Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- based on a new Technology -

Peter Renzel

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- History of Krautkramer's digital Thickness Gauges
  (from DM 1 to DMS 2 TC)
- State-of-the-art procedures to determine the Sound Entrance Point
- State-of-the-art procedures to determine the Sound Velocity

- New Principles 1: 2 Crystals for AutoV
- New Principles 2: plus 2 Crystals for Thickness Measurement
- New Principles 3: Through Coat Measuring by DualMulti
- New Principles 4: 2 Crystals for Coating Measurement (TopCoat)

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

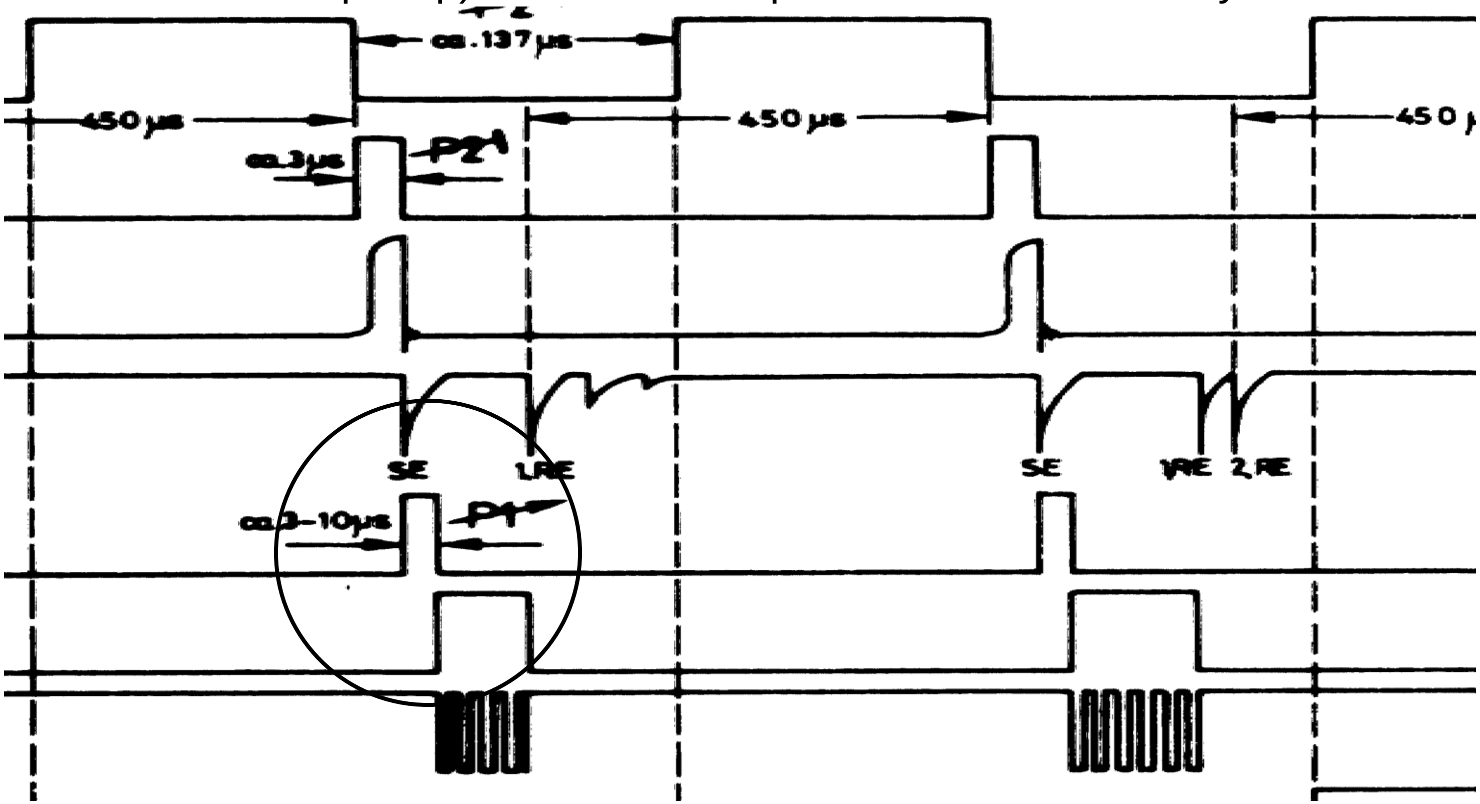
History of Krautkramer Thickness Measurement (from DM 1 to DMS 2 TC)

- 1960: TM by superimposing echoes and (sharp) electronic pulses in a USIP
- 1965: Analog TM with artificial Zeroing, 1 Sound Velocity (internally adjustable only: WSG and CM)
- 1970: DM 1: artificial Zeroing, 6 Sound Velocities (externally adjustable with quartz stability)
- 1976: DM 2: artificial Zeroing, 2-Point Calibration available, all Sound Velocities adjustable with quartz stability)
- 1983: DM 3: automatic Zeroing (on-block), all Sound Velocities adjustable, simple V-Path correction for all DA 3... probes
- 1992: DM 4: automatic Zeroing (on- and off-block), 2-Point Calibration available, all Sound Velocities adjustable, individual V-Path correction for all DA 4... probes
- 1995: DM 4: plus DualMulti for Through Coating Measurement
- 1999: DMS 2 TC: automatic Zeroing (on- and off-block), 2-Point Calibration available, all Sound Velocities adjustable, individual V-Path correction for all DA 4... probes, improved DualMulti, Auto-V, TopCoat

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

<u>State-of-the-art procedures to determine the Sound Entrance Point:</u>

- Presetting of an artificial Zero Signal between SE and 1. RE by hand (i.e by a monostable Flip Flop) in order to compensate the Probe Delay Line:



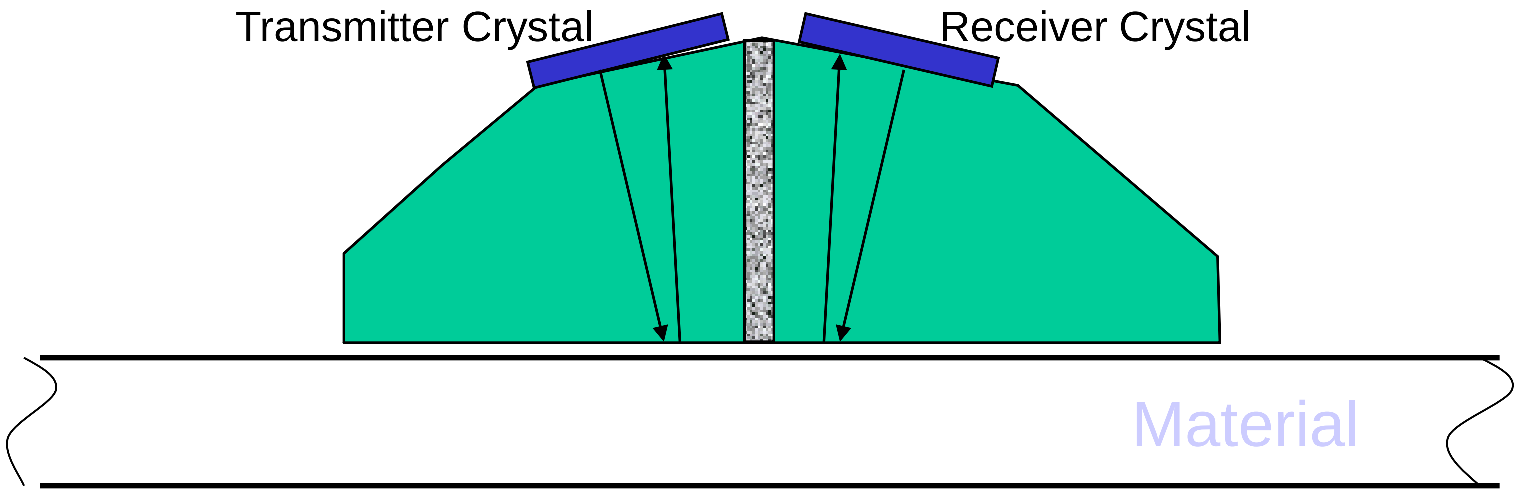
Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

State-of-the-art procedures to determine the Sound Entrance Point:

- Determination of Probe Delay NOT coupled to the Material to be tested (coupled against Air) Off-Block-Zeroing. Best results to be expected in case of:
  - rough, uneven Material Surfaces,
  - Material with low acoustical impedance (Plastics etc.)
  - Material in ambient temperature only(!)
- Determination of Probe Delay COUPLED to the Material to be tested On-Block-Zeroing. Best results to be expected in case of:
  - Material with higher acoustical impedance
  - Material of all temperatures
  - the need for very stable and reproducible Readings

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

Both Crystals as Transceivers



- Determination of Probe Delay COUPLED to the Material to be tested: On-Block-Zeroing.

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

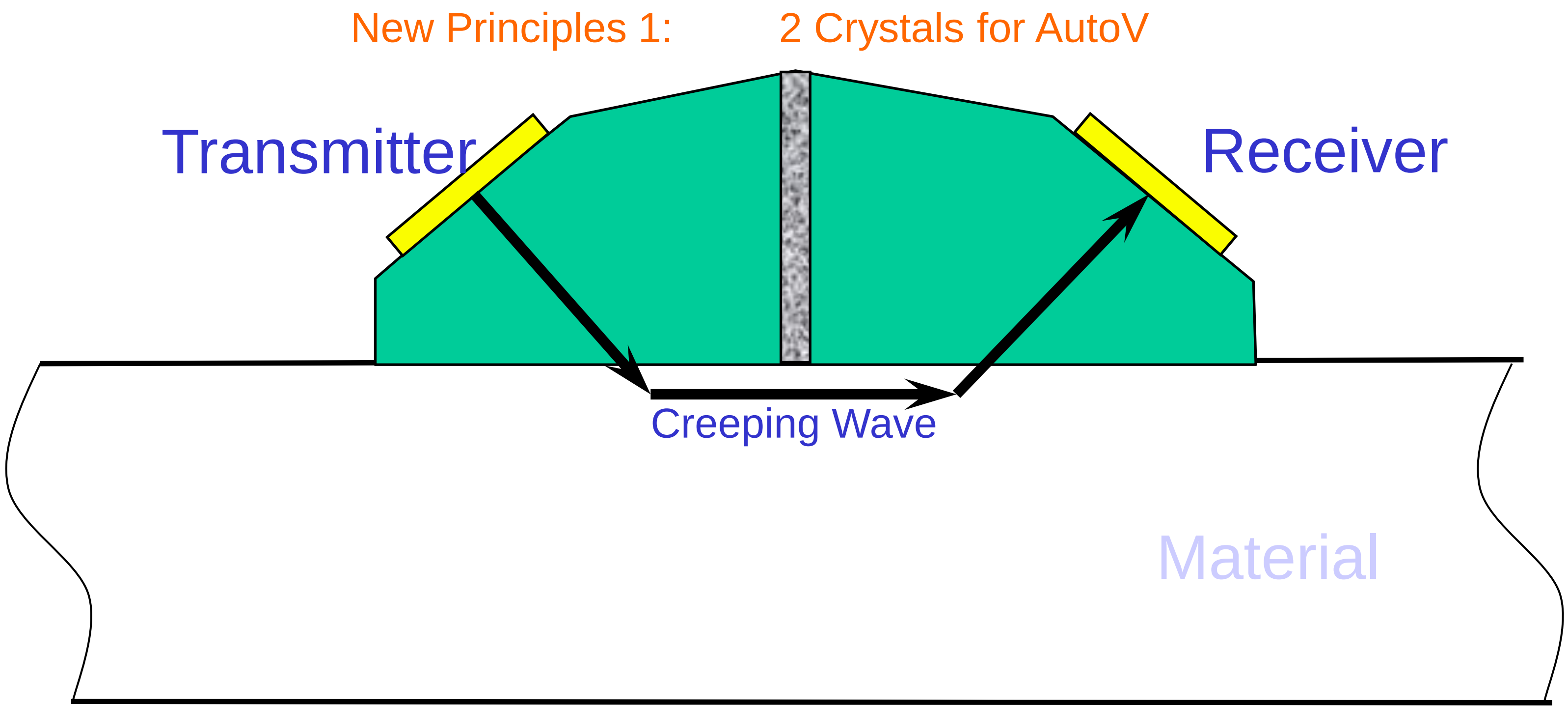
<u>State-of-the-art procedures to determine the Sound Velocity</u>:

- Manual Procedure using two test blocks of different known thickness but same material (2 - Point Method)
- Manual Procedure using multiple Backwall Echoes of a test block of known thickness
- Manual Procedure using an artificial Zero Point (from a built-in thickness gauge test block) and the first Backwall Echo of a test block of known thickness (Sound Velocity-Meter (DM V DL))

All those Procedures have one disadvantage in common: the determination of the Sound Velocity happens in separated steps!

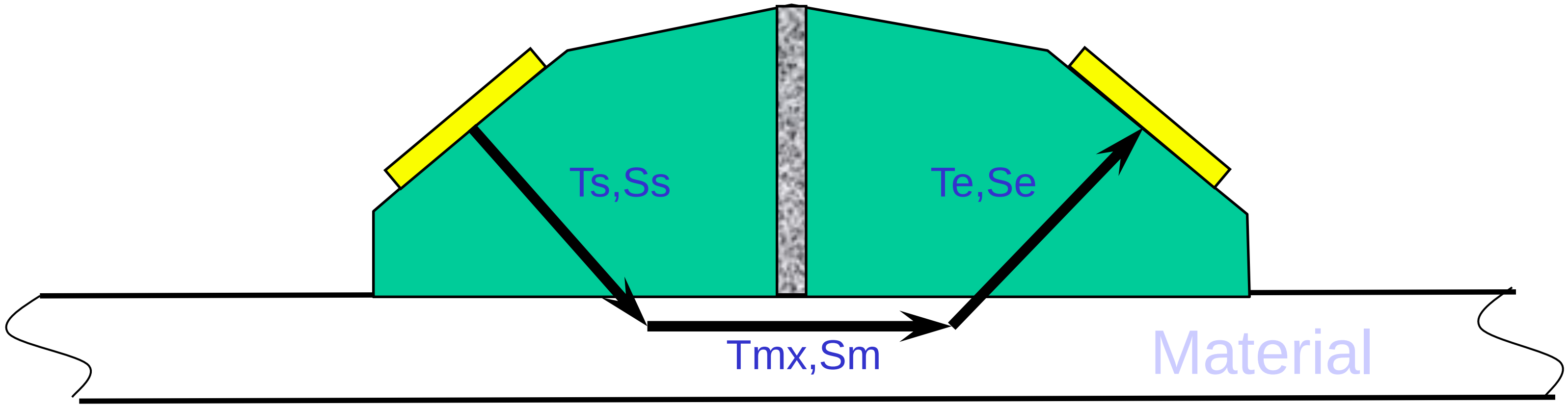
How to simplify that ???

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity



- Determination of Material's Sound Velocity by using a Longitudinal Wave Creeping very closely beneath Material's surface
- Principle: „fastest traveling wave will be registered first"

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity



Calibration of System using 2 Materials with different but known Sound Velocities

C1 (f.e. Copper) and C2 (f.e. Steel) : Goal: Sm

Ttot1 = Ts + Tm1 + Te

Ttot2 = Ts + Tm2 + Te

C1 = Sm/Tm1

DeltaT = Ttot1 – Ttot2

DeltaT = Tm1 – Tm2

C2 = Sm/Tm2

DeltaT will be determined by the instrument using Ttot1 and Ttot2 !

DeltaT= Sm (1/C1 – 1/C2)

Sm = DeltaT / (1/C1 – 1/C2)

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- After Calibration of the System this Formula is now used to determine the unknown Sound Velocity (AutoV):

  Sm = DeltaT / (1/C1 – 1/C2)   C1 = 1/ (Sm / DeltaT + 1/C2)

  Depending on the "Distance" of the unknown Sound Velocity Cun to one of the two known Velocities (Cx = C1 or C2) we'll get a different DeltaTx (= DeltaT1 or DeltaT2). The instrument selects the bigger difference value of DeltaTx:

Formula for AutoV:

Cun = 1 / (Sm / DeltaTx + 1/Cx)

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

Typical Applications for AutoV:

- Test of steadily changing Materials between 4000 and 8000 m/s (f.e. for almost all Metals)
- Testing of Sound Velocity differences within the same lot of parts made from the same Material
- Testing of Isotropy (dependencies on direction) within the same Material under Test (f.e. rolled Steel)

Advantages of AutoV:

- No further reference blocks needed
- No mechanical measurements needed
- Ideal basis for further Measurements “online”

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

AUTO-V SYSTEM

Automated Thickness/Velocity Measurement System

Measures Thickness When Velocity is Unknown or Variable

AUTO-V System Key Features

<u>The very first practical realization:</u>

The AUTO-V SYSTEM

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

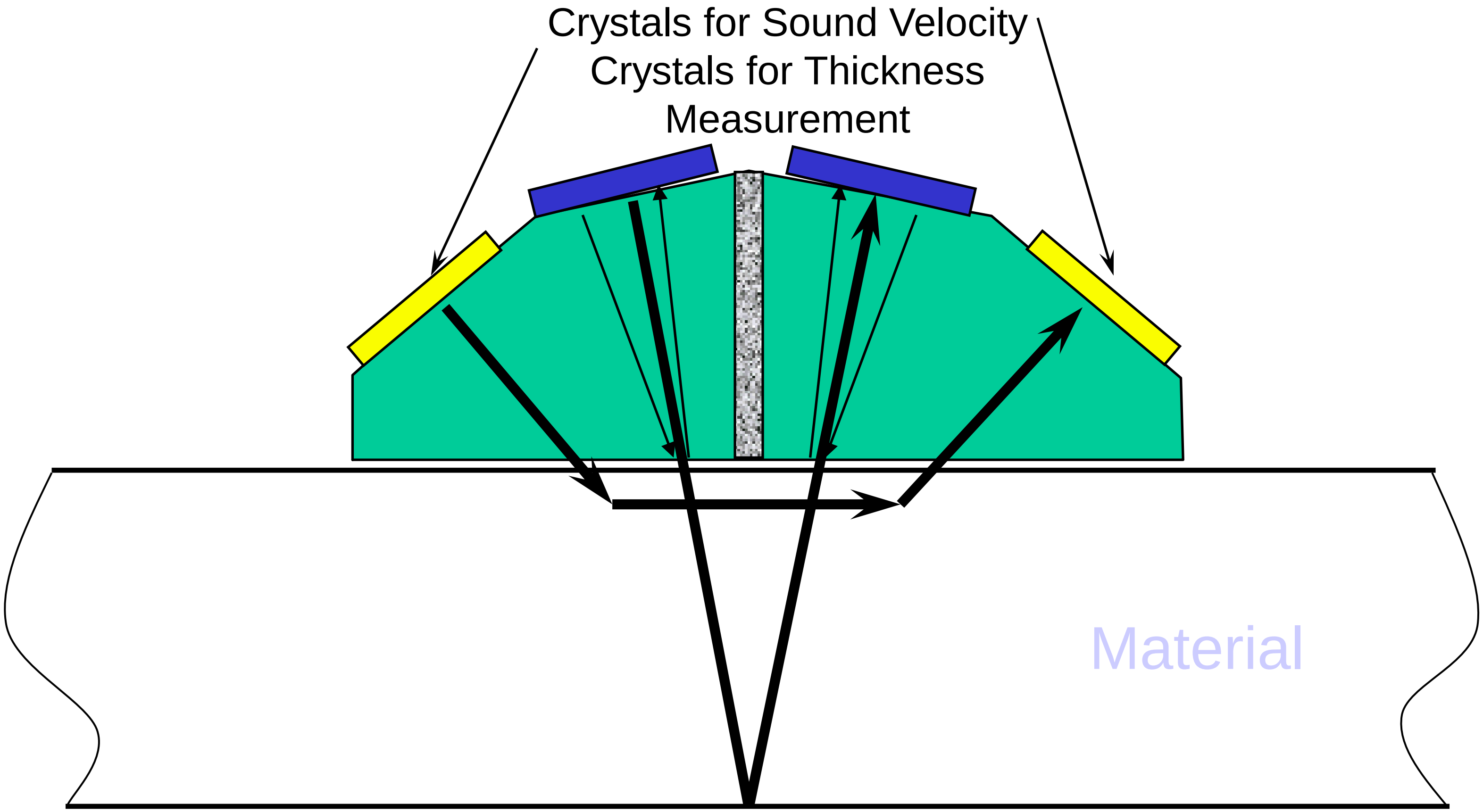
Is that all we can do with AutoV?

No!

Imagine our probe has two more Crystals!

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

New Principles 2: plus 2 Crystals for Thickness Measurement



Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- **By adding two Crystals we are now able to measure the Thickness without knowing anything about the Sound Velocity of the Material under Test!**

- **Sequence of the complete Measurement Procedure:**
  - Determination of Sound Velocity using the two Sound Velocity Crystals
  - Determination of the Delay Line Times (DT) (f.e. by On-Block-Zeroing))
  - Measuring the total Transit Time (TT) of a Backwall Or Flaw Echo
  - Reduction of the TT by DT
  - Calculation of the True Thickness using the already known Sound Velocity
  - Indication of Thickness AND Sound Velocity „online“

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- We reached the Goal of our new Method:

We are able to perform Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- Advantages of this Method:
  - Easy Measurements at most Materials
  - changing Material w/o manually changing the Sound Velocity Value
  - even at corroded Materials (1. Backwall Echo only !)
  - Thickness and Sound Velocity are indicated simultaneously
  - Good visibility of Isotropy during running Tests

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

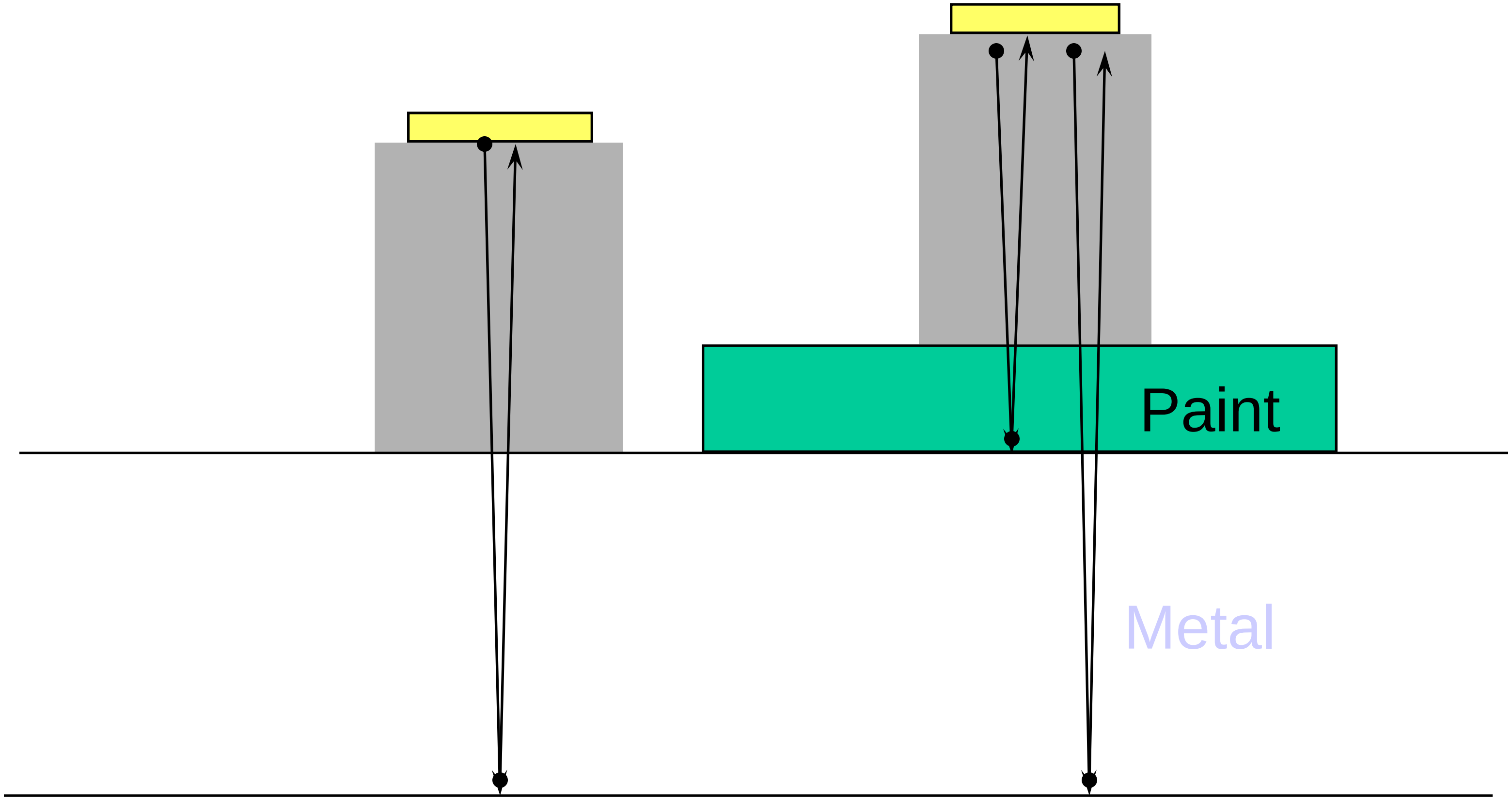
Is that all we can expect from a 4 Crystal Probe?

No!

Imagine your Material under Test is covered with layers of Painting or Coating...

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

New Principles 3: Through Coat Measuring by DualMulti

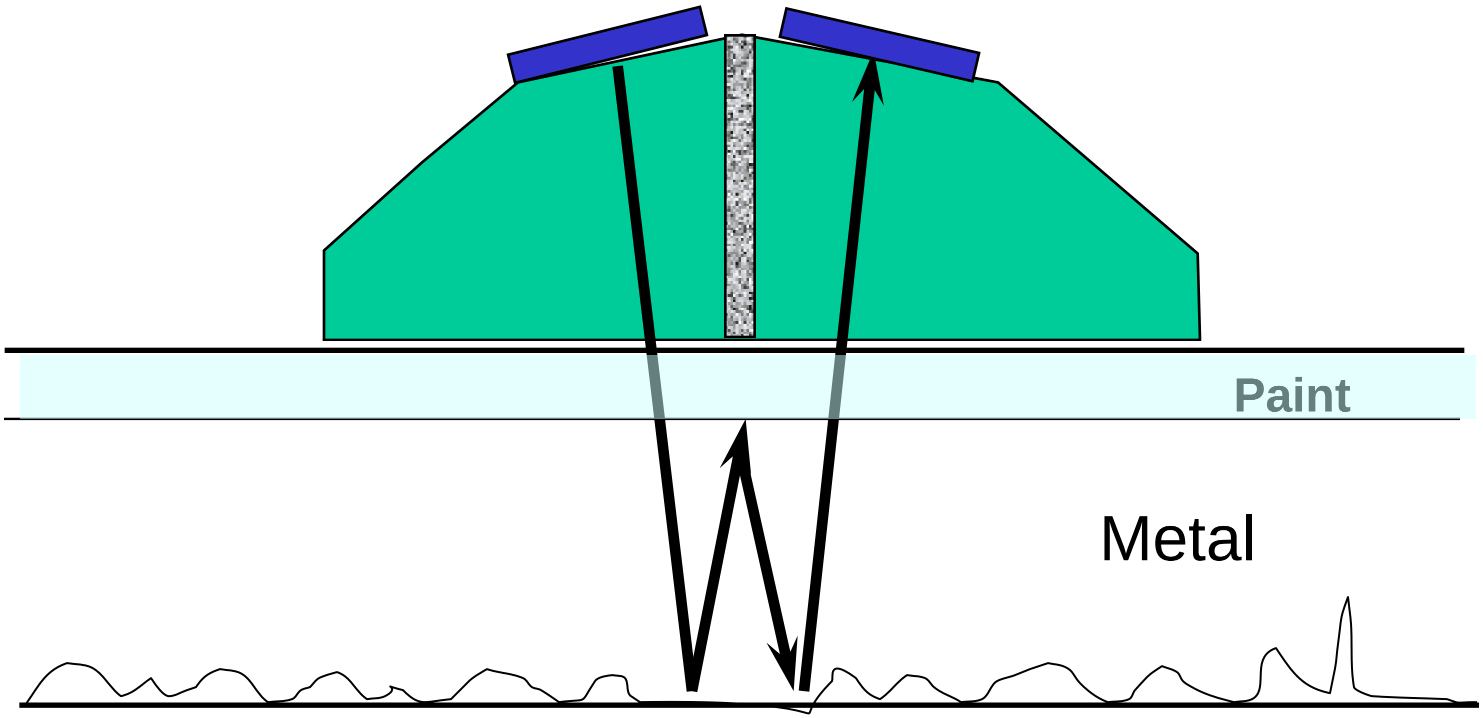


Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

- Layers of Paint or Coating influence our Indications:
  - especially thick layers are very inconvenient. If thick enough they produce Echoes with sufficient Amplitude...
  - Thinner layers increase the displayed Values by 2- to 3-times their own thickness!
  - In some Thickness Gauges we therefore know the so called DualMulti – Mode:
  - The Transit time of 2 Backwall Echoes are measured, evaluated by the known Sound Velocity of the base Material (Metal), and displayed.

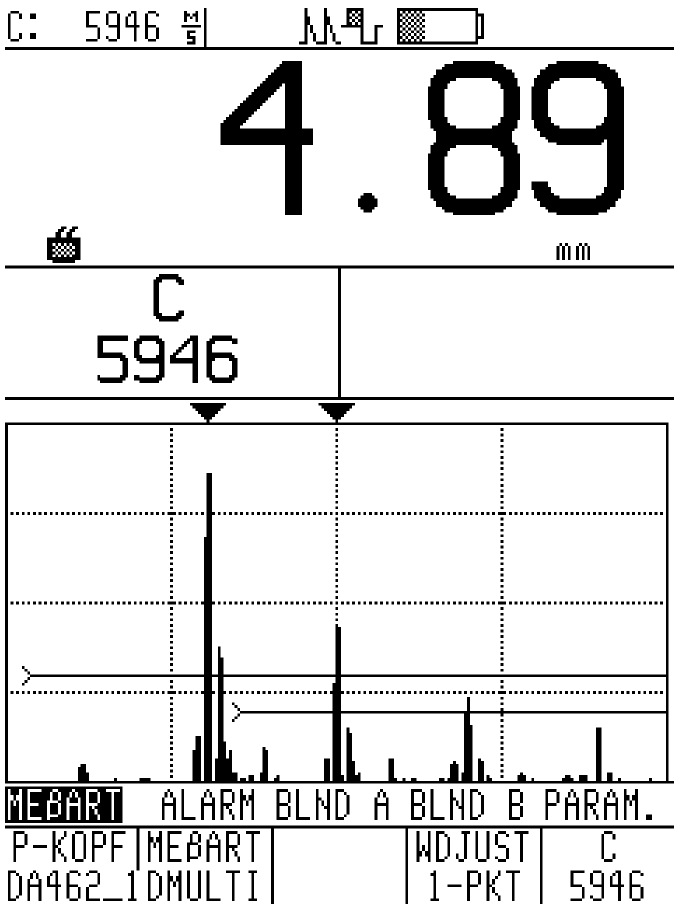
Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

Thickness Measurement with DualMulti

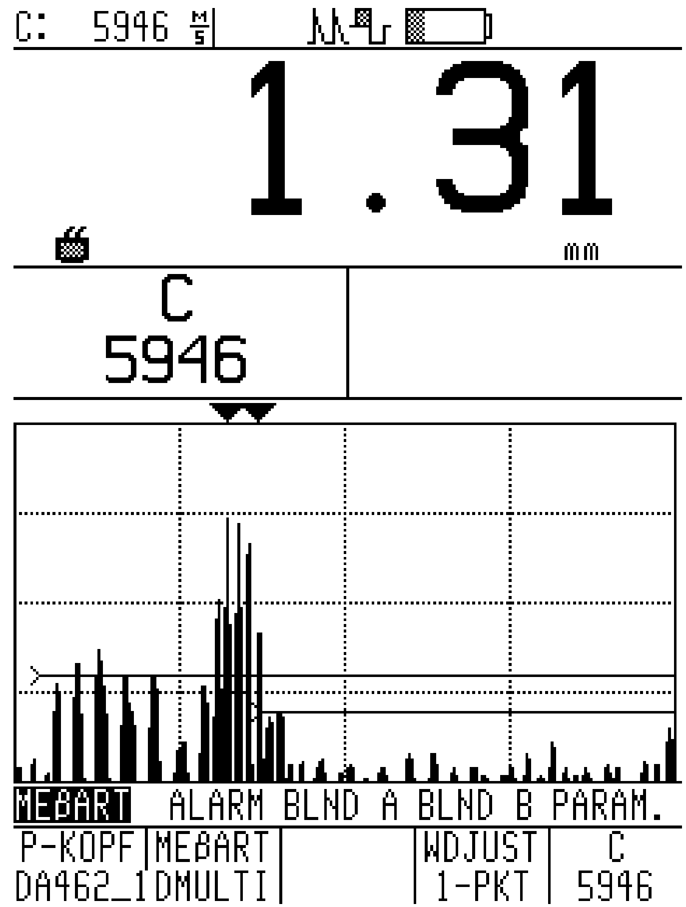


- Requirement 1: no or only very little Corrosion
- Requirement 2: Thickness of Layers not too high

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity



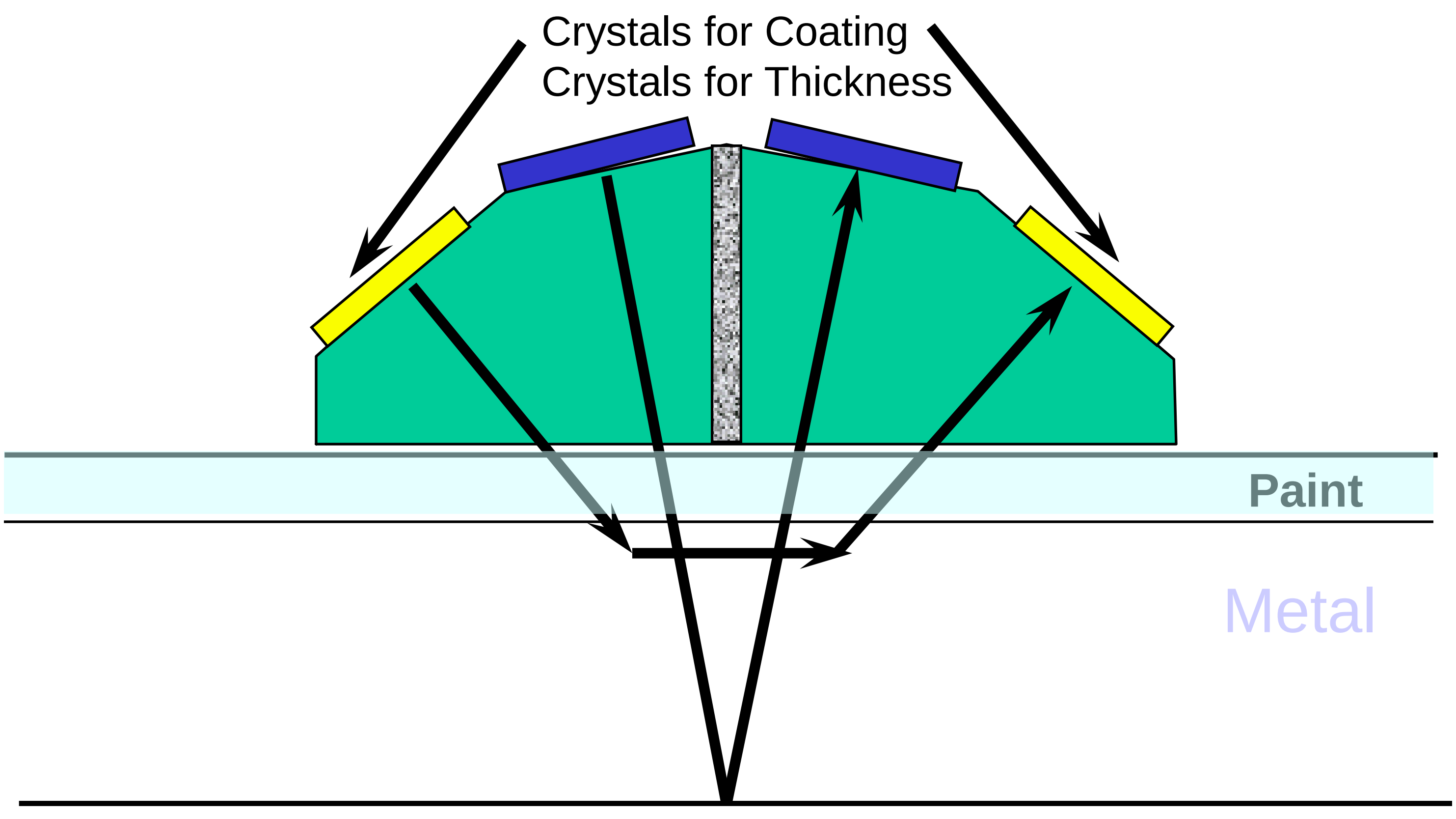
Non-corroded Sheet Metal (ideal)



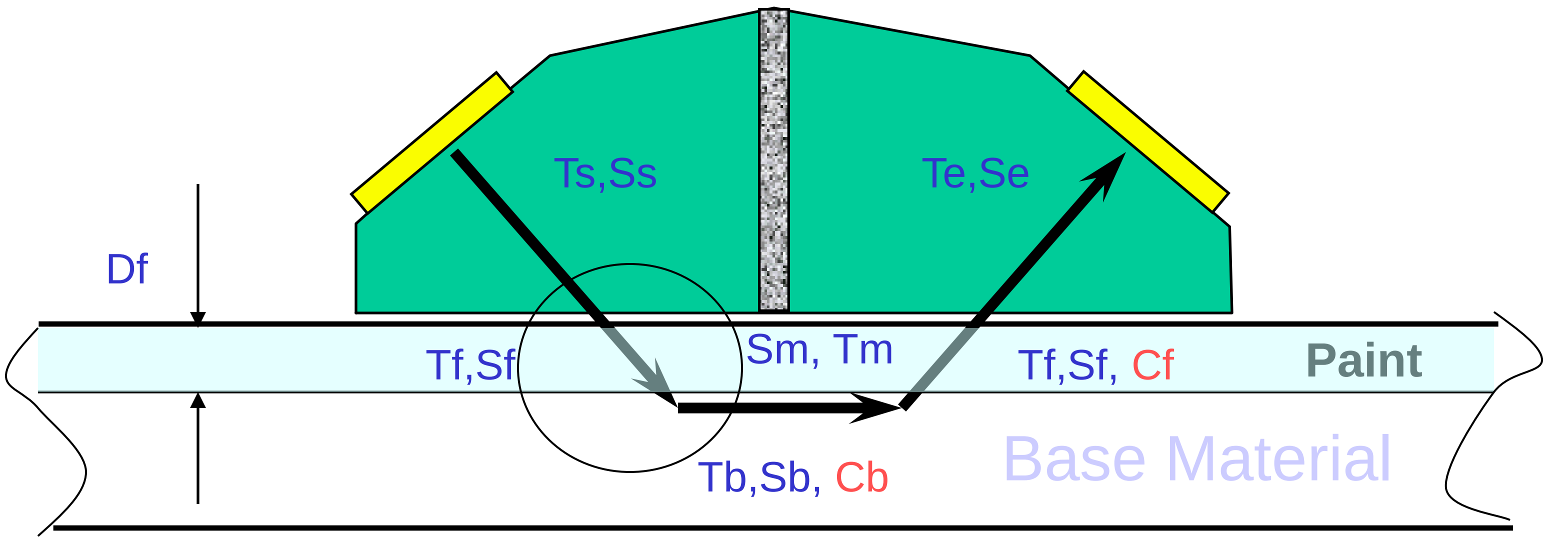
Corroded Sheet Metal (not useful)

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

New Principles 4: 2 Crystals for Coating Measurement (TopCoat)



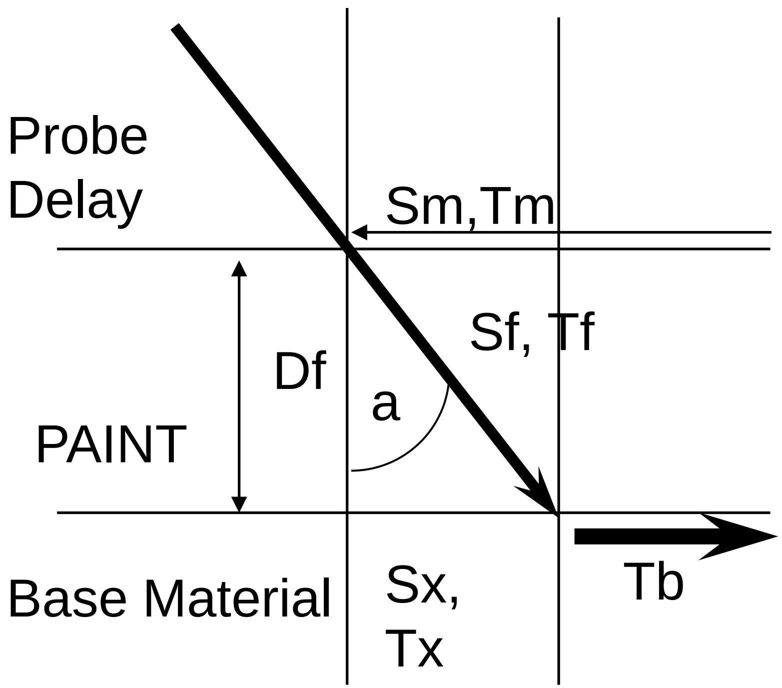
Thickness Measurement with Ultrasound NOT knowing the Sound Velocity



Directly retrievable Transit Times:

- w/o Paint: Ttoto = Ts + Tm + Te
- Paint included: Ttotm = Ts + Tf + Tb + Tf + Te
- DeltaT: DeltaT = Ttotm – Ttoto = 2Tf + Tb - Tm

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity



DeltaT = 2Tf + Tb - Tm

Tm = Tb + 2Tx

Cf = Sf/Tf

Cb= Sx/Tx

DeltaT = 2 (Tf – Tx)

DeltaT = 2 (Sf/Cf – Sx/Cb)

Sin(a) = Sx / Sf   Cos(a) = Df / Sf

DeltaT = 2 Sf (1/Cf – Sin(a)/Cb)

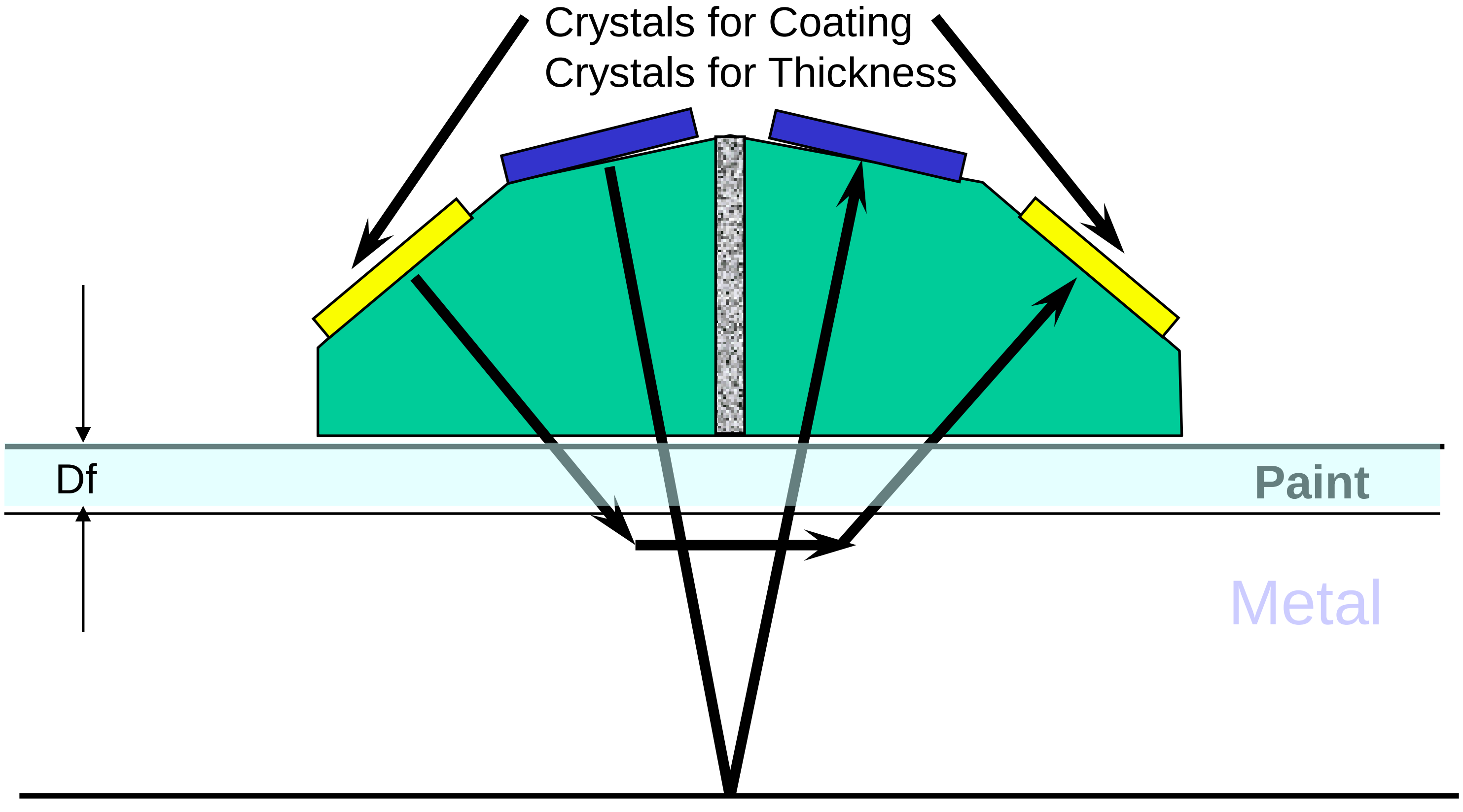
DeltaT = (2 Df / Cos(a)) (1/Cf – Sin(a)/Cb)

Formula for TopCOAT:

Df = DeltaT Cos(a) / (2 (1/Cf – Sin(a)/Cb))

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

Measuring Thickness Through Paint Df:



Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

<u>Requirements for TopCOAT:</u>

- Cf, the Sound Velocity of the Coating/Paint has to be known
- Cb, the Sound Velocity of the Base Material has to be known
- Delay line Material should not be to different from Cf

  → a = const

<u>Advantages of the TopCOAT Method:</u>

- Thickness of Coating/Paint and Base Material are displayed simultaneously
- Thickness of layer can be as low as 0 mm (no syst. Minimum Value)
- Rear Surfaces of Base Material may be corroded
  (1 Echo to be evaluated only!)
- Top Coat Procedure can simply be combined with AutoV

Thickness Measurement with Ultrasound NOT knowing the Sound Velocity

The decribed Methods

AutoV and TopCOAT

are protected by patents for Agfa NDT GmbH in

America
Europe
Japan

You need more info? Click:www.geinspectiontechnologies.com