EyeCon

Purpose

The **EyeCon (A1220 Monolith 3D)** is a portable hand-held instrument that can be used for ultrasonic pulse velocity measurements and, as a pulse-echo tester, for flaw detection and thickness measurements. As a pulse-echo tester, the device is based on the ultrasonic pitch-catch method and uses an antenna composed of an array of dry point contact (DPC) transducers, which emit shear waves into the concrete. The 4 by 6 transducer array is under computer control and the recorded data are analyzed to create 2-D images of the reflecting interfaces within the cross sections below the antenna. Test results can be displayed as individual A-Scans (reflection amplitude versus time or depth) or as B-scans or D-scans showing cross sections of the test object along a scan line.

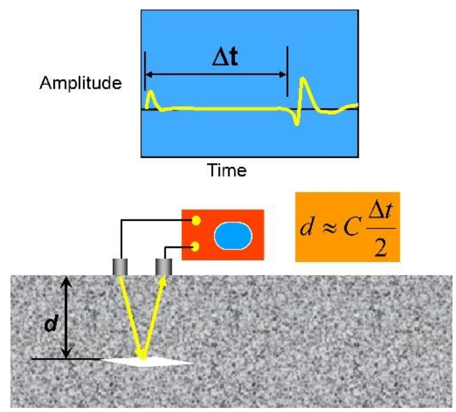
The series of 2-D images obtained from the test object can also be transferred to a computer with **IntroView** imaging software. The software assembles the 2-D slices into a complete 3-D image of the test object. The 3-D image can then be manipulated for interpretation of test results.

EyeCon can be used for the following applications:

- Thickness measurement
- Detection of voids in grouted tendon ducts
- Detection of poor quality bond in overlays and repairs
- Detection of delaminations
- Detection of voids and honeycombing in concrete members

Principle

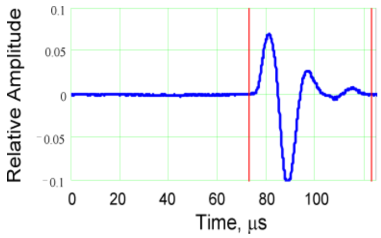
EyeCon is based on the ultrasonic pulse-echo method using transmitting and receiving transducers in a "pitch-catch" configuration as shown on the right. In the pitch-catch method, one transducer sends out a stress-wave pulse and a second transducer receives the reflected pulse. The time from the start of the pulse until the arrival of the echo is measured. If the wave speed ***C*** is known, the depth of the reflecting interface can be calculated as shown (the equation assumes that the two transducers are close to each other).

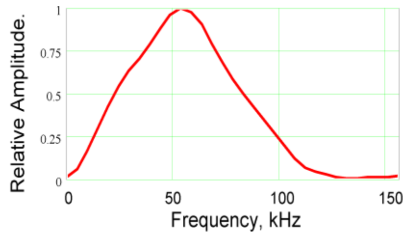


The key features that distinguish **EyeCon** from other flaw detection devices include:

- The use of dry point transducers (DPC) to introduce into the concrete pulses of **shear waves** with an adjustable frequency of 25 to 250 kHz
- Each transducer is spring loaded to conform to an irregular surface and they do not require a coupling medium, that is, testing is done in the dry
- The handheld, light-weight electronic unit with display facilitates the job in areas with difficult access
- The transit times are analyzed using the synthetic aperture focusing technique (SAFT) to reconstruct, in real time, 2-D color images of the cross section below the antenna which can be displayed as B-Scans or D-Scans along each scan line.
- The data captured can be transferred to a computer and the 3-D visualization software allows views of different slices of the reconstructed internal structure.

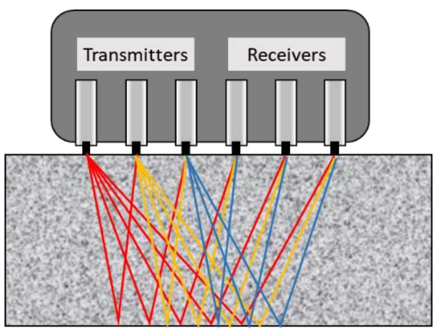
The antenna is composed of of 24 transducers arranged in a 4 by 6 array of point transducers. The transducers are heavily damped so that a short duration pulse is created. The plot in blue shows the typical shape of the

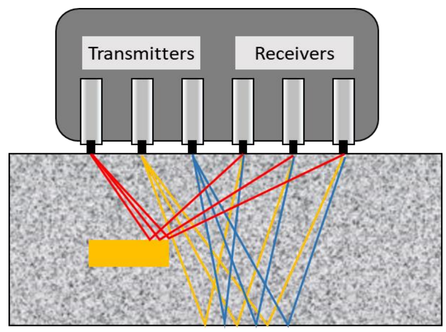




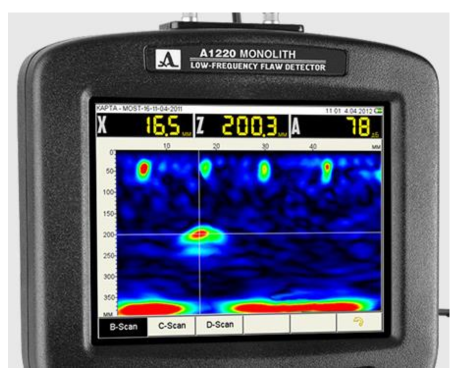
received pulse after it has reflected from an air interface. The plot in red to the right shows the amplitude spectrum of the pulse (the nominal center frequency is about 50 kHz but can be varied from 25 to 250 kHz, allowing the user to control both penetration depth and image resolution).

Basically, the first three rows of transducers act as transmitters and the other three rows act as receivers. By using the multiple transmitters and receivers, the signal noise ratio is improved because random reflections from aggregate particles will tend to cancel, while reflections from large concrete-air interfaces will be superimposed. The averaged signal recorded by the receiving transducers is stored in the hand-held unit as a time-domain waveform (A-Scan). Multiple stored A-Scans taken on a testing line can be used to create cross-sectional views: B-scans or D-scans. These reconstructed images show the locations of the reflecting interfaces, which could be the opposite side of the member (back wall reflection), reinforcing bars, and most importantly internal concrete-air interfaces (such as voids, cracks, delaminations, etc.).





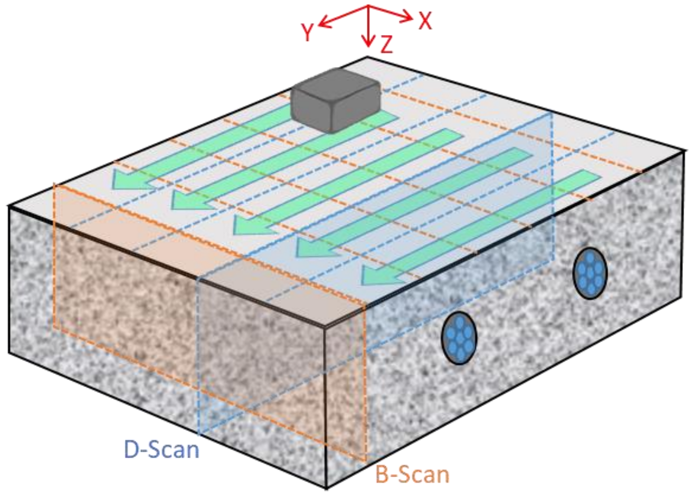
If there is a sufficiently large concrete-air interface, like a defect within the member, a portion of the emitted stress pulse will be reflected by the defect. As illustrated in the right figure above, because of the shorter ray paths, reflections from the defect will arrive at the receivers sooner than reflections from the back wall. The instrument uses the arrival times of the reflected pulses at each row of transducers to determine the location of the defect within the member. Note in the figure that some transducers do not receive a reflection from the flaw or the back wall. This is because the flaw intercepts the rays that would normally be reflected from the back wall. This behavior accounts for a so-called "shadow" zones in some 2-D images.



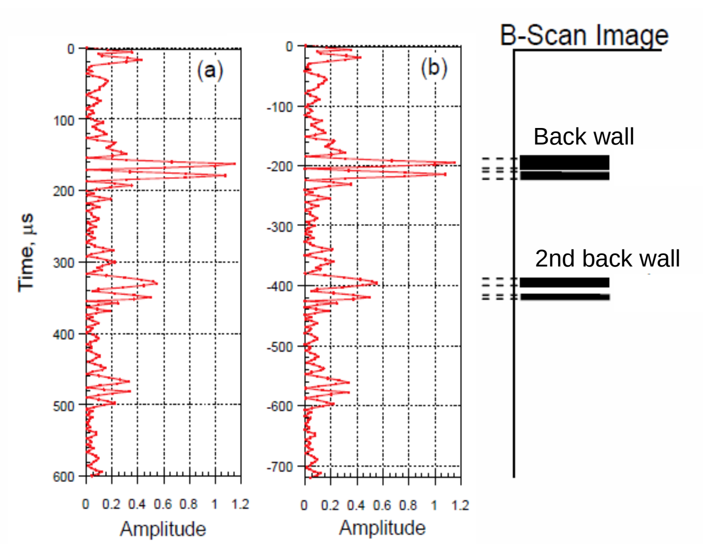
Method of operation

Setup parameters for recording and displaying signals are entered using a menu system. These parameters can be stored in memory for reuse. A series of icons is used to select the active display mode for the instrument:

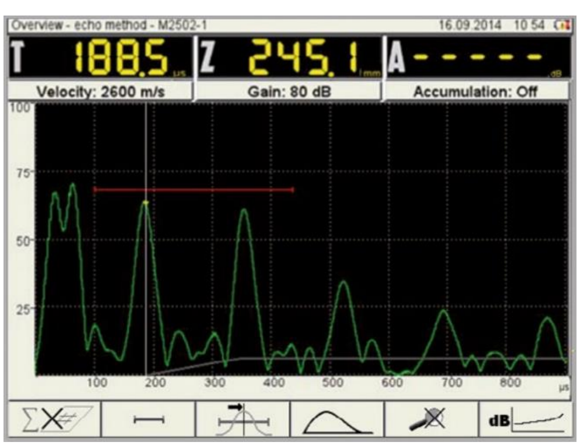
- A-Scan - Display mode used to show the results of individual measurements. The amplitude of the received signal can be displayed as a function of time or as a function of distance (depth) if the shear-wave speed is known.
- B-Scan - This display mode uses the stored A-Scan records to create cross-sectional views along the *X* direction scan lines.
- D-Scan - This display mode uses the stored A-Scan records to create cross-sectional views of the perpendicular scan lines.



To carry out a complete inspection of a specific area of a concrete member, the user first lays out a 2-dimensional grid on the testing surface. The step spacing depends on the size of defects to be detected, with a smaller spacing for smaller defects. The long axis of the antenna is preferably oriented perpendicular to the longitudinal direction of long objects like tendon ducts. The data are recorded at each step along each scan line. The grid layout (step distance, number of steps per line, and the number of lines) is entered into the hand-held unit and that information is used in referencing the displayed test results to the testing position on the test object.



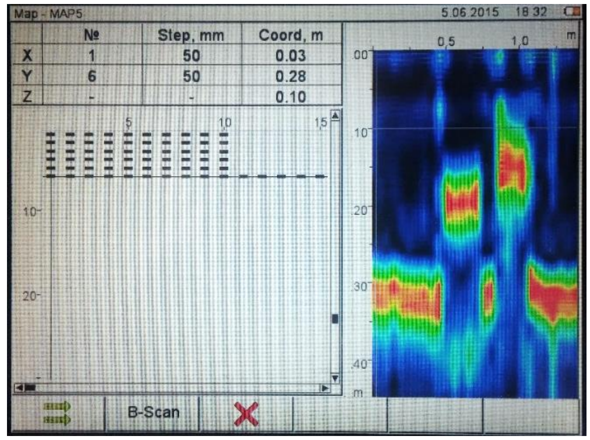
After the scanning is completed, the signal at each test point is plotted as an A-scan with time in the vertical direction as exemplified in the left hand figure (a). If the shear-wave speed in the concrete is known, the time axis can be converted to distance from the surface by multiplying by one-half of the wave speed (because the travel time is for a round trip equal to twice the depth). If the shear wave speed is assumed to be 2400 m/s, the distance axis is as shown in figure (b). To construct a cross-sectional view, a threshold level of signal amplitude is chosen and a colored dash (in this representation black) is drawn at the depth where the signal exceeds the threshold amplitude. In this example, a low threshold is used and the second echo from the back wall is plotted. If a higher threshold were used, only the first back wall echo would be shown. This process is repeated for each signal along the scan line, and the end result is a 2-dimensional representation (or a B-Scan) of the locations of reflecting interfaces along each scan line. Each scan line in the X-axis has therefore an associated B-Scan plane and each scan line in the Y-axis has an associated D-Scan plane that can be displayed.

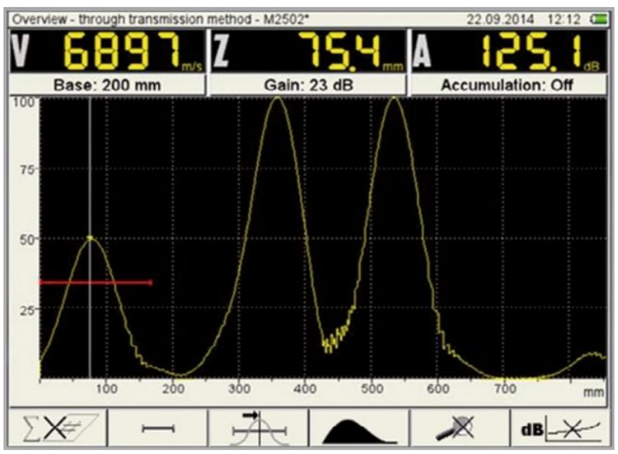


The three operation modes available in **EyeCon** are:

A-SCAN Echo Method: The recorded signal at a single antenna position is processed. The signal can be from one set of pulses or an average of several sets of pulses. Different display formats are available. In this case, the signal has been rectified and is not filled in. The horizontal axis is in units of time (microseconds), but it could also be displayed in units of distance if the wave speed is entered. Various measurements can be made such time to first peak or peak-to-peak interval. A portion of the signal can be zoomed in for a more detailed view.

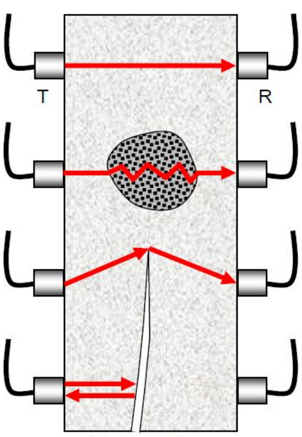
MAP: This mode is used to review results acquired if a 2-dimensional testing grid is used. The upper left box shows the grid layout. The horizontal cursor is used to select the scan line for which the B-Scan cross section is to be shown on the right side. The vertical cursor is used to select the scan line for which the D-Scan cross section is to be shown. The lower box is used to select the scan (B or C) that is going to be displayed. In this case the locations of reflecting interfaces are assigned a color to indicate intensity of reflection from those elements (constructive superposition). The end result is 2-D color images of the B or C cross sections.
The positions of the horizontal and vertical cursors in terms of X and Y coordinates are shown in the top left position of the screen.





A-SCAN Propagation method: The **EyeCon** can be also used to measure the speed of ultrasonic stress waves between two points by the well-known through transmission method. Dedicated pairs of transducers are available as optional accessories for performing this test method which is governed by various standards like ASTM C597, BS 1881:203 and EN 12504-4.
The interface of this mode is very similar to the echo method and most of the display options and functions are also available.
Provided there is access to both sides of the element, the ultrasonic pulse velocity (UPV) can be used for applications like:

- Evaluating the uniformity of concrete within a structural member
- Inferring the presence internal voids and cracks
- Estimating the depth of surface-opening cracks
- Estimating severity of deterioration
- Estimating depth of fire damaged concrete
- Evaluating effectiveness of crack repairs
- Identifying anomalous regions for invasive sampling with drilled cores
- Estimating early-age strength (with project specific correlation)



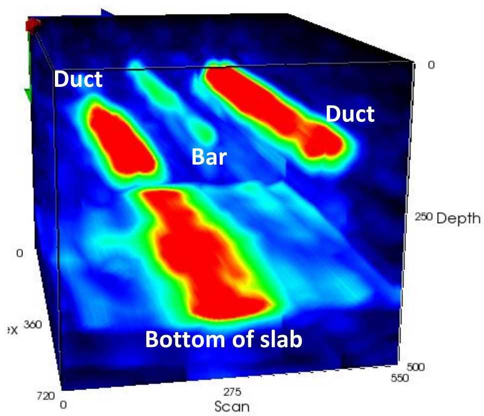
T = Transmitter
R = Receiver

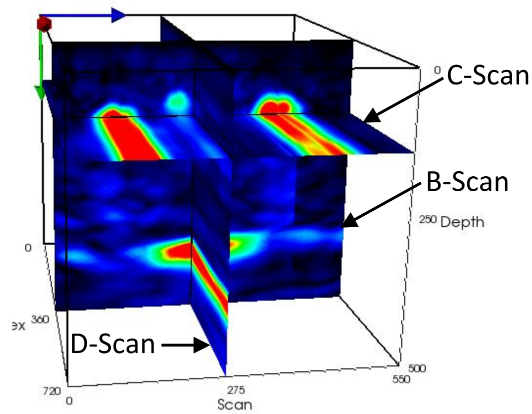
The figure illustrates different conditions that may be encountered when testing an element using the UPV method. At the top, the path between the transducers is through solid concrete, and the travel time would be the shortest. Below that is the case where there is an internal pocket of porous concrete, such as honeycombed concrete. The pulse is scattered as it travels though the contiguous portions of the honeycombed concrete. As a result, the actual travel path and time are longer and this results in a reduced pulse velocity. In the next case, the transducers are located so that the direct travel path is near the edge of a crack. The pulse cannot travel across a concrete-air interface but it is able to travel from the transmitter to the receiver by diffraction at the crack edge. Because the travel path is longer than the distance between the transducers, the apparent pulse velocity is lower than through sound concrete. In the lowermost case, the pulse is reflected completely by the crack, and travel time is not measurable.

3-D Image Reconstruction

At the completion of testing, the data can be transferred to a laptop computer that contains the **IntroView** 3-D visualization software. The software "stiches" together all the 2-D images to create a 3-D model of the test object. As an example, the figure at the right is the reconstructed 3-D model from a scan of a portion of a slab containing two tendon ducts and a reinforcing bar. The bottom of the slab is indicated.

The user can manipulate the 3-D model by rotating it or looking at different orthogonal planes cutting through the model. The views on the three orthogonal planes have formal names as shown in left figure below. A **C-scan** shows the reflecting interfaces on a plane parallel to the test surface and at different depths (Z-axis); that is, it provides a "plan view" of the reflectors. A **B-scan** provides an "end view" of the reflectors. The **D-scan** provides a side view of the reflectors. The user can look at specific "slices" through 3-D model by defining the Z-coordinate for a C-scan image, the Y-coordinate for a B-scan image, and the X-coordinate for a D-scan image. For example the right figure below shows three slicing planes through the 3-D model of the slab with the ducts.





EyeCon (A1220 Monolith 3D) Specifications

- Dry point contact shear-wave transducers with wear-resistant ceramic tip
- Spring loaded 4 x 6 transducers antenna array
- 25 to 250 kHz working frequency range
- Nominal frequency converter = 50 kHz
- Ultrasound speed range: 1,000 to 10,000 m/s
- Dimensions of the electronic unit: 260 × 153 × 43 mm
- Weight of the electronic unit: 0.8 kg
- Dimensions of the antenna array: 139 × 105 × 89 mm
- Weight of the antenna array: 1.1 kg
- Testing depth: 10 to 600 mm (depending on the concrete quality, member dimensions and amount of reinforcement)
- TFT (640 x 480) color screen
- 11.2 V rechargeable battery, 8 h operating life
- USB 2.0 interface
- Maximum number of A-scans in memory = 200
- Protection class IP54
- 3-D tomographic display with **IntroView** software
- Operating conditions: -20 °C to 45 °C, < 95% RH
- Error of the depth of a defect, mm, where H is the measured depth = $\pm(0.1 \cdot H + 5)$
- Minimum flaw diameter to be detected: 30 mm
- Maximum area in MAP mode = 2 m^2

EyeCon-1000 Kit Ordering Numbers

Item	Order #
EyeCon (A1220 Monolith 3D) electronic unit	EYE-1001
Antenna array for flaw detection with 24 low-frequency DPC transducers, shear wave.	EYE-1010
IntroView software license	MIR-1003
AC Charger	EYE-1004
USB Cable	EYE-1005
Double LEMO 00 – LEMO 00 cable 1,2 m	EYE-1006
Soft cover	EYE-1007
Carrying case	EYE-1008
Laptop with NVIDIA GeForce graphics card **(optional)**	MIR-1002

Optional antenna arrays and transducers

Item	Order #
For the echo method	
Antenna array for flaw detection with 24 low-frequency DPC transducers, longitudinal wave.	EYE-1020
For the through transmission UPV method[1]	
Antenna array with 12 DPC transducers, deep penetration, shear wave, 50 kHz.	EYE-1030
Antenna array with 12 DPC transducers, deep penetration, longitudinal wave, 100 kHz.	EYE-1031
DPC[2] transducer, shear wave, 50 kHz	EYE-1040
DPC[2] transducer, longitudinal wave, 100 kHz	EYE-1041
DPC[2] transducer, shear wave, 250 kHz	EYE-1042
[3]Liquid contact transducer, longitudinal wave, 25 kHz	EYE-1050
[3]Liquid contact transducer, longitudinal wave, 50 kHz	EYE-1051
[3]Liquid contact transducer, longitudinal wave, 100 kHz	EYE-1052

[1]For the through transmission method 2 antennas or transducers are needed.
[2]DPC = Dry Point Contact transducers.
[3]Liquid contact transducers require a coupling medium.

EYE-1030 or EYE-1031

EYE-1040, EYE-1041 or EYE 1042

EYE-1050, EYE-1051 or EYE 1052