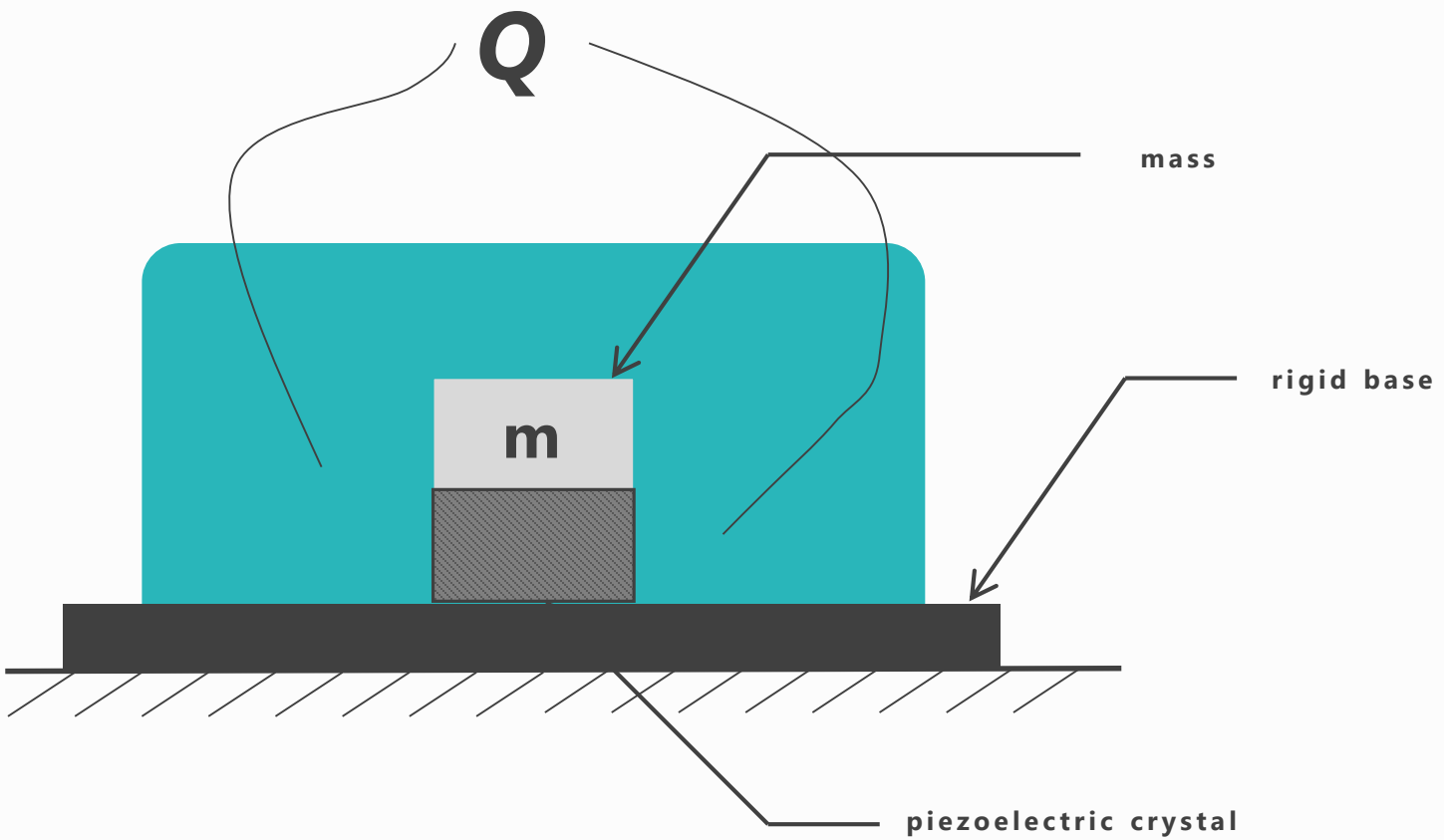
Sensor

- amplification
- filtering
- convertion

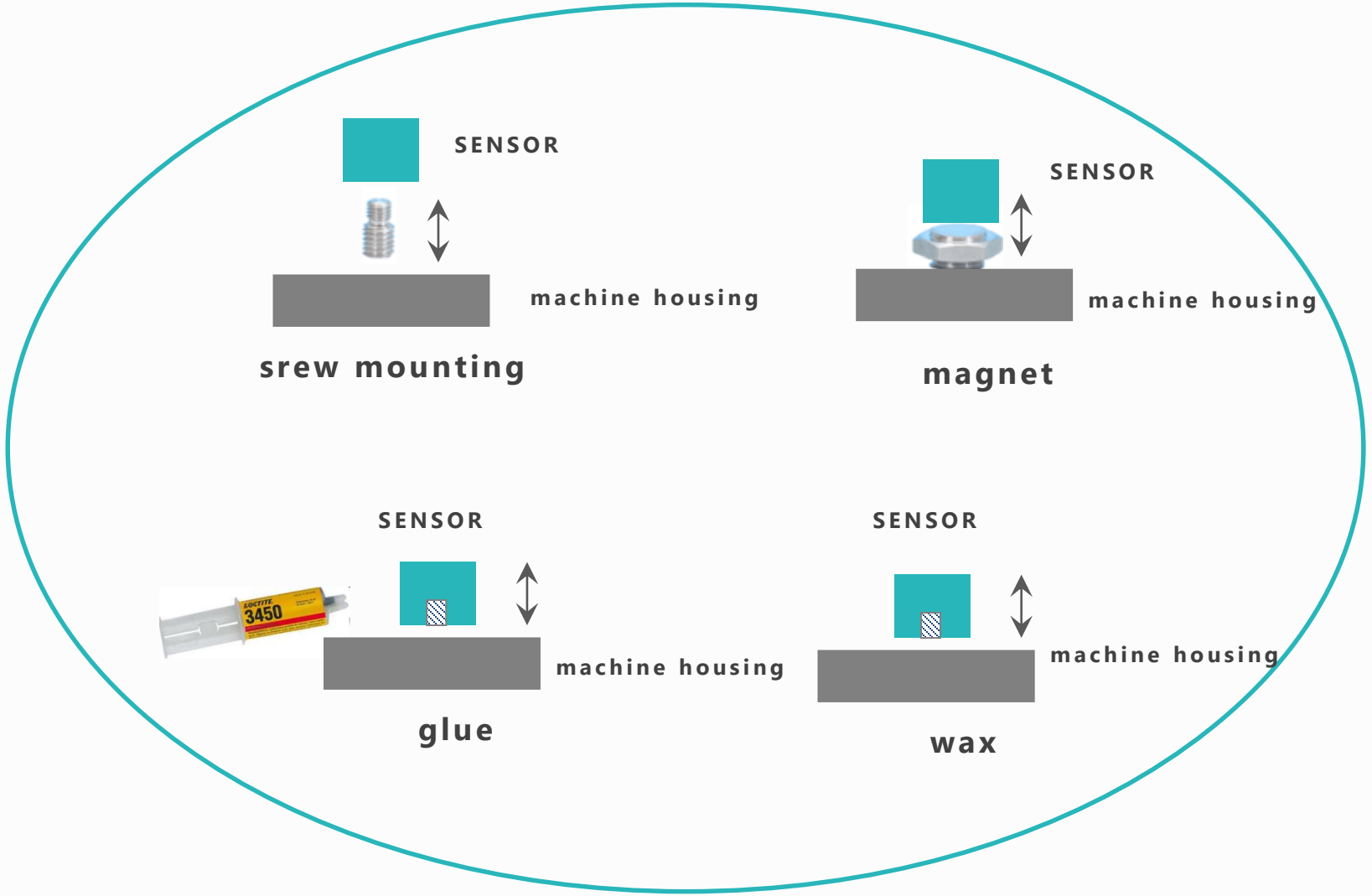
Conditioning

Analysis

Piezoelectric sensor



Sensor mounting methods



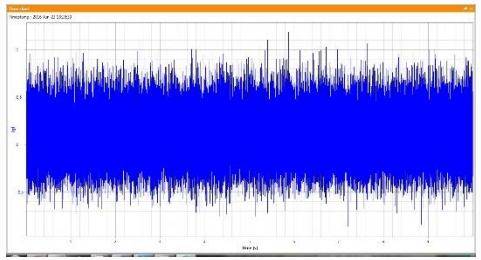
Industrial sensors

- **Accelerometers**
  - General purpose industrial;
  - ATEX certified for use in potentially explosive atmospheres;
  - High temperature;
  - Low and high frequency;
  - With 4-20mA current output;
  - Triaxial;
  - Relative vibrations (eddy current sensor)
- **Temperature**
- **Pressure**
- **Rotational speed**
- **Others**

Analog-to-digital conversion

Converting an analog signal to its digital representation

- sampling
- quantization
- coding



przetwornik ADC

...	...
0.3453	0.3453
3.4343	3.4343
2.3353	2.3353
4.3421	4.3421
1.2324	1.2324
0.2433	0.2433
...	...

Calculating diagnostic estimates

- **RMS**

$$u_{rms} = \sqrt{\frac{1}{T}\int_0^T u^2(t)dt}$$

- **Peak**

$$u_{zp} = \max_{0<t<T}|u(t)|$$

- **Kurtosis**

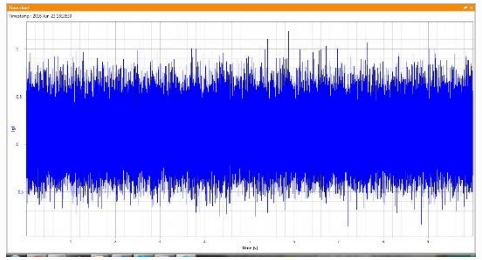
$$K = \frac{\mu^4}{\sigma^4} = \frac{\left(\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i)^2}\right)^4}{\left(\sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - x)^2}\right)^4}$$

- **Crest factor**

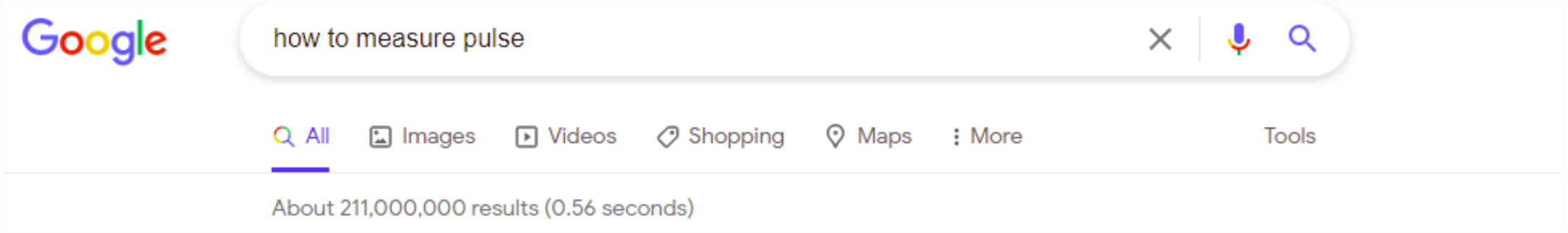
$$C = \frac{u_{zp}}{u_{rms}}$$

Sensor

Raw signal



How to measure pulse?



How to measure pulse?

Method 1: Radial pulse

To check your pulse using this me

1. Place your pointer and middle
   thumb

Method 2: Carotid pulse

To check your pulse using this method, yo

1. Place your pointer and middle finger
   jawbone. You may need to shift your

Method 3: Pedal pulse

You can also find your pulse on the top o

1. Place your index and middle fingers
   the top of your foot. You may have t
   either side to feel the pulse

Method 4: Brachial pulse

Another location for checking your pulse is the brachial artery. This method is used most commonly in young children.

1. Turn your arm so it's slightly bent and your inner arm is facing up toward the ceiling.
2. Place your index and middle fingers along the side of your arm between the crook of your elbow on the top and the pointy part of your elbow bone on the bottom. Then move your

Step by step

1. Place your pointer and middle fingers on the inside of your opposite wrist just below the thumb.
2. Don’t use your thumb to check your pulse, as the artery in your thumb can make it harder to count accurately.
3. Once you can feel your pulse, count how many beats you feel in 15 seconds.
4. Multiply this number by 4 to get your heart rate. For instance, 20 beats in 15 seconds equals a heart rate of 80 beats per minute (bpm).

Normal rate

Resting Heart Rate Chart

Men (beats per minute)

Age	18 - 25	26 - 35	36 - 45	46 - 55	56 - 65	65 +
Athlete	49 - 55	49 - 54	50 - 56	50 - 57	51 - 56	50 - 55
Excellent	56 - 61	55 - 61	57 - 62	58 - 63	57 - 61	56 - 61
Great	62 - 65	62 - 65	63 - 66	64 - 67	62 - 67	62 - 65
Good	66 - 69	66 - 70	67 - 70	68 - 71	68 - 71	66 - 69
Average	70 - 73	71 - 74	71 - 75	72 - 76	72 - 75	70 - 73
Below Average	74 - 81	75 - 81	76 - 82	77 - 83	76 - 81	74 - 79
Poor	82 +	82 +	83 +	84 +	82 +	80 +

Women (beats per minute)

Age	18 - 25	26 - 35	36 - 45	46 - 55	56 - 65	65 +
Athlete	54 - 60	54 - 59	54 - 59	54 - 60	54 - 59	54 - 59
Excellent	61 - 65	60 - 64	60 - 64	61 - 65	60 - 64	60 - 64
Great	66 - 69	65 - 68	65 - 69	66 - 69	65 - 68	65 - 68
Good	70 - 73	69 - 72	70 - 73	70 - 73	69 - 73	69 - 72
Average	74 - 78	73 - 76	74 - 78	74 - 77	74 - 77	73 - 76
Below Average	79 - 84	77 - 82	79 - 84	78 - 83	78 - 83	77 - 84
Poor	85 +	83 +	85 +	84 +	84 +	85 +

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ISO 10816

Średniokwadratowa wartość prędkości drgań mm/s RMS	Klasa I	Klasa II	Klasa III	Klasa IV
0,28	A	A	A	A
0,45				
0,71				
1,12	B			
1,8		B		
2,8	C		B	
4,5		C		B
7,1	D		C	
11,2		D		C
18			D	
28				D
45				

Entry-level portable systems

Benstone vPod Pro

Sensor:

- Dual-use (vibrations+temperature)

Measurement:

- Range: ± 50 g, -40 ° - +115 ° C
- Sensitivity: 100mV/g
- Shock resistance: 5000 g
- Frequency range: 1-8 kHz (± 1 dB), 0,3-10 kHz (± 3 dB)

Options

- Route
- Spectrum analysis

Calculated estimates:

- RMS
- Peak (0 – P)
- Peak-to-peak (P – P)
- Bearing condition

Other features:

- Bluetooth connectivity for headphones
- WiFi
- Camera

Portable systems vs stationary systems

Basic stationary systems

AVM 1000 SERIES

Single-channel modules for continuous monitoring and preliminary diagnostics of rotating machines with constant and variable rotational speed. An affordable option for customers who want to avoid major breakdowns

- One vibration measurement channel
- 2 relay outputs, 4..20 mA analog output, raw sensor signal output
- Vibration measurement according to the ISO standard
- LED display
- 4 versions for specific applications

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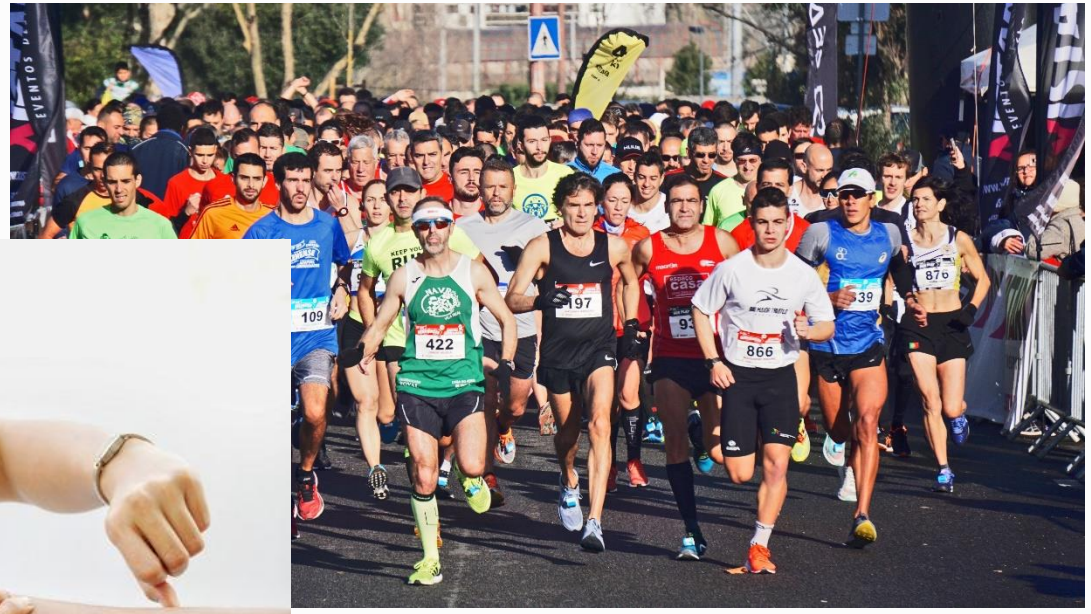
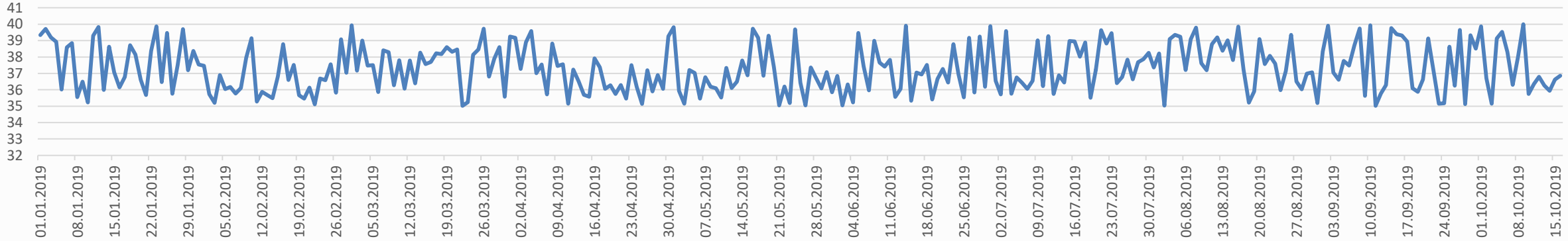
MONITOR 1000

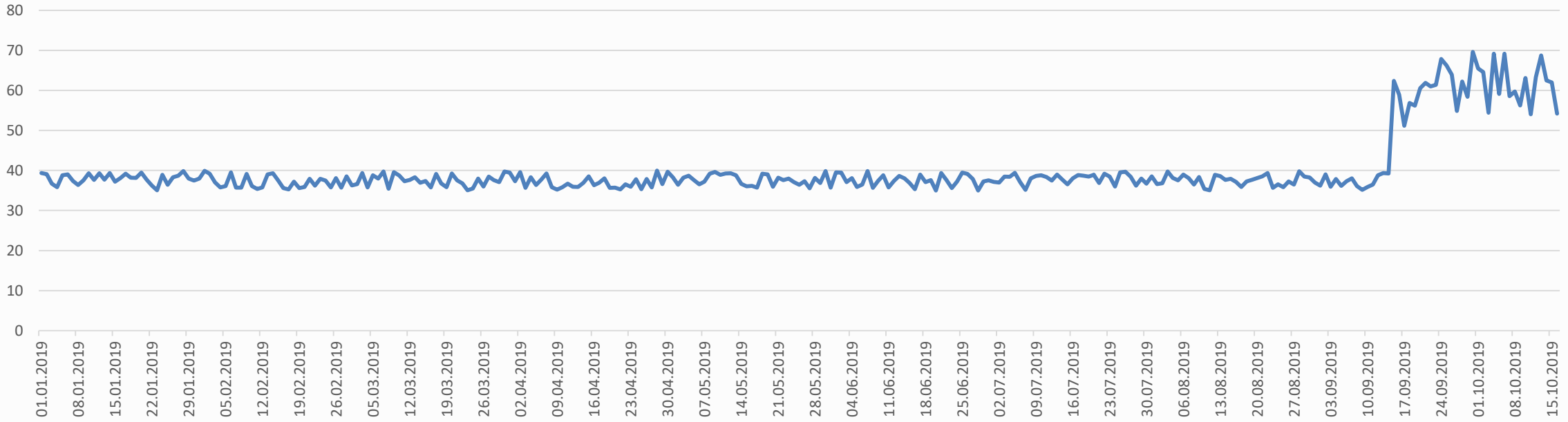
Values vs. trends



Values vs. trends



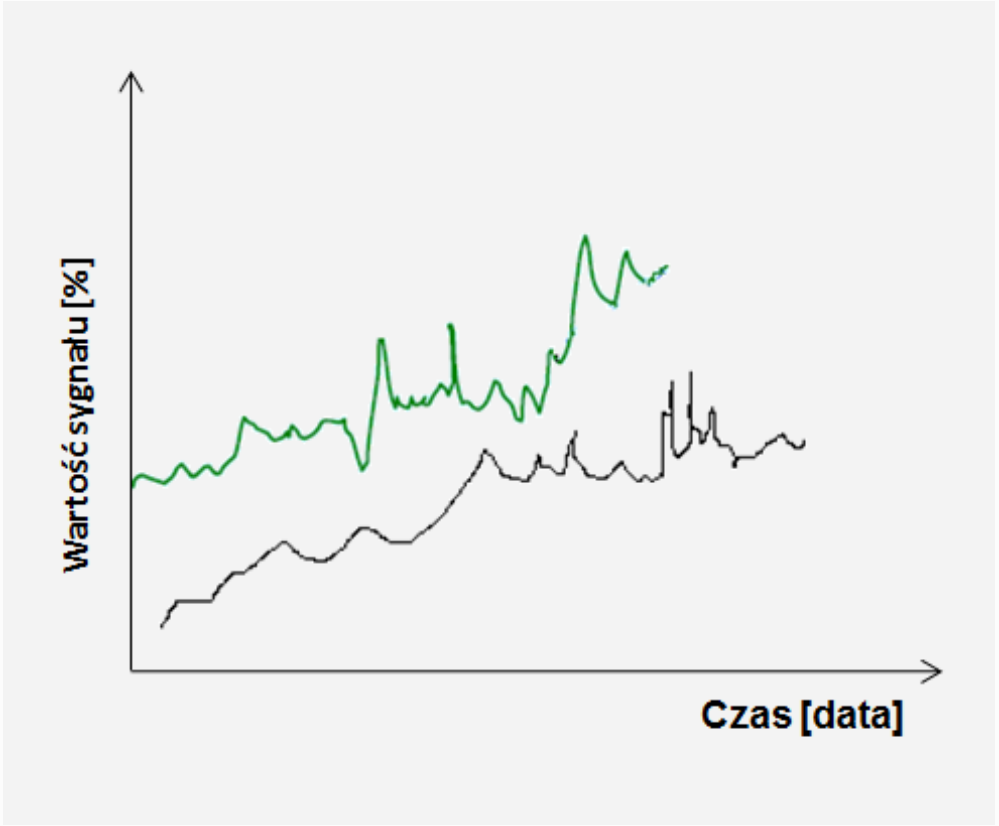
Values vs. trends



Historical data recording - trend analysis

Time trends are graphs showing changes in monitored quantities / signals over time.

- Development of a monitored fault
- Percentage change from the selected level
- Correlations of signals over time
- Identification of long-term process changes



Basic monitoring systems

AVM 2000 SERIES

Dual-channel modules for continuous monitoring and diagnostics of machines, including the detection of damage such as imbalance, misalignment or bearing damage.

› Two channels for vibration measurement + rotational speed measurement

› 5 relay outputs, 2 analog outputs 4..20mA, 2 raw signal outputs from sensors,

› Modbus

› Detection and identification of faults

› Data recording on SD card

› LED display

› 4 versions

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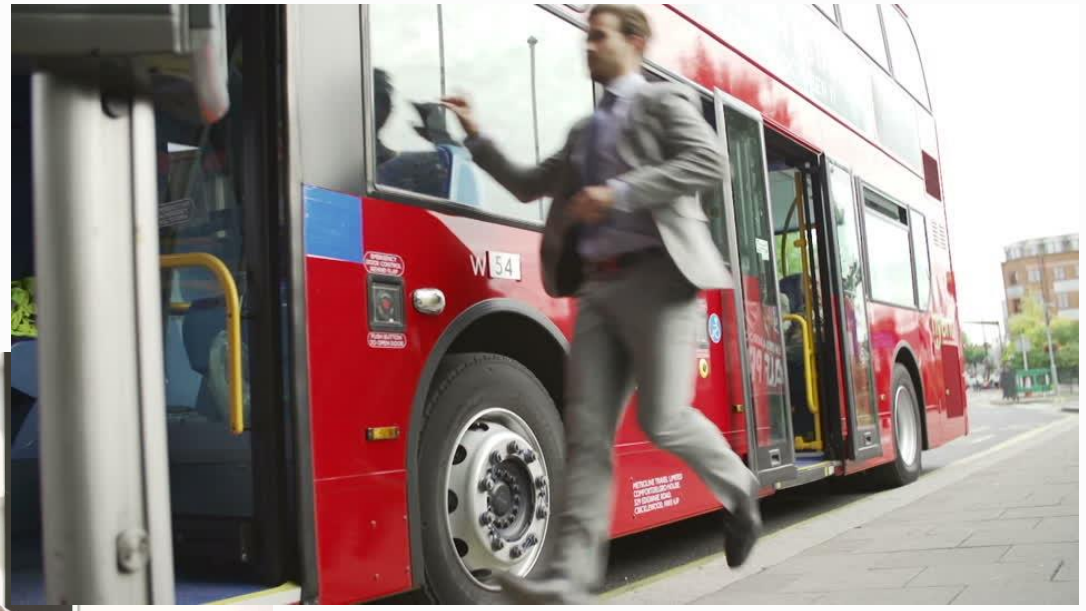
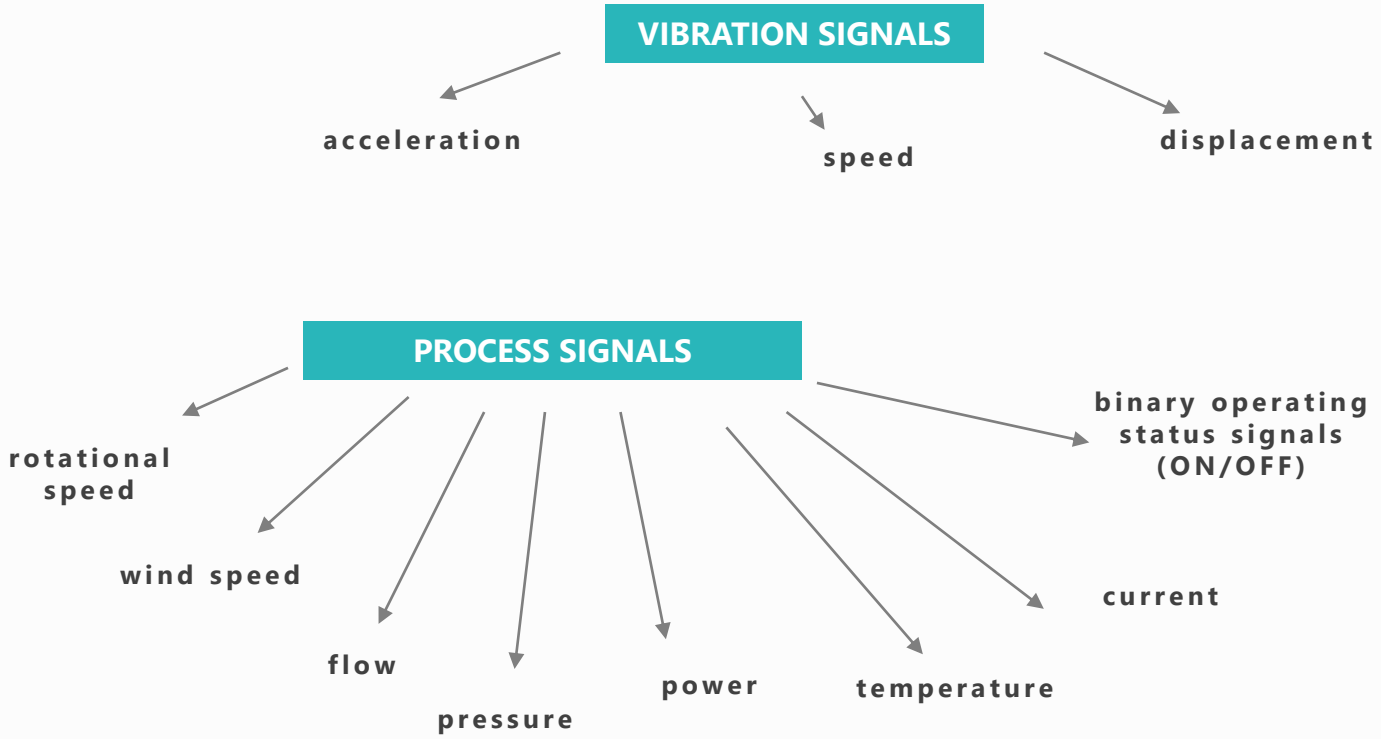
Operational states



Process signals

Process signals are treated in vibrodiagnostics as a "description" of the recorded vibration signal. Process signal values are used to classify vibration signals in the context of machine operating parameters, the so-called "Operating states" of the machine.



Advanced stationary systems

AVM 4000

- True Data Validator™
- Advanced diagnostic analyses
- Modular structure based on funtional cards
- Historical data recording
- 24bit resolution, up 100kHz sampling
- SCADA integration
- Access from any place of the globe (Ethernet)

- **AVM 4000EU**
- **AVM 4000+U**
- **AVM 4000+V**
- **AVM 4000+P**

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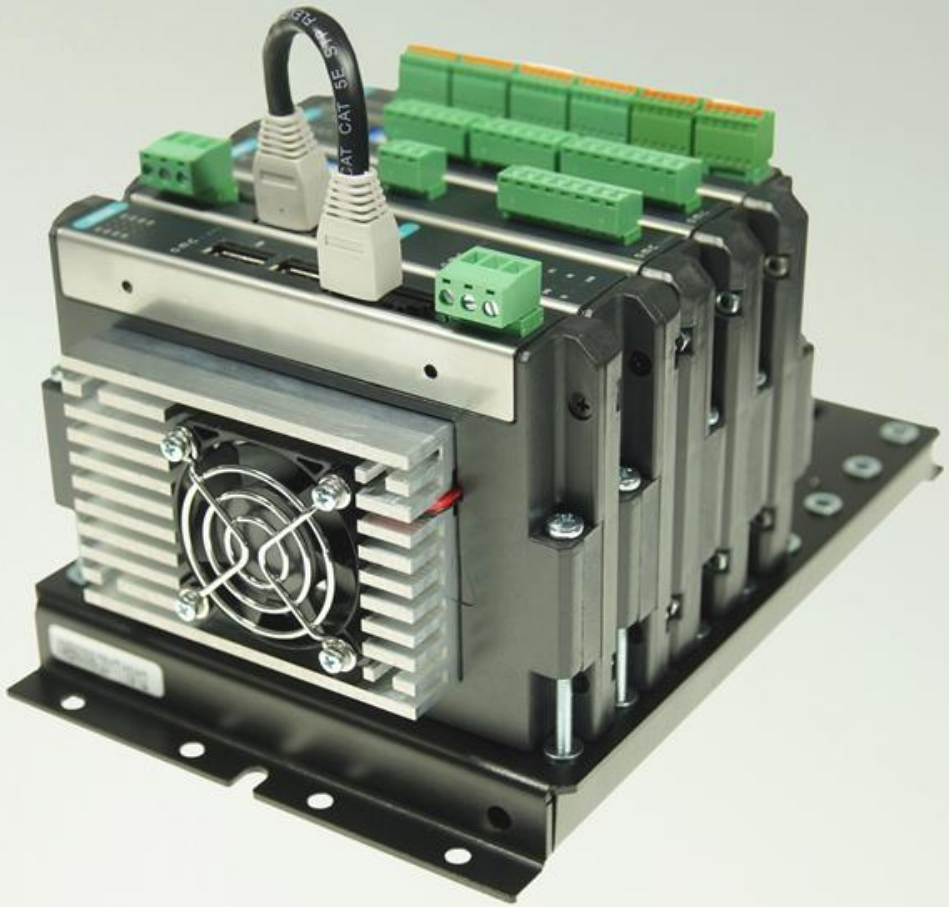

MONITOR 4000

Software

VIBnavigator is the user interface of the AVM 4000 platform.

Funtions:

- System configuration and administration
- Preview of current and historical data
- Event monitoring

VIBNAVIGATOR

Wireless system

An answer to the limitations of both portable and stationary systems:

- No cables
- Monitoring in hard-to-reach places
- Monitoring of distributed systems
- Easy to assemble
- Low system maintenance costs

AV SENSOR 2000R

Key information

- 2 axis
- 8 calculated estimates
- 8 customizable narrowbands
- Temperature measurement
- Wireless data transmission
- Range up to 150 m in industrial environment
- Up to 6 years without battery replacement
- Compact housing

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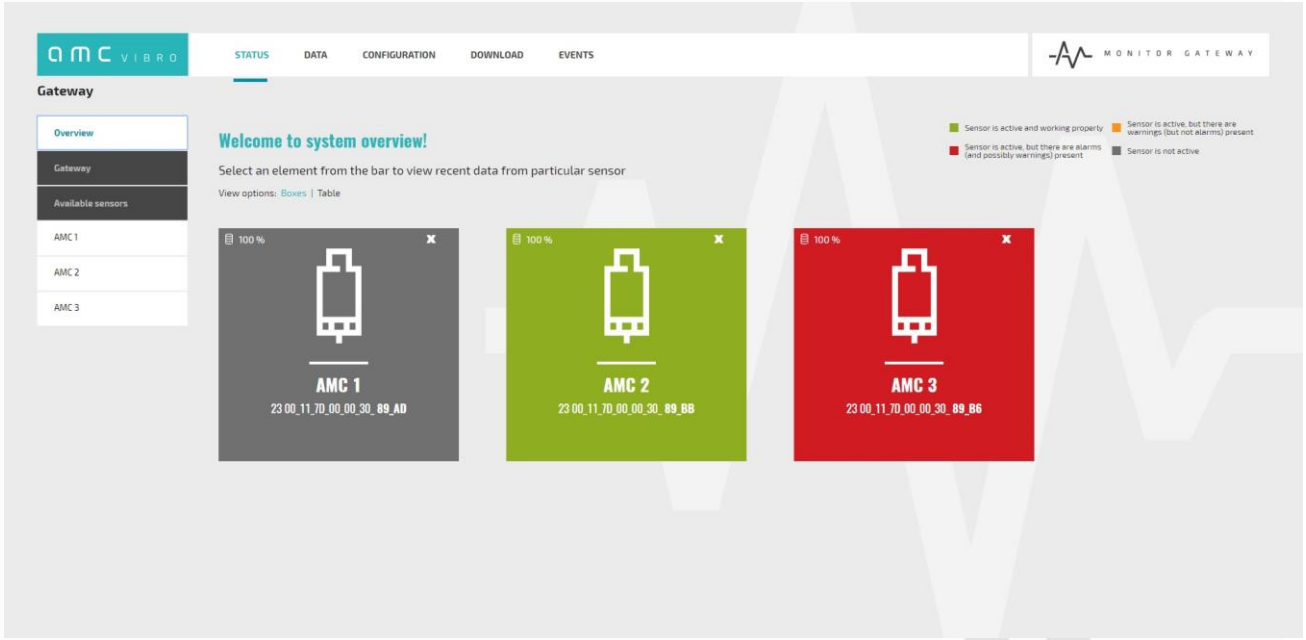
AVM GATEWAY

Features:

- Manages the network of up to 32 AVS2000R sensors
- Ethernet communication
- Built-in web server
- Network connection monitoring
- Data collection, saving on SD card
- Responses to warning and alarm signals
- Sensor battery monitoring

AV SENSOR 2000R software



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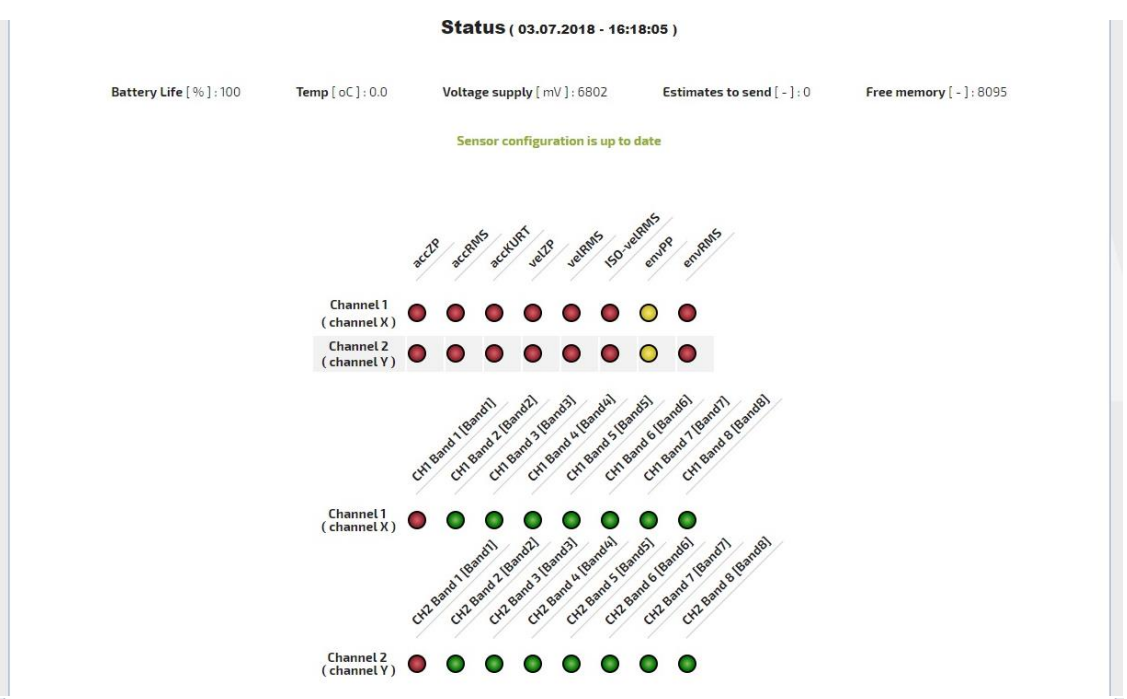


Current Values

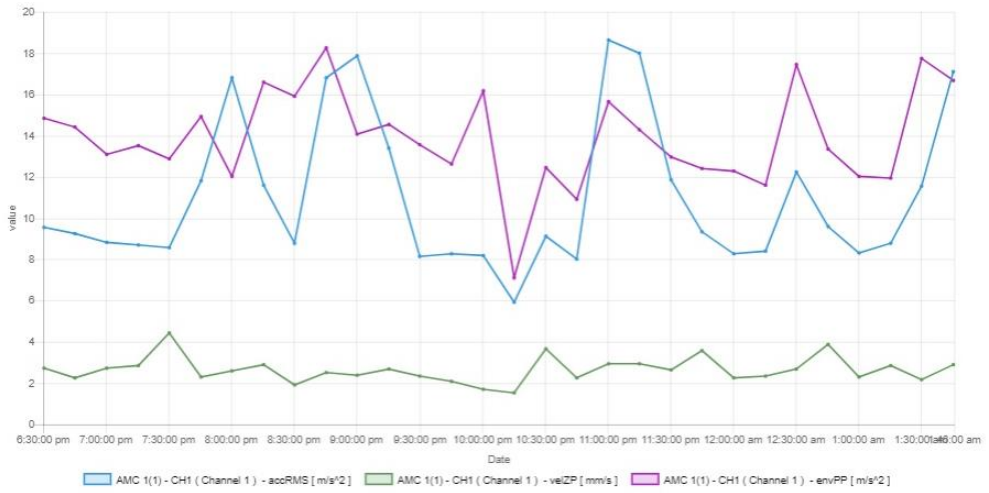
Channel time: 03.07.2018 - 16:18:05

Value	Channel 1 (channel 1)	Channel 2 (channel 2)
accZP [m/s^2]	74.29	12.10
accRMS [m/s^2]	4.98	4.75
accKURT [-]	14.94	1.98
velZP [mm/s]	140.17	139.09
velRMS [mm/s]	60.57	59.43
ISO-velRMS [mm/s]	33.50	32.85
envPP [m/s^2]	1.05	0.93
envRMS [m/s^2]	1.39	1.43

Value	Name (channel 1)	Channel 1 (channel 1)	Unit	Name (channel 2)	Channel 2 (channel 2)	Unit
Band 1	CH1 Band 1	4.60	m/s2 RMS	CH2 Band 1	4.56	m/s2 RMS
Band 2	CH1 Band 2	0.39	m/s2 RMS	CH2 Band 2	0.50	m/s2 RMS
Band 3	CH1 Band 3	0.51	m/s2 RMS	CH2 Band 3	0.35	m/s2 RMS
Band 4	CH1 Band 4	0.25	m/s2 RMS	CH2 Band 4	0.33	m/s2 RMS
Band 5	CH1 Band 5	0.40	m/s2 RMS	CH2 Band 5	0.26	m/s2 RMS
Band 6	CH1 Band 6	0.58	m/s2 RMS	CH2 Band 6	0.39	m/s2 RMS
Band 7	CH1 Band 7	0.71	m/s2 RMS	CH2 Band 7	0.42	m/s2 RMS
Band 8	CH1 Band 8	0.57	m/s2 RMS	CH2 Band 8	0.59	m/s2 RMS

AV SENSOR 2000R software

Date [dd.mm.yyyy]	Time [hh:mm:ss]	accZP [m/s^2]	accRMS [m/s^2]	accKURT [-]	velZP [mm/s]	velRMS [mm/s]	ISO-velRMS [mm/s]
03.07.2018	18:45:22	40.33	9.23	0.02	2.28	0.73	0.67
03.07.2018	19:00:22	37.90	8.82	-0.12	2.74	0.88	0.83
03.07.2018	19:15:22	30.98	8.68	-0.14	2.84	0.95	0.89
03.07.2018	19:30:22	27.82	8.55	-0.04	4.43	1.54	1.39
03.07.2018	19:45:22	42.52	11.79	-0.37	2.32	0.80	0.73
03.07.2018	20:00:22	45.48	16.82	-0.89	2.61	0.74	0.55



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Acquisition parameters

	CH X		CH Y		
	Warning	Alarm	Warning	Alarm	
Wakeup interval	5 min	5 min	5 min	5 min	
Repeat	2	2	2	2	[-]

Level configuration

	CH X		CH Y		
	Warning Threshold	Alarm Threshold	Warning Threshold	Alarm Threshold	
accZP	0,8	1,2	0,8	1,2	[m/s^2]
accRMS	0,8	1,2	0,8	1,2	[m/s^2]
accKURT	3,8	4,2	3,8	4,2	[-]
velZP	0,8	1,2	0,8	1,2	[mm/s]
velRMS	0,8	1,2	0,8	1,2	[mm/s]
ISO-velRMS	0,8	1,2	0,8	1,2	[mm/s]
envPP	0,8	1,2	0,8	1,2	[m/s^2]
envRMS	0,8	1,2	0,8	1,2	[m/s^2]
Band1	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band2	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band3	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band4	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band5	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band6	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band7	0,8	1,2	0,8	1,2	[m/s^2 RMS]
Band8	0,8	1,2	0,8	1,2	[m/s^2 RMS]

Narrowband analyses parameters

	CH X					CH Y				
	From	To		Name	Type	From	To		Name	Type
Band1	0	100	[Hz]	CH1 Band 1	Acceleration	0	100	[Hz]	CH2 Band 1	Acceleration
Band2	100	200	[Hz]	CH1 Band 2	Acceleration	100	200	[Hz]	CH2 Band 2	Acceleration
Band3	200	400	[Hz]	CH1 Band 3	Acceleration	200	400	[Hz]	CH2 Band 3	Acceleration
Band4	400	600	[Hz]	CH1 Band 4	Acceleration	400	600	[Hz]	CH2 Band 4	Acceleration
Band5	600	1000	[Hz]	CH1 Band 5	Acceleration	600	1000	[Hz]	CH2 Band 5	Acceleration
Band6	1000	2500	[Hz]	CH1 Band 6	Acceleration	1000	2500	[Hz]	CH2 Band 6	Acceleration
Band7	2500	5000	[Hz]	CH1 Band 7	Acceleration	2500	5000	[Hz]	CH2 Band 7	Acceleration
Band8	5000	10000	[Hz]	CH1 Band 8	Acceleration	5000	10000	[Hz]	CH2 Band 8	Acceleration

AV SENSOR 2000R system integration

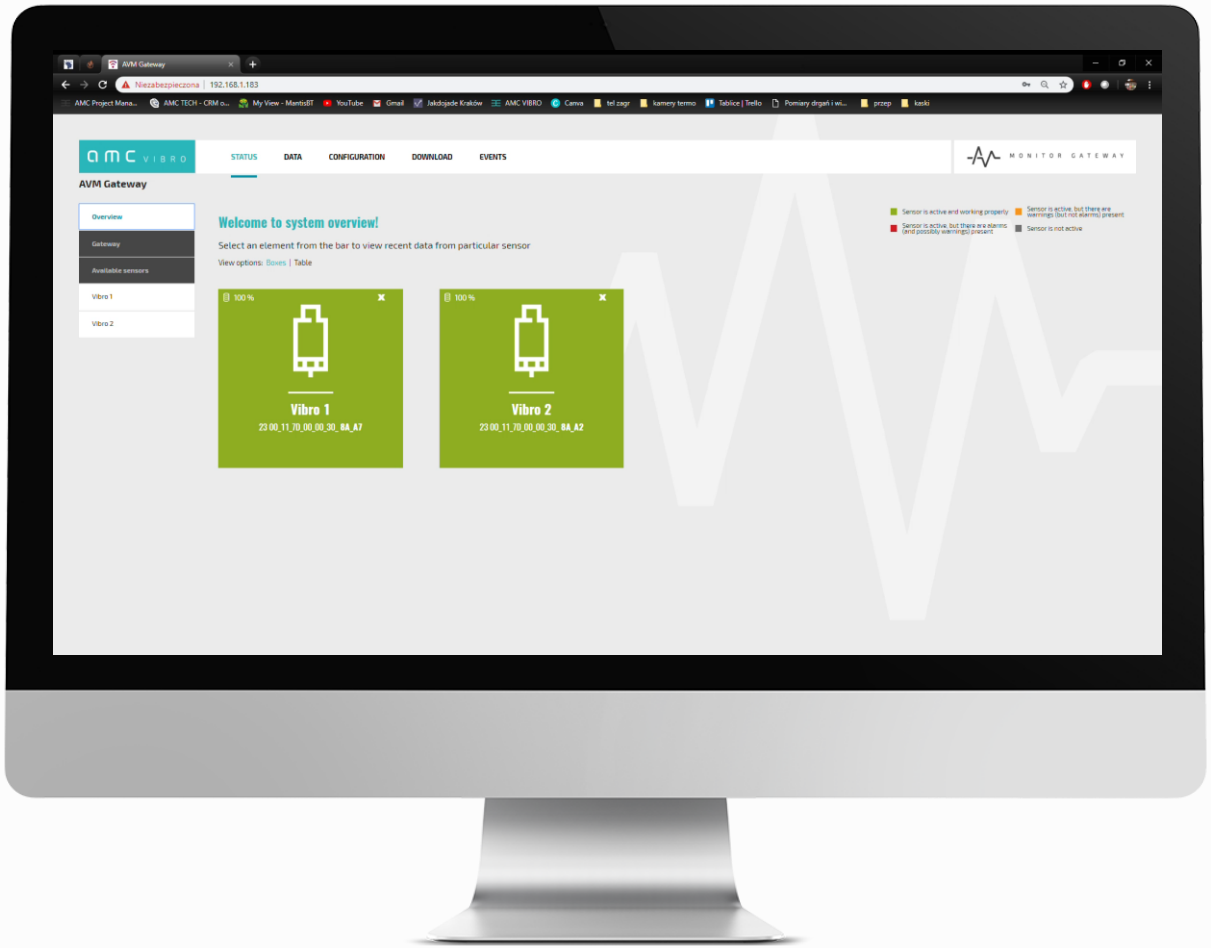
Ethernet (web server)

OPC UA

Modbus

SCADA / DCS

AVS 2000R
AVM GATEWAY



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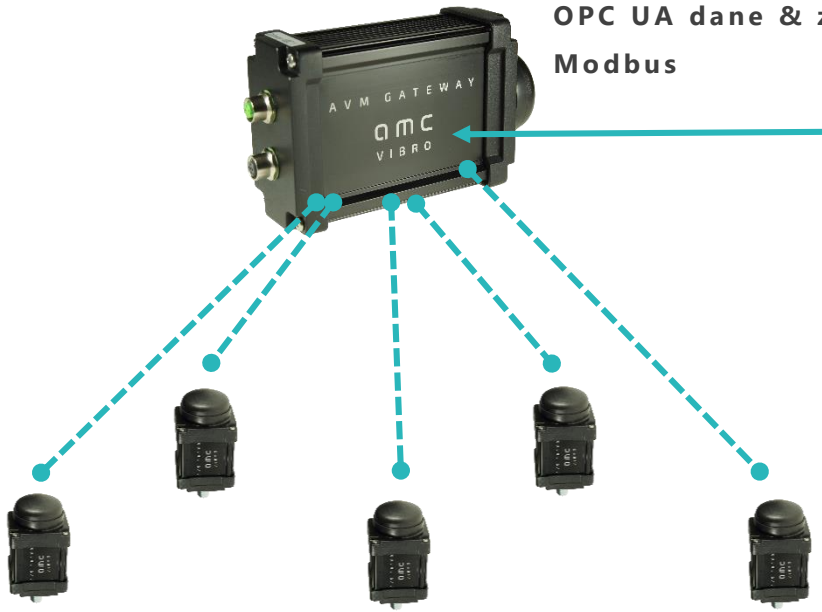
AV SENSOR 2000R
Integracja systemu



Ethernet,
OPC UA dane & zdarzenia
Modbus

SCADA / DCS

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