en

Model CG60
Model CG60DL

Corrosion Gauge

Operating Instructions

en

elcometer NDT

This product meets the Electromagnetic Compatibility Directive.
The product is Class A, Group 1 ISM equipment according to CISPR 11.
Group 1 ISM product: A product in which there is intentionally generated and/or used conductively coupled radio-frequency energy which is necessary for the internal functioning of the equipment itself.

Class A product are suitable for use in all establishments other than domestic and those directly connected to a low voltage power supply network which supplies buildings used for domestic purposes.

elcometer is a registered trademark of Elcometer Limited.

All other trademarks acknowledged.

© Copyright Elcometer Limited. 2011.

All rights reserved. No part of this document may be reproduced, transmitted, transcribed, stored (in a retrieval system or otherwise) or translated into any language, in any form or by any means (electronic, mechanical, magnetic, optical, manual or otherwise) without the prior written permission of Elcometer Limited.

A copy of this Instruction Manual is available for download on our Website via www.elcometer.com.

Doc.No. TMA-0498 Issue 01
Text with Cover No: 23225

Contents

1 About your gauge 2
2 The keypad 4
3 Getting started 8
4 The display 10
5 Measurement modes 13
6 Setting up the gauge 15
7 Measurement - Taking readings 21
8 Measurement options 23
9 Measurement - Recording your readings (CG60DL only) 28
10 Transferring readings to a computer 31
11 Storage 33
12 Maintenance 34
13 Technical specification 34
14 Warranty 36
15 Spares 38
16 Transducers 38
17 Condition and preparation of surfaces 43
18 Application notes 43
19 Sound velocities of common materials 46

Thank you for purchasing this Model CG60/Model CG60DL Corrosion Gauge. Welcome to Elcometer NDT.

The Elcometer CG60 and CG60DL Corrosion Gauges are world beating products. With the purchase of this gauge you now have access to the worldwide service and support network of Elcometer NDT . For more information visit our website at www.elcometerndt.com.

1 ABOUT YOUR GAUGE

The Model CG60 and CG60DL Corrosion Gauges are handheld gauges for fast and accurate measurement of material thickness.

The Model CG60 and CG60DL are both capable of measuring the thickness of various materials with accuracy as high as ± 0.1 mm (± 0.004"). The principal 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.

The multi-mode feature of the Model CG60 and CG60DL allows the user to toggle between pulse-echo mode (standard measurements) and echo-echo mode (eliminate paint or coating thickness).

The Model CG60DL model includes all the features of the Model CG60 model plus a data-logging (memory) facility which allows readings to be stored in batches before being downloaded to a computer.

This manual describes the operation of the Model CG60 and the Model CG60DL.

1.1 STANDARDS

The Model CG60 and CG60DL Corrosion Gauges can be used in accordance with the following Standards and test methods ASTM E 797, EN 14127 & EN 15317.

1.2 WHAT THIS BOX CONTAINS

Model CG60 Gauge or Model CG60DL Gauge, Bottle of couplant, Battery, 2 x, Carrying case, Test certificate, Operating instructions, CD with data transfer and data collection software - CG60DL only, RS232 cable and USB to Serial converter CG60DL only

Note: The box does **not** *include a transducer; these must be ordered separately. To order a transducer, contact Elcometer or your local Elcometer NDT supplier.*

Figure 1. Model CG60 and CG60DL Corrosion Gauges

2 THE KEYPAD

2.0.1 Model CG60 keypad

	The ON/OFF key switches the gauge on or off. To switch the gauge on, press the ON/OFF key. The gauge will perform a brief test by illuminating all of the segments in the display. After one second, the display will show the internal software version number and then the measurement mode ‘P-E’ or ‘E-E’. The display then shows ‘0.00’ (or ‘0.000’ if using imperial units), indicating the gauge is ready to take readings. To switch the gauge off press the ON/OFF key. The gauge retains all of its settings even when the power is off. The gauge also features an ‘auto-power down’ function designed to conserve battery life. If the gauge is idle for 5 minutes, it will switch itself off.
	The PRB-0 key sets the gauge to zero in much the same way that a mechanical micrometer is set to zero. If the gauge is not set to zero correctly, all of the measurements that the gauge makes may be in error by some fixed value. See “Setting up the gauge” on page 15.
	When the Model CG60 is taking readings, press the CAL key to adjust calibration. *Calibration adjustment* sets the sound-velocity value that the gauge uses 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. See “Calibration” on page 17.
	The IN/MM key toggles between metric (mm) and imperial (inches) units. This key may be used at any time, whether the gauge is displaying a thickness (MM or IN) or a velocity value (M/s or IN/µs)

	The UP arrow/SCAN key has two functions. When the Model CG60 is in CAL or ALARM mode, press this key to increase numeric values on the display. An auto-repeat function is built in, so that when the key is held down, numeric values increment at an increasing rate. When the Model CG60 is taking readings, this key switches SCAN measurement on and off. See “Measurement options” on page 23.
	The DOWN arrow/Backlight key has two functions. When the Model CG60 is in the CAL or ALARM mode, press this key to decrease numeric values on the display. An auto-repeat function is built in, so that when the key is held down, numeric values decrease at an increasing rate. When the Model CG60 is taking readings, the DOWN arrow key switches the display backlight between three settings; on, off and auto. See “Backlight” on page 27.
	The ALRM key has two functions. Hold down the ALRM key when switching on the Model CG60 to switch the audible beeper on or off. When the Model CG60 is taking readings, press the ALRM key to toggle the alarm on or off, and to allow the nominal thickness value to be adjusted. See “Alarm” on page 24.
	The DUAL/MULTI key toggles between pulse-echo measurement mode and echo-echo measurement mode. This enables the user to switch very conveniently between measurement modes depending on application requirements. See “Measurement options” on page 23.
	The SEND key sends the currently displayed thickness measurement to an external storage device via the RS232 port. See “Transferring readings to a computer” on page 31.

2.0.2 Model CG60DL keypad

	The ON/OFF key switches the gauge on or off. To switch the gauge on press the ON/OFF key. The gauge will perform a brief test by illuminating all of the segments in the display. After one second, the display will show the internal software version number, the current batch location and location status, and then the measurement mode 'P-E' or 'E-E'. The display then shows '0.00' (or '0.000' if using imperial units), indicating the gauge is ready to take readings. To switch the gauge off press the ON/OFF key. The gauge retains all of its settings even when the power is off. The gauge also features an 'auto-power down' function designed to conserve battery life. If the gauge is idle for 5 minutes, it will switch itself off.
	The PRB-0 key sets the gauge to zero in much the same way that a mechanical micrometer is set to zero. If the gauge is not set to zero correctly, all of the measurements that the gauge makes may be in error by some fixed value. See "Setting up the gauge" on page 15.
	When the Model CG60DL is taking readings, press the CAL key to adjust calibration. *Calibration adjustment* sets the sound-velocity value that the gauge uses 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. See "Calibration" on page 17.
	When the Model CG60DL is taking readings, press the MODE key to adjust the features and settings of the gauge (alarm, scan, units, P-E/E-E, backlight, and beeper). The MODE key is used in conjunction with the arrow and SEND keys to enable/disable the features and settings.

	The UP arrow key has three functions. When the gauge is in CAL or ALARM mode, press this key to increase numeric values on the display. An auto-repeat function is built in, so that when the key is held down, numeric values increment at an increasing rate. When MODE key has been pressed, the UP arrow key scrolls through the various features and settings of the gauge. When the data-logging feature has been activated by pressing the MEM key, pressing the UP arrow key scrolls through the various files, memory locations, and functions of the data logger.
	The DOWN arrow key has three functions. When the gauge is in the CAL or ALARM mode, press this key to decrease numeric values on the display. An auto-repeat function is built in, so that when the key is held down, numeric values decrease at an increasing rate. When MODE key has been pressed, the DOWN arrow key scrolls through the various features and settings of the gauge. When the data-logging feature has been activated by pressing the MEM key, pressing the DOWN arrow key scrolls through the various files, memory locations, and functions of the data logger.
	The MEM key enables/disables the data logging feature of the Model CG60DL. This key is used in conjunction with the UP/DOWN arrows, SEND, and CLR keys. These keys, in combination, control the data logging features of the Model CG60DL. See “Measurement options” on page 23.
	The CLR key is used with the data-logging feature of the Model CG60DL. This key clears the contents of an entire batch, or individual memory locations. The CLR key is also used to send an obstruct message (ObSt) to an individual memory location. The ObSt symbol would indicate that the user was unable to take a reading at a particular location. See “Measurement options” on page 23.
	The SEND key is used for sending data to internal memory locations, and external peripheral devices (serial printer or computer). The SEND key is also used to select data logging functions in the Model CG60DL.

3 GETTING STARTED

3.1 FITTING BATTERIES

The Model CG60/CG60DL may be used with dry cell batteries or rechargeable batteries.

2 x LR6 (AA) alkaline batteries are supplied in the kit.

When the battery voltage is low the entire display will start to flash. When this occurs the batteries should be replaced.

To fit or replace batteries:

1. Locate battery compartment cover (Figure 2) at top of gauge.
2. Unscrew battery compartment cover.
3. Referring to battery polarity instructions on rear of gauge, insert batteries into gauge ensuring correct polarity.
4. Replace battery compartment cover.

Note: Remove the batteries from the gauge if it is to remain unused for a long period of time. This will prevent damage to the gauge in the event of malfunction of the batteries.

Figure 2. Fitting batteries

3.2 CHOOSING THE TRANSDUCER

When you purchased your gauge you should have also purchased a suitable transducer for your application. If you have not yet done so, refer to “Transducers” on page 38, which will help you identify the correct transducer type. Alternatively contact Elcometer NDT, your local Elcometer NDT supplier or visit www.elcometerndt.com.

3.3 FITTING THE TRANSDUCER

The transducer (Figure 3) transmits and receives ultrasonic sound waves that the gauge uses to calculate the thickness of the material being measured.

The transducer connects to the gauge via the attached cable, and two coaxial connectors. When using transducers manufactured by Elcometer NDT, the orientation of the dual coaxial connectors is not critical; either plug may be fitted to either socket.

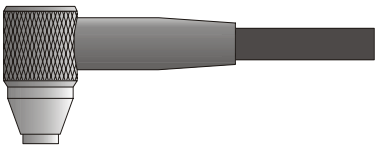


Figure 3. Typical Transducer

The transducer must be used correctly in order for the gauge to produce accurate, reliable measurements.

Figure 4 shows the two semicircles of the wearface and the barrier separating them.

One of the semicircles transmits ultrasonic sound into the material being measured, and the other semicircle receives the sound echoes back into the transducer. When the transducer is placed against the material being measured, it is the area directly beneath the centre of the wearface that is being measured.

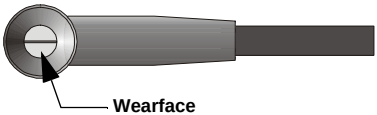


Figure 4. Transducer - bottom view

3.4 SWITCHING ON/OFF

To switch on or off, press the on/off key The gauge will switch off automatically after 5 minutes of inactivity.

4 THE DISPLAY

The display segments for the Model CG60 and the Model CG60DL are shown in Figure 5.

The following section describes the individual parts of the display and their meaning.

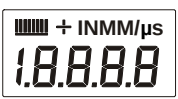
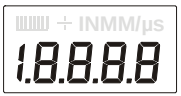
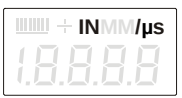


Figure 5. The LCD Display - Elcometer CG60 and

Display segment	Information displayed
	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 which indicate the status of various settings. When the gauge is displaying thickness measurements, the display will hold the last value measured, until a new measurement is made. Additionally, when the battery voltage is low, the entire display will begin to flash. When this occurs, the batteries should be replaced.
	These eight vertical bars form the Stability Indicator. Only the left-most bar and the underline will be on when the gauge is idle. Six or seven of the bars should be on when the gauge is taking a measurement. If fewer than five bars are on, the gauge is having difficulty achieving a stable measurement, and the thickness value displayed could be in error. Refer to "Read display" on page 22 and "Transducers" on page 38 for information on how to achieve a stable measurement.
	When the + symbol is on and blinking, this indicates that the Model CG60DL is currently operating in echo-echo (through-paint/coating) mode.

Display segment	Information displayed
	When the MM symbol is on, the gauge is displaying a thickness value in millimetres. The maximum value displayed is 25.40 millimetres (MM).
	When the IN symbol is on, the gauge is displaying a thickness value in inches. The maximum thickness that can be displayed is 1.0000 inches (IN).
	When the M symbol is on, in conjunction with the /s symbol, the gauge is displaying a sound-velocity value in metres-per-second (M/S).
	When the IN symbol is on, in conjunction with the /µs symbol, the gauge is displaying a sound-velocity value in inches-per-microsecond (IN/µS).

4.1 FRONT PANEL LIGHTS

Green light illuminates when:

- The alarm mode is active, and
- the measured thickness is greater than the alarm value.

Red light illuminates when:

- The alarm mode is active, and
- the measured thickness is less than the alarm value.

5 MEASUREMENT MODES

Your gauge has two measurement modes, Pulse-Echo and Echo-Echo.

5.1 PULSE-ECHO MODE (P-E)

This mode measures from the initial pulse (sometimes referred to as an artificial zero) to the first echo (reflection). This mode only requires one reflection and it is therefore the most sensitive mode for measuring weak reflections (flaws) typically found when measuring heavily corroded metals. If this mode is used to measure a coated sample, then the thickness of the substrate plus coating will be measured.

Note: Rough surface conditions can have an effect on the overall accuracy in this mode. If the surface condition is in question, the pulse-echo mode should be used in conjunction with performing an off block automatic zero as the temperature gradient changes.

5.2 ECHO-ECHO MODE (E-E)

This mode measures between two reflections. This technique is commonly used to eliminate errors from surface coatings and also to make measurements in multiple layered materials. The disadvantage is that two echoes are needed which requires a much stronger echo (reflection).

Note: Echo-echo mode cannot be used for flaw or pit detection. Therefore, inspectors may need to use this mode in conjunction with the standard coating off (pulse-echo) flaw detection mode for some applications. Chassis tubing inspectors and sanctioning bodies will typically use the echo-echo mode for tubing with powder coatings, and pulse-echo mode for tubing without coating. This combination of using both modes is ideal for very detailed inspections.

To select measurement mode:

Model CG60

1. Press **ON/OFF** key to switch on the gauge.
2. Press **DUAL/MULTI** key to toggle between the measurement modes. The gauge will display **P-E** or **E-E**, depending on which mode the gauge is in.
3. Repeat step 2 until correct mode is displayed.

Model CG60DL

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MODE** key to activate features and settings. The gauge will display **GAtE P-E** or **GAtE E-E**, depending on which mode the gauge is in.
3. Press **SEND** key to toggle between the measurement modes.
4. Press **MODE** key when correct mode is displayed.

Selection of measurement mode is now complete.

6 SETTING UP THE GAUGE

6.1 TRANSDUCER - ZEROING

Setting the zero point of the gauge is important for the same reason that setting the zero on a mechanical micrometer is important. If the zero point of the gauge is not set correctly, all of the measurements the gauge makes will be in error by some fixed number. When the zero point of the gauge is set, this fixed error value is measured and automatically corrected for in all subsequent measurements.

Though the gauge will remember the last zero point, it is generally a good idea to set the zero whenever the gauge is switched on, as well as any time a different transducer is used. This will ensure that the zero point of the instrument is always correct. The zero probe routine must be done prior to calibration.

To set the zero point:

1. Plug the transducer into the gauge ensuring that the connectors are fully engaged. Check that the wearface of the transducer is clean and free of any debris.
2. Press **ON/OFF** key to switch on the gauge.
3. The battery compartment cover on the top end of the gauge acts as a metal ‘probe-disc’. Apply a single droplet of ultrasonic couplant to the face of this disc.

4. Make sure that the gauge is in P-E (pulse-echo mode):

Model CG60

1. Press **DUAL/MULTI** key to toggle measurement mode to P-E.

Model CG60DL

1. Press **MODE** key.
2. Press **SEND** key to toggle measurement mode to P-E.
3. Press **MODE** key to confirm selection.

Note: The Probe-Zero feature is not used in Echo-Echo through-paint mode, and has been disabled. If the **PRB-0** key is pressed, while in this mode, 'nO' followed by 'Prb0' will be displayed.

4. Press the transducer against the probe-disc, making sure that the transducer is flat against the surface (Figure 6). The display should show some thickness value, and nearly all the bars of the stability indicator should be illuminated.
5. While the transducer is firmly coupled to the probe-disc, press the **PRB-0** key on the keypad. The gauge will display 'Prb0' while it is calculating the zero point.
6. Remove the transducer from the probe-disc.

Figure 6. Transducer pressed against probe-disc

When setting the zero point, the gauge 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 gauge will remember the last zero point, it is generally a good idea to set the zero point whenever the gauge is switched on, as well as any time a different transducer is used. This will ensure that the zero point of the instrument is always correct.

6.2 CALIBRATION

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

Different types of material have different sound-velocities. For example, the velocity of sound through steel is 5918 m/s (about 0.233 in/µs) and the velocity of sound through aluminium is 6350 m/s (about 0.248 in /µs).

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.

There are three methods of calibrating the Model CG60 and Model CG60DL gauges:

One-point CALIBRATION: This is the simplest and most commonly used calibration procedure - optimising linearity over *large* ranges. One-point calibration is carried out using a known thickness.

Two-point CALIBRATION: This allows for greater accuracy over *small* ranges. Two-point calibration is carried out using two known thicknesses.

Known velocity CALIBRATION: The sound-velocity of the material being measured is entered directly into the gauge.

Note: Although the gauge has a through-paint/coating feature, one-point and two-point calibrations must be performed on material with the paint or coating removed. Failure to remove the paint or coating prior to calibration will result in a multi-material velocity calculation that may be different from the actual material velocity intended to be measured.

6.2.1 One-point calibration

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

1. Press **ON/OFF** key to switch on the gauge.
1. Set the zero point of the gauge - see “Setting up the gauge” on page 15.
2. Apply couplant to the sample piece.
3. Press the transducer against the sample piece, making sure that the transducer is flat against the surface of the sample. The display should show some (probably incorrect) thickness value, and nearly all the bars of the stability indicator should be illuminated.
4. Having achieved a stable reading, remove the transducer.

   If the displayed thickness changes from the value shown while the transducer was coupled, repeat step 3 and 4.
5. Press the **CAL** key. The **MM** (or **IN**) symbol should begin flashing.
6. Use the **UP** and **DOWN** arrow keys to adjust the displayed thickness up or down, until it matches the known thickness of the sample piece.
7. Press the **CAL** key again. The **M/s** (or **IN/µs**) symbols should begin flashing. The gauge is now displaying the sound-velocity value it has calculated.
8. Press the **CAL** key once more to exit the calibration mode.

The gauge is now ready to perform measurements.

6.2.2 Two-point calibration

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. Set the zero point of the gauge - see “Setting up the gauge” on page 15.
2. Apply couplant to the sample piece.
3. Press the transducer against the sample piece, at the first calibration point, making sure that the transducer is flat against the surface of the sample. The display should show some (probably incorrect) thickness value, and nearly all the bars of the stability indicator should be illuminated.
4. Having achieved a stable reading, remove the transducer.

   If the displayed thickness changes from the value shown while the transducer was coupled, repeat steps 3 and 4.
5. Press the **CAL** key. The **IN** (or **MM**) symbol should begin flashing.
6. Use the **UP** and **DOWN** arrow keys to adjust the displayed thickness up or down, until it matches the thickness of the sample piece.
7. Press the **PRB-0** key. The display will flash **1OF2**.
8. Repeat steps 3 to 6 on the second calibration point.
9. Press the **CAL** key again. The **M/s** (or **IN/µs**) symbols should begin flashing. The gauge is now displaying the sound-velocity value it has calculated.
10. Press the **CAL** key once more to exit the calibration mode.

The gauge is now ready to perform measurements within this range.

6.2.3 Known velocity calibration

This procedure requires that the operator knows the sound-velocity of the material to be measured. A table of common materials and their sound-velocities can be found in “Sound velocities of common materials” on page 46.

1. Press **ON/OFF** key to switch on the gauge.
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/µs**) 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 gauge is now ready to perform measurements.

*Note: At any time during the gauge calibration procedure (***IN***,* **MM***,* **IN/µs***, or* **M/s** *flashing in the display), pressing the* **PRB-0** *key will restore the gauge to the factory default sound-velocity for steel, 5918 m/s (0.233 in/µs).*

To achieve the most accurate measurements possible, it is generally advisable to calibrate the gauge 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.

7 MEASUREMENT - TAKING READINGS

Disclaimer

Inherent in ultrasonic thickness measurement is the possibility that the instrument will use the second echo rather than the first echo from the back surface of the material being measured while in standard pulse-echo mode. This may result in a thickness reading which is TWICE what it should be.

In addition, measurements through very thick paint or coatings while using echo-echo mode may result in the paint or coating being measured rather than the material intended. The responsibility for proper use of the instrument and recognition of these types of phenomenon rests solely with the user of the instrument.

7.1 Before you start

- *Set the zero point of the gauge.*
  See “Setting up the gauge” on page 15.
- *Calibrate the gauge.*
  See “Calibration” on page 17.
- *Select the correct measurement mode.*
  See “Measurement options” on page 23.
- *Prepare the surface.*
  See “Condition and preparation of surfaces” on page 43.

7.2 PROCEDURE

7.2.1 Apply couplant

For the gauge to work correctly there must be no air gap between the transducer and the surface of the material to be measured. This is achieved using a couplant.

Before the transducer is placed on the surface, put a small amount of couplant supplied with the gauge on the surface of the material. Typically a single drop is sufficient.

7.2.2 Place transducer onto surface of material to be measured

Press the transducer wearface into the couplant. Moderate pressure on the top of the transducer using the thumb or index finger is sufficient; it is only necessary to keep the transducer stationary and the wearface seated flat against the surface of the material.

7.2.3 Read display

If six or seven bars of the stability indicator are showing, the display will be reading the correct thickness of the material directly beneath the transducer.

If the stability indicator has fewer than five bars showing, or the numbers on the display seem erratic, 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.

The gauge will perform four measurements every second when the transducer is in contact with the surface of the material. The display is updated as each reading is taken.

7.2.4 Remove transducer from surface

The display will show the last measurement made.

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 gauge 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. If this happens, take the reading again using less couplant.

8 MEASUREMENT OPTIONS

8.1 SCAN MODE

Although the gauge excels at making single point measurements, it is sometimes desirable to examine a larger region, searching for the thinnest point. The Model CG60 and CG60DL include a feature, called **Scan Mode**, which allows it to do just that.

In normal operation, the gauge performs and displays four measurements every second, which is quite adequate for single measurements. In **Scan Mode**, however, the gauge performs eight measurements every second, but does not display them. While the transducer is in contact with the material being measured, the gauge memorises 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 gauge will display the lowest value it found.

Note: The Scan mode is not available in echo-echo mode, and has been disabled. If scan mode is selected while in echo-echo mode, 'nO' followed by 'SCAn' will be displayed.

8.1.1 To switch scan mode on/off

Elcometer CG60

1. Press **ON/OFF** key to switch on the gauge.
2. Press **UP/SCAN** key to toggle the status of the Scan mode. The gauge will display **SCAn OFF** or **SCAn On** depending on which mode the gauge is in.
3. Repeat step 2 to switch scan mode on or off.

Elcometer CG60DL

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MODE** key to activate features and settings.
3. Press **UP** and **DOWN** arrow keys to scroll to **SCAn** symbol. The gauge will display **SCAn OFF** or **SCAn On** depending on which mode the gauge is in.
4. Press **SEND** key to switch scan mode on or off.
5. Press **MODE** key when finished.

Selection of scan mode is now complete.

8.2 ALARM

The **Alarm** feature of the Model CG60 and CG60DL allows the user to set an audible and visual alarm when taking measurements.

If the alarm is switched on, the green light on the front panel of the gauge is illuminated. If the measurement falls below the value set by the user, a red light shows on the front panel of the gauge and the beeper is sounded if it is switched on.

Use of the red light and beeper improves the speed and efficiency of the inspection process by eliminating constant viewing of the reading displayed.

8.2.1 To switch beeper on/off

Elcometer CG60

1. While the gauge is off, press and hold down **ALRM** key.
2. Press **ON/OFF** key to switch on the gauge.
3. Release **ALRM** key. The gauge will display **bEEP OFF** or **bEEP On** depending on whether the beeper is on or off.
4. Repeat steps 1 to 3 to toggle between **bEEP ON** and **bEEP OFF**.

Elcometer CG60DL

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MODE** key to activate features and settings.
3. Press **UP** or **DOWN** arrow keys to scroll to **bEEP**. The gauge will display **bEEP OFF** or **bEEP On** depending on whether the beeper is on or off.
4. Press **SEND** key to toggle the status of the beeper on/off.
5. Press **MODE** key when finished.

Selection of beeper on/off is now complete.

8.2.2 To set alarm value and switch alarm on

Elcometer CG60

1. Press **ON/OFF** key to switch on the gauge.
2. Press **ALRM** key to toggle the status of the alarm until the gauge displays:

   ALAr followed by a thickness value and flashing **MM** (or **IN**) symbol.
3. Press **UP** and **DOWN** arrow keys to adjust thickness value.
4. Press **ALRM** key when correct value is displayed.

Elcometer CG60DL

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MODE** key to activate features and settings.
3. Press **UP** or **DOWN** arrow keys to scroll to **ALAr**. The gauge will display:

   ALAr OFF
4. Press **SEND** key. The gauge will display:

   A thickness value and flashing **MM** (or **IN**) symbol.
5. Press **UP** and **DOWN** arrow keys to adjust thickness value.
6. Press **SEND** key when correct value is displayed.
7. Press **MODE** key.

The alarm value is now set and the alarm is switched on.

8.2.3 To switch alarm off

Repeat the steps in 8.2.2, but select **ALAr OFF**.

8.3 BACKLIGHT

The gauge display includes a backlight. The backlight can be set to one of three modes - on/off/auto.

- ON - backlight is on
- OFF - backlight is off
- AUTO - backlight automatically illuminates while the gauge is making a measurement and switches off after several seconds (to conserve battery life).

8.3.1 To set backlight mode

Model CG60

1. Press **ON/OFF** key to switch on the gauge.
2. Press **DOWN** key to toggle the status of the backlight. The gauge will display **OFF**, **On** or **AutO**, depending on backlight setting.
3. Repeat step 2 until the correct setting is displayed.

Model CG60DL

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MODE key** to activate features and settings.
3. Press **UP** and **DOWN** arrow keys to scroll to the **LItE** symbol. The gauge will display **LItE OFF**, **LItE On** or **LItE AutO**, depending on backlight setting.
4. Press **SEND** key until the correct setting is displayed.
5. Press **MODE** key.

Selection of backlight mode is now complete.

9 MEASUREMENT - RECORDING YOUR READINGS (CG60DL ONLY)

The Model CG60DL is equipped with a data logging feature. This is a valuable reporting gauge for inspection purposes. It increases efficiency by reducing the time it takes to manually record the measurements during the inspection process. The gauge can then be connected to a computer or serial printer to save and print the results of the inspection.

The gauge has a memory capacity of 1000 readings. Measurements are stored in up to 10 batches (files), each consisting of up to 100 readings (memory locations).

9.1 SETTING-UP THE DATA LOGGER

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MEM** key to activate the data logger.

   The display will flash **FILE F-01** (or the last batch used). There are 10 batches, numbered **F-01 to F-10**.
3. Press the **SEND** key to enter batch setup. The current batch will be displayed (F-01, F-03, etc.)
4. Press the **UP** / **DOWN** arrow keys to scroll to the batch (1-10) that will be used.
5. Press the **SEND** key once again to select the batch.

   The display will flash **FILE F-04** (or the selected batch).
6. Press the **MEM** key, to access the memory locations in the batch selected.

   The display will flash the current memory location (L007, L039, etc.), followed by the status of the memory location. The memory location can contain one of three possible things:

   • a measurement that was previously stored

- **CLr** in the display, indicating that the memory location is empty
- **ObSt** (obstruct) in the display, indicating that a measurement could not be obtained

7. Press the **UP** / **DOWN** arrow keys to advance to the desired memory location.

9.2 STORING A MEASUREMENT

1. Take a measurement and press the **SEND** key to store a reading in the memory location.
   The data logger will then **automatically advance** to the next memory location in sequential order.
2. Repeat **step 1** as required.

9.3 DELETING CONTENTS OF A MEMORY LOCATION

The user may require a memory location that is currently full to be over written. The procedure for deleting (clearing) the contents of the memory location is outlined in the following steps:

Note: This procedure assumes the steps in 9.1 and 9.2 have been completed, and 9.2 is being repeated.

1. Press the **UP** / **DOWN** arrow keys to move to the memory location to be cleared.
   If the memory location is currently full, the display will flash the **FuLL** symbol.
2. Press the **CLR** key to delete the contents of the memory location. The display will flash the memory location (L011, L099, etc.) and the **CLr** symbol.
3. Take another measurement, and press the **SEND** key to write to the same memory location just cleared.

9.4 DELETING CONTENTS OF AN ENTIRE BATCH

The user may require the contents of an entire batch to be cleared of all measurements. This would allow the user to start a new list of measurements starting at memory location L001, for example. The procedure is outlined in the following steps:

1. Press **ON/OFF** key to switch on the gauge.
2. Press **MEM** key to activate the data logging functions and settings.
3. Press **SEND** key to enter batch setup.
4. Press **UP** / **DOWN** arrow keys to scroll to the batch that is to be cleared of all measurements.
5. Press **SEND** key once again to select the batch. The display will flash **FILE F-05** (or the batch selected).
6. Press **UP** / **DOWN** arrow keys to scroll to the flashing **CLr F-05** (or the batch selected).
7. Press **SEND** key to select the clear batch option. The display will show **CLr?**
8. Press **CLR** key to confirm and clear the contents of the entire batch.
9. Press **MEM** key at any time to exit data logging functions.

9.5 DELETING CONTENTS OF ALL BATCHES

1. Press **ON/OFF** key to switch on the gauge.
2. Immediately press the **CLR** key. The display will show **CLr?**
3. Press CLR key once again to clear all batches.

10 TRANSFERRING READINGS TO A COMPUTER

Readings can be transferred from the Model CG60 and Model CG60DL to a computer. The Model CG60 will transfer readings as they are taken. The Model CG60DL will transfer readings as they are taken and also transfer the contents of its memory.

A data transfer cable is used to connect the gauge to the computer. This cable is supplied with the Model CG60DL and is available as an optional accessory for the Model CG60 (see “Spares” on page 38).

Elcometer recommends the use of NDT Link available from www.elcometerndt.com but other types of software may also be used.

10.1 CONNECTING THE DATA TRANSFER CABLE

1. Plug the 9-pin female D-type connector on one end of the data transfer cable into the COM port on the PC, or USB to COM adapter.
2. Plug the jack connector on the other end of the data transfer cable into the RS232 data connection socket on the bottom of the gauge (Figure 7).
3. Start the communications software.
4. Select gauge type Elcometer CG60 or CG60DL.

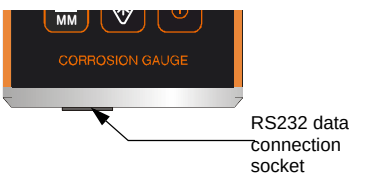


Figure 7. RS232 data connection socket

10.1.1 Transferring data

Model CG60

After taking a measurement, press the **SEND** key to send the measurement to the computer.

Model CG60DL

Follow the instructions in “Measurement options” on page 23

10.1.2 Transferring one batch

1. Connect the gauge to a computer and start the data transfer software - see “Transferring readings to a computer” on page 31.
2. Press **ON/OFF** key to switch on the gauge.
3. Press **MEM** key to activate the data logging functions and settings.
4. Press **SEND** key to enter batch setup.
5. Press **UP** / **DOWN** arrow keys to scroll to the batch that is to be sent to the computer.
6. Press **SEND** key once again to select the batch. The display will flash **FILE F-05** (or the batch selected).
7. Press **UP** / **DOWN** arrow keys to scroll to **LISt F-05** (or the batch selected) flashing on the display.
8. Press the **SEND** key to send readings to the computer. The display will show **buSY** during data transfer. Wait until all the data has been transferred.
9. Press the **MEM** key to exit the data logging functions.

10.1.3 Transferring all batches

1. Connect the gauge to a computer and start the data transfer software.
2. Press **ON/OFF** key to switch on the gauge.
3. Press **MEM** key to activate the data logging functions and settings.
4. Press **UP** / **DOWN** arrow keys to scroll to **SEnd ALL** flashing on the display.
5. Press the **SEND** key to send readings to the computer.
   The display will show **buSY** during data transfer.
   Wait until all the data has been transferred.
6. Press the **MEM** key to exit the data logging functions.

11 STORAGE

The Model CG60/CG60DL gauge has a Liquid Crystal Display. If the display is heated above 50°C (120°F) it may be damaged. This can happen if the gauge is left in a car parked in strong sunlight.

Always store the gauge in its case when it is not being used.

If the gauge is to remain unused for long periods of time, remove the batteries and store them separately. This will prevent damage to the gauge in the event of malfunction of the batteries.

12 MAINTENANCE

The Model CG60/CG60DL is designed to give many years reliable service under normal operating and storage conditions.

12.1 Transducer

The transducer will wear with repeated use. Transducer life depends on the number of measurements taken and the manner in which readings are taken. To extend transducer life, always set the transducer down so that it is perpendicular to the panel surface. Dragging the transducer along the surface will reduce the life of the transducer. Replacement transducers are available from your local Elcometer NDT supplier or directly from Elcometer.

12.2 Faults

The gauge does not contain any user-serviceable components. In the unlikely event of a fault, the gauge should be returned to your local Elcometer NDT supplier or directly to Elcometer. The warranty will be invalidated if the instrument has been opened.

13 TECHNICAL SPECIFICATION

13.1 Performance

Range (pulse-echo):	0.63 mm to 500 mm (0.025" to 19.999")
Range (echo-echo):	2.54 mm to 25.4 mm (0.1" to 1.0")
Resolution:	0.01 mm (0.001")
Accuracy:	±0.1 mm (±0.004"), depends on material and conditions

Sound-velocity range:	1250 m/s to 10 000 m/s (0.0492 in/μs to 0.3937 in/μs)
Physical Weight:	295 g (10 oz) including batteries
Size:	63.5 mm x 120.6 mm x 31.5 mm (2.5" x 4.5" x 1.24")
Operating temperature:	-30°C to 50°C (-20°F to 120°F) (depending upon climatic conditions)
Case:	Extruded aluminium body, Nickel plated aluminium end caps

13.2 Keypad

Type:	Sealed membrane
Properties:	Resistant to water and petroleum products

13.3 Power supply

Type:	Internal batteries
Battery type:	2 x LR6 (AA), alkaline[a] dry batteries or rechargeable[b] equivalents
Battery life:	200[c] hours continuous (alkaline dry batteries)

a. Alkaline batteries must be disposed of carefully to avoid environmental contamination. Please consult your local environmental authority for information on disposal in your region.
Do not dispose of any batteries in fire.
b. Rechargeable batteries can be used if they are charged outside the gauge.
c. Battery life is reduced to approximately 120 hours when using rechargeable batteries. Follow the instructions provided by the battery manufacturer when charging and disposing of rechargeable batteries.

14 WARRANTY

Elcometer NDT warrants the Model CG60 and Model CG60DL ultrasonic gauges against defects in materials and workmanship for a period of two years from receipt by the end user.

Additionally, Elcometer NCT warrants transducers and accessories against such defects for a period of 90 days from receipt by the end user. If Elcometer NDT receives notice of such defects during the warranty period, Elcometer NDT will either, at its option, repair or replace products that prove to be defective. The warranty will be invalidated if the instrument has been opened.

Should Elcometer NDT be unable to repair or replace the product within a reasonable amount of time, the customer's alternative exclusive remedy shall be refund of the purchase price upon return of the product.

14.1 Exclusions

The above warranty shall not apply to defects resulting from: improper or inadequate maintenance by the customer; unauthorised modification or misuse; or operation outside the environmental specifications for the product.

Elcometer NDT makes no other warranty, either express or implied, with respect to this product. Elcometer NDT specifically disclaims any implied warranties of merchantability or fitness for a particular purpose. Some states or provinces do not allow limitations on the duration of an implied warranty, so the above limitation or exclusion may not apply to you. However, any implied warranty of merchantability or fitness is limited to the two-year duration of this written warranty.

This warranty gives you specific legal rights, and you may also have other rights, which may vary from country to country, state to state or province to province.

14.2 Obtaining service during warranty period

If your hardware should fail during the warranty period, contact Elcometer NDT and arrange for servicing of the product. Retain proof of purchase in order to obtain warranty service.

For products that require servicing, Elcometer NDT may use one of the following methods:

- Repair the product
- Replace the product with a re-manufactured unit
- Replace the product with a product of equal or greater performance
- Refund the purchase price.

14.3 After the warranty period

If your hardware should fail after the warranty period, contact Elcometer NDT for details of the services available, and to arrange for non-warranty service.

15 SPARES

The Model CG60/CG60DL gauge is complete with all the items required to get started and take measurements (transducers must be ordered separately). Over the life of the gauge replacement items may be required. The following replacement and optional items are available from your local Elcometer NDT supplier or directly from Elcometer.

Description	Sales Part No.
2.25 MHz 1/4" Potted Side Transducer	TX2M25CP-2
5 MHz 1/4" Potted Side Transducer	TX5M00CP-4
5 MHz 1/4" Potted Side High Damped Transducer	TX5M00CP-10
7 MHz 1/4" Potted Side High Damped Transducer	TX7M50CP-6
10 MHz 1/4" Potted Side Transducer	TX10M0CP-4
Ultrasonic Couplant, 120 ml (4 oz)	TC-24034-1
Ultrasonic Couplant, 360 ml (12 oz)	TC-24034-2
Ultrasonic Couplant, High Temperature 340°C (650°F), 60 ml (2 oz)	TC-24034-4
Ultrasonic Couplant, High Temperature 480°C (896°F), 60 ml (2 oz)	TC-24034-5

A wide range of other transducers are available - see "Transducers" on page 38 for further details.

16 TRANSDUCERS

The Model CG60 and Model CG60DL are capable of performing measurements on a wide range of materials, from various metals to glass and plastics. Different types of material, however, have different properties. The following paragraphs highlight the important properties of transducers which should be considered when assessing a particular measurement task.

The best measurement condition is one where sufficient ultrasonic energy is sent into the material being measured such that a strong, stable echo is received by the gauge.

Several factors affect the strength of ultrasound as it travels. These are outlined below:

16.1 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. Therefore a 6 mm (1/4”) transducer will emit a stronger signal than a 3 mm (1/8”) transducer.

16.2 ABSORPTION AND SCATTERING

As ultrasound travels through any material, it is partly absorbed. If the materials through which the sound travels have any grain structure, the sound waves will experience scattering. Both of these effects reduce the strength of the waves.

Higher frequency ultrasound is absorbed and scattered more than ultrasound of a lower frequency. It may seem therefore that using a lower frequency transducer might be better in every instance, however low frequencies are less directional than high frequencies.

16.3 GEOMETRY OF THE TRANSDUCER

The physical constraints of the measuring environment sometimes determine the suitability of a transducer for a given job. The transducer may simply be too large to be used in confined areas. Also, the surface area available for contacting with the transducer may be limited. Measuring on a curved surface may require the use of a transducer with a matching curved wearface.

16.4 TEMPERATURE OF THE MATERIAL

When it is necessary to measure on surfaces that are exceedingly hot, special high-temperature transducers may be necessary. Additionally, care must be taken when performing a 'Calibration to Known Thickness' with a high temperature application - see "Measuring hot surfaces" on page 44.

16.5 SELECTING THE CORRECT TRANSDUCER

Elcometer NDT have a complete range of transducers to meet your requirements, including:

- A range of frequencies and sizes
- Straight and right angle
- Transducers available as potted or microdot transducers:

  Potted transducers - transducer cable is permanently fixed to the transducer head.

  Microdot transducers - transducer cable is fixed to the transducer head by a connector - allows transducer heads to be replaced quickly and easily.
- High temperature transducers - temperature up to 480ºC (896ºF)

When selecting a transducer, it is important to choose one which will best meet your application, taking into consideration:

- The measurement range
- The type of material to be tested
- The design of the transducer probe type

The following table gives guidance on the type of transducer required for a range of measurement tasks:

Material being measured	Mode	Transducer type required	Notes
High penetration plastics and castings	PULSE-ECHO (P-E)	Cast iron - 1MHz to 5MHz transducer. Cast aluminium - 10MHz transducer. Plastics typically require lower frequency transducers depending on the thickness and make-up of the material.	Larger diameters offer greater penetration power because of the crystal size, for difficult to measure materials.
Corrosion and pit detection in steel and cast materials	PULSE-ECHO (P-E)	Typically a 5MHz transducer or higher is required.	Use lower frequencies for greater penetration and use higher frequencies for better resolution.
Material thickness measured through a coating	ECHO-ECHO (E-E)	Special high damped transducers are required; typically the 3.5MHz, 5MHz, and 7.5MHz hi damped transducers.	These transducers are suitable for use in both pulse-echo and echo-echo modes. This enables you to measure overall material thickness using the Echo-echo mode, and then switch to pit detection mode (Pulse-echo) without changing transducers.

Material being measured	Mode	Transducer type required	Notes
Thin materials	PULSE-ECHO (P-E)	High frequency transducers are required; typically the 7.5MHz and 10MHz models with extra resolution.	The higher frequencies provide greater resolution and a lower minimum thickness rating overall.
High temperature	PULSE-ECHO and ECHO-ECHO	Special 2.25MHz and 5 MHz High temperature transducers are required.	Echo-echo mode will eliminate error caused by temperature variations in the delay line of the transducer.
Noisy material		Select a higher frequency transducer to reduce this noise - 7.5MHz and higher for better resolution.	Materials such as titanium, stainless steel, and aluminium may produce surface noise. This is a signal that appears at the surface of the material when using a dual element delay line probe.
Measuring extreme curvatures or areas of restricted access		Higher frequency transducers with smaller diameters are required. The smallest diameter uses 3/16" crystals with a contact area of .250"	

17 CONDITION AND PREPARATION OF SURFACES

The shape and roughness of the test surface are of paramount importance when carrying out ultrasonic thickness testing. 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 particles, 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 iron, will prove most difficult to measure. These kinds of surfaces act on the sound beam like frosted glass acts 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.

18 APPLICATION NOTES

18.1 MEASURING 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”), measurements should be made with the transducer oriented so that the gap in the wearface is perpendicular (at right angles) to the long axis of the pipe.

If the diameter of the pipe is small, two measurements should be performed, one with the wearface gap perpendicular to the long axis of the pipe, another with the gap parallel to the long axis of the pipe (Figure 8). The smaller of the two displayed values should then be taken as the thickness at that point.

Figure 8. Transducer positioning on small diameter pipe

18.2 MEASURING HOT SURFACES

The velocity of sound through a material depends upon the temperature of the material. As materials heat up, the velocity of sound in the material decreases. In most applications with surface temperatures less than approximately 100°C (~200°F), no special procedures are required. At temperatures above 100°C (~200°F), the change in sound-velocity of the material being measured starts to have a noticeable effect upon the accuracy of ultrasonic measurement.

At such elevated temperatures, it is recommended that the user perform a calibration procedure (see “Calibration” on page 17) on a sample piece of known thickness, which is at, or near, the temperature of the material to be measured. This will allow the gauge 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 high-temperature transducer. It is recommended that the transducer 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, and through thermal expansion and other effects, may adversely affect the accuracy of measurements.

18.3 MEASURING LAMINATED MATERIALS

The density (and therefore sound-velocity) of laminated materials 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 minimised.

An additional consideration when measuring laminates, is that any air gaps or pockets within the laminate will reflect the ultrasound beam. This 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 positive indication of air gaps in the laminate.

18.4 MEASURING THROUGH PAINT AND COATINGS

When measuring through paints and coatings the sound-velocity of the paint/coating may be significantly different from the sound-velocity of the actual material being measured. An example of this would be a mild steel pipe with approximately 0.6 mm (.025") of coating on the surface. The sound-velocity of the pipe is 5918 m/s (.2330 in/µsec), and the sound-velocity of the paint is 2286 m/s (.0900 in/µsec). If the gauge is

calibrated for mild steel pipe and measures through both materials, the actual coating thickness will appear to be 2.5 times thicker than it actually is, as a result of the differences in sound-velocity.

The error can be eliminated by using the echo-echo mode to perform measurements for applications such as these. In echo-echo mode, the paint/coating thickness will be eliminated entirely and the steel will be the only material measured.

19 SOUND VELOCITIES OF COMMON MATERIALS

Material	Sound velocity (m/s)	Sound velocity (in/µs)	Material	Sound velocity (m/s)	Sound velocity (in/µs)
Aluminium	6350	0.250	Paraffin	2210	0.087
Bismuth	2184	0.086	Platinum	3962	0.156
Brass	4394	0.173	Plexiglas	2692	0.106
Cadmium	2769	0.109	Polystyrene	2337	0.092
Cast Iron	4572	0.180 (Approx.)	Porcelain	5842	0.230 (Approx.)
Constantan	5232	0.206	PVC	2388	0.094
Copper	4674	0.184	Quartz Glass	5639	0.222
Epoxy Resin	2540	0.100 (Approx.)	Rubber, Vulcanised	2311	0.091
German Silver	4750	0.187	Silver	3607	0.142
Glass, Crown	5664	0.223	Steel	5918	0.233
Glass, Flint	4267	0.168	Steel, Stainless	5664	0.223
Gold	3251	0.128	Stellite	6985	0.275 (Approx.)
Ice	3988	0.157	Teflon	1422	0.056

Material	Sound velocity (m/s)	Sound velocity (in/µs)	Material	Sound velocity (m/s)	Sound velocity (in/µs)
Iron	5893	0.232	Tin	3327	0.131
Lead	2159	0.085	Titanium	6096	0.240
Magnesium	5791	0.228	Tungsten	5334	0.210
Mercury	1448	0.057	Water	1473	0.058
Nickel	5639	0.222	Zinc	4216	0.166
Nylon	2591	0.102 (Approx.)			