DIAMOND 401

User's guide

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User's guide version: D401-I / 1.0 / 2004

It is recommended to read the manual prior to using the instrument.

Contents

1. Description of Diamond 401

DIAMOND 401 is a modern measurement instrument designed for performing multiple tasks in the field of machinery monitoring:

- the machine vibration measurements and analysis,
- the evaluation of machine condition,
- the verification of bearings condition,
- the measurement of rotational speed and temperature,
- the balancing of the rotating machinery,
- the data collection allowing the user to register the measurements according to the predefined route.

The instrument case is made of aluminium what provides great mechanical resistance and good protection against the electro-magnetic perturbations. The IP65 protection level does not allow the humidity and the dust to penetrate inside the housing. The connectors are easy to manipulate and insure reliable and lasting connections. The LCD display with backlighting allows the instrument to be used even in the condition of poor visibility.

DIAMOND 401 is shipped together with the MBJLab software for post-processing, archiving and visualisation of the measurement results.

DIAMOND 401 is available in four versions allowing the customer to choose the version that best suits his application. The following table summarizes the functionalities that are available with each of these four versions:

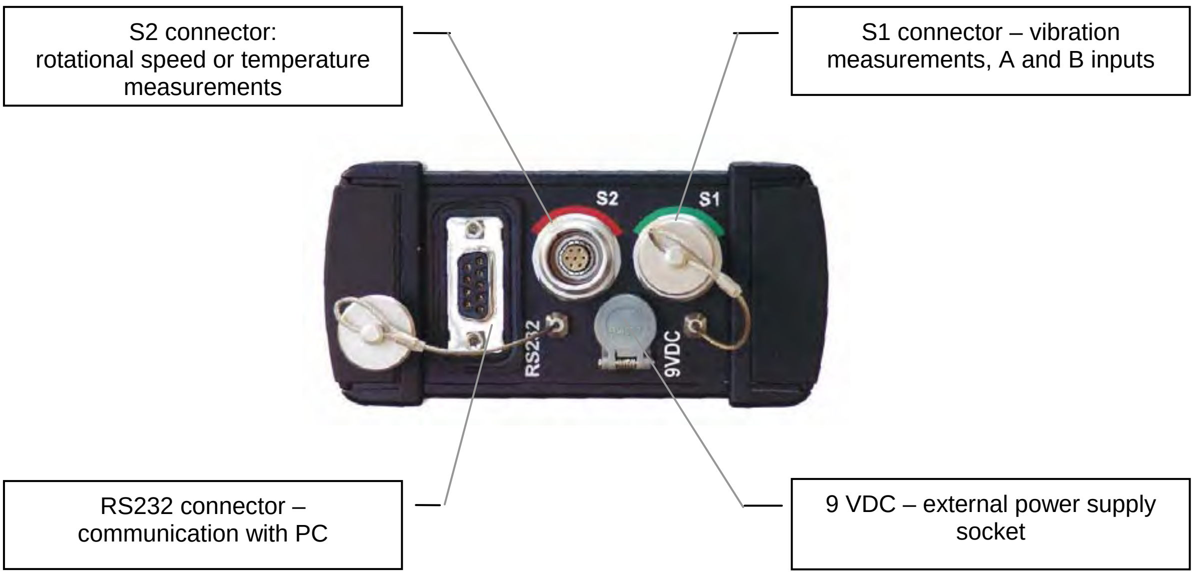
Functionality\Version	S	ST	D	DT
Number of channels	1	1	2	2
Vibration measurement	X	X	X	X
Machinery condition evaluation	X	X	X	X
Bearings verification	X	X	X	X
Cavitation	X	X	X	X
Data collection	X	X	X	X
Rotation speed measurement			X	X
Phase meausrement			X	X
Balancing			X	X
Temperature measurement		X		X

This user manual covers all four versions.

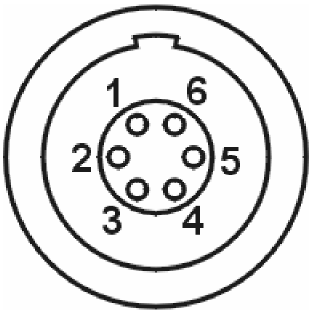
1.1 Front panel

1.2 Connectors

Below is shown the localization of the connectors :



1.2.1 S1 connector



1 – not connected

2 – Input A (for vibration measurements)

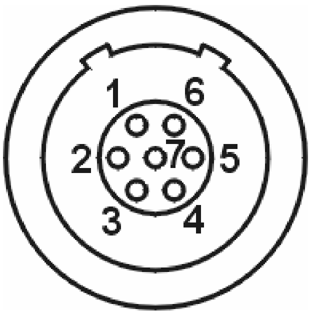
3 – A input ground

4 – B input ground

5 – Input B (only used for balancing)

6 – not connected

1.2.2 S2 connector



1 – 3,3 VDC power supply

2 – RPM measurements (pulses input)

3 – Digital ground

4 – Analog ground

5 – DC measurement input (+)

6 – DC measurement input (-)

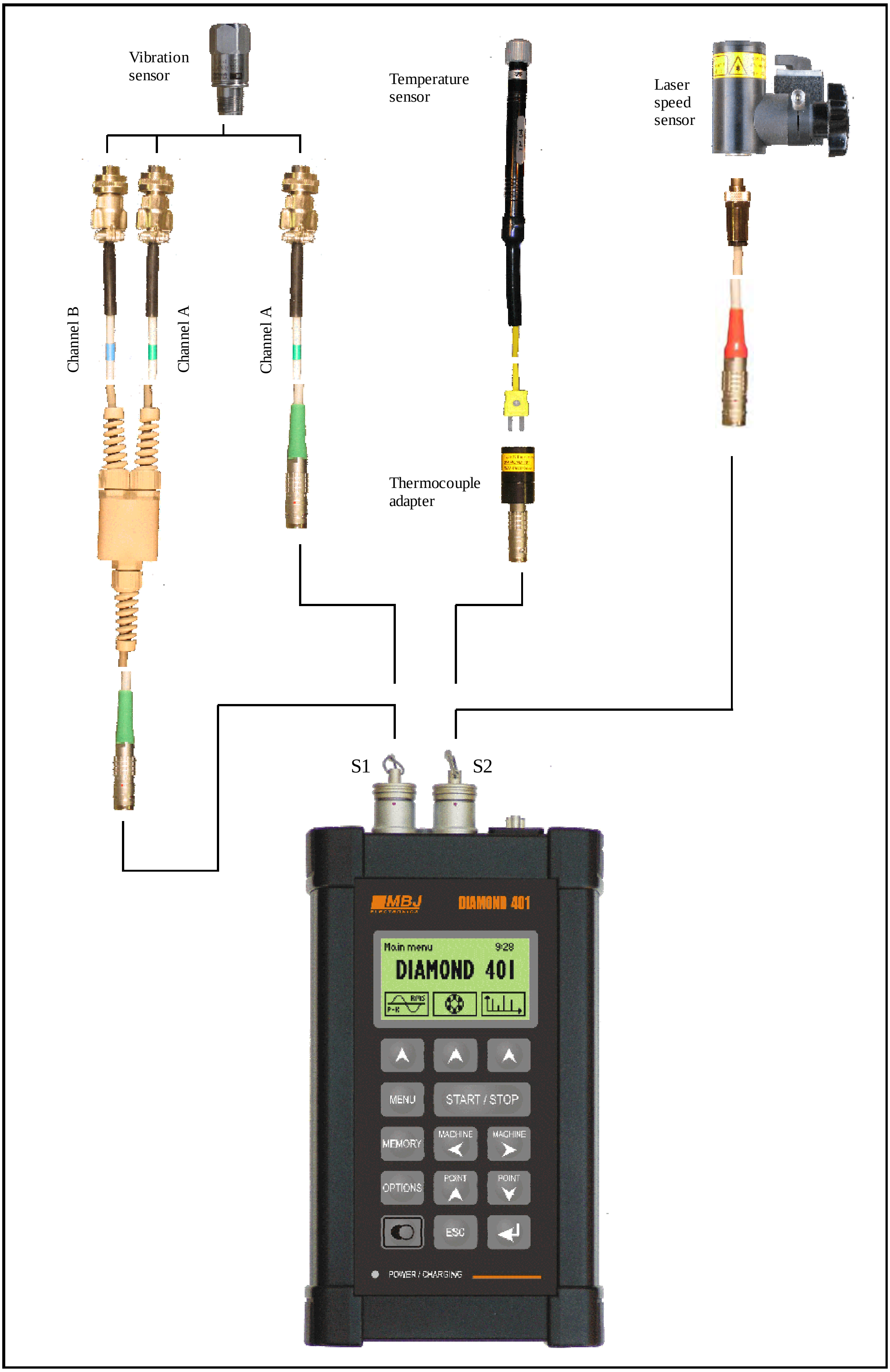
7 – 5 VDC power supply

1.2.3 Power supply socket

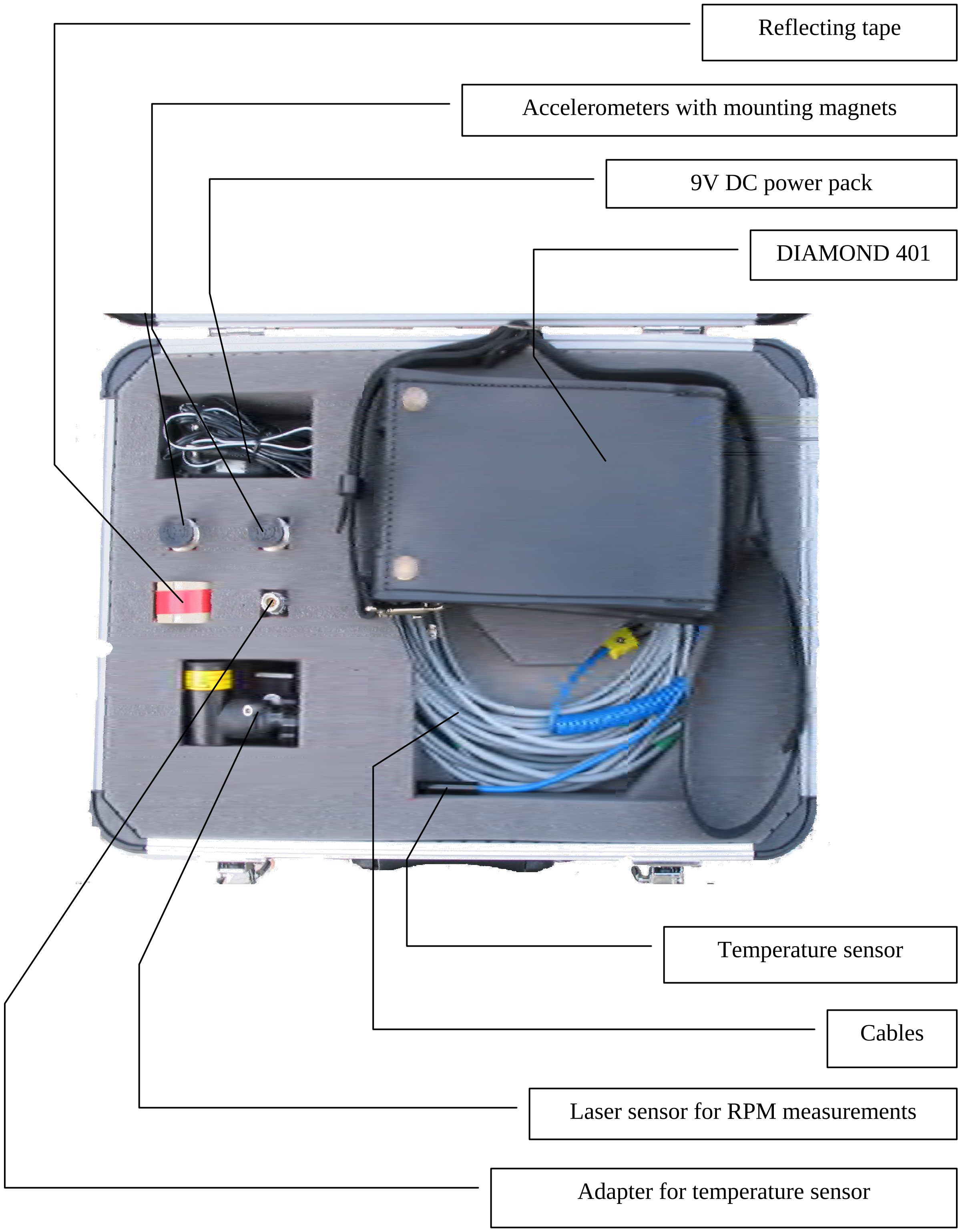
The power supply socket is described on the back panel of the instrument. The central pin of the socket should be connected to the positive end of power supply.

Only the power pack, cables and accessories provided together with the instrument or recommended by the manufacturer are compatible and may be connected to the instrument. Using other accessories and cables may damage the instrument and invalidate the warranty.

1.2.4 Connecting cables


Vibration sensor
Temperature sensor
Laser speed sensor
Channel B
Channel A
Channel A
Thermocouple adapter
S1
S2
DIAMOND 401
Main menu
9:28
DIAMOND 401
MENU
START / STOP
MEMORY
MACHINE
MACHINE
OPTIONS
POINT
POINT
ESC
POWER / CHARGING

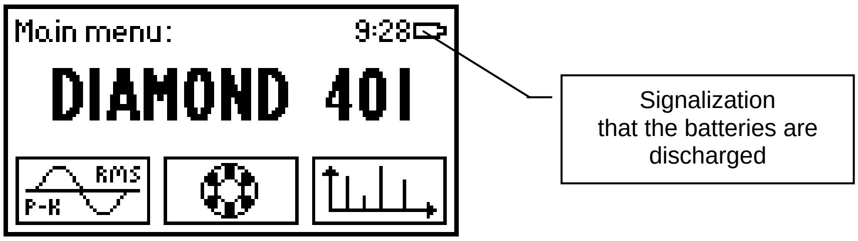
1.3 Carrying case



2. Operating the Diamond 401

2.1 Power supply

Normally the instrument is powered from the built-in rechargeable accumulators (four NiMH accumulators). Alternatively it may be powered from the external 9 VDC power supply (included with the instrument) which is also used to charge the batteries. It connects to the external power supply socket. The diode on the front panel is turned on when external power supply is connected. Its color is green in normal operation and red while the batteries are being charged. When the batteries are almost discharged then in the upper right corner of the display appears the icon symbolizing a battery:



One should then connect the external power supply and in the Option menu turn the charging on. This is confirmed by changing the color of the diode from green to red. The charging is controlled by the instrument and after about 4 to 5 hours it is turned off and the diode returns to the green color. You will find more information in the paragraph concerning the options.

⚠ ***At the beginning of charging the diode changes its color from green to red. The batteries should be charged without interruption until the diode returns to the green color, what typically takes place after 4 to 5 hours. It is not recommended to shorten the duration of charging, or to charge by fits and starts, or to start charging when the batteries are not discharged completely. This may reduce the capacity of accumulators or even they may get damaged.***

2.2 Main menu

The key  is used to switch the instrument on and off. When the instrument is switched on the display comes on and the main menu appears. The three keys  and the key 

are used to navigate throughout the menu. On the bottom of the display and above the keys  are displayed the icons representing various functionalities of the instrument. By pressing one of these keys we select the corresponding function. Pressing the key 

changes cyclically the available functionalities by sets of three. Below are shown the displays with icons corresponding to various functionalities available in the main menu of DIAMOND 401DT (DIAMOND 401 exists in four versions which differ by the number of available functionalities):

From left to right: vibrometer, bearings verification, spectral analysis.

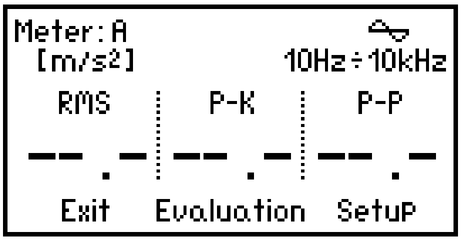
From left to right: RPM measurement, temperature measurement, balancing.

From left to right: phase measurement, cavitation detection.

Obviously the number of functions that are displayed in the main menu depends on the version of the instrument. All these function are described in the following paragraphs.

2.3 Vibration level meter

The following screen appears when the function « vibrometer » is selected:



The character immediately after the word « Meter » in the first line indicates the quantity being measured (in this case « A » for acceleration). Completely to the right of the first line there is a space for a symbol of discharged batteries, next to it is a symbol indicating that the measurement is being executed (it changes cyclically during the measurement), and then there is the place for the overload indicator (streak of lightning). To the left of the second line are displayed the measurement units, and to the right – the selected frequency band. Below, in place where will be shown the measurement results, are displayed horizontal lines. At the bottom of the display are shown three functions that may be selected with the  keys:

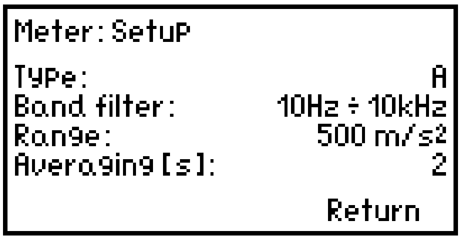
Exit – return to the main menu

Evaluation – selecting this function will get you to the machine condition evaluation (based on ISO 10816 standards)

Setup – opening the menu that will allow you to set-up the vibrometer

2.3.1 Setting-up the vibrometer

By pressing the key  underneath the function ***Setup*** we enter the menu where we can adjust the settings of the vibration level meter. The following display appears:



We can now adjust the following parameters:

Type – quantity being measured

Band filter – frequency bands

Range – measurement range

Averaging – duration of averaging

To navigate inside the menu we use the keys 

and 

. The selected parameter is singled out. To change the value of a parameter we use the keys 

and 

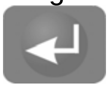
. If the value of the parameter is a number, like for example the duration of averaging (a number in the range from 1 to 60) then the change takes place in steps of 1. The alternative way of editing a value is the following:

we start the editing by pressing the key . On the display appear two positions that may be edited: one is flashing and we change it with the vertical arrows 

and 

. To get to the other position we use the horizontal arrows 

and 

. By pressing  we confirm the selection and if we want to cancel the selection and return to the previous value then we should press 

. The table below shows the possible choices for the parameters and the measurement ranges:

Symbol	Measured quantity	Detectors			Measurement ranges (P-K)
		RMS	P-K	P-P	
A	Acceleration	X	X	X	5, 50, 500 m/s² and AUTO
V	Velocity	X	X	X	5, 50, 500 mm/s and AUTO
D	Displacement	X	X	X	50, 500, 5000 µm and AUTO
V / D	Velocity	X			5, 50, 500 mm/s and AUTO
	Displacement	X		X	

Explanations:

A - vibration acceleration measurement
V - vibration velocity measurement
D - displacement measurement
V/D - simultaneous measurement of velocity and displacement. Such measurement simplifies the machine condition evaluation (it is recommended by the ISO 10816-3 standard)
AUTO - automatic selection of the measurement range. The instrument samples the signal and selects the adequate range. The signal is evaluated on continuous basis and if necessary the range will be changed. During the change no result is displayed and instead there are displayed flashing horizontal lines.

For each quantity being measured it is possible to choose the desired frequency band. The choice of available filters is the following:

Measured quantity	Frequency band	Averaging duration
A, V, D, V/D	2 Hz ÷ 1 kHz	1 sec ÷ 60 sec
	10 Hz ÷ 1 kHz	1 sec ÷ 60 sec
	100 Hz ÷ 1 kHz	1 sec ÷ 60 sec
	1 kHz ÷ 10 kHz	1 sec ÷ 60 sec

Explanations:

Averaging duration – it is the record length in seconds that is used to calculate the results. For example, if the selected averaging duration is 5 sec then the RMS values are calculated on the block of data corresponding to this duration, while the P-K and P-P values represented the maxima during the last 5 seconds. The results are updated every 0,5 sec but the first result will be displayed after 5 sec. It is possible to select a different averaging duration for each filter and these settings are memorized.

Once we are done with the settings we can quit by selecting ***Return*** with the corresponding  key. We are now ready to start the measurement by pressing the 

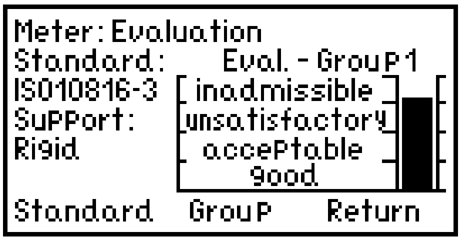
key. The horizontal lines begin to flash. The instrument picks up the selected measurement range (or if AUTO was programmed then it searches the adequate range), starts the measurement, and displays the result on the screen. The first result will appear after the time corresponding to the selected Averaging duration and is updated every 0,5 sec. To stop the measurement we press again the 

key. The last result remains displayed on the screen.

The execution of the measurement is indicated by the symbol in the upper right corner that is changing cyclically. Once the measurement is finished the symbol does not move any more.

2.3.2 Evaluation of machine condition accordingly to standards

In order to evaluate the machine condition one should pick on with the key  the ***Evaluation*** function. The following information will be displayed on the screen:



The ***Standard*** function allows you to choose among the ISO 10816 standards the one corresponding to your machine. If a given standard classifies the machines into groups then the ***Group*** function allows you to select the corresponding group. The table below summarizes the available standards:

Standard	Additional classification
ISO 10816 - 1	---
ISO 10816 - 2	1500 ÷ 1800 rpm
	3000 ÷ 3600 rpm
ISO 10816 - 3	Rigid support
	Flexible support
ISO 10816 - 4	---

By choosing Return we quit the Evaluation function. In order to return to the main menu we should press the key 

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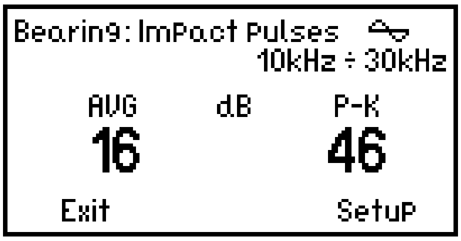
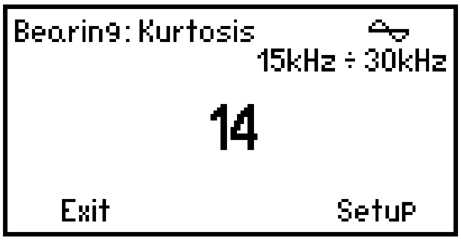
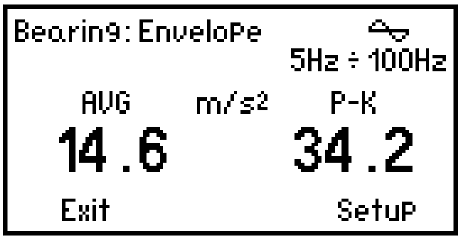
2.4 Bearings

In order to do the measurements that will allow us to evaluate the condition of bearings we must open the corresponding menu by selecting in the main menu with the key the symbol of a bearing. With DIAMOND the condition of a bearing is estimated using several methods that are based on the analysis of impact pulses, envelope and kurtosis. The menus corresponding to these different methods are shown below:



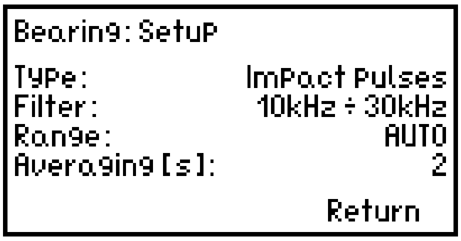




On the first line, immediately after the word « Bearing » is listed the quantity being currently measured, and on the second line the frequency range. Below on the left side is displayed the average value, in the middle the measurement units, and on the right the peak value. The display for kurtosis is different since it is a dimensionless value.

2.4.1 Settings for measurements on bearings

To enter into the menu that will allow us to setup the measurement we should press the key just below the word ***Setup***. The example of a display is shown below:



The selection of various parameters is done in a similar way as in the preceding chapter. The table below summarizes the possible choices:

Measured quantity	**Measurement ranges**	**Available frequency bands**	**Averaging duration**
Impact pulses	5,50,500 m/s², AUTO	10 kHz ÷ 30 kHz	1 ÷ 60 sec
Kurtosis	5,50,500 m/s², AUTO	5 kHz ÷ 10 kHz 10 kHz ÷ 20 kHz 15 kHz ÷ 30 kHz	1 ÷ 60 sec
Envelope	5,50,500 m/s², AUTO	5 Hz ÷ 100 Hz 50 Hz ÷ 1 kHz 500 Hz ÷ 10 kHz 5 kHz ÷ 30 kHz	1 ÷ 60 sec

Explanations :

Impact pulses - measurement of impact pulses that are generated by bearings. This measurement is done in the frequency range corresponding to the resonance frequency of accelerometer. The result is given in dB.

Envelope - measurement of the acceleration envelope which contains the information about the state of a bearing. The frequency band should be selected in such a way that the lower frequency is greater than 10 x rpm/60:

Rotational speed of the machine	**Filter**
< 30 rpm	5 Hz ÷ 100 Hz
< 300 rpm	50 Hz ÷ 1 kHz
< 3000 rpm	500 Hz ÷ 10 kHz
< 30000 rpm	5 kHz ÷ 30 kHz

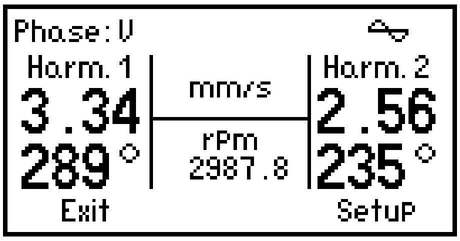
Kurtosis

- this dimensionless parameter indicates the impulsive content of the measured signal. The frequency band (i.e. the filter) should be selected experimentally for each case.

To quit the settings and return to the main menu press the arrow key underneath the word ***Return***. Starting and stopping the measurement is done similarly as in the previous chapter on vibration level meter.

2.5 Phase measurements (versions D and DT)

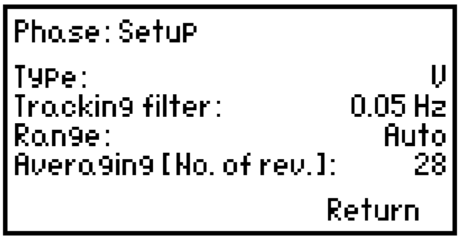
It is possible with DIAMOND 401 to measure simultaneously the phase of the first and the second harmonic of the rotational frequency, as well as the rotational speed. Obviously to achieve that one should use in addition to an accelerometer also the sensor measuring the rotational speed. We access the phase measurement function by selecting from the main menu the corresponding symbol. The screen looks then like this:



The quantity being measured is displayed in the first line, just after the word ***Phase***. Below, on the left side is shown the result for the first harmonic, on the right for the second harmonic, and in the middle the rotational speed.

2.5.1 Settings for phase measurement

After having selected ***Setup*** in the menu above we get the following display:



The table below shows the parameters that are measured for given quantities:

Quantity	Name	Range	Filter bandwidth	Averaging (number of rotations)
A	Acceleration	5,50,500 m/s^2, AUTO	0,05 Hz	
V	Velocity	5,50,500,mm/s, AUTO	0,5 Hz	1 ÷ 99
D	Displacement	50,500,5000 µm, Auto		

Explanations:

Averaging - the rotational speed is averaged from the selected number of rotations. The selective filter is tuned to this speed.

Filter bandwidth - the bandwidth of the selective filter that is used to filter out from the vibration signal the first and second harmonic components.

To start and stop the measurement we use the key 

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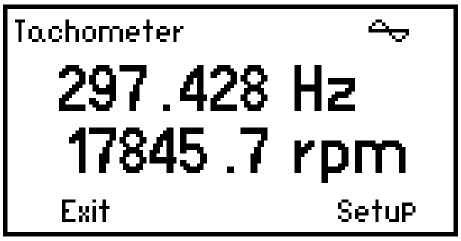
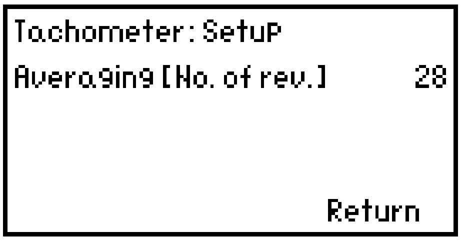
2.6 Rotating speed measurements (versions D and DT)

By selecting the appropriate symbol we access the function ***Tachometer***. The measurement result is displayed simultaneously in two units: Hz and rpm:



2.6.1 Settings for speed measurements

In the corresponding menu we are able to adjust only one parameter ***Averaging [No. of rev.]***. The rotational speed will be averaged from the selected number of rotations:



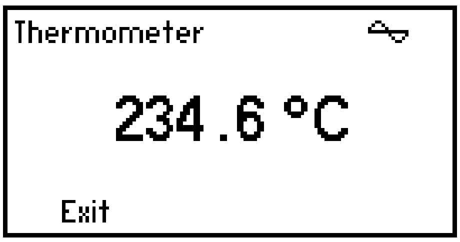
The keys 

and 

are used to select the number of rotations.

2.7 Temperature (versions ST and DT)

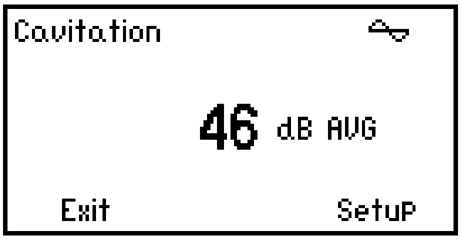
The temperature measurement is possible with versions ST and DT of DIAMOND 401. The measurement is done with the thermocouple of type K, which is connected to the instrument through an adequate converter. To access the function ***Thermometer*** we should press the arrow underneath the corresponding symbol. We get then the following display:



There are no parameters to be setup for this function.

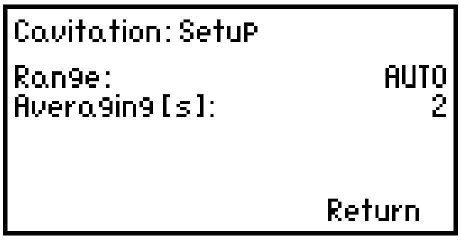
2.8 Cavitation

The cavitation measurements are very useful for the machines where this harmful phenomenon may occur, like pumps. DIAMOND 401 evaluates the cavitation by measuring the mean value of acceleration in the frequency bandwidth between 5 kHz and 30 kHz. To facilitate the interpretation the result is given as a relative value in dB:



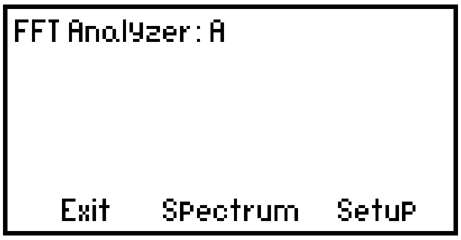
2.8.1 Settings for cavitation measurement

We can adjust two parameters: range and averaging time.



2.9 FFT analysis

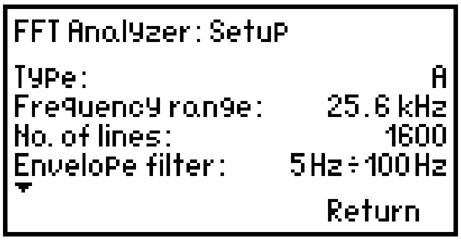
To choose this function we press the key  underneath the spectral analysis symbol and then the following display appears:

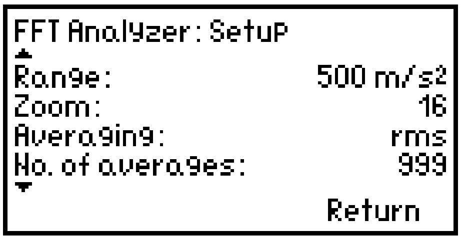


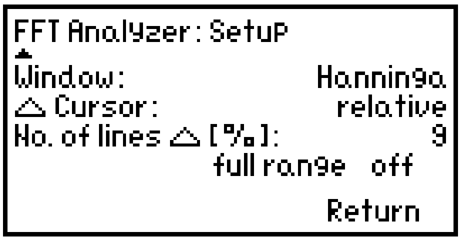
Immediately after the words ***FFT Analyzer*** is indicated the quantity chosen for analysis (for example, “A” for acceleration). To display the result of analysis, once the measurement is completed, one should press the arrow underneath the word ***Spectrum***. By selecting Setup we can adjust the measurement parameters which are more numerous than in previous functions.

2.9.1 FFT analyzer settings

The following three screens show the parameters that may be setup for the FFT analysis :







As we can see there are 9 parameters that may be setup, the last two do not concern the analysis but the display of the results. The table below shows the parameters that are different for different quantities:

Quantity	Description	Envelope filter	Frequency ranges	Measurement ranges P-K
A	Acceleration	X	100 Hz, 200 Hz, 400 Hz, 800 Hz, 1.6 kHz, 3.2 kHz, 6.4kHz, 12.8kHz, 25.6kHz	5,50,500 m/s², AUTO
V	Velocity	X		5,50,500 mm/s, AUTO
D	Displacement	X		50,500,5000 µm, AUTO
E	Envelope	5 Hz ÷ 100 Hz	100 Hz	5,50,500,m/s², AUTO
		50 Hz ÷ 1 kHz	100Hz, 200Hz,…1.6kHz	
		500Hz ÷ 10kHz	100Hz, 200Hz,…12.8kHz	
		5 kHz ÷ 30 kHz	100Hz, 200Hz,…25.3kHz	

The next table shows the parameters that are the common to all the quantities:

Parameter	Possible choices
Number of spectral lines	100, 200, 400, 800, 1600
Zoom	1, 2, 4, 8, 16
Averaging type	RMS, P-K, OFF
Number of spectra	1 ÷ 999
Window	Rectangular, Hanning

Explanations :

Envelope filter - corresponds to the frequency band that is chosen only for envelope analysis accordingly to rules that are applicable for bearing condition evaluation.

Frequency range - the analysis is done between 0 Hz and the selected frequency.

Number of spectral lines - this parameter defines the number of spectral lines that are calculated within the previously selected frequency range. The ratio of frequency range to the number of spectral lines defines the spectral resolution.

Zoom - this capability allows us to increase the spectral resolution around a given frequency. This frequency is picked up with a cursor and the whole number of spectral lines previously selected will be calculated in the frequency range that is narrower by a selected zoom factor.

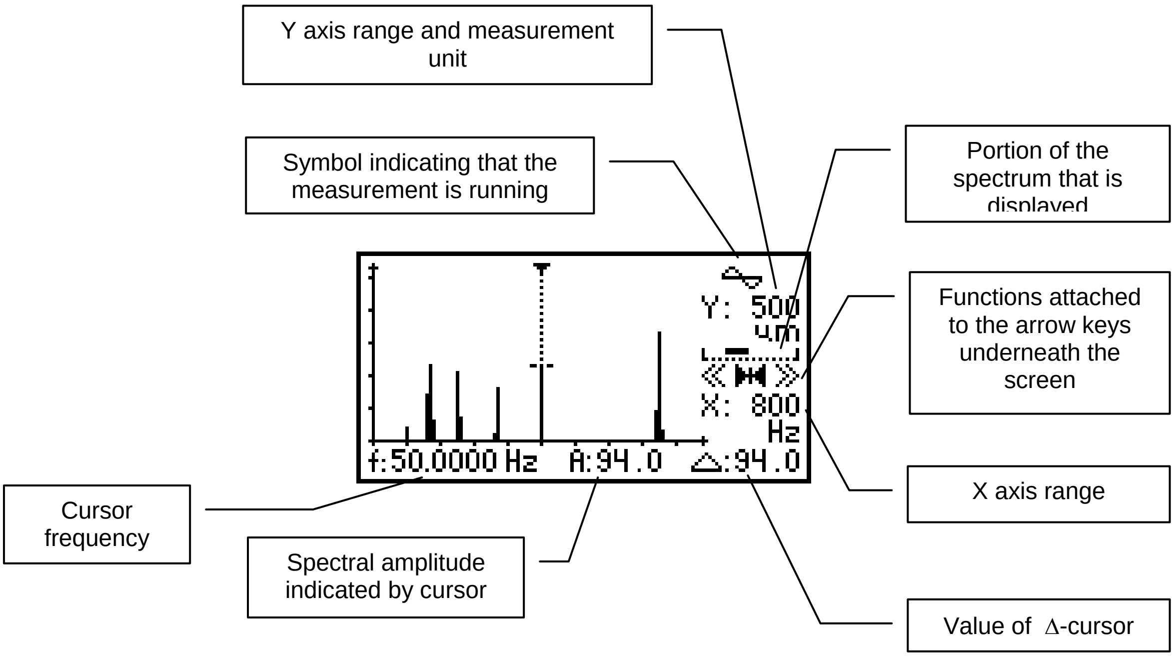
Averaging type - concerns the procedure that is applied to calculate the average spectrum from the spectral lines measured consecutively. The **RMS** averaging gives the result which is the square root of the sum of squares of lines entering into calculation (***Number of spectra***). The **P-K** averaging registers the max values of all lines being averaged.

Window - this function is used to improve the quality of the spectral estimation by reducing the so called « leakage ». The effect of leakage is that the amplitudes are underestimated and the spectral energy is « smeared » into a broadened spectral lines. The Δ-cursor function helps to find the real values of

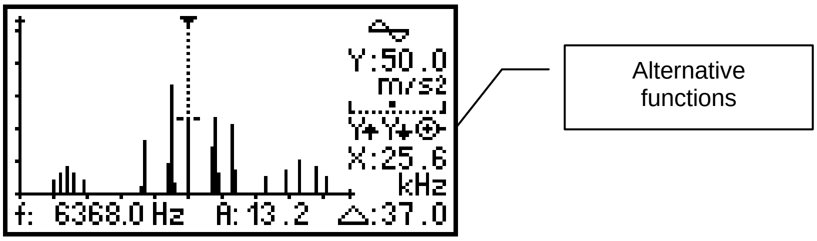
2.9.2 Running the FFT analysis

Once we are done with the setup we can start the analysis by pressing the key 

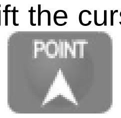
. The coordinates and the word "wait" appear on the screen. After some time the first spectrum is displayed which is then refreshed continuously. Here is an example of screen during the FFT analysis:



At the bottom of the screen is shown the frequency corresponding to the position of the cursor on the X axis, followed by the amplitude of the spectral line selected by the cursor, and the value of the function ∆-cursor. Vertically, below the sign indicating that the measurement is being executed is shown the Y-axis range and measurement units, further below is indicated schematically which portion of the entire spectrum is currently being displayed on the screen, followed by three symbols which are currently linked to the three arrow keys below the screen, and finally the X-axis range. The three symbols "<<", "►I◄", and ">>" represent, starting from the left: shifting the cursor by 1/10 of the display to the left, centering the cursor at the middle of the display, and shifting the cursor by 1/10 of the display to the right. By pressing the key  we change these functions as shown below:

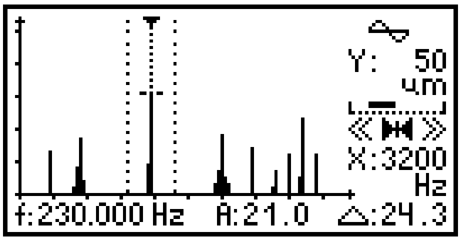


Now, starting from the left we have: vertical expansion of the display, vertical contraction of the display, and zoom function.

Some other keys on the front panel are also available to modify the display: the keys  and  allow us to shift the cursor step by step (spectral line by spectral line) to the left or to the right, and the keys  and  can be used to expand or to contract the X-axis.

The function ∆ **- cursor** helps to add the values of the spectral lines. While setting up the FFT analysis one can choose several modes for ∆ **- cursor:** ***off***, ***total***, ***constant*** and

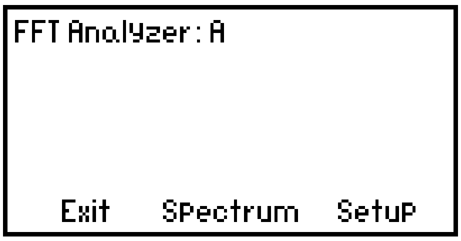
relative. When this function is ***off*** then the spectral value indicated by **Δ - cursor** is equal to the value indicated by cursor. When it is set to ***total*** then its value is equal to the sum of all spectral lines. When **Δ - cursor** is set to ***constant*** or ***relative*** then we should also specify the number of the spectral lines. When the choice is ***constant*** then this number indicates the absolute width of the window, while in the case of ***relative*** the width of the window is expressed as the percentage of the central frequency of the cursor. The portion of the spectrum that was thus selected is indicated on the screen by two vertical dotted line disposed symmetrically on both sides of the cursor. These two modes of **Δ - cursor** are used to eliminate the error introduced by the leakage: the frequencies generated by a machine usually do not correspond to the locations where are calculated by FFT the spectral lines and therefore the energy contained in a frequency generated by a machine is redistributed on several spectral lines. The function **Δ - cursor** helps to gather up this energy by adding the spectral lines delimited by the dotted lines and therefore it produces the accurate value. Below is shown an example with **Δ - cursor** activated:



The results of the spectral analysis are continuously refreshed on the screen. To stop the analysis we should press the key 

. The last result remains on the display. The key 

 is used to erase the display:



To review the last result we should with the arrow key underneath the screen select ***Spectrum***. To quit the FFT analysis we can select ***Exit*** or press 

.

2.10 Balancing (versions D and DT)

The unbalance of rotating parts is the most commonly encountered reason for the deterioration of a machine’s condition. It is characterized by a high level of radial vibrations having the frequency which corresponds to the rotating frequency. DIAMOND 401 has options for balancing the machines in their bearings and it can be used to perform the measurements and calculations necessary to get the job done. To be able to perform the balancing we need to have the access to the rotor, how it is possible for example in fans.

The balancing is done in several steps: first we must evaluate the mass distribution on the rotor, and then to correct this distribution by adding or removing some mass at specific locations in order to obtain the desired residual unbalance or the satisfactory level of vibrations. Most often the balancing is done in one or two planes. When the length of the rotor compared to its diameter is small then one-plane balancing will do the job, but for rotors of bigger dimensions two-plane balancing is necessary.

The steps for one-plane balancing:

START

Installation of an accelerometer close to a bearing, placing the marker on the rotor and installation of the tachometer.

Preliminary measurement of vibrations and phase

Placing the test weight

Measurement of vibrations and phase with the test weight – mp

Interpreting the result – correction m0, dismantling the test weight and mounting the correction mass

Measurement verifying the effect of the correction mass m0

Interpreting the result – installation of the correction mass m1

Measurement verifying the effect of the correction mass m

Etc.

We continue this procedure as long as we get the satisfactory level of vibrations or of the residual unbalance.

The steps for two-plane balancing:

START

Installation of two accelerometers close to bearings at the ends of the rotor, placing the marker on the rotor and installation of the tachometer.

Preliminary measurement of vibrations and phase on both planes

Placing the test weight on the first plane

Measuring vibrations and phase on both planes with test weight – mp on the first plane

Dismantling the test weight from the first plane and its installation on the second plane

Measuring vibrations and phase on both planes with test weight – mp on the second plane

Interpreting the results – corrections m0/P1 et m0/P2 separately for the first and the second plane, dismantling the test weight and mounting the correction masses on their respective planes

Measurement to verify the effect of the correction masses m0/P1 et m0/P2

Interpreting the results – corrections m1/P1 et m1/P2 separately for the first and the second plane, and mounting the correction masses on their respective planes

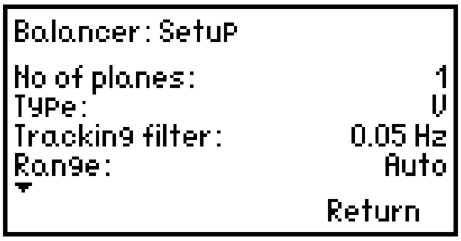
Measurement to verify the effect of the correction masses m1/P1 et m1/P2

Etc.

We continue this procedure as long as we get the satisfactory level of vibrations or of the residual unbalance.

2.10.1 Balancer settings

By choosing in the main menu the symbol of a balance we enter the balancing function. As usual, first we have to adjust the settings and therefore we enter the setup menu:



Explanations:

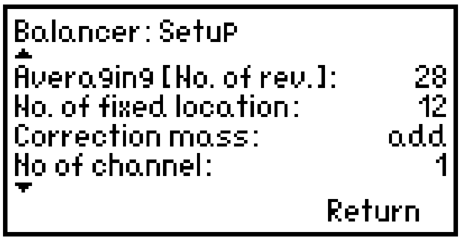
No of planes - we choose one-plane or two-plane balancing (the choice is 1 or 2)

Type - defines the vibration quantity that will be measured during the balancing. In the case of DIAMOND it is fixed and it is the velocity (so we cannot change this parameter and "V" is displayed for information only°.

Tracking filter - defines the bandwidth of the tracking filter. The choice is between 0,05 Hz and 0,5 Hz. Typically, for the machines rotating at speeds greater then 600 rpm the 0,5 Hz filter will be used, while for the rotations below 600 rpm the 0,05 Hz filter is recommended.

Range - measurement range, choice is similar like with the other measurements.

The arrow underneath the word ***Range*** indicates that there is another screen with more parameters to be setup:



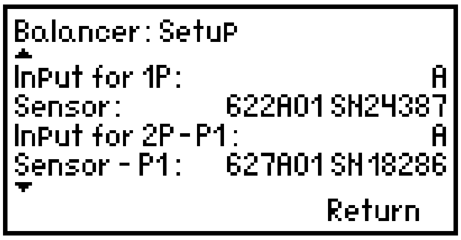
Averaging [No of rev.] - number of rotations used to calculate the average rotating speed. The choice is between 1 and 99.

No of fixed location - indicates the number of locations that are available on the rotor for the installation of corrective masses. These locations should be disposed uniformly in the correction plane. Is it possible to program between 3 and 90 locations.

Correction mass - for information only. ***add*** means that during the edition of the test weight we indicate the location where this weight should be placed. Also when we interpret the result the angle indicates the location where to place the corrective mass.

No of channels - we can set 1 or 2, but we can select 2 only if the No of planes is also set to 2. If for two-plane balancing we select 1 channel, then we do the measurements in one plane after another, while if we select 2 channels then the measurements in both planes are made simultaneously.

… cont'd …



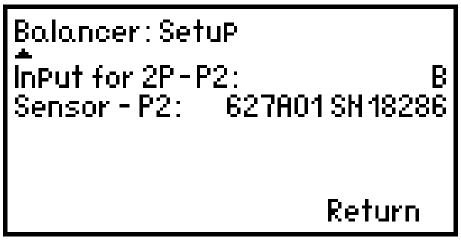
Input for 1 P - active input for one plane balancing. We can choose A or B.

Sensor - description of the transducer that will be connected to the channel selected above.

Input for 2P – P1 - input that will be associated with the plane 1 in two-plane balancing. The choice is between A and B.

Sensor – P1 - description of the transducer that will be connected to the channel selected above.

… cont'd…



Input for 2P – P2 - input that will be associated with the plane 2 in two-plane balancing. The choice is between A and B.

Sensor – P2 - description of the transducer that will be connected to the channel selected above.

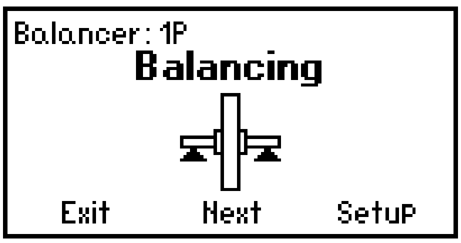
> ***In the case when we do the two-plane balancing and we choose the number of channels equal to 2, then if we have associated the input A with plane 1, the input B will be automatically assigned to the plane 2, and vice versa.***

> ***The cable with a branching for two transducers is specially designed for the balancing and furnished with the instrument. The cable with the green mark is destined for the input A, while the one with the blue mark – for channel B.***

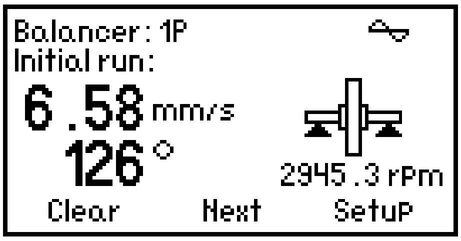
Once we have completed the settings we press ***Return***.

2.10.2 One-plane balancing

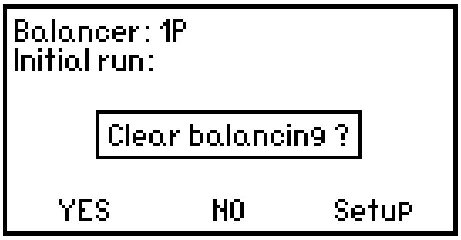
If we have selected one-plane balancing (No of planes = 1) then the following screen appears after having pressed ***Return***:



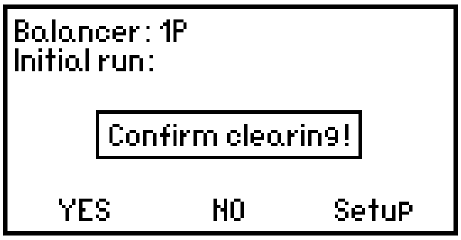
In order to continue you should press the arrow underneath the word ***Next***. Appears the first screen related to the preliminary measurement as shown on the following example:



If in the buffer memory remain the results from the previous balancing then they will be displayed on the screen. We have now the possibility to either continue the previously started balancing or to start a new one. To clean the results from the buffer memory one should select ***Clear,*** and anwser the following question:



If we have chosen ***YES*** then we are asked to confirm:



We will then get back the intitial screen with buffer memory erased.

The whole balancing procedure consists of consecutive steps which are shown on the following screens. In order to get to the next step we should select Next, and should we need to return then we select Back.

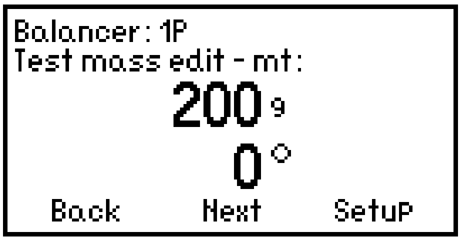
In order to perform the preliminary measurement we press the 

button. DIAMOND first activates the tachometer, mesures the rotational speed and then starts to measure the amplitude and the phase of vibrations at a given rotational frequency. As soon as we see that the displayed results have stabilized we can stop the measurement by pressing the 

button.

The time necessary for the result to stabilize on the display depends on the choice of the Tracking filter. If we have chosen the 0,5 Hz filter then this time is about 4 seconds, while for the 0,05 Hz filter we must wait about 40 seconds.

The last result remains displayed on the screen. To pass to the next step, that is the edition of the test mass, we press the arrow below ***Next***:



The weight and the angular position of the test mass are displayed on the screen. In order to start the editing one should press the button . It is possible to edit three digits, the position of the decimal point, and the measurement unit. The selection of the consecutive elements for the edition is made with the horizontal arrows 

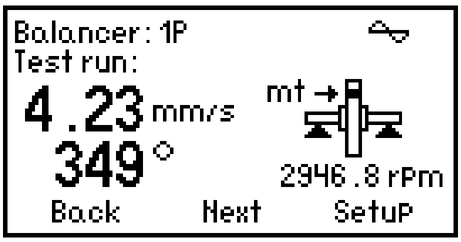
and 

, while the change of digits, of the position of the decimal point and of units is obtained with the vertical arrows 

and 

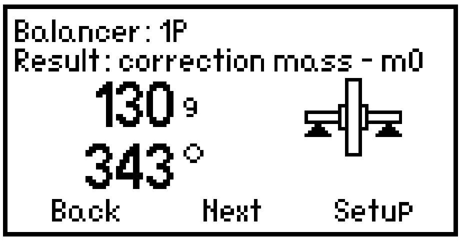
. To confirm the value of the mass that we have edited we press the button  and automatically we pass to the edition of the angular position. As previously it is possible to edtit three digits and as previously by pressing  we confirm and close the edition. To quit the edition without making any change one should press 

. Once the edition is completed we select ***Next*** and we move on to the measurement with test mass. Obviously, before starting the measurement we should place the test weight in the indicated location.



To start and to stop the measurement we use, as always, the button 

and we continue once the measurement is completed. On the next screen appears the first balancing result indicating the correction mass m0 :

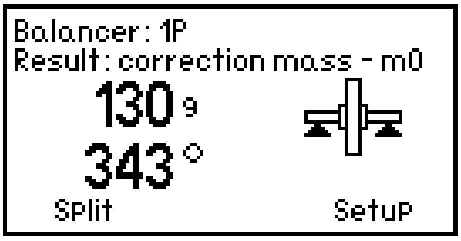


We remove from the rotor the test mass and we install, at the indicated on the screen location, the correction mass m0.

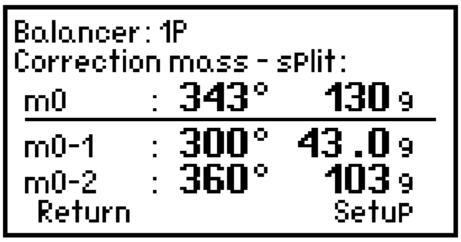
> ***The location at which was installed the test mass is considered as reference 0°. We measure the angle with respect to this reference in the direction opposite to the rotations of the machine. This rule holds for all locations of the correction masses.***

When it is not possible to place the weights at the indicated locations, then the solution consists in breaking down the results into components. If for example we have 6 mounting points rellocated every 60° that means that in the settings we have selected *No of fixed location* = *6*. To break down into the authorized components we press the button 

and the functions above the arrow keys change and we get the following display:

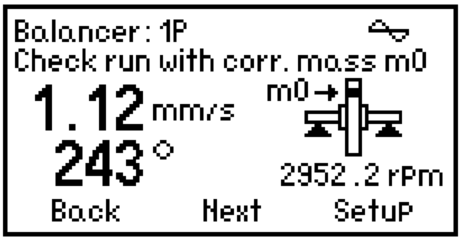


By selecting ***Split*** we get a display on which the calculated location is broken down into two locations where we can now place the corrective masses. In this example these locations are at 300° and 360°:

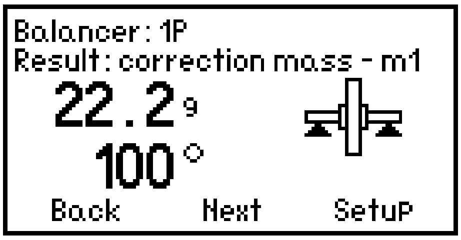


By selecting ***Return*** we quit this procedure and return to the measurement. We do a new measurement with the correction mass m0 installed by pressing 

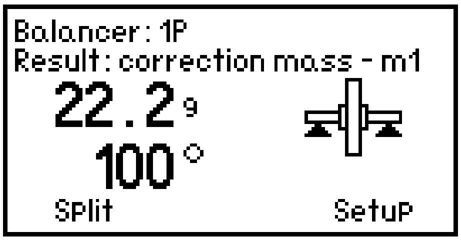
:



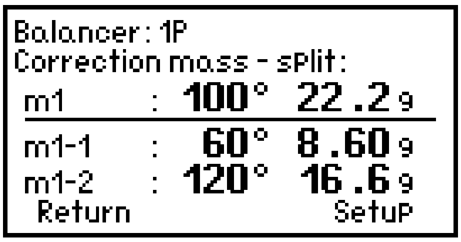
We notice that once the correction mass m0 installed, the vibration component is six times smaller than during the preliminary measurement. This improvement was obtained after the first step in the balancing procedure. To continue we press ***Next*** and we get the correction mass m1 :



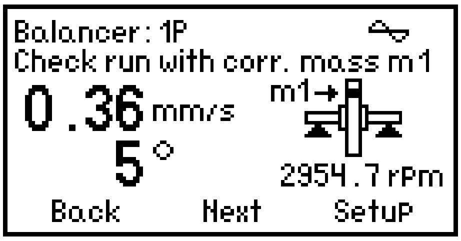
As we can see this mass is already significantly smaller than m0 and step by step we get closer to the situation when the rotor is perfectly balanced. Let us assume that we are already satisfied and in this case we would consider the mass m1 as the residual unbalance. But let's continue and in this case we should ask to break down this mass into several locations so we press  and we get new functions at the bottom of the display. Now we select ***Split***.



The result appears on the next display:



Without removing the mass m0, we install at the indicated locations the mass m1, and in order to check the efficiency of this modification, we repeat the measurement:



We find out that compared to the previous result the installation of the correction mass m1 has reduced the vibrations by a factor of three, and in total the installation of the m0 and m1 masses has reduced the vibration by a factor of almost 20.

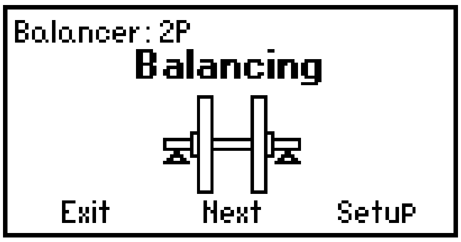
We could continue this process up to the correction mass m9 but in most cases it is not necessary, and usually after two or three steps the results are entirely satisfactory. The last correction mass that was calculated may be considered as the residual unbalance of the balancing procedure. To quit the procedure we hit .

2.10.3 Two-plane balancing

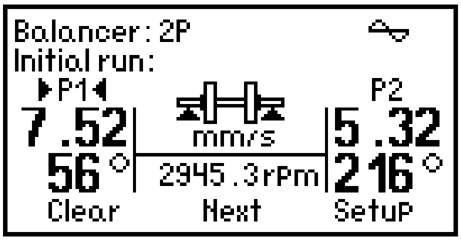
Two-plane balancing is a dynamic balancing where one places correction masses on two planes. Therefore it will be necessary to perform the measurements on the planes corresponding to two bearings, preferably at opposite ends of the rotor. Before starting the balancing one should select ***No of planes = 2***. If we have at our disposal only one accelerometer then we will have to move it from one plane to another. On the other hand, if we have two transducers then we can fix them and we won't be obliged to move them around. This reduces the risk of committing errors, shortens the time necessary to complete the balancing, and renders the procedure easier to handle.

If in the settings we have selected the number of channels equal to one (***No of channels = 1***) then the measurements will be performed alternatively on one and another plane. On the contrary, if we have selected the number of channels equal to two, then it will be possible to perform the measurements simultaneously on both planes. It is important to assign each plane to one of the two channels and to have the related transducer installed on the corresponding plane.

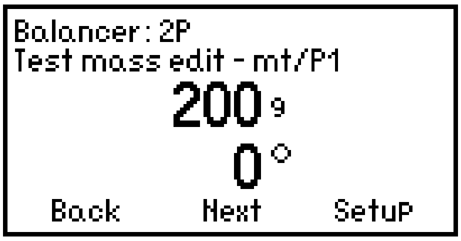
The settings are adjusted in the same way as it was discribed in a previous paragraph. Once we are done with the settings we get the following display:



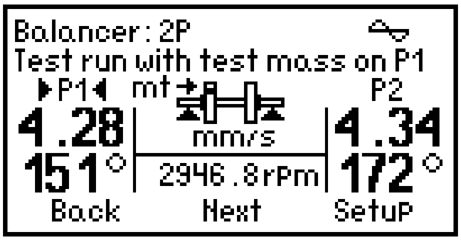
Selecting ***Next*** will get us to the preliminary measurement :



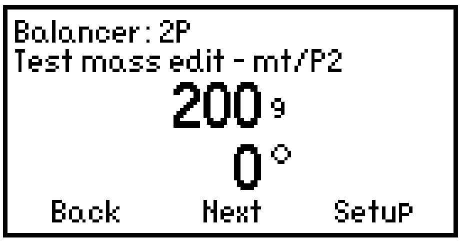
If we have selected only one channel then the arrows ▶ and ◀ next to P1 or P2 indicate the plane that is currently chosen for the measurement. With ***Back*** and ***Next*** we move the arrows from one plane to another. In the case of instrument version D and having selected two channels, the arrows will indicate both planes. We launch and stop the measurement with the button START / STOP. If we use only one channel, then we do the measurement on one plane and afterwards, by selecting ***Next*** we move to the other channe on which we repeat the measurement. Once the preliminary measurements on both planes are completed we move on to the edtion of the test mass for the plane 1.



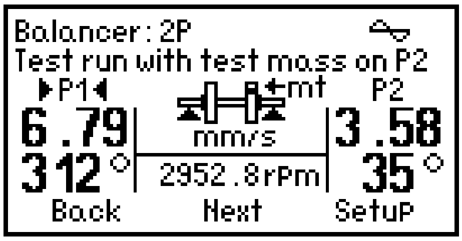
We do it in a similar way as in the case of the one-plane balancing and after installing this mass on the plane 1 of the rotor we do the measurement.



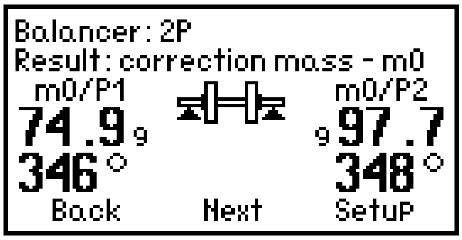
Next we remove the test mass from the plane 1 and we move on to the edition of the test mass for the plane 2 and we install it on this plane.



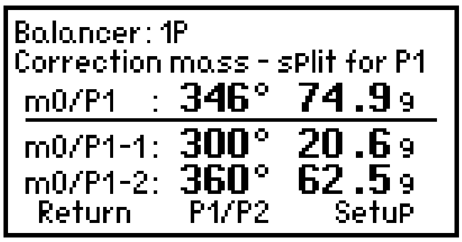
We do the measurement with this mass installed:



Once the measurements are completed we can read the first results. The correction masses m0 are indicated separately for the two planes: m0/P1 et m0/P2.



Similarly as in the case of one-plane balancing we can break down the correction masses in order to place them at the reserved for this purpose locations. The center button-arrow below ***P1/P2*** allows us to switch between planes:

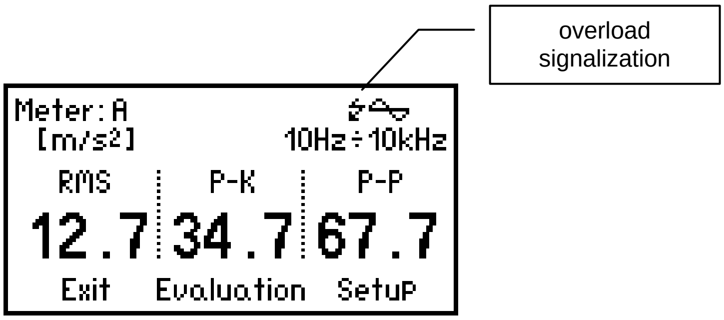


Next, we install these masses at the indicated locations, each on its respective plane, and we do the measurement to see the improvement resulting from the correction masses m0.

We continue the procedure with the correction masses m1 and following (the total number is limited to 10), each for its respective plane, until we obtain the satisfactory results.

2.11 Measurement overload

The overload occurs when the signal's amplitude exceeds temporarily or permanently the measurement range and it results in signal deformation. The user should be immediately informed about its occurrence since the overload introduces a significant measurement error. In DIAMPOND the overload is signalled by a symbol of lightning that appears in the upper left corner of the display:



This symbol tells the user that the measurement result that is displayed on the screen may be affected by an error. If the overload is temporary and disappears after a while then the lightning symbol will disappear as well and the measurement result is correct. If the overload sign reappears quite often then we should increase the measurement range. On the other hand if we have selected the range AUTO then the instrument will take care of this problem and will change the range automatically. However if we have reached the highest measurement range and we still have the overload condition then it means that the signal exceeds the measurement range of the instrument. This is a rare case which may happen with some high speed machines in which the bearings or transmissions are out of order. If such is the case then the solution consists in replacing the accelerometer with another one 10 times less sensitive.

2.12 Memory management

DIAMOND 401 is equipped with the Flash memory for recording and storage of measurement results. There are two ways of using this memory depending on the type of measurement to be saved. Therefore we distinguish two types of memory called: "regular" memory and "route" memory.

To enter the memory we hit the button 

and to leave it we have the choice between pressing again 

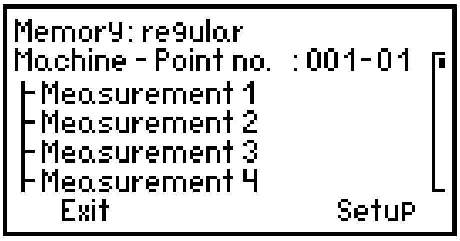
or 

.

 ***In order to avoid the errors all operations on the memory are locked if the batteries are low. One should then use the external power supply.***

2.12.1 Regular memory

In this memory the machines and the measurement points are designated by consecutive numbers. A machine can have the number between 1 and 100 while the measurement points are numbered from 1 to 15. Therefore, when working with the regular memory we can distinguish up to 100 machines and on each machine 15 measurement points. Here is how looks the display of a regular memory:



To select the number of a given machine we use the keys and , while to pick up the measurement point on the selected machine we use the keys and .

2.12.1.1 Measurements recording in the regular memory

If, once the measurement is completed and its result displayed on the screen, we would like to register it in the regular memory then we should first press the button and then using the respective keys we must enter the number of the machine and the number of the measurement point. The recording is accomplished after pressing the key underneath the word ***Save***. To return to measurements we should press either the key , or select ***Exit*** with the key .

2.12.1.2 Displaying and cancelling the measurements

In order to visualize or to cancel the measurements that are recorded under the currently displayed number of the machine and the measurement point one should press the key . The first measurement that was recorded for this point is then highlighted. With the keys and we can select another point. To delete the selected measurement we should press the key that is just underneath the word ***Delete***. If instead we press the key then the corresponding result will be displayed on the screen. The letter « ***M*** » on the top of the screen reminds that this measurement is displayed from the memory. To return to the list of measurements we should either pres the key . Pressing again the key or selecting ***Exit*** will get us back to the departure level in the memory, where we can select another machine and the measurement point number.

2.12.1.3 Repeating a recorded measurement

Should we would like to repeat a measurement that was previously recorded in the regular memory, then we just need to highlight this measurement and press 

. The question whether we want to repeat the measurement will be displayed on the screen and when we answer ***YES*** then we shall be asked to confirm our choice. In case of positive reponse the measurement will be executed. To stop the measurement we press the button 

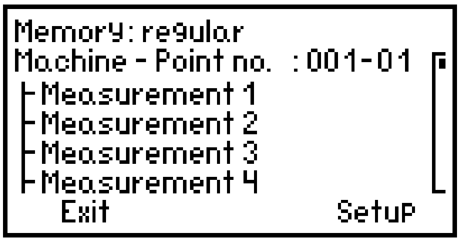
. To return to the memory menu we should either press 

, or choose the word ***Exit***. At the moment when we return to the memory menu, the old measurement is replaced by the new one.

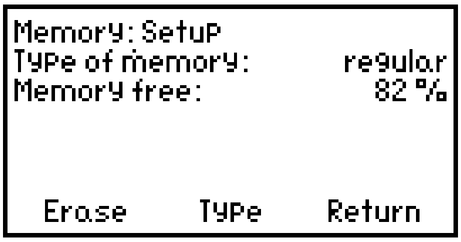
2.12.1.4 Erasing the regular memory

The choice of the memory type or the complete erasing of the memory are done with the help of memory ***Setup***. When we are in the memory menu and we press the key 

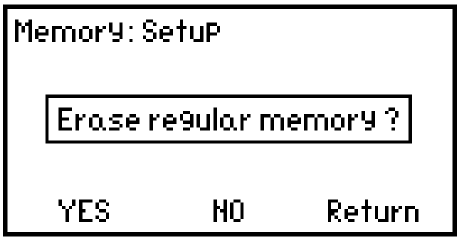
then the screen will look like this:



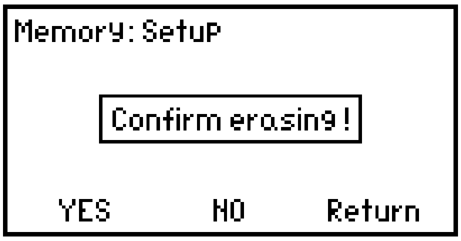
By choosing ***Setup*** we get into the memory management menu:



By choosing ***Type,*** we can switch between the regular and route memories (if the information concerning the route wasn't introduced into the instrument then the choice of route memory is not available). If we have chosen the regular memory and we would like to erase it, then we should hit the arrow underneath the word ***Erase*** :



To confirm we choose ***YES***, if not – ***NO*** or ***Return***. If we have chosen ***YES***, then we must confirm our choice :



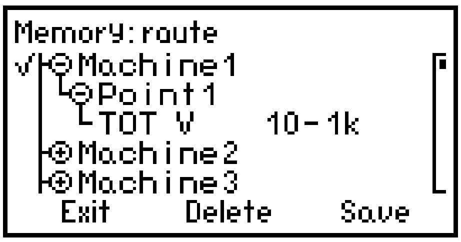
This is the last moment when we can still avoid the erasing of the memory by either selecting ***NO***, or ***Return***. If however we confirm and choose ***YES,*** then the regular memory will be erased.

2.12.2 Route memory

This type of memory is designed for collecting the data accordingly to the predefined measurement route. In this mode all machine and measurement point names are downloaded from the computer. This measurement route is first conceived on the computer using the MBJLab software. The information concerning the measurements that should be performed at each of the measurement points is downloaded together with their names. This mode of operation allows the user to easily and efficiently collect the measurement data. At any point along the route it is possible to add measurements that were not planned. However it is not possible to add the machines or the measurement points. If we want to perform additional measurements at points which were not planned then we can always switch back to the regular memory mode and register these measurements under any machine or measurement point number.

2.12.2.1 Collecting the measurements in the route memory

The route memory has a tree structure: the first level is reserved for machines, the second for the measurement points on respective machines, and the third one concerns the measurements that should be executed at these points. The following display reflects the structure of the route memory:



It is possible to unfold and fold back the tree of the route memory. When the tree is folded up then on the screen are listed only the names of machines. One of the machine names is always highlighted. Using the keys 

and 

we can move around the list until we locate the desired machine. By pressing  we unfold the corresponding branch and get the list of measurement points available on this machine. Using the same keys we can move the highlighted zone on the list of points. By pressing again  we unfold the branch of the selected point. The reversed video will appear now on the list of measurements that should be performed in a given point. To fold back the branches we use the key 

.

If the reverse video characters are on the list of measurements then by pressing the 

key we launch the highlighted measurement. To stop the measurement we press again the 

key. The instrument returns then to the memory mode, records the measurement that was just executed and the sign (✓) is placed in the list next to this measurement. Afterwards the next measurement in the list is highlighted and we can launch it immediately by pressing 

. When the sign (✓) appears next to all measurements for a given point (what means that all the measurements for this point are done) then this sign will appear also next to the name of this point. We should press then 

and select the next measurement point. If we have completed all measurements for all points of a given branch then the sign (✓) will appear next to the name of the machine to which belong all these points. In this case we can select another machine, unfold the branch, and again unfold the branch of the selected point and continue to collect the measurements. Once we have completed all measurements of the route then the sign (✓) will be displayed on the first line, next to the word ***Route***.

2.12.2.2 Adding extra measurements to the route memory

It is possible to record an additional measurement at each measurement point of the route memory. To do that, and once this extra measurement is completed, we switch to the memory mode, place the reverse video on the corresponding point and press the arrow underneath the word ***Save***. The measurement will be saved alongside this point.

2.12.2.3 Displaying the measurements from the memory

To visualize a measurement one should select this measurement by highlighting it in the list and press . The selected measurement will be displayed on the screen and the letter ***M*** which appears on the top of the screen indicates that this measurement originates from the memory. By pressing 

we return to the memory tree. Obviously, we can only view the measurements which are completed, that is those having the sign (✓) next to their names.

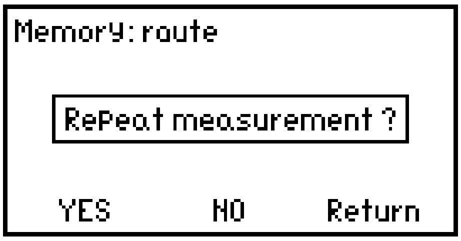
2.12.2.4 Canceling the measurements

To delete a measurement we must select it by placing the reverse video on its name and press  which is just below the word ***Delete***.

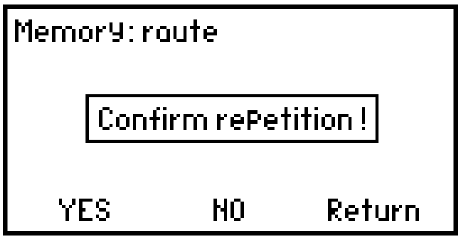
2.12.2.5 Repeating the measurement on the route

If for any reason we would like to repeat a measurement that is already recorded in the route memory then we should place the reverse video on its name and press 

. The following question is displayed on the screen:



By choosing ***NO*** or ***Return*** we return to the memory mode. If we have chosen ***YES*** then we have to confirm:



The last chance to avoid the replacement of the recorded measurement by a new one is by selecting either ***NO***, or ***Return***. By choosing ***YES*** we launch the new measurement. As usual, to stop the measurement we press 

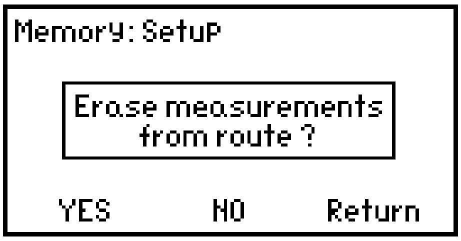
. Once the measurement is completed we return to the memory mode by selecting ***Exit*** or by pressing 

. At this point the old measurement result is replaced by the new one.

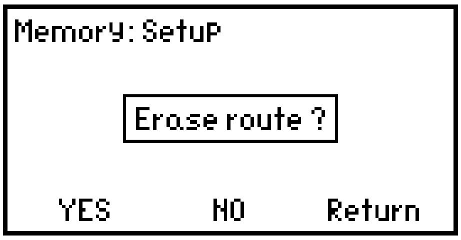
2.12.2.6 Erasing the route memory

In the case of route memory one should first erase the recorded measurements and only afterwards it is possible to erase the route. To do that we need to enter into the memory settings and select ***Type of memory : route***.

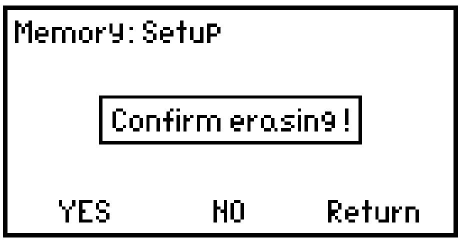
Next, using the arrow  we select ***Erase***. The question will appear :



By choosing ***YES*** we get ready to erase the measurements or the measurements together with the route (in order to avoid this we should choose ***No*** or ***Return***) :



Now we have three choices: by choosing ***YES*** we erase the measurements *and* the route, if we have chosen ***NO*** then only the measurement results will be erased, and nothing will be erased if we choose ***Return***. Finally, if we have decided to erase something by selecting ***YES*** or ***NO*** then we still have to answer the following question:



By selecting ***YES*** we erase the memory. By choosing ***NO*** or ***Return*** we can still safely withdraw from this operation.

2.12.3 Designating the measurement types in the memory

In the memory each measurement has its concise description. These descriptions are displayed on the screen both with regular and route memories. Here is the scheme that is used for the measurement descriptions:

TOT A 10-1k

Field 1 (three letters): description of the type of the measurement:

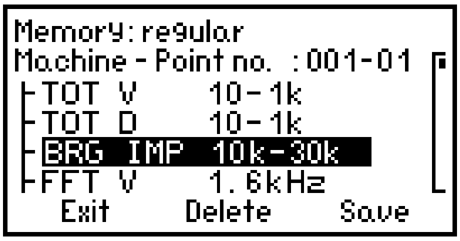
TOT – global level (vibrometer)
BRG – bearings verification
FFT – frequency analysis
BAL – balancing
SPD – rotational speed
TMP – temperature
CAV – cavitation
PHI – phase

Field 2 :

A – acceleration
V – velocity
D – displacement
V/D – velocity with displacement
ENV – envelope
IMP –pulses
KRT – kurtosis
E – envelope for FFT
1 – one-plane balancing
2 – two-plane balancing

Field 3: description of the filter or the frequency range

Example :



2.12.4 Formatting the memory

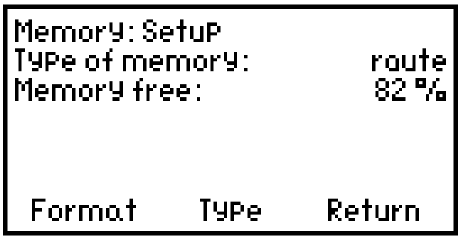
This operation will erase the whole memory and as a result all information contained in the memory will be lost.

In order to format the memory one should open the memory menu by pressing 

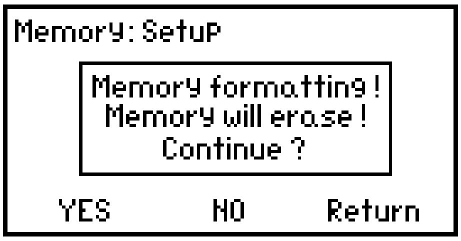
.

Next with the help of the key 

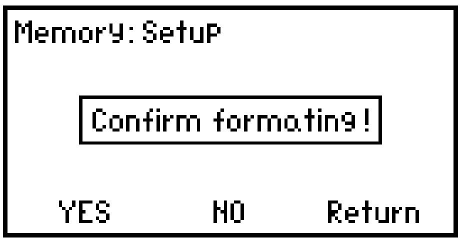
we change the functions that are displayed at the bottom of the screen in order to get the access to the function ***Format*** :



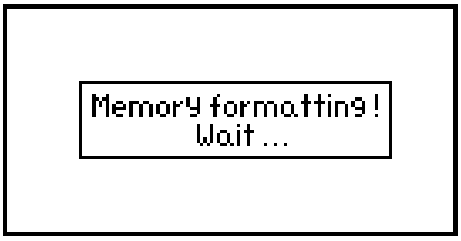
We select this function with the key  and the following message and question are displayed:



Anwsering ***YES*** requires still the confirmation:



At this point the formatting begins and during the formatting the following message is displayed:

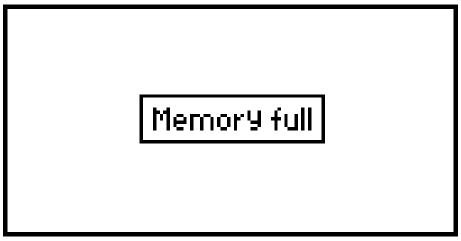


The formatting lasts about one minute.

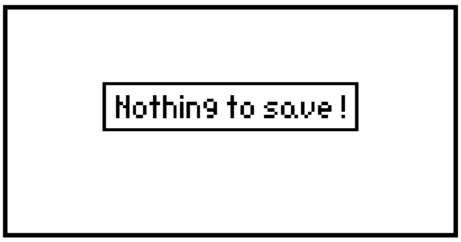
You should make sure that during the formatting the power supply of the instrument is working properly. If the batteries are weak then the formatting is not possible. It is recommended to do the formatting with external power supply which should remain connected the whole time. It is not allowed to switch off the instrument during the formatting and for this reason the button is disabled while formatting is in process.

2.12.5 Memory messages

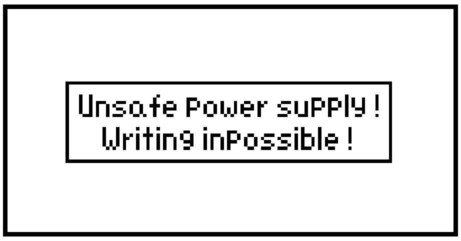
The following message will appear if during the recording the memory is full:



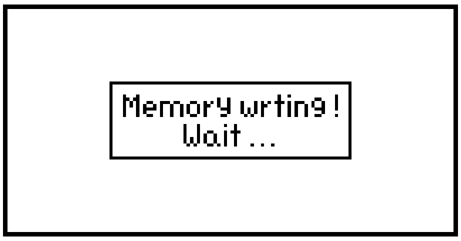
If we open the memory from the main menu or while executing the measurement but without any result to save, then if we select ***Save*** we get the following message:



Another message will appear when we would try to write into the memory while the batteries are weak:

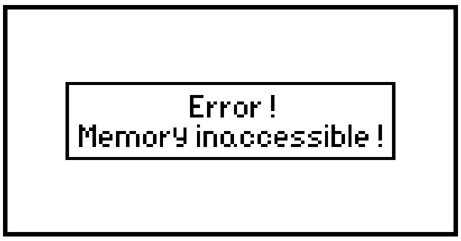


During the recording or erasing the following message is displayed:

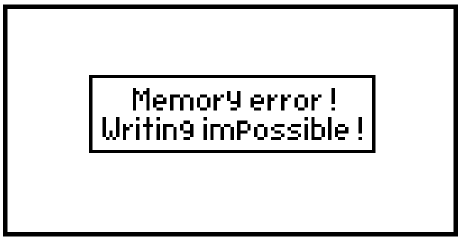


From time to time the memory needs to be refreshed and then the message shown below will appear. This happens very rarely but when it happens then you should wait until it disappears:

In case of error the access to the memory is forbidden:



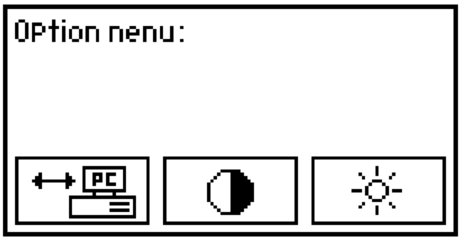
Finally, if there is an error during the recording then the following message appears:

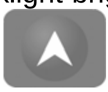


2.13 Options

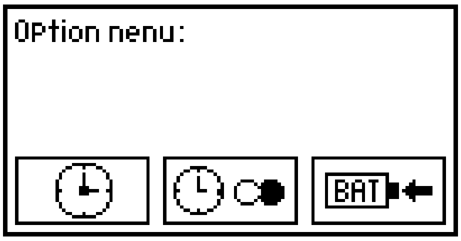
The remaining functions and settings are dealt with in the menu ***Option***. To access this menu you should press the button 

:



The meaning of the symbols starting from the left is: communication with PC, adjusting the contrast and adjusting the backlight brightness of the display. As usual we select the desired option with the corresponding  key. In order to get the remaining functions that are available under Options we should press 

. Here are the two additional screens:



From left: adjusting time and date, selecting the time of power self-release, connecting and disconnecting charging of batteries.

The meaning of the symbols starting from left: selecting the accelerometer, information concerning the calibration and the self-test function.

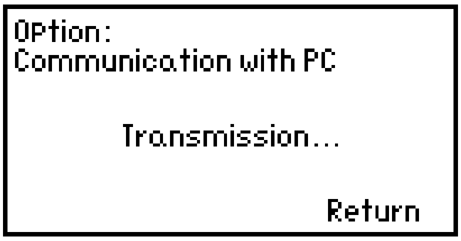
2.13.1 Data transfer to the computer

In order to communicate with the computer the user should do the following:

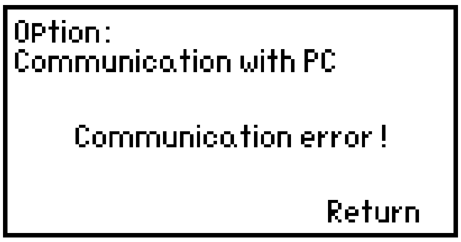
1. Connect the DIAMOND to the RS232 port of the PC
2. Select from the Options menu communication with PC
3. From the PC program launch the transmission

Once the option of communication with PC is selected the following message is displayed:

The message changes when the transmission is launched:



If there is an error in the transmission then we are warned by the following message:



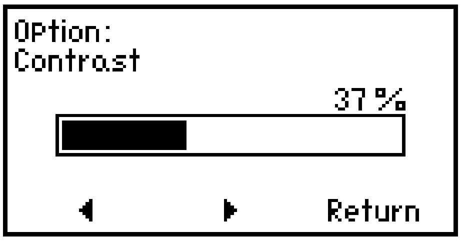
Once the transmission is completed the instrument returns to the Options menu. It is possible to interrupt the transmission either by pressing 

, or by selecting on the screen the word ***Return***. However, in practice it is recommended to avoid interrupting the transmission without having a serious reason, since it may result in the partial loss of information.

It is important to make sure that during the transmission there won't be a problem with the power supply. If the batteries are low then during the transmission one should use the external power supply. The external power supply should be connected to the instrument only after the connection with RS232 is made. Once the transmission is over then we first disconnect the external power supply and only afterwards we disconnect the RS232 cable. This sequence is important to avoid any damage to the RS232 link.

2.13.2 Contrast

This option allows us to optimize the contrast of the display. The range of the adjustment is between 0% and 100%. The contrast of the LCD display is sensitive to the ambient temperature and therefore it is very useful to have this possibility when the working environment is changed quite often. The screen for changing the contrast looks like this:



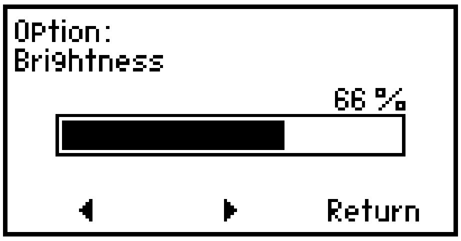
We make the adjustments by pressing the arrows  located underneath the respective signs ◀ or ▶.

The contrast adjustment is memorized. So if the last adjustment before switching the instrument off was so weak that we see nothing on the screen, then when we turn the instrument on we won't see anything again. This is a problem since we won't be able to change the adjustment of the contrast in order to recover the information being displayed on the screen! That's why there is a protection to avoid such a situation: while turning the instrument on one should keep the key 

depressed. This will restore the normal value of contrast and we shall be able to work with the instrument again.

2.13.3 Brightness

This option allows us to regulate the luminosity of backlight of the display:

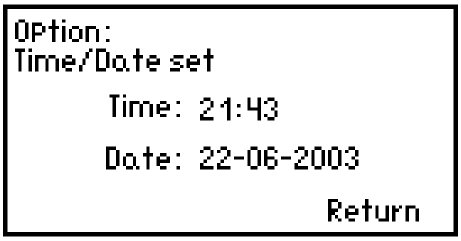


The following choices are possible: 0, 33, 66, 100%. 0% means that the backlight is turned off. Us for contrast the adjustment is made by pressing the arrows underneath ◂ or ▸.

Using the backlight increases the consumption of the energy and it speeds up the discharging of batteries. Therefore, one should use the backlight only when it is really necessary.

2.13.4 Time and date

DIAMOND 401 is equipped with the real time clock which needs to be adjusted. From Options menu we select the symbol of a clock and we get the following message:



To start the adjustment we press the key . The first digit starts to blink. To change it we use the keys 

and 

. To move to other digits for adjustment we use the keys 

and 

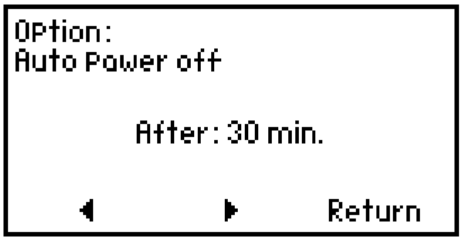
. To confirm the setting we press again . To quit the adjustments without the modifications we press 

and to quit the time and date option we select ***Return*** or we press again 

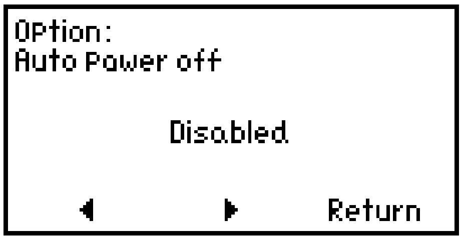
. If we have tried to introduce erroneous data they won't be accepted by the instrument and we shall be obliged to do it again correctly.

2.13.5 Power self release

This option allows us to set the period of time after which the instrument will be switched off automatically. This period is measured from the last time we have pressed any key. It is the protection against discharging the batteries needlessly in case we have forgotten to switch off the instrument. We have the choice between 15, 30, 45, 60 minutes:



To disable this option we should select:



The selection is made with the arrows underneath the display.

2.13.6 Battery charging

Using this option we can initiate and stop the battery charging. The color of the diode at the bottom of the front panel indicates whether battery is being charged or not: the diode is red while battery is being charged, and it is green when there is no charging. We activate this option by selecting the battery symbol at the bottom of the Options menu:

At the center of the screen is displayed the message informing us what was the status of the last charging:

OK ! - the previous charging went well

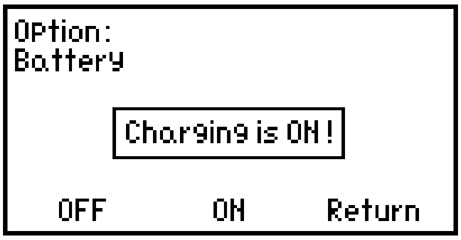
break - the user has interrupted the charging

error - there was a problem during the charging

The error can occur if the batteries are damaged or if surrounding temperature was too high. The problem during the charging is signalled at the end of charging by blinking of the red diode. The selection of the battery charging option cancels this signalization.

To activate the charging we select ***ON***, to stop it – ***OFF***. To optimize the usage of battery it is not recommended to interrupt the charging, so the possibility to turn it off is there in case we have launched the charging by mistake.

When we connect the external power supply then the charging is indicated by the fact that the diode changes the color from green to red and we get the following message on the screen:



The charging takes from 4 to 5 hours. If the charging went well then the diode returns to green color and if there was a problem then it will be blinking alternatively with red and green colors.

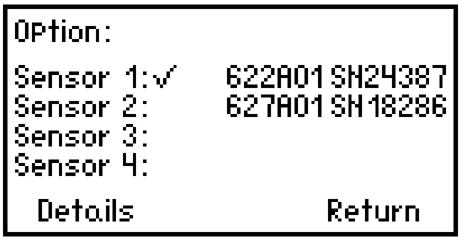
We charge the battery only when the symbol on the screen indicates that the battery is weak. We should let the charging fill the battery completely. It is not recommended to interrupt the charging without any serious reason. The instrument controls the charging and after 4 – 5 hours turns it off automatically. This is indicated by the diode changing its color from red to green. Only then we are allowed to disconnect the adapter.

It is not recommended to shorten or to interrupt the charging by disconnecting the external power supply. Neither it is recommended to start charging while the battery is not completely discharged. By not respecting these recommendations we may provoke a partial loss of the battery capacity or even damage it.

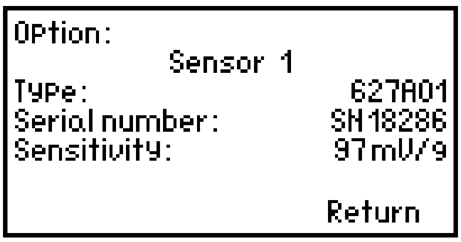
2.13.7 Accelerometers

This option will provide us with the information concerning the accelerometers that are intended to be used with the instrument and choose the one for standard usage (there is a different procedure concerning the transducers that will be used for balancing). It is possible to introduce the information concerning four transducers which are designated: ***Sensor 1***, ***Sensor 2***, ***Sensor 3*** et ***Sensor 4***. This information should be introduced in the factory (if the instrument is shipped together with accelerometers) or by the user (if it’s him who installs the transducers). A PC program used for calibration will help him to do so.

The information concerning each transducer should contain the following: the type of accelerometer, its serial number and its sensitivity. After having selected this option we get the following message:



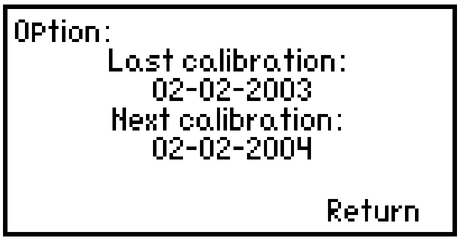
In this example two transducers were introduced. The transducer number 1 was chosen for standard measurements (what is indicated by the symbol ✓). To select the transducer we use  and , and to confirm it as the one to be used for standard measurements we should press . By pressing the arrow underneath the word ***Details*** we get the complete information concerning the selected transducer:



To quit this option we select ***Return*** or press .

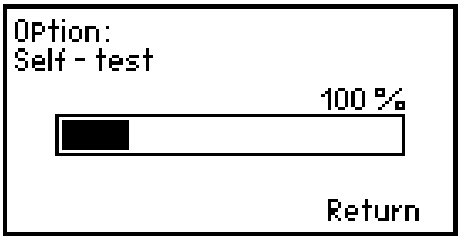
2.13.8 Calibration

This option will tell us when took place the last calibration and when should be performed the next one. It is recommended to calibrate the instrument once per year but it is obligatory to do it at least every second year. The customer may return the instrument to the factory or give it to the laboratory that is equipped for the job. The PC program guiding through the calibration procedure is provided with the instrument. Selecting ***CAL*** will bring the following display:

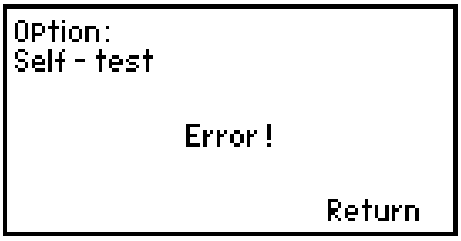


2.13.9 Instrument self-test

DIAMOND 401 is capable of testing its measurement channels in order to verify whether they are working correctly. By selecting ***TEST*** we get:



If the result of self-test is positive then we are sent back to the Options menu. On the other hand, if there is a problem then we get the following message:



In this case we should repeat the test by selecting ***Return*** and once more ***TEST***. If the result is again negative we should contact the factory.

To quit this option we select ***Return*** or press 

.

3. Accessories

3.1 Transducers

DIAMOND 401, being a multifunction instrument, requires several types of transducers. Hereafter there is some information concerning these transducers.

3.1.1 Accelerometers

DIAMOND 401 requires IEPE (ICP®) accelerometers. The recommended accelerometers are 786A from Wilcoxon or M622A01 and M623A01 from PCB. The user can choose other IEPE accelerometers but he should first verify whether they satisfy the requirements of DIAMOND 401.

The magnetic mounting adapters are used to attach the accelerometer to a machine Attention should be paid that the surface between the transducer and the magnetic adapter is clean and that the transducer adheres well to the surface of the magnet. In particular, strong magnets may attract ferromagnetic rubbish which should be removed. Also the magnetic adapter should adhere well to the surface of the machine. All this is very important since it may influence the accuracy of the measurement. The accelerometers should be protected against the shocks, for example by falling on hard surfaces.

3.1.2 Rotational speed measurement sensor

For rotational speed measurements the DIAMOND models 401D and 401DT are equipped with the laser tachometer. It is also used as reference sensor for phase measurements and for balancing.

The laser tachometer should be installed in a distance of 10 cm to 100 cm from the surface of the rotor on which a reflective strip is stuck. The Class 2 semiconductor laser generates the light beam (650 nm). The sensor is installed on the adjustable support which allows us to direct the laser beam in the desired direction. All this is attached to the machine with the magnetic holder. The location where the transducer is attached should be selected in such a way that during the measurement it does not change its position with respect to the rotor. The laser beam should be directed towards the reflective strip.

For the phase measurements and for balancing the boundary where the beam goes from the dark part of the rotor onto the reflective strip is considered to be the reference point. The angle increases in the direction opposite to the rotation.

The laser beam sensor should be protected against the humidity and the dust. The mechanical shocks should also be avoided and the ambient temperature should not exceed 40°C.

For safety reasons it is not allowed to look directly into the aperture of the laser beam! One should not direct the laser beam towards the sparkling surfaces nor in the direction of other people. Avoid getting the beam directly or indirectly into your eyes!

3.1.3 Temperature sensor

The K-type thermocouple is used for the temperature measurements. It has weak thermal capacity and is well suited for the temperature measurements of flat surfaces. The measurement is not instantaneous and one should wait a while until the display gets stabilized. The K-type thermocouple converter included with the set should be used to connect the sensor to the instrument.

During the measurement one should avoid to move the sensor around the surface since it may get damaged. The surface being measured should be flat and clean. The measurement range is up to 250°C.

3.2 Cables

The instrument is provided with high quality cabling made of cables of great elasticity. The connectors should be kept clean to insure the good operation. The instrument sockets have different colors. The sockets for accelerometers are marked with the green color, while the socket for the temperature and the rotational speed sensors is designated with red color. The corresponding connectors on the cables are identified with the same colors. The cable for accelerometers has the color identifiers also on the transducer side: the green connector jacket indicates that the corresponding transducer connects to the channel A, the blue jacket indicates the channel B.

All vibration measurements are made on channel A. The channel B is used only for balancing.

3.3 External power supply

DIAMOND 401 is provided with the external power supply which is also used for charging the battery. It is a typical stabilized supply 9 V DC and 1200 mA. The positive end is inside the socket, the negative end is outside.

Attention ! Don't open the power supply in operation and don't connect it when it is wet! The power supply is turned on at the same moment it is plugged into the mains what is signalled by a diode located on its housing.

4 Theory

4.1 Vibration measurements and machine condition evaluation

4.1.1 Machinery vibrations

A side-effect of any operating machine is the energy emission in the form of vibrations. A correctly constructed machine and in a good condition exhibits a low level of vibrations. During the exploitation different parts of a machine wear out, suffer the abrasion and deformation, its foundations settle. As a result the play between different parts increases, the rotating elements get unbalanced and rotors misaligned. All these factors provoke that as the condition of a machine deteriorates more and more energy is dissipated in the form of vibrations. This close relationship between the condition of a machine and its level of vibrations is the justification for using the vibration measurements for machinery diagnostics.

4.1.2 Inspections and maintenance

The fundamental rule of the machinery diagnostics based on vibration measurements is that these measurements should be carried out systematically. The periodical measurements will allow us to observe the evaluation of the vibration levels with time and thus the deterioration of the machine condition. This is essential for a good management of machinery maintenance. Traditionally the repairs were done either once the machine was broken, or preventively (but often unnecessarily!) at a fixed periods of time. Both methods are economically unjustified. The diagnostic based on the vibration measurements allows us to rationalize the machinery management since a given machine is taken for a repair only when its condition it requires. The advantages are numerous:

- Extension of periods between the repairs (better productivity of machinery, reduced cost of repairs)
- Elimination of unexpected breakdowns (it is possible to predict that the breakdown may happen)
- Reduction of the maintenance costs (the repair is much more expensive once the breakdown occurred)
- A repair that was planned takes less time than a repair after the accident.

4.1.3 Vibration measurements

- Where to measure?

Most often the vibration measurements are carried out on these parts of a machine which are most heavily exposed to the mechanical forces. Principally these are the enclosures of bearings which are easily accessible from outside. The transducers are fixed in the plane that is perpendicular to the axis of the rotor (radial vibrations) and in the direction of this axis (axial vibrations).

- The parameters to be measured

The parameters that best reflect the dynamic condition of a machine and which are most often used are the **RMS** value of the displacement and of the vibration velocity. These two parameters allow us to observe the beginnings of unbalance and of misalignment, the bending and the deformations of machine elements, the growing play in its structure. That's why various standards that were established to evaluate the machinery condition are based on the measurements of these parameters. The separate but related issue are the measurements of parameters allowing us to verify the condition of bearings.

- The periodicity of measurements

The time between two consecutive measurements depends on the type of a machine. Machines having shorter life time should be verified more often than those having longer life time. If the vibration level of a given machine remains unchanged then the measurements can be carried out less frequently. On the contrary, when growing vibration level is noticed, then the measurements should be done more frequently. What is essential is to identify the moment when the vibration level begins to change. On average the vibration measurements are carried out about 10 times during the period between two consecutive revisions.

4.2 Standards

In order to facilitate the diagnostic about the condition of a machine various standards were elaborated. The most popular are the family of international standards ***ISO 10816*** where each one is destined for a specific type of machinery. The following paragraphs explain how to apply these standards to the machinery condition verification.

4.2.1 ISO 10816-1 standard

This is a general standard which is used when a given machine does not fit the more specific standards. It is based on vibration measurements and the machines are classified into four groups:

Group	Description
1	small machines, including motors of power below 15kW
2	middle size machines and motors from 15 to 75kW without foundations, and motors up to 300kW installed on foundations
3	big machines and motors installed on rigid foundations
4	big machines and motors installed on flexible foundations

In order to be able to use this standard one should measure the vibrations with the instrument having the possibility to measure the RMS value of the vibrations velocity within the recommended frequency range. To evaluate the condition of a given machine one should compare the measurement results against the values indicated in the table below.

Table with the RMS values of vibration velocity
authorized by the ISO 10816-1 standard

Category boundaries	Group 1	Group 2	Group 3	Group 4
	mm/s RMS			
A/B	0,71	1,12	1,8	2,8
B/C	1,8	2,8	4,5	7,1
C/D	4,5	7,1	11,2	18

Depending on the results of vibration measurements, the ISO 10816 standard classifies the working conditions of a machine into four categories A, B, C and D. Hereafter the evaluation of machine condition for each category:

A - the vibrations of machinery recently introduced to operation – good condition
B - machine which can work for a long time without limitations – satisfactory condition
C - machine which cannot work continuously for a long time, it can work for a predefined time until the preventive actions are undertaken – condition still temporarily acceptable
D - the vibration level in this category is considered to be serious enough to cause the machinery breakdown – unacceptable condition

4.2.2 ISO 10816-2 standard

This standard is used to evaluate the vibrations of turbo generators of the power greater than 50MW. It differentiates the machinery in function of the rotational speed. The evaluation of the machine condition is based on the measurement of the RMS value of the vibrations velocity.

Category boundaries	Rotational speed	
	1500 - 1800	3000 - 3600
	mm/s RMS	
A/B	2,8	3,8
B/C	5,3	7,5
C/D	8,5	11,8

4.2.3 ISO 10816-3 standard

This more detailed standard is designed for the condition evaluation of machines, motors and pumps. It is important to pay attention that for the machinery rotating at speeds greater than 600 rpm the measurements should be done in the frequency range from 10Hz ÷ 1000Hz, while for those rotating at speeds between 120 and 600 rpm, the frequency range should be from 2Hz ÷ 1000Hz. The machine classification accordingly to this standard is shown in the following table:

Group	Description
1	Big machinery (power from 300kW to 50MW) and electrical motors with shaft height H ≥ 315mm
2	Middle size machinery (power from 15kW to 300kW) and electrical motors with shaft height 160mm ≤ H < 315mm
3	Pumps with multi-blade wheels with separate power transmission (centrifugal, with mixt or axial flow) with the nominal power >15kW
4	Pumps with multi-blade wheels with integrated power transmission (centrifugal, with mixt or axial flow) with the nominal power >15kW

The following table shows the authorized values at the category boundaries. The standard additionally classifies the machines into those that are installed rigidly or flexibly:

Foundations	Category boundaries	Group 1		Group 2		Group 3		Group 4	
		RMS		RMS		RMS		RMS	
		mm/s	μm	mm/s	μm	mm/s	μm	mm/s	μm
rigid	A/B	2,3	29	1,4	22	2,3	18	1,4	11
	B/C	4,5	57	2,8	45	4,5	36	2,8	22
	C/D	7,1	90	4,5	71	7,1	56	4,5	36
flexible	A/B	3,5	45	2,3	37	3,5	28	2,3	18
	B/C	7,1	90	4,5	71	7,1	56	4,5	36
	C/D	11	140	7,1	113	11	90	7,1	56

4.2.4 ISO 10816-4 standard

It concerns the machinery assemblies driven by gas turbines at rotational speeds between 3000 rpm and 20000 rpm. Only the vibrations velocity is taken into consideration:

Category boundaries	mm/s RMS
A/B	2,5
B/C	4,0
C/D	6,0

4.3 Bearings

The parts which get worn fastest and which are most exposed to failures are the bearings. The defects of balls or rollers and of bearing external or inner tracks become the sources of high frequency vibration pulses. These pulses are not visible in vibration velocity or displacement signals that are measured in the frequency range 10Hz ÷ 1000Hz. The vibration velocity or displacement signals are very useful for evaluation of the overall dynamic condition of a machine but do not contain any information about the bearings condition. The information concerning the bearings is found in the vibration acceleration signal.

4.3.1 Measurements of shock pulses

The periodic measurements of the acceleration pulses generated by a bearing allow us to detect a developing defect and to observe its evolution. These measurements should be carried out systematically in order to monitor the deterioration of bearing condition. The increase of the ***peak value (P-K)*** of pulses with respect to their initial value (when the bearing was in a good condition, for example when it was new) is the indication of the bearing condition at a given time. This reference value (the initial condition) may be different for different machines and is related to the fact that some bearings are more enclosed (weaker signal) or less enclosed (stronger signal), some are less loaded (weaker signal) while some are more loaded (stronger signal).

The table below indicates the bearing condition in function of the increase in the pulses peak value with respect to the initial state:

Increase Δ	Bearing condition
Δ < 20 dB	GOOD
20 dB < Δ < 35 dB	ATTENTION
Δ > 35 dB	BAD

- The increase of the peak value by 20 dB to 35 dB indicates that a flaw has appeared in the bearing. The bearing should be now observed more carefully and the measurements carried out more frequently.
- The increase greater than 35 dB attests that the bearing is seriously damaged and should be replaced.

In the situations where we are lacking the reference information concerning the initial condition, then for the diagnostic purposes we can observe the **difference between the peak and the mean values**. This difference is less than 20 dB for bearings in good condition. If it is between 20 dB and 30 dB it may indicate the appearance of a flaw, and when it is more than 30 – 35 dB then the bearing is broken.

Higher values of both peak and mean values may indicate that the bearing lubrication is insufficient.

4.3.2 Acceleration envelope measurement

The proper frequency range selection is important for the envelope measurement. It should be adjusted in function of the rotational speed of the machine. The peak value of the envelope indicates a local deterioration, while its mean value contains the information about the general condition of bearing and about its working environment, like for example its lubrication. The possibility of selecting the frequency range allows us to monitor the wear of a bearing, for example for slow machines.

4.3.3 Kurtosis

The kurtosis is not informing us about the amplitude of the signal generated from within the bearing, but about its waveform. The value of the kurtosis coefficient is about 3 when the signal does not contain strong pulses. But as soon as a flaw appears and the pulses grow in amplitude then the kurtosis value grows as well. The kurtosis value for new bearings is in the range 3 to 4, while for a bearing that is damaged its value may be from 10 to 20, and more.

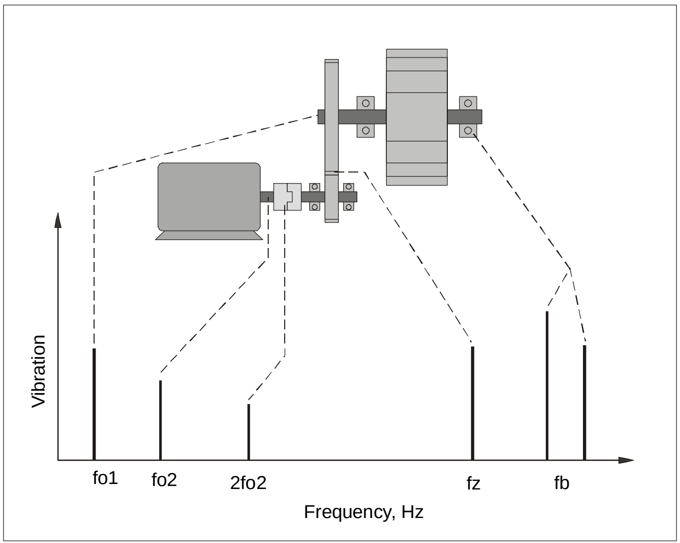
The diagnostic methods for bearings described above do not have a normative character. They should be considered as indicative criteria that are applicable in typical cases. In order to raise the certainty of the evaluation it is recommended to use at least two of these methods or to check empirically which of these methods is the most reliable.

The diagnostic measurements on bearings should always be done using the same accelerometer. Some of the measurements are sensitive to the characteristics of the transducer (the resonance frequency, the resonance quality factor) and therefore different transducers may give different results.

4.4 Spectral analysis of vibrations

The progressive increase of the vibrations level tells us that the dynamic condition of a machine deteriorates. The measurements of the overall level of vibrations (vibration velocity or displacement) allow us to evaluate the current condition of a machine and to monitor its evolution. However, these measurements do not contain the information concerning the source of the deterioration. We can obtain this information with the spectral analysis.

Each part of a machine or a defect generates the vibrations of a characteristic frequency (or several characteristic frequencies) as it shown in the Figure below. The spectral analysis allows us to identify the elements that have caused the problem.



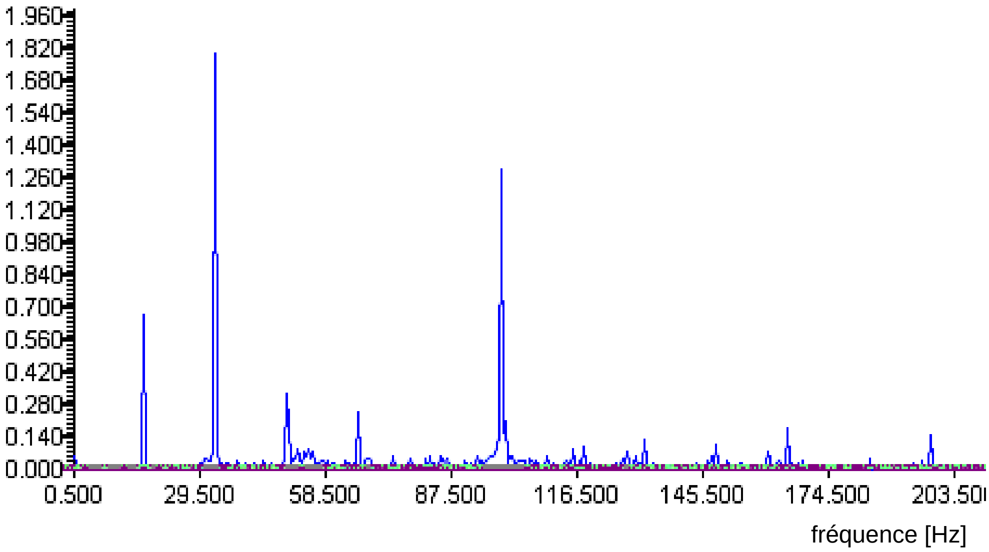
This drawing illustrates the relationship between the condition of various elements of the machine and the vibration spectrum. We can clearly see where the dominant components are. It is recommended to first perform the spectral analysis when the machine is in a good condition. When the machine condition deteriorates then the spectral analysis immediately indicates which spectral components have increased their amplitude. By comparing the spectra we can draw the conclusions concerning the eventual causes of the problem.

The degree of difficulty in the interpretation of results depends on the complexity of the machine. Ii is necessary to know well the construction of the machine and its characteristics in order to be able to interpret properly the spectral analysis results. Most often the reasons of the problem are the unbalance or the misalignment of rotors, or the flaws in bearings.

The typical failures and their characteristic frequencies are summarized in the table hereafter:

Type of failure	Characteristic frequency f_0 = rotational frequency [Hz]	Direction of vibrations	Comments
Unbalance of rotary elements	1 x f_0	radial	Very often this is the reason of the high level of vibrations
Misalignment or inflexion of the rotor	1 x f_0 , 2 x f_0	radial axial	Frequent fault
Flaw of bearing element	The percussive pulses depend on the rotational speed and on bearing elements: - rolling element $f_r = 1/2\ f_0\ D/d\ [1-(d/D\ \cos\varphi)^2]$ - inner race $f_{int} = 1/2\ N\ f_0\ (1 + d/D\ \cos\varphi)$ - external race $f_{ext} = 1/2\ N\ f_0\ (1 – d/D\ \cos\varphi)$ - bearing cage $f_c = 1/2\ f_0\ (1 – d/D\ \cos\varphi)$ high frequency vibrations from 2kHz to 60kHz	radial axial	d – rolling element diameter D – pitch diameter of a bearing φ - angle of incidence N – number of rolling elements f_0 – rotational frequency of the inner race with respect to the external race
Play of slide bearing in its enclosure	1/2 x f_0 1/3 x f_0	radial	
Instability of the oil layer in the slide bearing	de 0,2 à 0,48 x f_0	radial	always < ½ f_0
Damaged or worn out gear	f_0 x z z – number of teeth	radial axial	Due to modulation the side bands can appear in the spectrum
Mechanical plays	1 x f_0, 2 x f_0	radial axial	
Damaged driving belt	1, 2, 3, 4 x frequency of the driving belt cycle	radial	
Increase of turbulences	n x f_0 n – number of blades	radial axial	
Electrically excited vibrations	1 x et 2 x power supply frequency	radial axial	Should disappear once the current is switched off

Here is an example of the spectrum obtained in real conditions:



4.5 Phase measurements

Vibration phase measurement is a very interesting tool for the machinery diagnostics. In particular it helps to identify the resonance frequencies of the machine structure and for the diagnostic of misalignment of rotors and clutches. When the vibrating machine crosses the resonance frequency there is a significant increase in amplitude and change in phase by 180°. On the other hand, the misalignment of a clutch is identified if the vibrations of bearing bodies on both sides of the clutch are out of phase by 180°. Similarly, the axial vibrations of bearing bodies are of opposite phase if the rotor is bended.

4.6 Cavitation

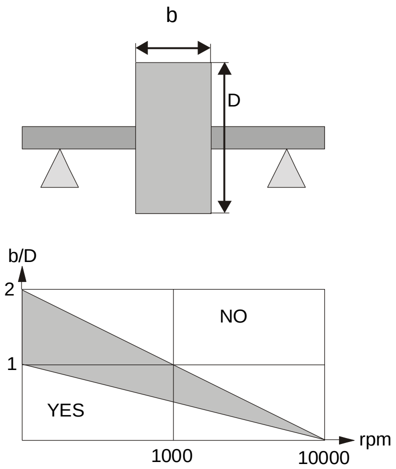
The cavitation is the strongest source of noise and vibrations in liquids. The cavitation originates when – in a given temperature – the pressure in the stream of liquid is lower than the pressure of its saturated vapours. This phenomenon most often takes place in pipes, for example in pumps, in valves, when the flow is swirling or turbulent. It consists of the formation and extinction of bubbles of saturated vapours. It is very harmful and provokes the cavitational erosion of machinery elements. The vibration signal which is generated (« the cavitational noise ») has a large bandwidth from several kHz to several dozens of kHz and it can be superposed on other vibro-acoustic phenomena, like signals from bearings. That's why in order to be able to measure the effects of cavitation, one should locate the measurement point as far as possible from other elements which may affect the measurement (like bearings). If there is no cavitation then the vibration level should be of similar magnitude as the one produced by other sources, but when the cavitation appears then this level increases significantly.

4.7 Balancing

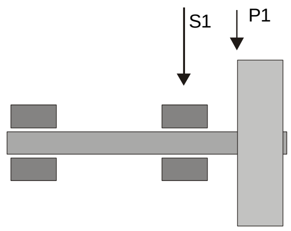
The unbalance of the rotary elements of a machine is the main reason for the excessive vibration levels. It manifests itself by a high level of radial vibrations at the rotational frequency. The balancing consists on analyzing the distribution of the mass of the rotor, and then on correcting this distribution by adding or removing a mass in order to obtain the « residual unbalance » or an acceptable level of vibrations. In most cases the balancing is performed in one or two planes.

4.7.1 One-plane balancing

The balancing in one plane is applicable when the width of the rotor is small compared to its diameter. This is illustrated in the following drawing:



This next drawing gives an example where one-plane balancing is applicable:



S1 – indicates the point where the measurement is carried out

P1 – indicates the plane where are applied the corrective masses

The steps in one-plane balancing:

START

Installation of an accelerometer close to a bearing, placing the marker on the rotor and installation of the tachometer.

Preliminary measurement of vibrations and phase

Placing the test weight

Measurement of vibrations and phase with the test weight – mp

Interpreting the result – correction m0, dismantling the test weight and mounting the correction mass

Measurement verifying the effect of the correction mass m0

Interpreting the result – installation of the correction mass m1

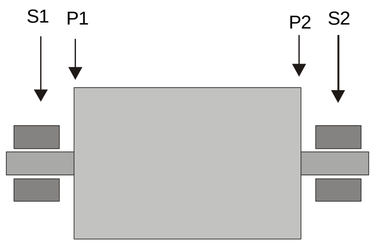
Measurement verifying the effect of the correction mass m

Etc.

One continues the procedure as long as the vibration level or the residual unbalance are reduced to the acceptable level.

4.7.2 Two-plane balancing

The two-plane balancing should be applied in the case of wide rotors of cylindrical shape. Any time it is possible one should choose for the corrections the two planes at the both ends of the rotor. The vibration measurements should be made in the planes corresponding to the location of bearings. It is illustrated in the following drawing:



S1, S2 – locations where the measurements are done

P1, P2 – planes where will be applied the corrective masses

The procedure for two-plane balancing:

START

Installation of two accelerometers close to bearings at the ends of the rotor, placing the marker on the rotor and installation of the tachometer.

Preliminary measurement of vibrations and phase on both planes

Placing the test weight on the first plane

Measuring vibrations and phase on both planes with test weight – mp on the first plane

Dismantling the test weight from the first plane and its installation on the second plane

Measuring vibrations and phase on both planes with test weight – mp on the second plane

Interpreting the results – corrections m0/P1 et m0/P2 separately for the first and the second plane, dismantling the test weight and mounting the correction masses on their respective planes

Measurement to verify the effect of the correction masses m0/P1 et m0/P2

Interpreting the results – corrections m1/P1 et m1/P2 separately for the first and the second plane, and mounting the correction masses on their respective planes

Measurement to verify the effect of the correction masses m1/P1 et m1/P2

Etc.

One continues the procedure as long as the vibration level or the residual unbalance are reduced to the acceptable level.

4.7.4 Choosing the test mass

The purpose of installing the test mass is to obtain a clear and measurable change of the unbalance. This is necessary to establish the value and the location of the corrective masses. The test mass should neither be too small (the change of unbalance may not be visible), nor too big since this could provoke very strong vibrations and damage the machine. Typically we consider that the test mass is adequate if the centrifugal force resulting from its installation is approximately equal to the 1/10 of the rotor’s weight. The following formula may be helpful in finding the right value of the test mass:

$$m_p = \frac{M_w}{r_p\left(\frac{n}{100}\right)^2}$$

m_p – the test mass

M_W – the mass of the rotor

n – the rotational speed in [rpm]

r_p – the radius in [cm] at which will be installed the test mass

Important precautionary measures to be taken while using the DIAMOND 401

1. Do not put the accelerometers on the machinery elements where could appear a dangerous voltage.
2. When using two measurement channels it is not allowed to put the transducers on the machinery elements between which could appear the difference of electric potential.
3. While making the vibration measurements on the rotating machinery one should avoid that the cables, the valise straps, etc. get snatched by the rotary parts. One should also respect the security recommendations related to the machinery.
4. Do not get the magnets near the devices that are sensitive to the magnetic field, like for example the computer disks, the audio and the video tapes, the magnetic cards, etc.
5. Do not use the instrument in the area where there is a danger of explosion.
6. The vibration transducer should be fixed firmly to the machine. Otherwise the measurement results may be affected by additional errors.
7. Do not use the alcohol or other solvents to clean the instrument.
8. Protect the transducer and its magnet against the shocks.
9. Do not place the instrument in places where the temperature may exceed 50°C.
10. In spite of its robust construction designed for severe industrial environments, one should avoid to use and to store the instrument while the humidity exceeds 95%.
11. This portable industrial instrument should be used by trained and/or experienced personnel.
12. If the instrument is out of order it should be returned to the vendor. Repairing the instrument oneself implies the loss of warranty.
13. Are authorized only those accessories (like power supply, cables, etc.) that were provided or recommended by the manufacturer.