NDT of Refractories

Basics – Methods – Examples

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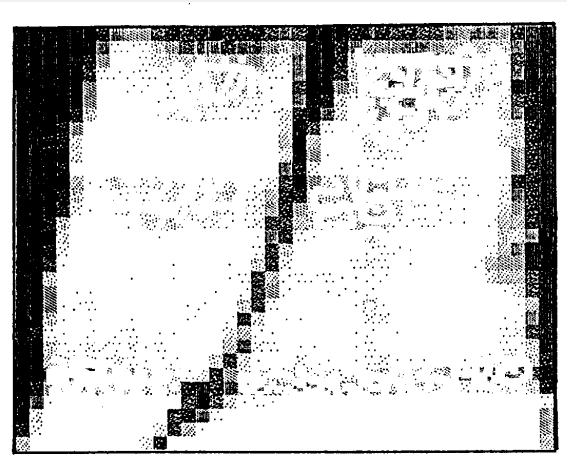
NDT: Defects and corrosion

- Looking for defects in the volume of new products
  - Flaw (defect in manufacture), fault
  - Crack, fissure
  - Void, gas bubble
  - Shrinkage cavity
  - Changes in (micro) stucture
    - Grain size, big grains
- During operation
  - Residual thickness
  - Corrosion progress



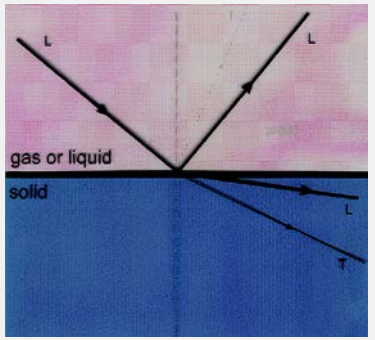
NDT: Non destructive testing

- Acoustic Test: porcelaine or glass
  hammer (with a small hammer) up on refractory and listen
  physics: frequency analysis of an acoustic wave

⇨ common charcteristics of NDT:

⇨ Wave

	medium	**kind of wave**
▪ Acoustic	yes (i.e. air, refractory)	transversal, longitudinal, …
▪ Electro-magnetic	no	transversal



⇨ Propagation characteristics

- Velocity
- Wave length
- Intensity

} frequency

absorption - reflection - scattering

Material properties:

Sound Wave — mechanical properties: modulus of elasticity, poisson ratio
Electro-magnetic Wave — electrical properties: permittivity, permeability
grain size

Challenges

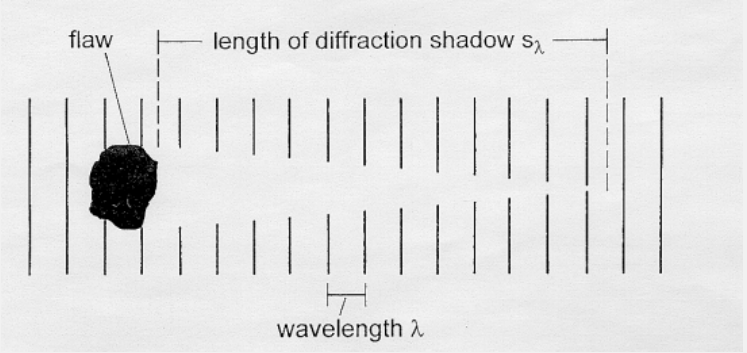
- High attenuation - Noise
- Coupling of wave into specimen - reflection
  ← (big) change in property when passing the boundary (air –) specimen

- High temperature (when investigating during operation)
- Physical properties change not in one step at corrosion boundary
  but alter more or less continious/stepless
  as components of the glass melt penetrate the refractory,
  as there is a saturation layer that „seperates“ refractory and glass melt

- Physical properties depend on
  - Frequency → filtering effect, wave length → resolution ($\lambda/4$)
  - Temperature (in most cases higher „attenuation“)

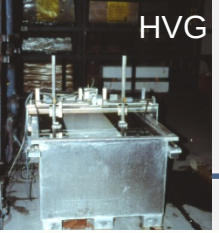
Challenges

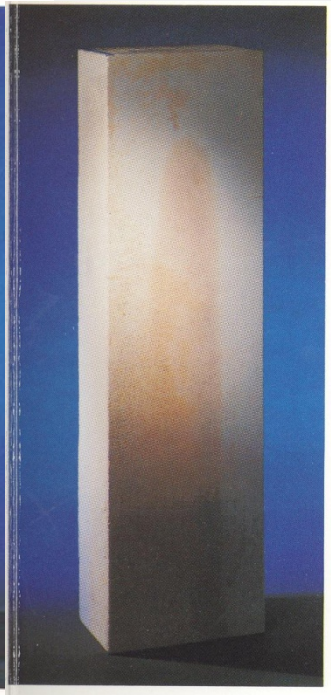
- Diffraction

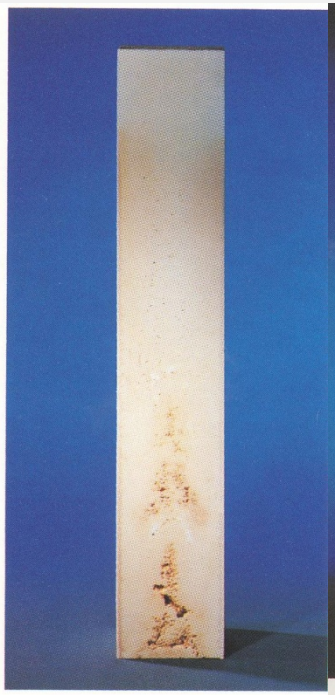


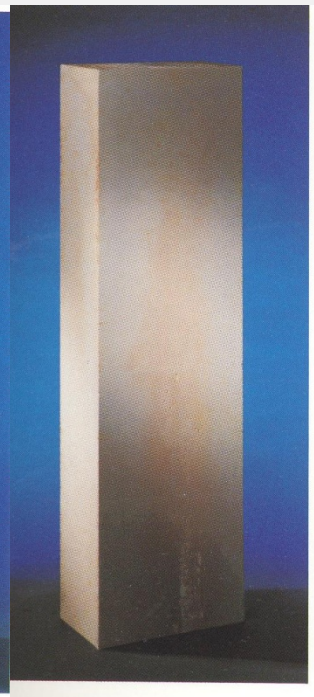
- Distinctive features of different wave types:
  - Gamma rays: more particle than wave
  - X-ray and Gamma ray: hazard of health
  - microwave: standing wave
  - Ultra sound: in solid materials: different modes of wave

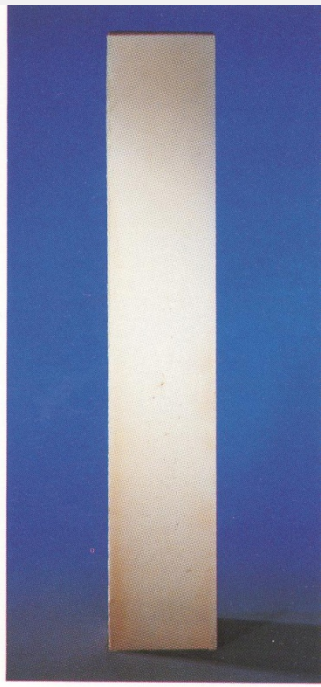
Ultrasound

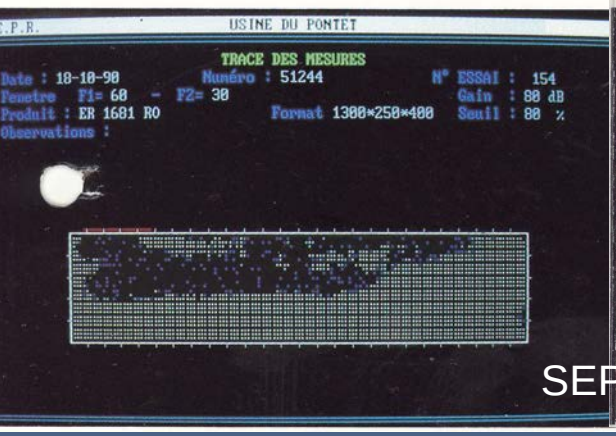


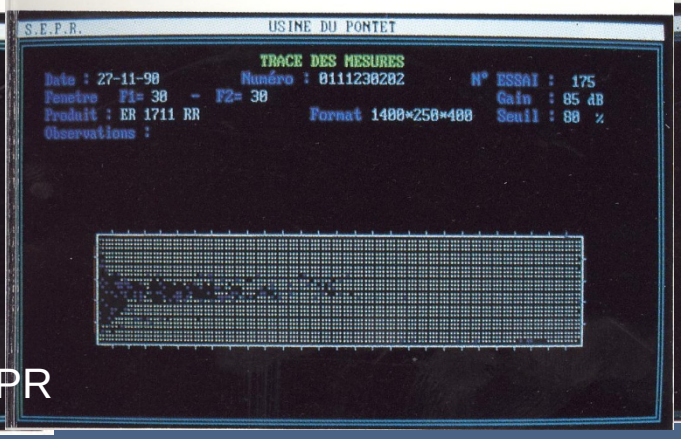


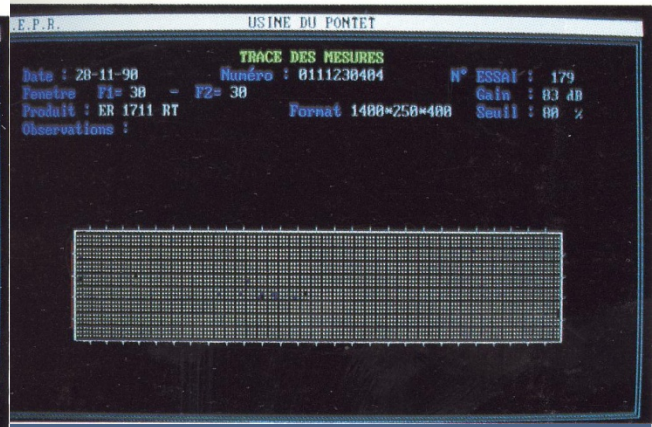






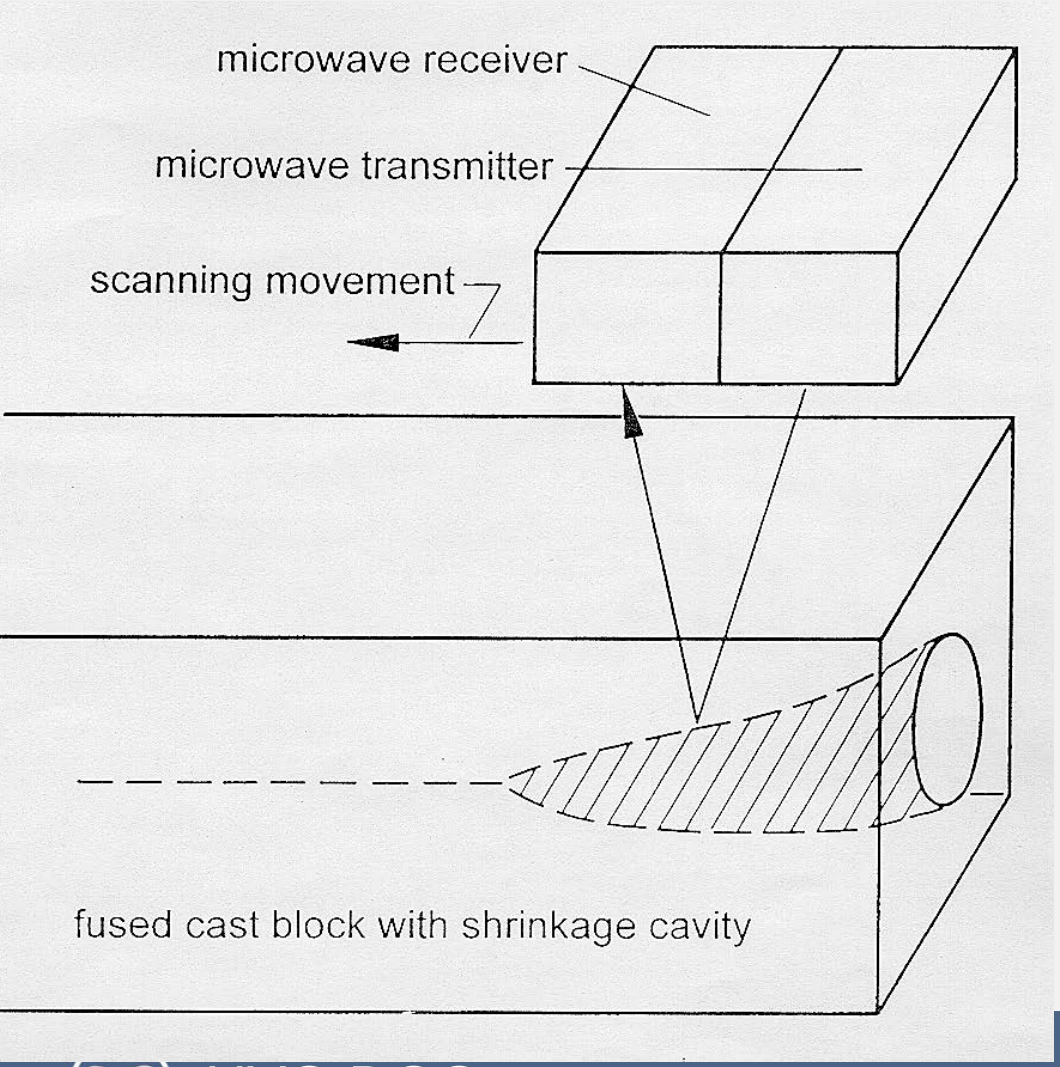


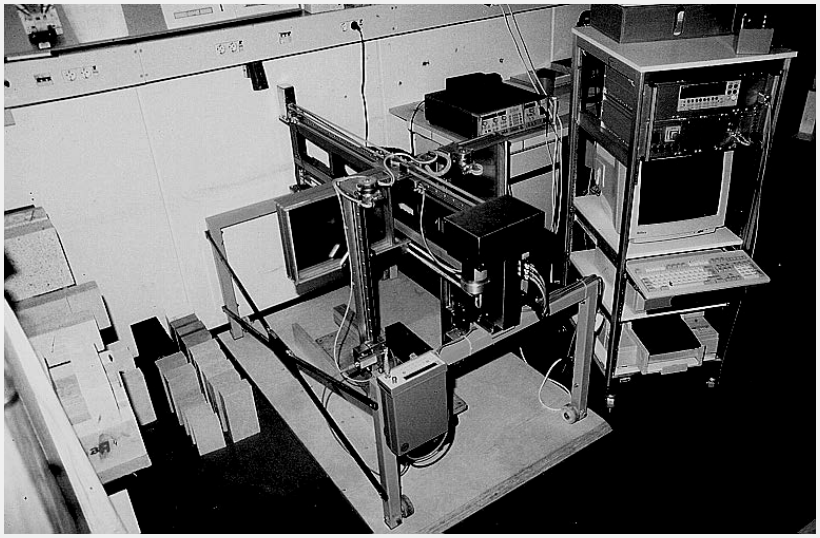


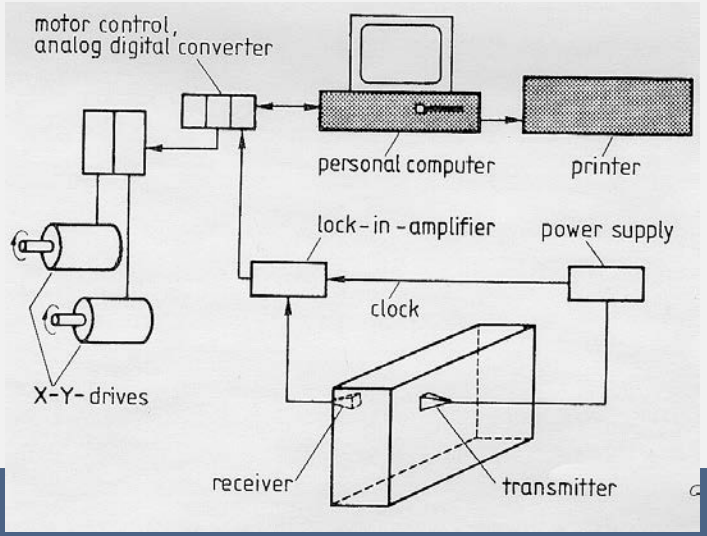


SEPR

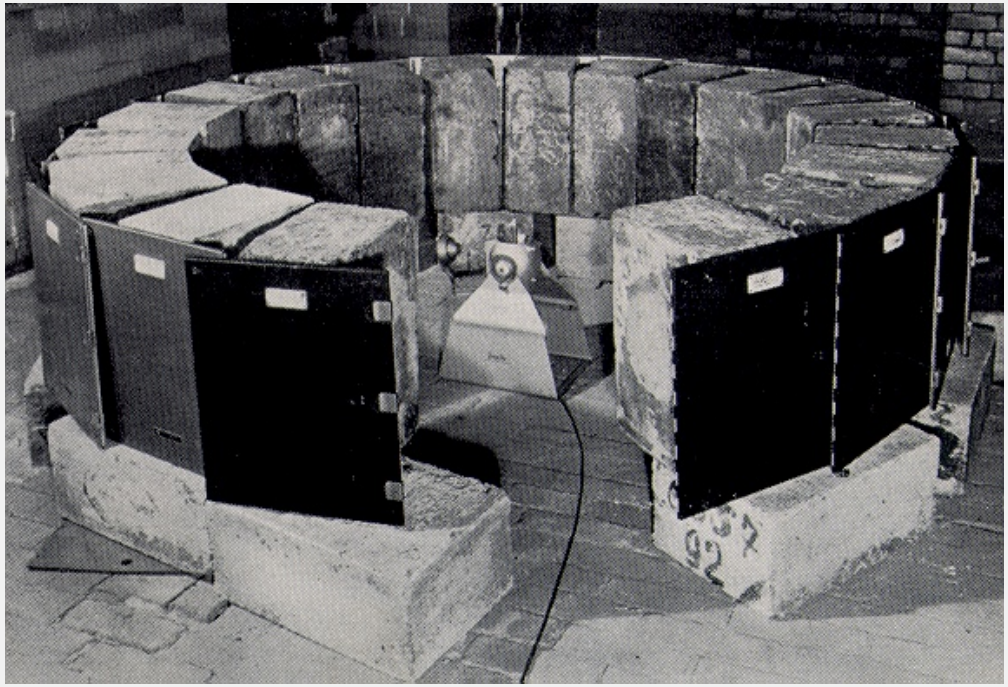
Micro Wave

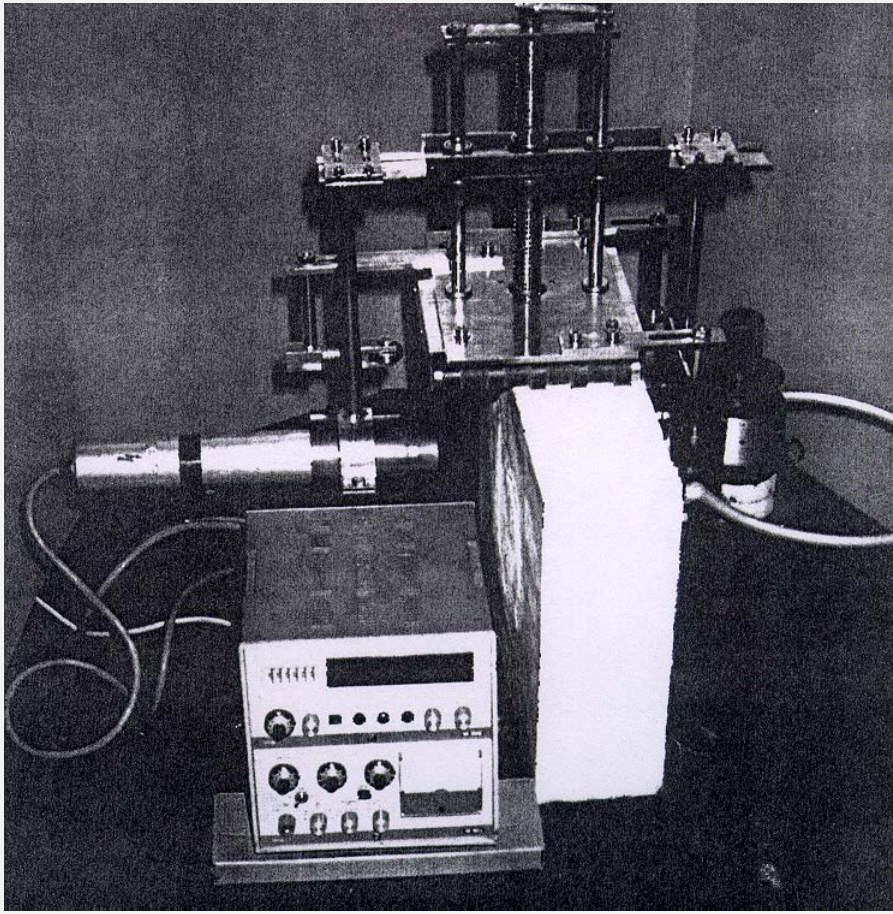

microwave receiver
microwave transmitter
scanning movement
fused cast block with shrinkage cavity

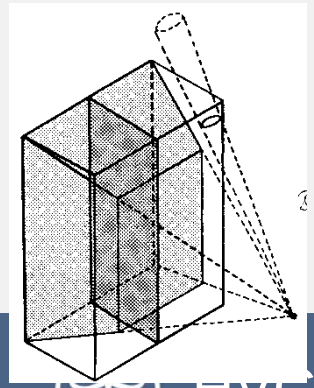


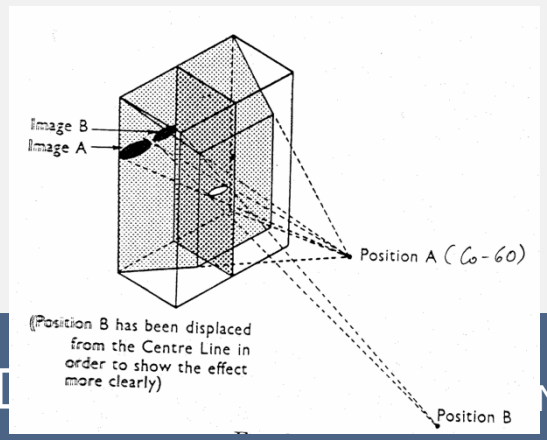

motor control,
analog digital converter
personal computer
printer
lock-in-amplifier
power supply
clock
X-Y-drives
receiver
transmitter

Gamma radiation









	γ-Strahlen	Mikrowellen	Ultraschall
Frequenzbereich typisch	10^{18} bis 10^{22} Hz 10^{20} Hz	10^{8} bis 10^{12}Hz 10^{9} Hz	10^{3} bis 10^{9}Hz 10^{6} Hz
Art der Welle	Felder, kein Medium nötig		Materialwelle
Wellenlänge im Stein	0,001 nm	5 mm	1 cm
Brechung und Reflexion	Brechungsindex	Dielektrische Konstante	Akustische Impedanz
Luft – Stein	$\Delta n \approx 10^{-6}$	Luft 1 Stein 2-3	Luft 400 Ns/m^3 Stein 10^{7}
Geschwindigkeit	$3 \bullet 10^{8}$ m/s	$1{,}6 \bullet 10^{8}$ m/s	$5 \bullet 10^{3}$ m/s