ECHOGRAPH
Ultrasonic Probes

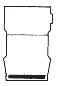
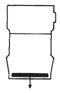
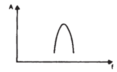
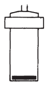
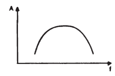
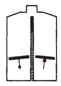
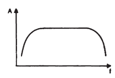
Brochure P 14 E • Printed in Germany 10/07 • Subject to change without notice

Theoretical Knowledge,
Practical Experience from Decades,
Manufacturing Know How:

Top Technology and Variety

KARL DEUTSCH

Criteria for Choice . . .

Testing Technique	Probe Type	Frequency Spectrum
 Contact Technique	 Vertical Probe (Code S) (Finger tip: Code DS)	 Narrow (Frequency indicated by a single figure)
 Automated/Immersion Technique (Code T)	 Angle Probe (Code W)	 Extended Bandwidth (Code B, frequency indicated by a single figure)
	 TR Probe (Code SE) (Finger tip: Code DSE)	 Extreme wide frequency range (Code B, with -6 dB-limit frequencies)

Brief Summary of Important Facts

Contact Technique

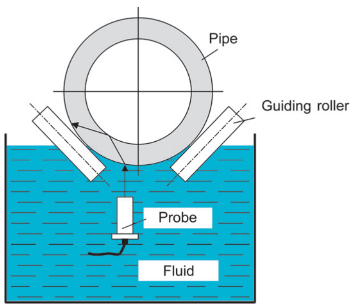
The tester places the probe directly onto the workpiece. He has to ensure good coupling. This can optimally be achieved with ECHOTRACE or ECHOFLUID couplants.

Automated/Immersion Technique

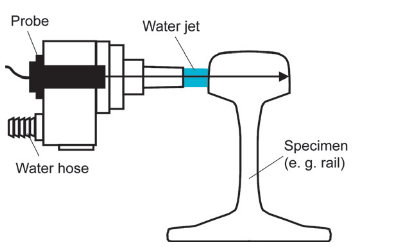
Is applied to avoid coupling fluctuations and wear, to mechanise or automate the testing, and to influence the ultrasonic sound beam, e.g. for focusing.

In practice, the following methods are widely used:

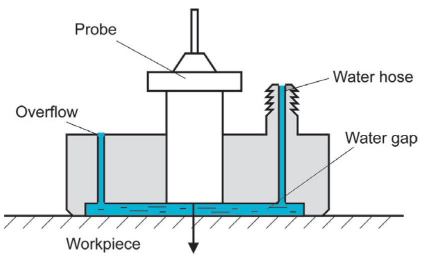
Partial Immersion:



Water Jet/Squirter Technique:
Long water jet, time-of-flight in water greater than in workpiece.



Water Gap Coupling:
Narrow water gap



ECHOGRAPH Probes for Automated Systems can easily be clamped in fixtures, are liquid- and pressure-proof, acoustically matched to fluids and resistant against aggressive liquids.

Vertical or Oblique Incidence?

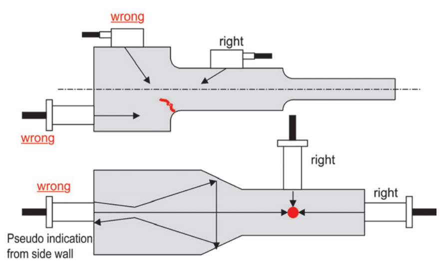
The direction of sound incidence depends on the test problem. The following criteria apply:

Flaws should be hit perpendicularly.

Control echoes (e.g. back wall echoes) from the end of the test range increase the reliability of test.

Pseudo indications in the test ranges should be avoided.

Examples for Correct and Faulty Probe Set-Ups:

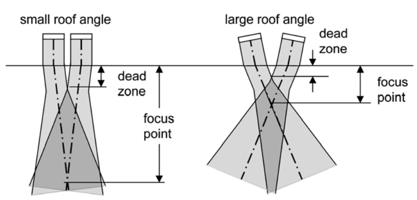


Vertical or Angle Probes
with One or Two Crystals?

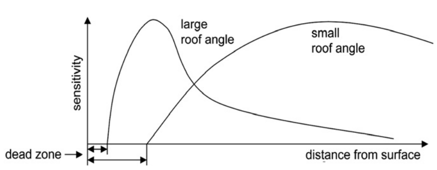
ECHOGRAPH probes with one crystal can be used for most testing problems. They are mostly used in pulse-echo technique (e.g. for transmission and reception) or sometimes also in tandem or delta technique (e.g. multiple probes with separate transmitter and receiver).

ECHOGRAPH TR Probes (dual crystal probes with separate transmitter and receiver) can improve the near resolution (detect flaws close to the surface) or can be used to focus on certain depths.

Sound Field Pattern for TR Probes with Different Roof Angles:



Influence of Roof Angle on the Characteristic of Sensitivity:



Frequency Spectrum and Pulse Shape

of an ultrasonic signal are closely linked together:

short, narrow pulses contain a wide band frequency spectrum, i.e. they transmit many of different frequencies simultaneously which are superposed to form the above-mentioned pulse. A shock wave pulse contains only a half-wave pulse.

Broad pulses of longer duration with several oscillations show a distinct centre frequency and a narrow-band spectrum.

Note: most ultrasonic flaw detectors display shape and duration, but not the frequency spectrum of an ultrasonic pulse.

ECHOGRAPH probes are available in three different bandwidths and may be chosen according to the following criteria:

Narrow Spectrum

Broad Pulses: Using a distinct centre frequency, all acoustical field data (e.g. near field length, divergence angle, wavelength, etc.) can be determined accordingly. These probes are well suited for DGS or similar evaluation methods. The testing frequency can be considered constant and relatively independent of the material properties.
However, certain changes of the pulse shape (i.e. change of frequency spectrum) can occur.

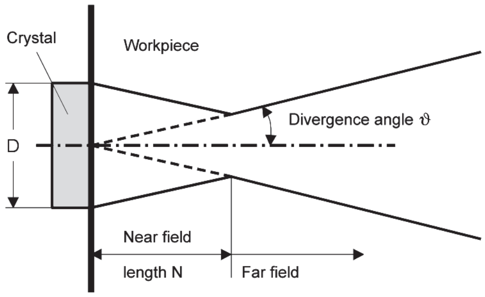
Extended Bandwidth

Narrow Pulses: These probes represent a good compromise between requirements of high resolution and distinct test frequency: They offer improved resolution properties. For materials with low scattering and absorption, only little change of the frequency spectrum is observed. The centre frequency is commonly used to calculate the wavelength and the sound field data.

Extremely Wide Spectrum

Spike Pulses: Probes with these properties are offering optimum resolution and signal-to-noise ratio. They are well-suited for testing materials with strong scattering (e.g. austenitic steels). Another application is shock-wave generation for precise wall-thickness measurement.

Sound Field Geometry of a Probe



Valid for round crystals with diameter D:

$$N = \frac{D^2}{4\lambda} = \frac{D^2 \cdot f}{4c} \qquad \sin \vartheta = k \frac{c}{f\,D}$$

Where k = 0.51 for 6 dB and 0.87 for 20 dB limit values (valid for pulse-echo method)
λ = c / f (wavelength)
c = sound velocity
f = frequency
ϑ = divergence angle

For ultrasonic transducers with round piezo crystals, the effective crystal diameter. D_{eff} is often used for the calculations. D_{eff} can be approximated by:

$$D_{eff} \approx 0.95 \cdot D$$

For More Detailed Information, Please Refer to the Special Prints (SD) of KARL DEUTSCH

Design of Hand / Contact Probes

1. Protective Layers for Vertical Probes

Hard wearplate of ceramic material or hard metal, e.g. tungsten or titanium carbide which cannot be replaced. They are extremely wear-proof. The edges of the wearplate are protected by a steel ring. Main applications: For smooth or rough surfaces and for broad-banded probes.

Soft Protective Layer of a nonskid and screwable vulcollan foil for optimum coupling on rough surfaces.

Due to wear, these probes should never be used without a cap or foil. Shock wave generation resp. extended frequency spectrum are normally not possible due to acoustical matching problems.

Delay Line made of special plastic or ceramic materials: For probes made for wall thickness measurements with high resolution. Ceramic delay lines can be used for measurements on hot surfaces. It is fitted to the probe by means of the foil retaining ring.

2. Wedges for Angle Probes

The material of the angle probe wedges is normally perspex. Perspex represent an optimum compromise between acoustical matching and losses. Either fixed wedges are used or if high wear can be expected, exchangeable wedges are supplied.

3. TR Probes

Fixed Delay Lines of wear-proof plastics, such as perspex or (for hot surfaces) heat-resistive plastic or ceramic materials are used.

Design of Immersion Probes

For immersion probes the aspects of mechanical wear and abrasion do not apply. The protective probe covers protect against penetration of water and its additives, e.g. chemicals for rust inhibition. The thickness of the layer ensures optimal acoustic matching. Adequately shaped delay lines are used to influence the ultrasonic beam (e.g. focusing). Immersion probes for automated systems can be straight beam probes, angle probes or TR probes. The probe surface is always immersed in water (e.g. gap coupling or water jet coupling).

Testing Frequency

The following paragraphs are valid for probes with a distinct centre frequency.

High Testing Frequencies are recommended for:

1. Small wavelength according to $\lambda = \frac{c}{f}$

   The higher the frequency, the smaller is the wavelength and, therefore, the minimal detectable flaw size (typical ≈ 0,5...0,8 λ).
2. Short pulse duration (echo width) leads to high resolution according to

   $$t = \frac{c}{f}$$
3. For short sound paths (thin specimen).
4. Sharp focusing allows for fine scanning applications (e.g. C-Scan).

Low Testing Frequencies are recommended for:

1. Materials of higher losses, where absorption losses increase proportionally with f to f^2, whilst scattering losses are proportional to f^4.
2. Lower directivity, i.e. larger divergence angles for the transmitted sound field of the probe and also for the reflected sound field from the defect. This leads to a higher probability of detection for defects which are not perpendicular to the incident sound beam.
3. For thick workpieces with long sound paths, since losses grow with increasing travel path.

Material Properties are important to consider:

A material can be tested with ultrasound, if the echo from a reference reflector (e.g. back wall, drilled hole, etc.) can be clearly distinguished (+ 6 ...10 dB) from electronic or structural noise. If high sound attenuation leads to a loss of the back wall echo, the transmission method is preferred against the pulse-echo method. For the transmission method only the single sound path applies.

Note:

The influence of the testing frequency and the crystal size are closely linked together (see above formulas).

Near Field

The length of the near field *N* can be computed by the above given formula. The near field length grows with increasing testing frequency *f* and crystal size *D*. The sound pressure and the sensitivity distribution within in the near field range is strongly inhomogeneous due to interferences in front of the probe surface. Therefore, a quantitative evaluation of flaws within the near field range is not possible. At the end of the near field range (distance = *N*), the maximum sensitivity is reached due to narrowing of the sound field (see figure above). The data sheets of all ECHOGRAPH probes contain the near field length computed for steel.

For **Optimum Detectability** of flaws, the distance between probe and flaw should be in the order of the near field length *N* (focusing at the near field length).

For a **Quantitative Evaluation** of defects according to the DGS or DAC method, the flaw distance should be 1.4 times larger than the near field length *N*.

Crystal Size

The acoustic field within the test object depends on the testing frequency *f*, the sound velocity *c* within the test object and also the crystal size *D*.

Small crystals produce a short near field and a wide divergence angle ϑ in the far field. They are mainly used for flaw detection in short distances. Also, an improved probability of detection for small defects is achieved with small crystals.

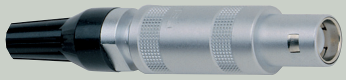
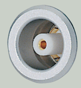
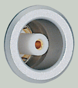
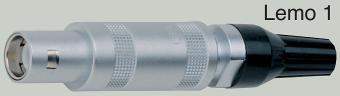
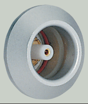
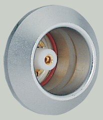
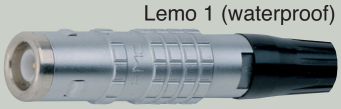
Large crystals produce long near field lengths *N* and small divergence angles ϑ in the far field (high directivity = focusing). More sound energy is produced with a large crystal compared to a small crystal. They are recommended to detect flaws in larger depths (e.g. thick specimens).

Note:

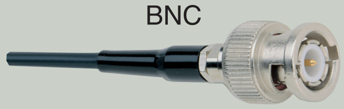
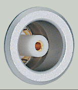
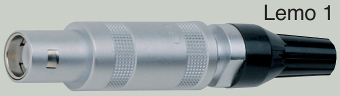
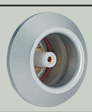
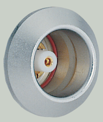
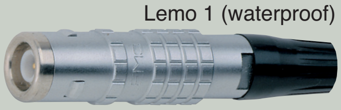
For **broadband probes**, the effects of the near field (inhomogeneity within near field, focusing at *N*) are not as pronounced. A quantitative evaluation with broadband probes according to the DGS method is generally not allowed, but nevertheless is often carried out as an approximate method for flaw sizing. The formulae for near field *N* and divergence angle ϑ can still give a good idea of the sound field geometry within the object under test. In many applications, a flaw detection within the near field (distance > 0,7 *N*) is possible without problems.

PROBE CABLES

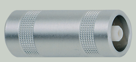
For ECHOGRAPH Flaw Detectors

Probe Socket	Plug Probe Side	Cable Length	Article No.	Plug Instrument Side	Instr. Socket
	Microdot 	2 m 2 x 2m Twin cable for TR probes	1615.200 1615.202	Lemo 1 	
	Lemo 00 	2 m 5 m 2 x 2 m Twin cable for TR probes	1614.020 1614.050 1614.022		
	Lemo 1 	2 m 5 m	1613.020 1613.050		
	Lemo 0 (waterproof) 	2 m	1611.021		
	Lemo 1 (waterproof) 	2 m	1611.022		

For ECHOGRAPH Testing Systems

Probe Socket	Plug Probe Side	Cable Length	Article No.	Plug Instrument Side	Instr. Socket
	FVN (pressure-tight) 	2,5 m	1611.026	BNC 	
	Microdot 	2 m	1619.020		
	Lemo 00 	2 m	1617.020		
	Lemo 1 	2 m 2 m 5 m	1612.020 1612.200 1612.500		
	Lemo 0 (waterproof) 	2 m	1611.020		
	Lemo 1 (waterproof) 	2 m	1611.023		

Cable extensions:

For Lemo 1 plugs: Cable connector  Art.-no. 1913 with additional cable (art.-no. 1613)

For BNC plugs: Cable connector  Art.-no. 1912 with additional cable (art.-no. 1610)

Adaptors:

Between BNC-socket and Lemo 1-plug:  Art.-no. 1696

Between Lemo 1-socket and BNC-plug:  Art.-no. 1695

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