

A man with short brown hair and a mustache, wearing blue safety glasses, is focused on his work. He is positioned in front of a green industrial lathe machine. The machine's tool rest and tool are visible, with a metal workpiece being turned. The background is slightly blurred, showing a workshop environment. The overall scene conveys a sense of precision and craftsmanship in a manufacturing setting.

Applus⁺

Catalogue Ultrasonic Probes
Design and manufacturing,
predicted behavior by calculation



www.applus.com
info@applus.com

Applus+ probe production



As one of the largest NDT service organizations in the world, Applus+ knows how important it is to select the correct probe, and has therefore given it a lot of attention. Thus, many years ago, the founding of a group particularly involved with the design of ultrasonic probes and accessories was justified. Gradually this service has attracted the attention of clients, and sales of optimized probes, often preceded by development work, became common practice.

In this way Applus+ ultrasonic probes are the product of more than 30 years of probe manufacturing and field experience.

Applus+ twin crystal compression and lens- focused probes are known worldwide. For example, these probes are used for inspection of coarse grained austenitic steel, location of under-cladding cracks or detection and sizing of IGSCC (Intergranular stress-corrosion cracking).

Design and manufacturing, predicted behavior by calculation!

Applus+ Probes and Probe Accessories are carefully designed and manufactured to strict tolerances and specifications. The probe design team uses modern tools to develop, model and engineer tailor-made ultrasonic probes.

Probes are built to client requirements for contact or immersion scanning and can be used at depth of up to 300 meters and temperatures up to 300°C.

Probes can be supplied with couplant ducts, wear resistant shoes and fittings to comply with any type of scanning. Applus+ probes can be documented with characteristics on bandwidth, beam spread, focus and sensitivity.

Innovation

Applus+ is constantly looking at new materials (for example piezo composites), production methods (CNC) and probe types to improve the performance of ultrasonic transducers and to develop probes for new applications (high temperature probes, TOFD probes and phased arrays). At the same time, we take care that you get the same performance of copies from ultrasonic transducers ordered in the past.

Support and service

Applus+ Probe Production is especially known for their client-specific probes. We have worked with clients worldwide to design or develop the ultrasonic probe best suited to their particular applications. We are always willing to discuss with you possible probe designs and solutions to any inspection tasks.

Delivery

If you need faster delivery, you are always free to call and we will do our utmost to meet your deadline.



Product information

All Applus+ products are well known, especially in the nuclear industry, for their quality and high performance. An overview is given of ultrasonic probe types, optional features, documentation, accessories and additional products, which could be of benefit for those involved in ultrasonic inspections.

Probes for the following testing techniques make use of longitudinal wave, creeping wave, transverse wave or special techniques, which can be a combination of these wave forms.

Manual testing

Probes for manual testing are available in a variety of housings. These probes are characterized by a plastic shoe wedge, which protrudes 4mm to allow for contouring to curved surfaces.

Connectors are at the back of the stainless steel housing, which makes handling easy..

Shown are a few examples of probes for manual inspection of welds in coarse grained, anisotropic materials such as austenitic steel. These probes

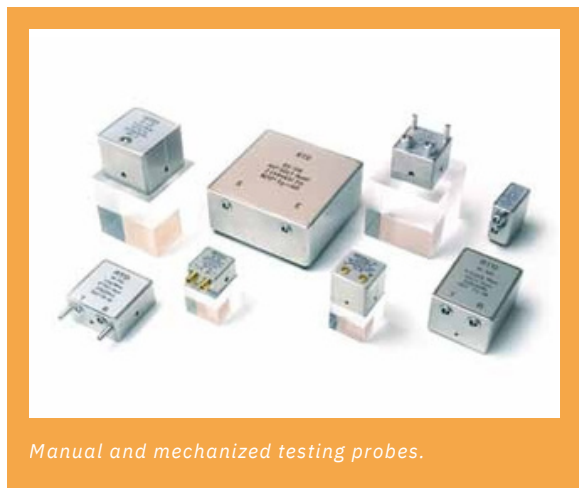
employ a dual element design, which produces refracted longitudinal waves in the test material.

Mechanised testing

These probes feature:

- P lastic shoe (wedge) flush with stainless steel housing, for better wear resistance. To improve wear resistance further, stainless steel inserts can be added. Mostly in probes 40x40mm and larger.
- On top of housing:
 - Water nozzles for internal couplant delivery
 - Connector(s) (chassis jacks)
- Fittings for use with a probe holder.

All Applus+ probes can be specially designed for use with special manipulators in automated inspection systems. These probes are built into stainless steel housings which allow attachment to gimbal-type probe holders.



Applus+ probe production

Immersion testing

These probes are for immersion testing and scanning of components and immersion thickness gauging. Applus+ immersion probes can be provided unfocussed with a flat front or with a lens focus to improve sensitivity and lateral resolution.

High temperature testing

Virtually all of Applus+ contact-type probes, including dual element and angle beam probes can be manufactured in a high temperature version. These probes are suitable for both continuous and intermittent use up to at least 350°C.



High temperature testing

Deep water testing

Most probes can be fitted with watertight connectors for use at depths up to 50 meter. For greater depths up to 300 meter, potted cables are normally used.

Immersion bolt testing

The probe shown is specially designed to detect fatigue cracks in the threaded portion of large bolts. Inspecting from the internal bore allows an "in service" inspection. The beam angle is optimized to obtain the highest amplitude ratio between the crack and thread echoes. A four-element probe is used to increase the speed of the inspection.



Immersion bolt testing

Internal bore wall testing

These are contact probes designed for tube testing from the ID (inside diameter), which can be configured for wall thickness measurements, weld inspection, or for multifunction inspections. These probes are typically fitted with stiff or flexible insertion rods up to 6 meter (20 ft) in length and can be provided with or without couplant delivery.

Multifunction probes

Applus+ also manufactures multifunction probes such as those used in the Applus+ Rotoscan system for automatic inspection of circumferential pipe welds. This is an example where many probes, each having its own function, are built into a single housing. The use of multiple elements and refracted angles increases inspection efficiency as it allows several regions in the test piece to be scanned simultaneously.



Multifunction probes

Probes can be build with the following options

Lens focusing

Focused contact probes provide more accurate flaw sizing capabilities or improved signal-to-noise characteristics by controlling the focal spot size at the focus distance. As a consequence of this design, the measurement range is often reduced, depending on the degree of focusing.

Quarter wave matching layer

By using quarter wave matching layer sensitivity is improved by 6 to 10dB and bandwidth is improved from 40% to 55% (measured at -6dB, in pulse echo). Quarter wave matching layer is very useful when equipment gain should be lowered to improve signal- to-noise or when extra bandwidth is needed.

Piezo composite

Most probes can be supplied with piezo composite elements. We recommend that the effects of using piezo composite be calculated for each application. In general, piezo composites are useful for broadband applications (BW > 80%) and applications where the electrical matching between probe and equipment could be improved.

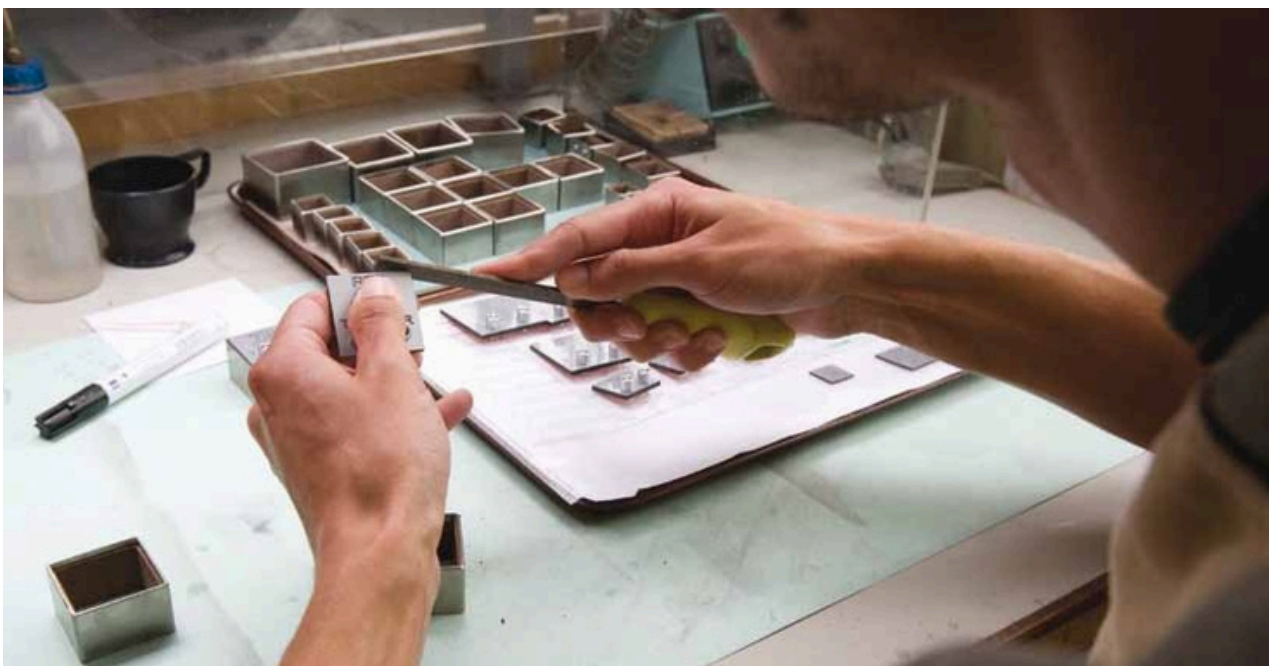
Couplant recycling

Excess couplant can be annoying. Sometimes components are in such a position or have such geometry that excess couplant is unacceptable. If seals or other means fail, or installation of these is impractical (e.g. at dose rate penalty), then couplant recycling can offer a solution.

Standard Applus+ probes can be equipped with couplant feeds that are surrounded by a couplant recycling frame, or a recycling frame can be integrated into the probe housing. Integration of the recycling frame into the probe allows more compact probe design.

Radiation resistance

Almost without exception ultrasonic probes are partly made using “plastics” in the widest sense. They are used for the wedge, electrical isolation, backing, filler material and last but not least as bonding and acoustic matching layers. Most polymers only survive low radiation levels. For radiation exposures up to 10^8 Rad, probes using conventional polymer materials break down. This is mainly due to the swell and embrittlement of the polymer. For application at high radiation levels, Applus+ has developed special Radiation Resistant probes (RR-probes) which do not show any deterioration effect even at maximum dose (10^8 Rad).



Accessories

Calibration blocks

High quality calibration blocks are needed for accurate time base setting of the ultrasonic equipment and probe index determination. Applus+ participation in international NDT committees gives us up-to-date knowledge of current requirements such as specially designed blocks for angle compression probes. Two examples, together with their stands, are shown. One block has radii of 25 and 50mm, the other 50 and 100mm. Both have a width of 40mm.

They are made of AISI 304L stainless steel, fine grained ASTM5 (E112). The sound velocity of these blocks is of 5745 ± 20 m/s, typical of commonly used stainless steels.



Calibration blocks

Characterization blocks

This block is also made of austenitic stainless steel (AISI 316L), fine grained ASTM5 (E112) with sound velocity of 5745 ± 20 m/s.

Although it is well known that acoustic behavior in stainless steel welds is different from that in parent material, it is valuable to know the basic characteristics of the probe under ideal conditions.

With the aid of the Applus+ designed stainless steel block a number of characteristics can be established, such as:

- Distance amplitude curve or so called “focal curve”
- Check of nominal focal distance marked on the probe
- Check on nominal probe angle marked on the probe
- Beam spread
- Zone height for focused probes
- Probe angle as function of sound path
- Nominal signal to noise ratio in fine grained steel.



Characterization blocks

Time base calibration standards

Time base calibration units consist of a fixed aluminum metal path with piezoelectric elements on one or both ends. When connected to an ultrasonic instrument, the time base calibration unit will produce a series of echoes, which correspond to a 50mm shear wave path or a 91mm longitudinal wave path in steel. These multiple echoes can be used for rapid time base calibration of flaw detectors while the echo amplitude can be used to check the vertical linearity of the instruments.



Time base calibration standards

Summary of tolerances

Standard probes

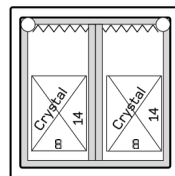
1. Refracted angle	Wave mode	
	Transverse (shear)	Longitudinal (compression)
0°	N/a	± 1°
45°	± 1°	± 1°
60°	± 1°	± 1°
70°	± 1°	+1°/ -3°
2. Center frequency (at -6dB)	± 10%	
3. Crystal size(s)	± 2%	
4. Focus sound path	± 10%	
5. Squint	± 1°	
6. Index point	± 1mm	
7. Housing size	± 0.25mm	
8. Probe shoe curvature	± 1%	
9. Temperature range 10.	-10°C (14°F) / +50°C (122°F)	
Radiation resistance	~10 ⁵ Rad accumulated	

Radiation resistant probes

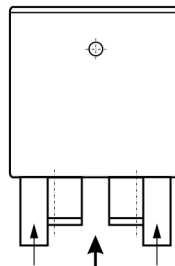
1. Refracted angle	Wave mode	
	Transverse (shear)	Longitudinal (compression)
0°	N/a	± 1°
45°	± 1°	± 1°
60°	± 1°	± 1°
70°	± 1°	+1°/ -3°
2. Center frequency (at -6dB)	± 15%	
3. Crystal size(s)	± 2%	
4. Focus sound path	± 15%	
5. Squint	± 1,5°	
6. Index point	± 2mm	
7. Housing size	± 0.25mm	
8. Probe shoe curvature	± 1%	
9. Temperature range 10.	-10°C (14°F) / +100°C (212°F)	
Radiation resistance	~10 ⁸ Rad accumulated	

Example: Probe for mechanised testing

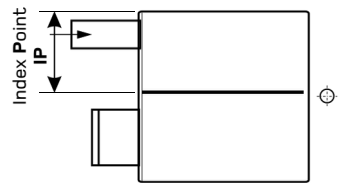
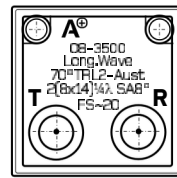
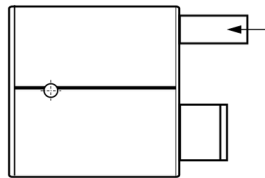
Dim. 25 x 25 x 25 mm



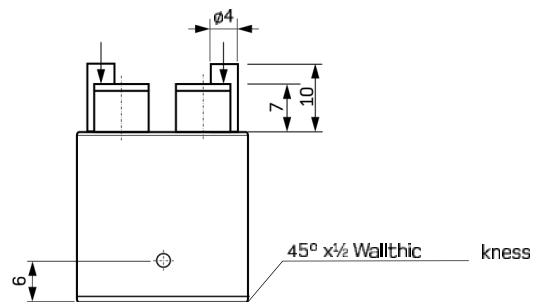
2x Couplant Feet
 2x Couplant Grooves 1,5x1,5 mm
 4x Holes or Pins for mechanised inspection
 Standard Holes are $\phi 2,4$ mm,
 max. Depth is wallthickness of housing
 Standard Pins are $\phi 6$ mm, length 3 mm



Sound Direction

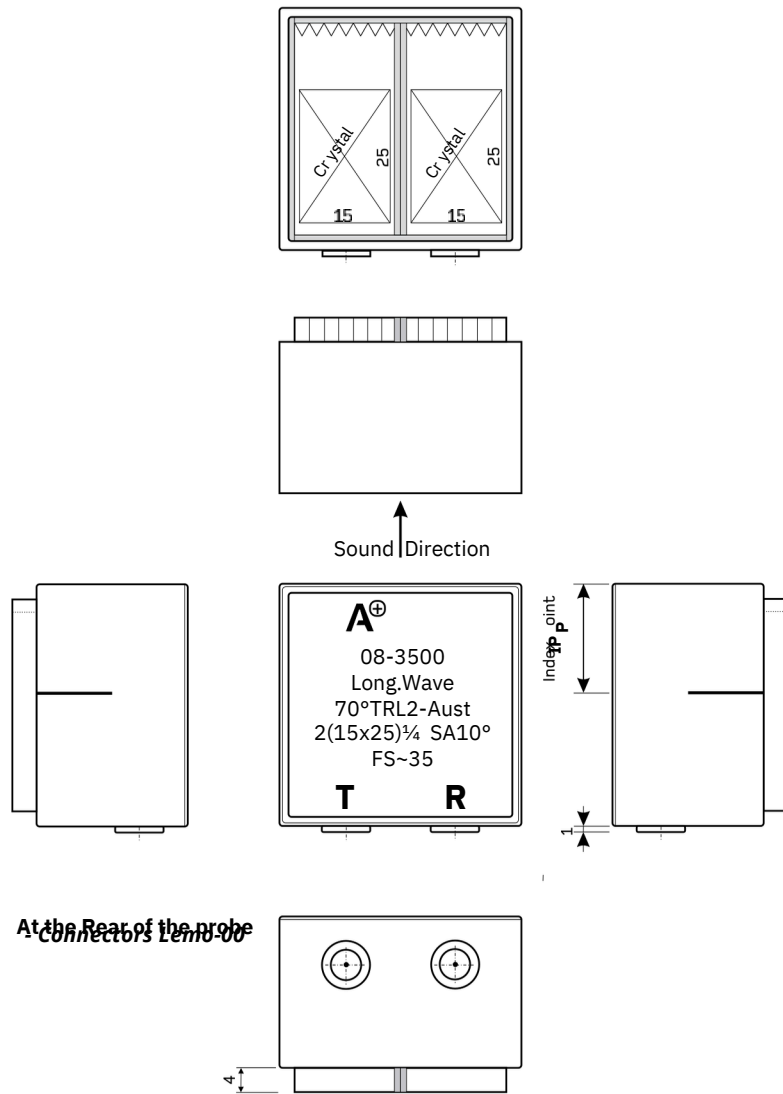


At the top of the probe
 - Couplant Tubes
 - Connectors Lemo-00

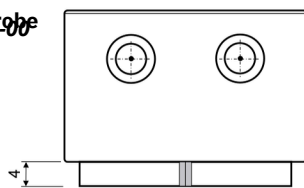


Example: Probe for manual testing

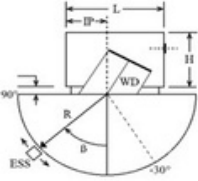
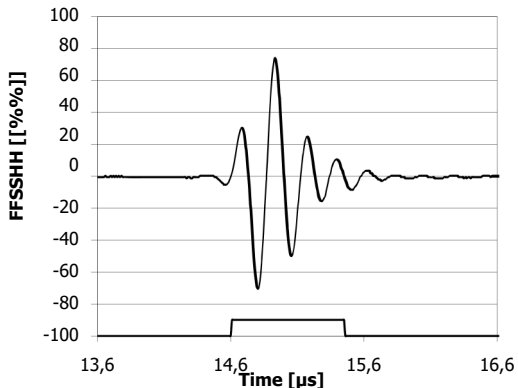
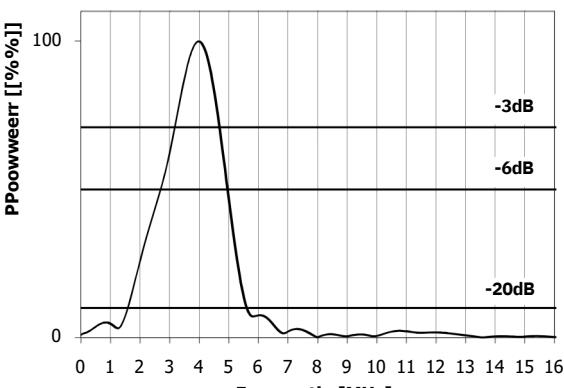
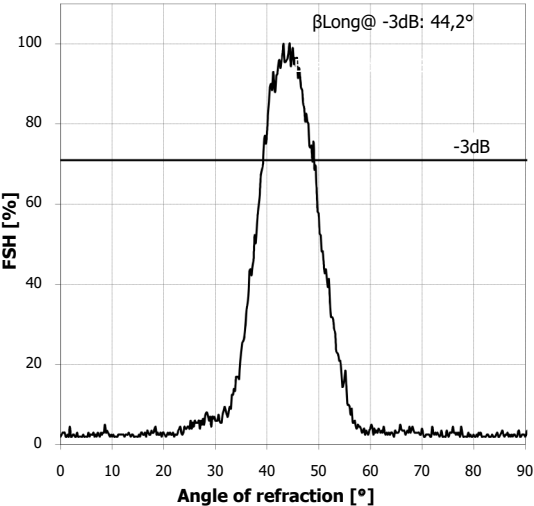
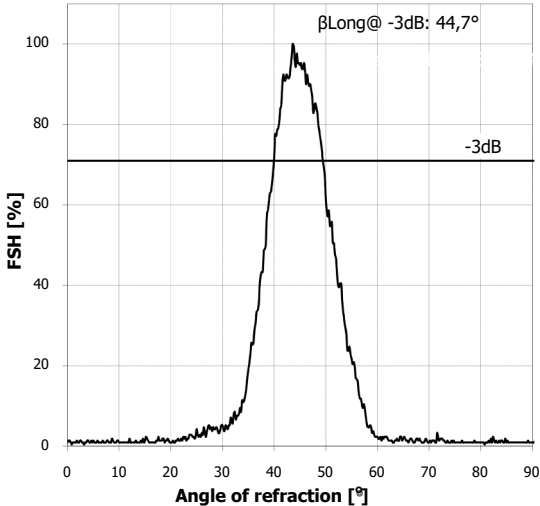
Dim. 40 x 40 x 25 mm



At the Rear of the probe



Frequency Spectrum Data Sheet & Ultrasonic Beam Plot

Applus+ Probes P.O.Box 10065, 3004 AB Rotterdam T +31 10 716 6000 Delftweg 144, 3046 NC Rotterdam F +31 10 716 6206 The Netherlands probes@applus.com										
Equipment settings Ultimo2000 V2.5 Pulser voltage :200 V HP Filter : Squarewave width :112 ns BP Filter : P.R.F. :2000 Hz LP Filter : Pulser damping :50 Ohm Receiver 50W Terminated										
Probe 09-### Long.Wave : 45°TRL4-Aust : 2(7x10)¼ □ : SA 14° FD~14										
Cable: 2meter Coax RG174/U 50W ADC: Sonic STR*8100@100MHz										
Schematic test setup Frequency data Gain 8,5dB Block no. 95-9 Aust Radius R 25mm ~5750 m/s Long ~3150 m/s Trans										
										
BeamPlot data Gain T 16dB Gain R 14dB Block no. 51 Radius R Aust Eddy Sonic 100mm Long										
Housing: L x W x H :20x20x20mm Style : Manual Connector : Lemo-00 Index point IP :10mm Wedge delay WD:17mm On Radius :25mm										
HF IMAGE  <p>Gate width / pulse length : 0,84µs</p>										
SPECTRUM (FFT) -Flat Measurement  <table border="1"> <thead> <tr> <th></th> <th>Center frequency</th> <th>Band width</th> </tr> </thead> <tbody> <tr> <td>At -3dB</td> <td>3,94MHz</td> <td>1,52MHz (39%)</td> </tr> <tr> <td>At -6dB</td> <td>3,84MHz</td> <td>2,26MHz (59%)</td> </tr> </tbody> </table>			Center frequency	Band width	At -3dB	3,94MHz	1,52MHz (39%)	At -6dB	3,84MHz	2,26MHz (59%)
	Center frequency	Band width								
At -3dB	3,94MHz	1,52MHz (39%)								
At -6dB	3,84MHz	2,26MHz (59%)								
BEAM PLOT I  <p>$\beta_{Long@ -3dB}: 44,2^\circ$</p>										
BEAM PLOT II  <p>$\beta_{Long@ -3dB}: 44,7^\circ$</p>										
Measured by Date	Frequency Spectrum Data Sheet & Ultrasonic Beam Plot									

Focus Data Sheet

Applus - Probes

P.O.Box 10065, 3004 AB Rotterdam T +31 10 716 6000
 Delftweg 144, 3046 NC Rotterdam F +31 10 716 6206
 The Netherlands probes@applus.com

Equipment settings Ultimo2000 V2.5

Pulser voltage :200 V HP Filter :
 Squarewave width :112 ns BP Filter :
 P.R.F. :2000 Hz LP Filter :
 Pulser damping :50 Ohm Receiver 50W Terminated

Probe 09-###

Long.Wave
 45°TRL4-Aust
 2(7x10)¼□
 SA 14° FD~14

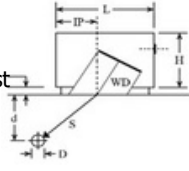
Cable: 2meter Coax RG174/U 50W

ADC: Sonic STR*8100@100MHz

Schematic test setup

Focus data

Gain 21,5dB
 Block no. 1981-1 Aust
 Ø Cyl.holes 3mm
 ~5750 m/s Long
 ~3150 m/s Trans



Housing

120x20x20mm
 Stylan
 Connect
 ID point IP
 Wedge delay WD:17mm
 On Radius :25mm

SIGNAL IN FOCUS (A -IMAGE) -Flat Measurement

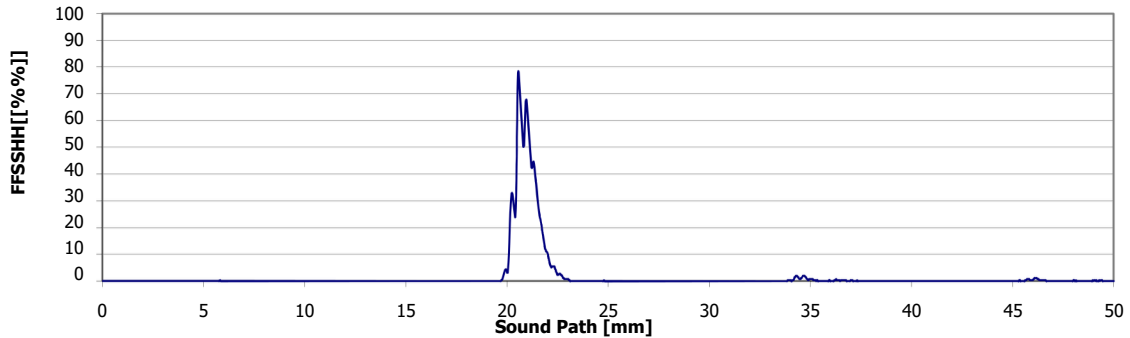


DIAGRAM I (Amplitude -Sound Path)

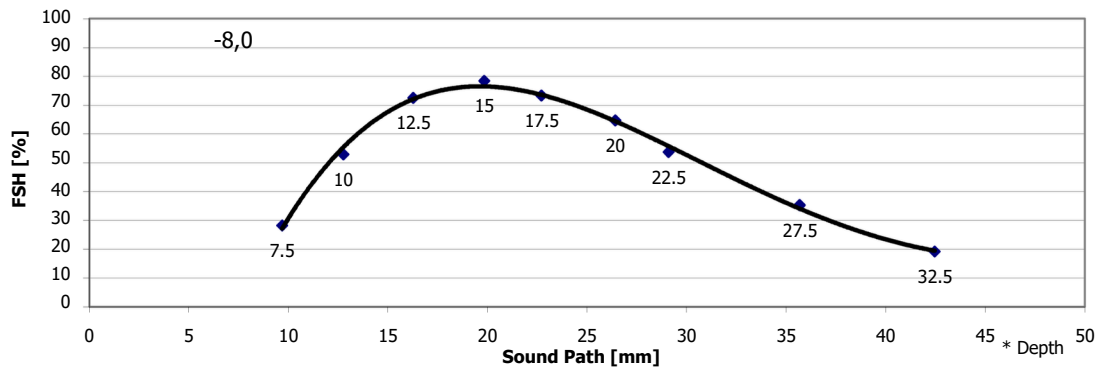
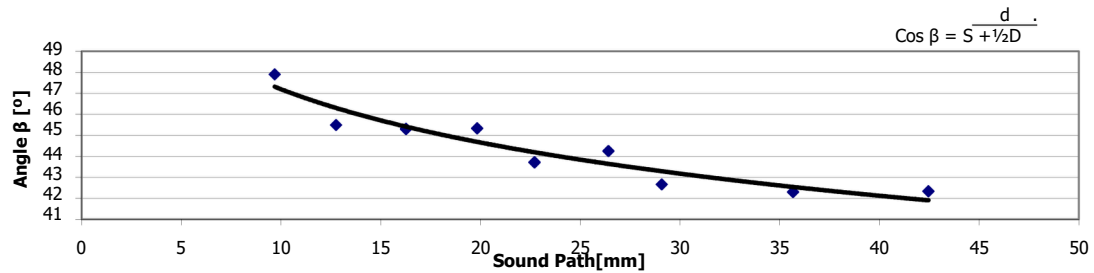


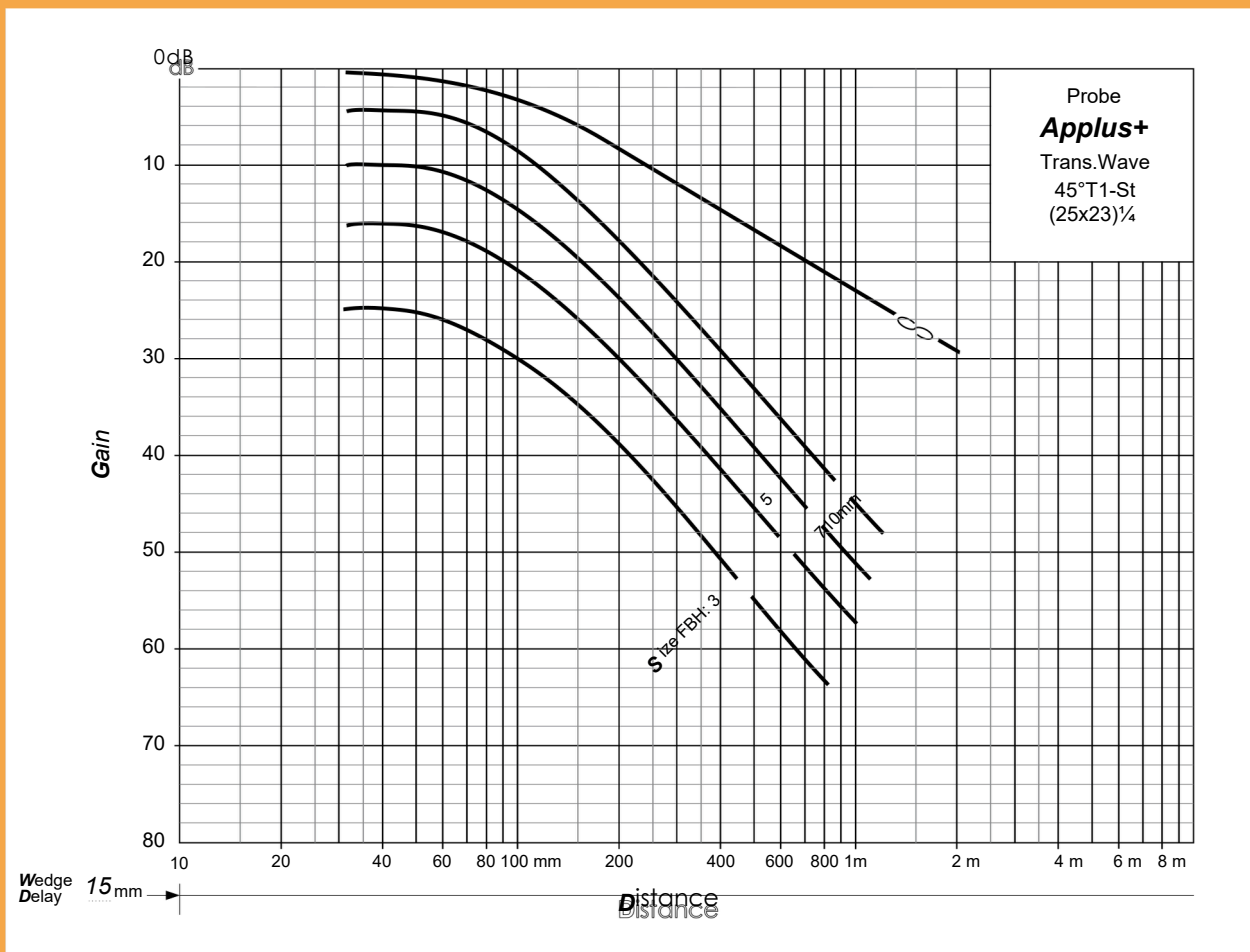
DIAGRAM II (Beam Angle -Sound Path)



Measured by
 Date

Focus Data Sheet

DGS - Diagram



Technical information

Longitudinal wave probes

For inspections using longitudinal waves we often use the following probes:

- dual element probes
- longitudinal wave probes
- angle beam probes

These are known as the so-called transmitter receiver longitudinal (TRL) probes.

This design provides superior penetration and a better signal-to-noise ratio than standard shear wave probes. The dual element design restricts the range of maximum sensitivity. This is called the focal range and is usually between $\frac{1}{2}xFS$ and $2xFS$, where the focus sound path FS is the transit distance in the material to the focal point. Angle compression wave probes can be manufactured with many different beam angles, frequencies, number of crystals, crystal sizes, and focal ranges (for more information see focus sound path information on page 18).



Multi-element probe with compression wave and shear wave functions

The nature of the inspection usually dictates the precise configuration.

Shear wave probes

Single crystal shear wave probes are the most commonly used probes for ultrasonic inspection,

usually with 45°, 60° and 70° beam angles. For some inspections, however, it may be useful to optimize the angle and the crystal size to get the best sensitivity and signal-to-noise ratio. By using elliptical or rectangular elements, the spot size in the material can be precisely defined and the beam can be directed to minimize beam spread.

To further improve signal-to-noise, it is possible to use dual element, transverse wave probes (TRT probes) or lens focused transverse wave probes. As a consequence, there is a restricted range of maximum sensitivity, just as with TRL probes.

Creeping wave probes

Creeping wave probes are a special type of TRL- probes, which generate compression waves at angles between 70° and 90° in the test material. These waves, commonly known as creeping waves, propagate parallel to the surface of the test piece; a shear wave beam is also generated, which radiates at an angle of about 33°.

Creeping wave probes are suitable for detection and sizing of flaws close to the surface like deep IGSCC (intergranular stress-corrosion cracking). Creeping waves are unaffected by liquid drops, welding spatters or other materials on the surface. However, the working range is short because of the steep energy decay. Usually, the most sensitive point, the so-called “focus” is located just in front of the probe itself.

Nominal focus distance ranges up to 20mm and the maximum useful range is typically 45mm.



Special techniques

Detection of vertical defects

LLT/RTT

If an angle compression transducer is used on a plate with parallel surfaces, mode conversion will occur when the beam hits the opposite surface. This is also valid for the shear wave beam that is generated.

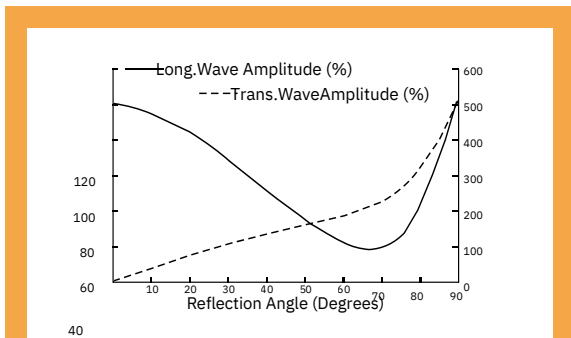


Figure 1 Amplitude of reflected waves (steel/air)

For the most commonly used probe angles (between 45° and 70°) most of the energy is in the converted beam rather than in the non-converted one. This is illustrated in figure 1 and 2. As stated before, this fact is often considered as making inspections over skip distance impossible.

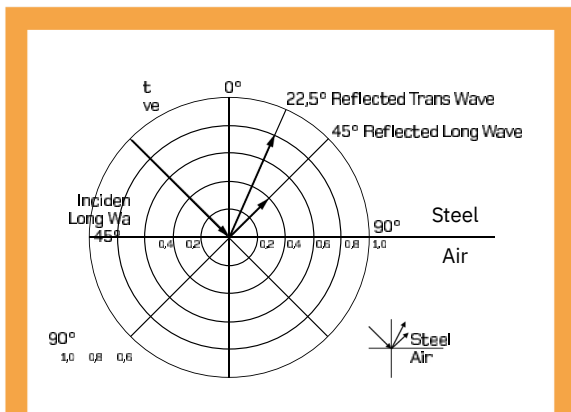


Figure 2 Compression and Shear Reflection

In weld inspection, the shear wave transmitted by the transducer travels through the base material, generally without any attenuation and scattering problems, and can thus be used without problems.

The secondary compression wave or creeping wave, generated at the opposite surface, appears to be strong enough to detect weld flaws. This can overcome the limitation of not being able to inspect over skip distance, usually associated with compression wave probes. Figure 3 illustrates this.

Of course, for defect location the different beam angles and propagation velocities in the shear and compression parts of the path must be accounted for.

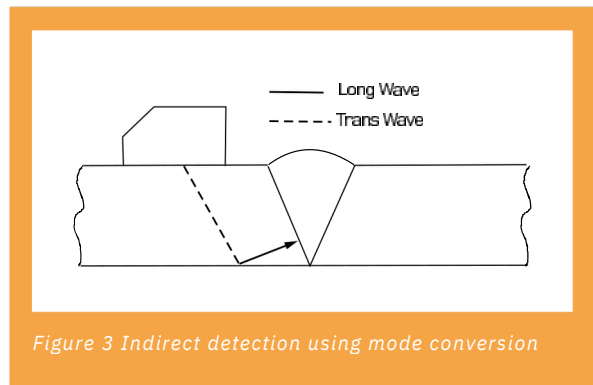


Figure 3 Indirect detection using mode conversion

Not only the “usual” mode, with identical transmit and receive paths, in which the mode converted “secondary” wave can be used. A very interesting possibility is the combined use of primary and secondary waves as shown in figure 4 and 5.

Figure 4 shows how two separated transducers with identical angles can inspect at two depths at a time, using wave mode conversion. This enables reliable detection of perpendicular flaws. The dept of the inspected zones somewhat depend on the used probe angle.

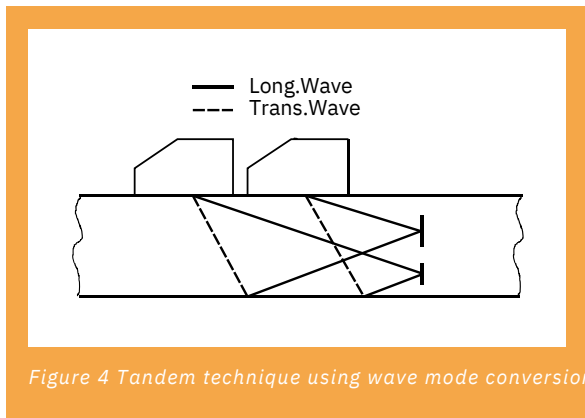


Figure 4 Tandem technique using wave mode conversion

Figure 5 shows how this technique can even be applied by using one transducer only. As in the case of figure 4, the ultrasound travels either way; the echoes from the two paths coincide and reinforce each other. The depth of the area of optimum sensitivity is here approximately 0.6 times wall thickness, depending slightly on the transducer angle.

This single transducer tandem technique is often referred to as round trip tandem (RTT). It was originally designed for the inspection of welds in high nickel alloys for liquefied natural gas containers (cryogenic application), where planar perpendicular flaws are of concern in maintenance inspections.

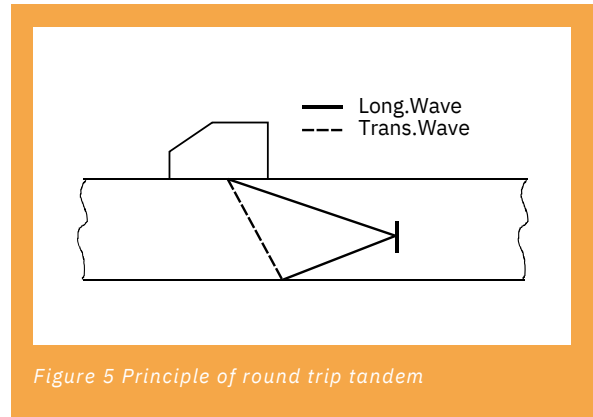


Figure 5 Principle of round trip tandem

LLT transducers

More recent development for detection of flaws perpendicular to the surface is the long/long/trans (LLT) technique. With this technique, mode conversion occurs at the defect instead of the back surface. The principle is explained in figure 6; this technique requires a special probe equipped with two crystals, since the angle of the shear wave is different from the compression wave. This technique allows a choice of inspection depth zones by selecting the appropriate probe characteristics.

This technique is less suitable for inspection inside austenitic welds, because one of the wave modes in the weld would be shear.

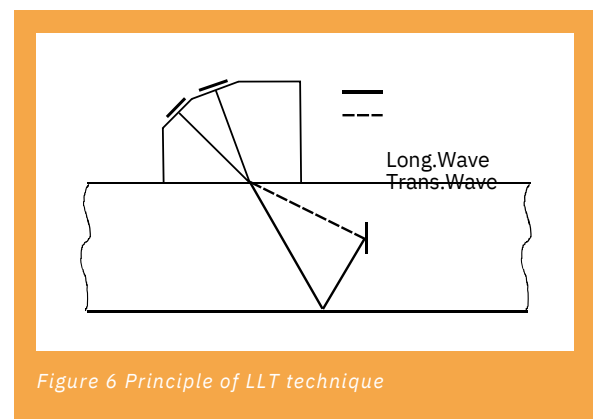


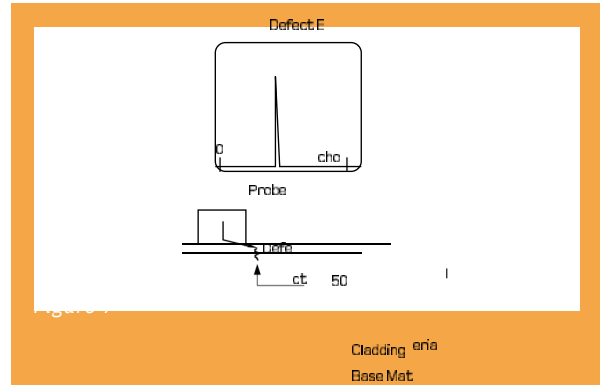
Figure 6 Principle of LLT technique

Crack detection

UCC probe

Probe for detection of notorious under cladding cracks. The “UCC-probe” was originally developed in the early seventies and is a good example of probe optimization for a single application.

Figure 7 shows the principle of this UCC-probe by selection of crystal size (near field), crystal geometry (spherical), squint angle and probe frequency. In this manner, a high signal to noise ratio is obtained.



ADEPT tandem probe

The ADEPT tandem probe is a double angle beam probe, which shows a very good performance to size IGSCC. ADEPT stands for: advanced dual element probe technology. Figure 8 shows the principle. Intelligent use is made of the longitudinal and shear waves generated by both probe halves arranged in tandem technique, which transmit and receive at different angles.

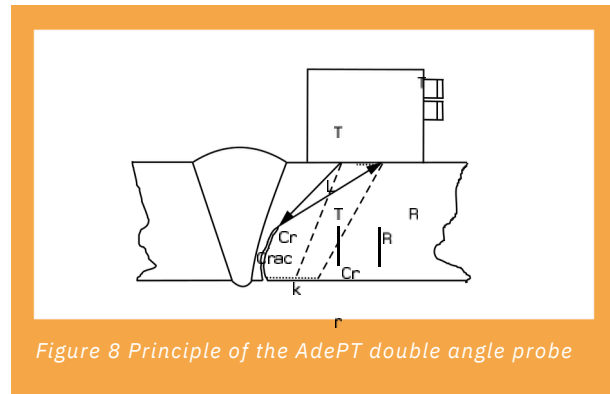


Figure 8 Principle of the AdePT double angle probe

This construction allows the probe to have small width, which is attractive for use on both small and large cracks. For very thin or large wall thicknesses, other non-standard probe angles and frequencies can be used. This requires test samples for probe optimization.

Delta tandem probe

Another probe for sizing of IGSCC uses the unique principle of the old Delta technique but in a new

application. By reducing angles and frequency of a probe can be developed whose principle is shown in figure 9. The crack tip diffraction method is applied. With small variations the required crystal combination can be selected. A more rugged single focus dual element probe is more attractive for use in difficult environments such as nuclear power plants.

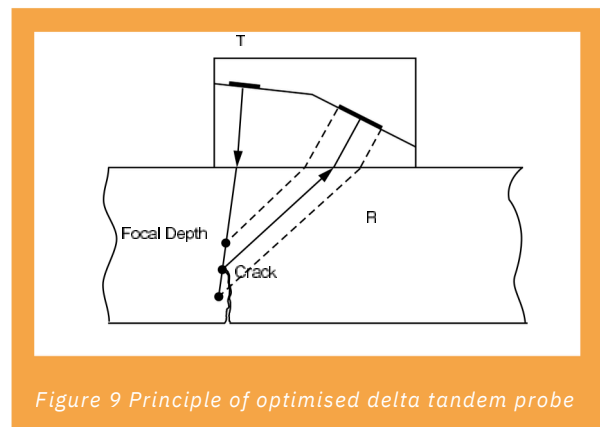


Figure 9 Principle of optimised delta tandem probe

Focus sound path information (TRL Probes)

Because TRL probes (i.e. dual element probes, longitudinal wave mode) have two overlapping beams, this type of probes has a natural focus. The focus distance can be selected within limitations according the table below. The focus distance is depending on frequency, beam angle, element size and squinting of the two elements. As a rule of thumb, the focus range at -6dB of a dual element probe is roughly between $\frac{1}{2}x$ focus and $2x$ focus. For example, a certain probe has focus FS~20, then the focus range at -6dB is about 10-40mm.

Minimum and maximum FS = Focus Sound path for TRL Transducers = Dual (Transmitter Receiver)
Longitudinal Angle Beam Transducers

Max element size (mm) 2(width x height)		2(7x10)	2(8x14)	2(10x18)	2(15x25)	2(20x34)	2(24x42)
housing size (mm)		20x20	25x25	30x30	40x40	50x50	60x60
Frequency (MHz)	Angle	FS ~ min/max achievable (estimated) - (mm)					
0,5	45°	-	-	-	15/30	25/60	35/80
	60°	-	-	-	15/25	20/40	30/70
	70°	-	-	-	15/20	20/35	25/60
1	45°	-	10/25	15/30	20/55	30/80	40/120
	60°	-	10/20	15/30	20/45	25/75	35/110
	70°	-	10/20	15/30	15/45	25/75	30/100
2	45°	10/25	15/30	20/45	25/85	40/130	45/160
	60°	10/25	10/30	15/40	20/75	30/120	40/140
	70°	10/20	10/25	15/35	20/70	30/110	35/125
4	45°	10/35	20/60	25/90	30/100	-	-
	60°	10/35	15/55	20/70	25/90	-	-
	70°	10/30	10/50	15/65	20/85	-	-

Note: for flat surfaces $FD = FS \cdot \cos \beta$, where β is beam angle.

Why do you require TRL probes on coarse grained materials?



A shear wave probe on carbon steel block



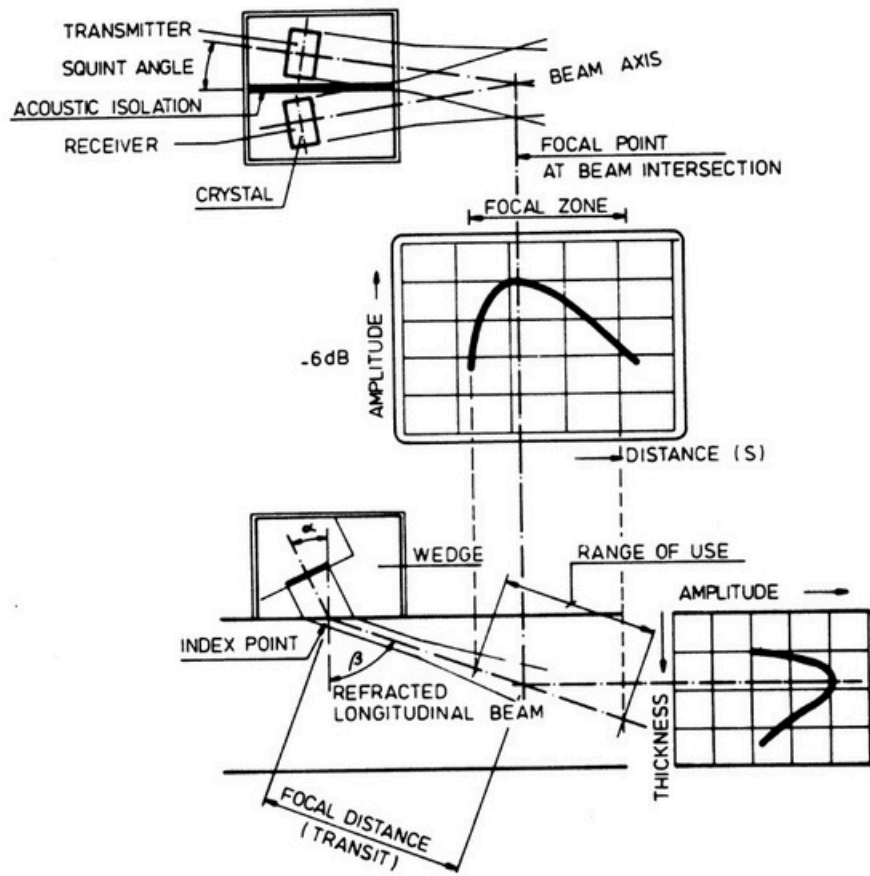
A dual element, longitudinal wave mode probe on carbon steel block



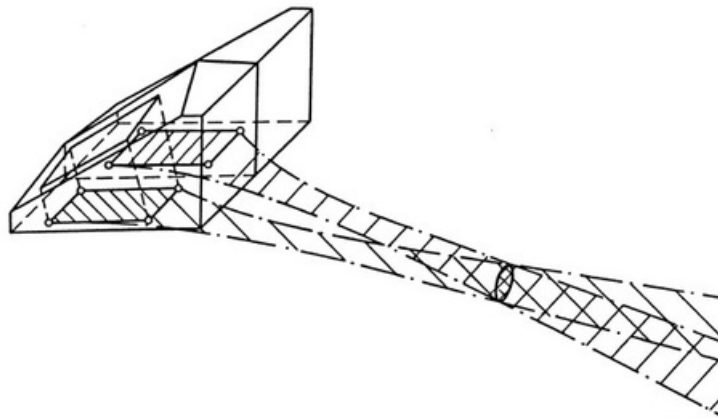
A shear wave probe on austenitic steel block



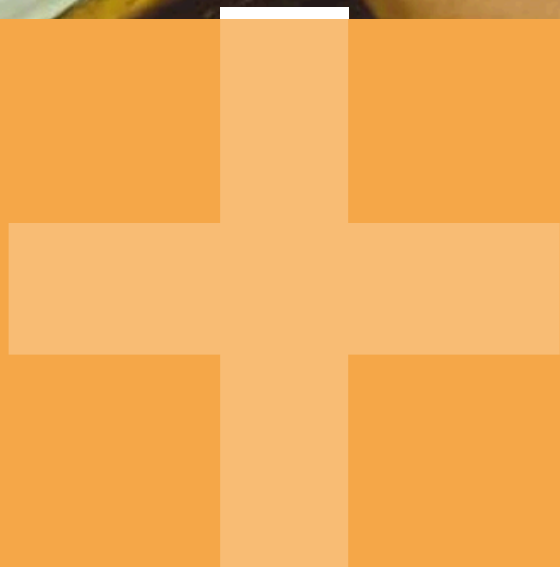
A dual element, longitudinal wave mode probe on austenitic steel



Sensitivity diagrams of TRL probes



Construction of TRL Probe with separate Transmitter and Receiver



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Against a background of some 70 years in NDT&I operations, Applus+ has gained an ability to develop **customized solutions** to enhance clients' process performance and assets integrity. The company's flexibility, whatever the challenge or working environment, also helps ensure tailor-made client-based solutions are provided and promises are kept.

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