MiniTest 403

Technical Reference and Operating Manual

Advancing with Technology **Elektro**Physik

© Print ref. # B-26-A1

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Disclaimer

Inherent in ultrasonic thickness measurement is the possibility that the instrument will use the second rather than the first echo from the back surface of the material being measured. This may result in a thickness reading that is TWICE what it should be. Responsibility for proper use of the instrument and recognition of this phenomenon rests solely with the user of the instrument.

Contents

1. Introduction

The *MiniTest 403* is a precision Ultrasonic Micrometer. capable of measuring the thickness of various materials with accuracy as high as ± 0.01mm or ± 0.001 inches. The principle advantage of ultrasonic measurement over traditional methods is that ultrasonic measurements can be performed with access to only one side of the material being measured.

This manual is presented in three sections. The first section covers operation of the ***MiniTest 403*** and explains the keypad controls and display. The second section provides guidelines in selecting a transducer for a specific application. The last section provides application notes and a table of sound velocity values for various materials.

ElektroPhysik maintains a customer support resource in order to assist users with questions or difficulties not covered in this manual. Customer support may be reached at any of the following:

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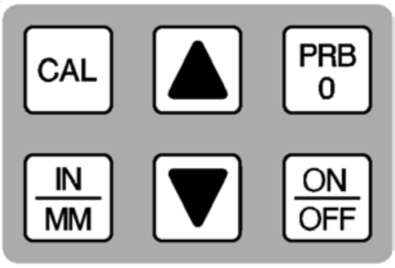
1.2 Supply Schedule

- Plastics carrying case
- Gauge with transducer
- 1 bottle coupling fluid
- 2 x AA 1,5V alkaline batteries
- Instruction manual (English/German)
- Calibration certificate NIST 04-25-174-A and 04-28146-A

2. Operation

The ***MINITEST 403*** interacts with the operator through the membrane keypad and the LCD display. The functions of the various keys on the keypad are detailed below, followed by an explanation of the display and its various symbols.

2.1 Keypad



ON/OFF Key

This key is used to turn the ***MINITEST 403*** on and off. When the gauge is turned ON, it will first perform a brief display test by illuminating all of the segments in the display.

After one second, the gauge will display the internal software version number. After displaying the version number, the display will show „0.000“ (or „0.00“ if using metric units), indicating the gauge is ready for use.

The ***MINITEST 403*** is turned OFF by pressing the **ON/OFF** key.

The gauge has a special memory that retains all of its settings even when the power is off.

The gauge also features an auto-powerdown mode designed to conserve battery life. If the gauge is idle for 5 minutes, it will turn itself

PRB-0 Key

The **PRB-0** key is used to „zero“ the ***MINITEST 403*** in much the same way that a mechanical micrometer is zeroed. If the gauge is not zeroed correctly, all of the measurements that the gauge makes may be in error by some fixed value. Refer to Section „Performing a probe Zero“ for an explanation of this important procedure.

CAL Key

The **CAL** key is used to enter and exit the ***MINITEST 403***'s calibration mode. This mode is used to adjust the sound-velocity value that the ***MINITEST 403*** will use when calculating thickness. The gauge will either calculate the sound-velocity from a sample of the material being measured, or allow a known velocity value to be entered directly. Refer to section „Calibration“ for an explanation of the two **CAL** functions available.

IN/MM Key

The **IN/MM** key is used to switch back and forth between English and metric units. This key may be used at any time, whether the gauge is displaying a thickness (**IN** or **MM**) or a velocity value (**IN/ms** or **M/s**).

Up Arrow Key

The **UP** arrow key has two functions. When the ***MINI-TEST 403*** is in calibration mode, this key is used to increase numeric values on the display. An auto-repeat function is built in, so that when the key is held down, numeric values will increment at an increasing rate. When the ***MINITEST 403*** is not in calibration mode, the **UP** arrow key switches the **SCAN** measurement mode on and off. Refer to section „SCAN Mode“ for an explanation of the **SCAN** measurement mode.

Down Arrow Key

The **DOWN** arrow key has two functions. When the ***MINITEST 403*** is in the **CAL** mode, this key is used to decrease numeric values on the display. An auto-repeat function is built in, so that when the key is held down, numeric values will decrement at an increasing rate

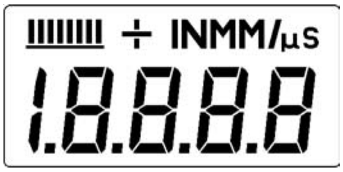
When the ***MINITEST 403*** is not in calibration mode, the **DOWN** arrow key switches the display backlight between three available settings.

OFF will be displayed when the backlight is switched off.

AUTO will be displayed when the backlight is set to automatic mode, and **ON** will be displayed when the backlight is set to stay on.

In the **AUTO** setting, the backlight will illuminate when the ***MINITEST 403*** is actually making a measurement.

2.2 Display

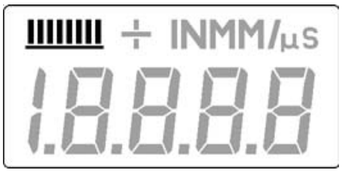


The numeric portion of the display consists of 4 complete digits preceded by a leading „1“, and is used to display numeric values, as well as occasional simple words, to indicate the status of various settings.

When the ***MINITEST 403*** is displaying thickness measurements, the display will hold the last value measured, until a new measurement is made.

Note:

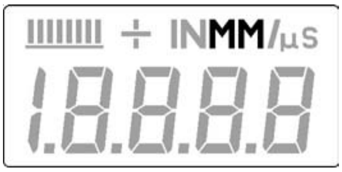
Additionally, when the battery voltage is low, the entire display will begin to flash. When this occurs, the batteries should be replaced immediately.



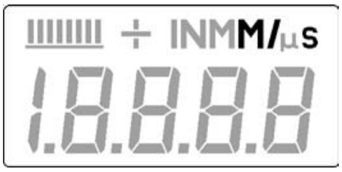
These eight vertical bars form the Stability Indicator. When the ***MINITEST 403*** is idle, only the left-most bar and the underline will be on.

When the gauge is making a measurement, six or seven of the bars should be on.

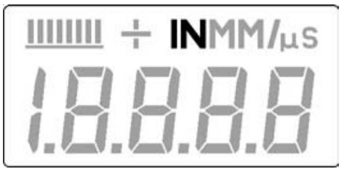
If fewer than five bars are on, the ***MINITEST 403*** is having difficulty achieving a stable measurement, and the thickness value displayed will most likely be erroneous



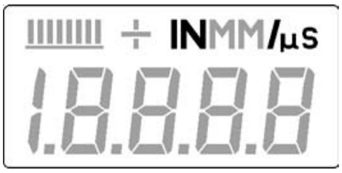
When the **MM** symbol is on, the ***MINITEST 403*** is displaying a thickness value in millimeters. If the displayed thickness exceeds 199.99 millimeters, the decimal point will shift automatically to the right, allowing values up to 1999.9 millimeters to be displayed.



When the **M** symbol is on, in conjunction with the **/s** symbol, the ***MINITEST 403*** is displaying a sound-velocity value in **meters-per-second**



When the **IN** symbol is on, the ***MINITEST 403*** is displaying a thickness value in inches. The maximum thickness that can be displayed is 19.999 inches.



When the **IN** symbol is on, in conjunction with the **/ms** symbol, the ***MINITEST 403*** is displaying a sound-velocity value in **inches-per-microsecond.**

3. Transducer

The transducer is the „business end“ of the ***MINITEST 403***. It transmits and receives the ultrasonic sound waves which the ***MINITEST 403*** uses to calculate the thickness of the material being measured. The transducer connects to the ***MINITEST 403*** via the attached cable, and two coaxial connectors. When using transducers manufactured by the same supplier, the orientation of the dual coaxial connectors is not critical: either plug may be fitted to either socket in the ***MINITEST 403.***

The transducer must be used correctly in order for the ***MINITEST 403*** to produce accurate, reliable measurements. Below is a short description of the transducer, followed by instructions for its use

This is a bottom view of a typical transducer. The two semicircles of the wearface are visible, as is the barrier separating them

One of the semicircles is responsible for conducting ultrasonic sound into the material being measured, and the other semicircle is responsible for conducting the echoed sound back into the transducer.

When the transducer is placed against the material being measured, it is the area directly beneath the center of the wearface that is being measured.

This is a top view of a typical transducer. Press against the top with the thumb or index finger to hold the transducer in place. Moderate pressure is sufficient, as it is only necessary to keep the transducer stationary, and the wearface seated flat against the surface of the material being measured

4. Making Measurements

In order for the transducer to do its job, there must be no air gaps between the wear-face and the surface of the material being measured. This is accomplished with the use of a „coupling“ fluid, commonly called „couplant“.

This fluid serves to „couple“, or transmit, the ultrasonic sound waves from the transducer, into the material, and back again. Before attempting to make a measurement, a small amount of couplant should be applied to the surface of the material being measured. Typically, a single droplet of couplant is sufficient

After applying couplant, press the transducer (wearface down) firmly against the area to be measured. The Stability Indicator should have six or seven bars darkened, and a number should appear in the display. If the ***MINITEST 403*** has been properly „zeroed“ (see section „Probe Zero“) and set to the correct sound velocity (see Sound Velecity Selection Table), the number in the display will indicate the actual thickness of the material directly beneath the transducer.

If the Stability Indicator has fewer than five bars darkened, or the numbers on the display seem erratic, first check to make sure that there is an adequate film of couplant beneath the transducer, and that the transducer is seated flat against the material. If the condition persists, it may be necessary to select a different transducer (size or frequency) for the material being measured. See section „Transducer Selection“ for information on this issue.

While the transducer is in contact with the material being measured, the ***MINITEST 403*** will perform four measurements every second, updating its display as it does so. When the transducer is removed from the surface, the display will hold the last measurement made.

Important Note:

Occasionally, a small film of couplant will be drawn out between the transducer and the surface as the transducer is removed. When this happens, the ***MINITEST 403*** may perform a measurement through this couplant film, resulting in a measurement that is larger or smaller than it should be.

This phenomenon is obvious when one thickness value is observed while the transducer is in place, and another value is observed after the transducer is removed.

4.1 Condition and Preparation of Surfaces

In any ultrasonic measurement scenario, the shape and roughness of the test surface are of paramount importance. Rough, uneven surfaces may limit the penetration of ultrasound through the material, and result in unstable, and therefore unreliable, measurements.

The surface being measured should be clean, and free of any small particulate matter, rust, or scale. The presence of such obstructions will prevent the transducer from seating properly against the surface. Often, a wire brush or scraper will be helpful in cleaning surfaces.

In more extreme cases, rotary sanders or grinding wheels may be used, though care must be taken to prevent surface gouging, which will inhibit proper transducer coupling.

Extremely rough surfaces, such as the pebble-like finish of some cast irons, will prove most difficult to measure. These kinds of surfaces act on the sound beam like frosted glass on light, the beam becomes diffused and scattered in all directions.

In addition to posing obstacles to measurement, rough surfaces contribute to excessive wear of the transducer, particularly in situations where the transducer is „scrubbed“ along the surface. Transducers should be inspected on a regular basis, for signs of uneven wear of the wearface. If the wearface is worn on one side more than another, the sound beam penetrating the test material may no longer be perpendicular to the material surface. In this case, it will be difficult to exactly locate tiny irregularities in the material being measured, as the focus of the soundbeam no longer lies directly beneath the transducer.

4.2 Probe Zero

Setting the Zero Point of the ***MINITEST 403*** is important for the same reason that setting the zero on a mechanical micrometer is important.If the gauge is not „zeroed“ correctly, all of the measurements the gauge makes will be in error by some fixed number.

When the ***MINITEST 403*** is „zeroed“, this fixed error value is measured and automatically corrected for in all subsequent measurements. The ***MINITEST 403*** may be „zeroed“ by performing the following procedure:

1. Make sure the ***MINITEST 403*** is on.
2. Plug the transducer into the ***MINITEST 403***. Make sure that the connectors are fully engaged. Check that the wearface of the transducer is clean and free of any debris.
3. On the top of the ***MINITEST 403***, above the display, is the metal probe-disc. Apply a single droplet of ultrasonic couplant to the face of this disc.
4. Press the transducer against the probe-disc, making sure that the transducer sits flat against the surface of the probe-disc. The display should show some thickness value, and the Stability Indicator should have nearly all its bars illuminated. While the transducer is firmly coupled to the probe-disc, press the **PRB-0** key on the keypad. The ***MINITEST 403*** will display „Prb0“ while it is calculating its zero point.
5. Remove the transducer from the probe-disc.

At this point, the ***MINITEST 403*** has successfully calculated its internal error factor, and will compensate for this value in any subsequent measurements.

When performing a „probe-zero“, the ***MINITEST 403*** will always use the sound-velocity value of the built-in probe-disc, even if some other velocity value has been entered for making actual measurements.

Though the ***MINITEST 403*** will remember the last „probe-zero“ performed, it is generally a good idea to perform a „probe-zero“ whenever the gauge is turned on, as well as any time a different transducer is used. This will ensure that the instrument is always correctly zeroed.

5. Calibration

In order for the ***MINITEST 403*** to make accurate measurements, it must be set to the correct sound-velocity for the material being measured.

Different types of material have different inherent sound-velocities. For example, the velocity of sound through steel is about 5920 m/s (0.233 inches-per-microsecond), versus that of aluminum, which is about 6350 m/s (0.248 inches-per-microsecond). If the gauge is not set to the correct sound-velocity, all of the measurements the gauge makes will be erroneous by some fixed percentage.

The **one- point** calibration is the simplest and most commonly used calibration procedure - optimizing linearity over large ranges.

The **two- point** calibration allows for greater accuracy over small ranges by calculating the probe zero and velocity.

The ***MINITEST 403*** provides three simple methods for setting the sound-velocity, described in the following pages.

5.1 Calibration to a known thickness

Note:

NOTE: This procedure requires a sample piece of the specific material to be measured, the exact thickness of which is known, e.g. from having been measured by some other means.

1. Make sure the ***MINITEST 403*** is on.
2. Perform a Probe-Zero (see section „Probe Zero“)
3. Apply couplant to the sample piece.
4. Press the transducer against the sample piece, making sure that the transducer sits flat against the surface of the sample. The display should show some (probably incorrect) thickness value, and the Stability Indicator should have nearly all its bars on.
5. Having achieved a stable reading, remove the transducer. If the displayed thickness changes from the value shown while the transducer was coupled, repeat step 4.

6. Press the **CAL** key. The **MM** (or **IN**) symbol should begin flashing.

7. Use the **UP** and **DOWN** arrow keys to adjust the displayed thickness up or down, until it matches the thickness of the sample piece.

8. Press the **CAL** key again. The **M/s** (or **IN/ms**) symbols should begin flashing. The ***MINITEST 403*** is now displaying the sound velocity value it has calculated based on the thickness value that was entered in step 7.

9. Press the **CAL** key once more to exit the calibration mode. The ***MINITEST 403*** is now ready to perform measurements.

5.2 Calibration to a known velocity

Note:

This procedure requires that the operator know the sound-velocity of the material to be measured. A table of common materials and their sound-velocities can be found in **Appendix C**.

1. Make sure the ***MINITEST 403*** is on.

2. Press the **CAL** key to enter calibration mode. If the **MM** (or **IN**) symbol is flashing, press the **CAL** key again, so that the **M/s** (or **IN/ms**) symbols are flashing.

3. Use the **UP** and **DOWN** arrow keys to adjust the displayed velocity up or down, until it matches the sound-velocity of the material to be measured.

4. Press the **CAL** key once more to exit the calibration mode. The ***MINITEST 403*** is now ready to perform measurements.

Note:

At any time during the calibration procedure (**MM, IN**, **M/s, or IN/ms** flashing in the display), pressing the **PRB-0** key will restore the gauge to the factory default sound-velocity for steel (5920m/s / 0.233 IN/ms).

To achieve the most accurate measurements possible, it is generally advisable to always calibrate the ***MINITEST 403*** to a sample piece of known thickness. Material composition (and thus, its sound-velocity) sometimes varies from lot to lot and from manufacturer to manufacturer. Calibration to a sample of known thickness will ensure that the gauge is set as closely as possible to the sound velocity of the material to be measured.

5.3 Two Point Calibration

Note:

This procedure requires that the operator has two known thickness points on the test piece that are representative of the range to be measured.

1. Make sure the ***MINITEST 403*** is on.
2. Perform a Probe-Zero (refer to section „Probe Zero“)
3. Apply couplant to the sample piece.
4. Press the transducer against the sample piece, at the first/second calibration point, making sure that the transducer sits flat against the surface of the sample. The display should show some (probably incorrect) thickness value, and the Stability Indicator should have nearly all its bars on.
5. Having achieved a stable reading, remove the transducer. If the displayed thickness changes from the value shown while the transducer was coupled, repeat step 4.
6. Press the **CAL** key. The **MM** (or **IN**) symbol should begin flashing.
7. Use the **UP** and **DOWN** arrow keys to adjust the displayed thickness up or down, until it matches the thickness of the sample piece.
8. Press the **Probe** key. The display will flash **1OF2**. **Repeat steps 3 through 8** on the second calibration point. The ***MINITEST 403*** will now display the sound velocity value it has calculated based on the thickness values that were entered in step 7.
9. The ***MINITEST 403*** is now ready to perform measurements.

6. Scan Mode

While the ***MINITEST 403*** excels at making single point measurements, it is sometimes desirable to examine a larger region, searching for the thinnest point. The ***MINITEST 403*** includes a feature, called Scan Mode, which allows it to do just that.

In normal operation, the ***MINITEST 403*** performs and displays four measurements every second, which is quite adequate for single measurements.

In Scan Mode, however, the gauge performs sixteen measurements every second. While the transducer is in contact with the material being measured, the ***MINITEST 403*** is keeping track of the lowest measurement it finds.

The transducer may be „scrubbed“ across a surface, and any brief interruptions in the signal will be ignored. When the transducer loses contact with the surface for more than a second, the ***MINITEST 403*** will display the smallest measurement it found.

When the ***MINITEST 403*** is not in calibration mode, press the **UP** arrow key to turn Scan Mode on and off. A brief message will appear in the display confirming the operation. When the transducer is removed from the material being scanned, the ***MINITEST 403*** will (after a brief pause) display the smallest measurement it found.

7. Transducer Selection

The ***MINITEST 403*** is inherently capable of performing measurements on a wide range of materials, from various metals to glass and plastics. Different types of material, however, will require the use of different transducers.

Choosing the correct transducer for a job is critical to being able to easily perform accurate and reliable measurements. The following paragraphs highlight the important properties of transducers, which should be considered when selecting a transducer for a specific job.

Generally speaking, the best transducer for a job is one that sends sufficient ultrasonic energy into the material being measured such that a strong, stable echo is received by the ***MINITEST 403***. Several factors affect the strength of ultrasound as it travels. These are outlined below:

· Initial Signal Strength

The stronger a signal is to begin with, the stronger its return echo will be. Initial signal strength is largely a factor of the size of the ultrasound emitter in the transducer. A large emitting area will send more energy into the material being measured than a small emitting area. Thus, a so-called „1/2-inch“ transducer will emit a stronger signal than a „1/4-inch“ transducer.

· Absorption and Scattering

As ultrasound travels through any material, it is partly absorbed. If the material through which it travels has any grain structure, the sound waves will also experience scattering. Both of these effects reduce the strength of the waves, and thus, the ***MINITEST 403***'s ability to detect the returning echo.

Higher frequency ultrasound is absorbed and scattered more than ultrasound of a lower frequency. While it may seem that using a lower frequency transducer might be better in every instance, low frequencies are less directional than high frequencies. Thus, a higher frequency transducer would be a better choice for detecting the exact location of small pits or flaws in the material being measured.

· Geometry of the Transducer

The physical constraints of the measuring environment sometimes determine a transducer's suitability for a given job. Some transducers may simply be too large to be used in tightly confined areas. Also, the surface area available for contacting with the transducer may be limited, requiring the use of a transducer with a small wearface. Measuring on a curved surface, such as an engine cylinder wall, may require the use of a transducer with a matching curved wearface.

· Temperature of the Material

When it is necessary to measure on surfaces that are exceedingly hot, high temperature transducers must be used. These transducers are built using special materials and techniques that allow them to withstand high temperatures without damage. Additionally, care must be taken when performing a „Probe Zero“ or „Calibration to Known Thickness“ with a high temperature transducer. See **Appendix B** for more information on measuring materials with a high temperature transducer.

Selection of the proper transducer is often a matter of tradeoffs between various characteristics. It may be necessary to experiment with a variety of transducers in order to find one that works well for a given job. ElektroPhysik can provide assistance in choosing a transducer, and offers a broad selection of transducers for evaluation in specialized applications.

8. Product Specifications

Product Specifications	
Weight of Gauge:	284 g / 10 ounces
Size of Gauge (W x H x D):	64 mm x 121 mm x 32 mm / 2.5 x 4.75 x 1.25"
Operating Temperature:	-20 to 50 °C (-20 to 120 °F)
Case:	Extruded aluminum body / nickel plated aluminum end caps.
Keypad:	Sealed mebrane, resistant to water and petroleum products.
Power Source:	2 x "AA", 1.5 Volt alcaline cells (typical operting time: 200 hours) or 2 x 1.2 Volt NiCad cells (typical operating time: 120 hours)
Display:	Liquid-Crystal-Display, 4.5-igits, 1.27cm / 0,500" high numerals, LED-backlight
Measuring Range:	0.63 to 500 mm (0.025 to 19.999")
Resolution:	0.01 mm (0.001")
Accuracy:	± 0.01 mm (0.001"), depends on material and conditions
Sound Velocity Range:	1250 to 10.000 m/s (0.0492 to 0.3930 in/µs)

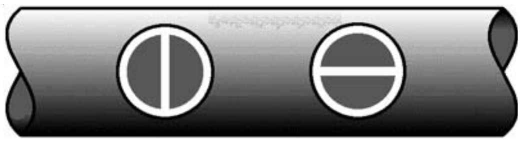
9. Application Notes

9.1 Measuring Pipe and Tubing

When measuring a piece of pipe to determine the thickness of the pipe wall, orientation of the transducers is important. If the diameter of the pipe is larger than approximately 100 mm/ 4 inches, measurements should be made with the transducer oriented so that the gap in the wearface is perpendicular (at right angle) to the long axis of the pipe.

For smaller pipe diameters, two measurements should be performed, one with the wearface gap perpendicular, another with the gap parallel to the long axis of the pipe.

The smaller of the two displayed values should then be taken as the thickness at that point.



perpendicualar parallel

9.2 Measuring Hot Surfaces

The velocity of sound through a substance is dependant upon its temperature. As materials heat up, the velocity of sound through them decreases. In most applications with surface temperatures less than about 100°C (200°F), no special procedures must be observed. At temperatures above this point, the change in sound velocity of the material being measured starts to have a noticeable effect upon ultrasonic measurement.

At such elevated temperatures, it is recommended that the user perform a **calibration** procedure (refer to section „Calibration“) on a sample piece of known thickness, which is at or near the temperature of the material to be measured. This will allow the ***MINITEST 403*** to correctly calculate the velocity of sound through the hot material.

When performing measurements on hot surfaces, it may also be necessary to use a specially constructed high-temperature transducer. These transducers are built using materials which can withstand high temperatures. Even so, it is recommended that the probe be left in contact with the surface for as short a time as needed to acquire a stable measurement. While the transducer is in contact with a hot surface, it will begin to heat up itself, and through thermal expansion and other effects, may begin to adversely affect the accuracy of measurements.

9.3 Measuring Laminated Materials

Laminated materials are unique in that their density (and therefore sound-velocity) may vary considerably from one piece to another. Some laminated materials may even exhibit noticeable changes in sound-velocity across a single surface. The only way to reliably measure such materials is by performing a calibration procedure on a sample piece of known thickness. Ideally, this sample material should be a part of the same piece being measured, or at least from the same lamination batch. By calibrating to each test piece individually, the effects of variation of sound-velocity will be minimized.

An additional important consideration when measuring laminates, is that any included air gaps or pockets will cause an early reflection of the ultrasound beam.

This effect will be noticed as a sudden decrease in thickness in an otherwise regular surface. While this may impede accurate measurement of total material thickness, it does provide the user with positive indication of air gaps in the laminate.

10. Sound Velocities

Material		Sound Velocities	
		m/s	in/µs
Aluminum		6350	0,250
Bismuth		2180	0,086
Brass		4400	0,173
Cadmium		2770	0,109
Cast Iron	(approx.)	4570	0,180
Constantan		5230	0,206
Copper		4670	0,184
Epoxy resin	(approx.)	2540	0,100
German silver		4750	0,187
Glass, crown		5660	0,223
Glass, flint		4270	0,168

Material		Sound Velocity	
		m/s	in/µs
Gold		3240	0,128
Ice		3990	0,157
Iron		5890	0,232
Lead		2160	0,085
Magnesium		5800	0,228
Mercury		1450	0,057
Nickel		5630	0,222
Nylon	(approx.)	2590	0,102
Paraffin		2210	0,087
Platinum		3960	0,156
Plexiglass		2690	0,106

Material		Sound Velocity	
		m/s	in/µs
Polystyrene		2340	0,092
Porcelain	(approx.)	5890	0,230
PVC		2395	0,094
Quartz glass		5640	0,222
Rubber, vulcanized		2300	0,091
Silver		3600	0,142
Steel, common		5920	0,233
Steel, stainless		5660	0,223
Stellite	(approx.)	6985	0,275
Teflon		1420	0,056
Tin		3320	0,131

Material		Sound Velocity	
		m/s	in/µs
Titanium		6100	0,240
Tungsten		5330	0,210
Zinc		4190	0,166
Water		1480	0,058

11. After-Sales Service

State-of-the-art methods using high-quality components as well as a quality management system certified to DIN EN ISO 9001 ensure an optimum quality of the gauge.

Should you nevertheless detect an error or malfunction on your gauge, please inform the ElektroPhysik Service responsible for your products, giving the details including a description of the error or malfunction.

If there is anything specific you would like to know about the use, handling, operation or specifications of the gauges, please contact your nearest ElektroPhysik representative, or the following addresses direct:

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Symbole

A

B

C

D

E

F

G

I

L

M