

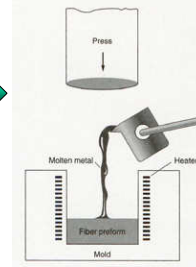
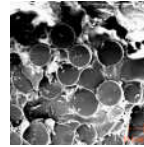
A Method for Evaluating Manufacturing Damage in Monolithic and Composite Materials

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Metal Matrix Composite Fabrication

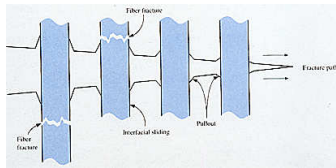
- Powder metallurgy - Hot isostatic press
- High Pressure Infiltration Cast



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Research Need

- Manufacturing process control/development → Fiber-matrix interface improvement
 - pressures
 - temperatures
 - fiber coatings
 - alloys

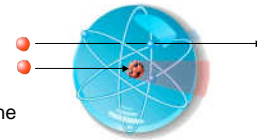


Need: Image internal damage & matrix-reinforcement debond → Solution: Neutron Radiography

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Unusual Attenuation Characteristics of Neutrons

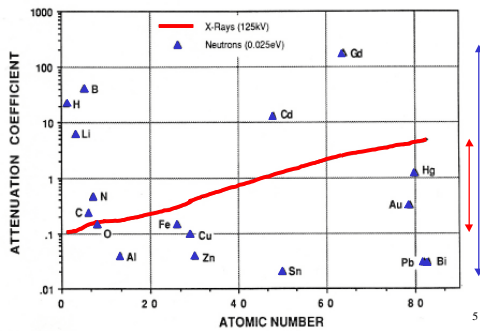
- Several low atomic number elements significantly attenuate neutrons
 - Hydrogen
 - Boron
- Neutrons interact with the nuclei of the object's constituent atoms



Many metals are transparent to neutrons

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Attenuation vs. Z Number



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Neutron Imaging Methods

- Static (film)
 - resolution: 40 μm
- Penetrant enhanced
 - resolution: 40 μm
- Real-time or radioscopy (motion)
 - resolution: 130 μm

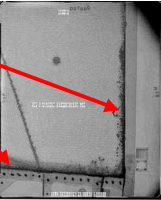
Neutron radiography effectively complements photon (X-ray, gamma-ray) radiography

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Established Applications of Neutron Radiography

- Corrosion detection
- Water entrapment
- Inspecting welds of dissimilar metals
- Imaging adhesives, polymers, or liquids inside metal assemblies



Airplane wing


Common Industrial Applications

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Breazeale Nuclear Reactor

- TRIGA Mark III 1000 Kw.
- Neutron Beam Laboratory
- Support Facilities

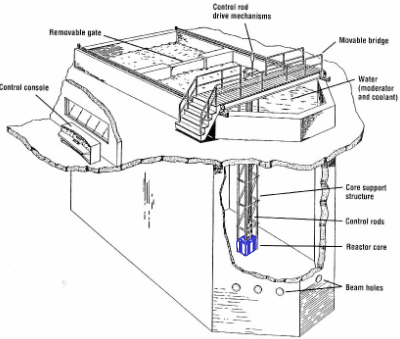


- 0.025 eV (thermal) $\lambda=1.08\text{\AA}$
- 1×10^7 n/cm²sec
- Collimated neutron beam
- (L/D=140)

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Breazeale Nuclear Reactor

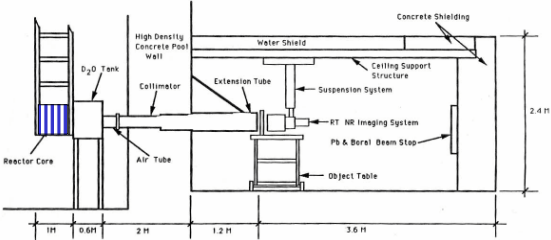


Removable gate
Control rod drive mechanisms
Movable bridge
Water (moderator and coolant)
Control console
Core support structure
Control rods
Reactor core
Beam holes

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Neutron Beam Laboratory




Reactor Core
D₂O Tank
Collimator
Extension Tube
Water Shield
High Density Concrete Pool Wall
Concrete Shielding
Ceiling Support Structure
Suspension System
RT NR Imaging System
Pb & Borel Beam Stop
Object Table

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Static (film) Neutron Radiography

- Gadolinium Direct Exposure
- Back screen configuration
- 25 micron thick gadolinium metal foil
- Single emulsion film (Kodak SR-75 film)
- Gd(n, γ) prompt to e⁻ by internal conversion
- 40 micron resolution



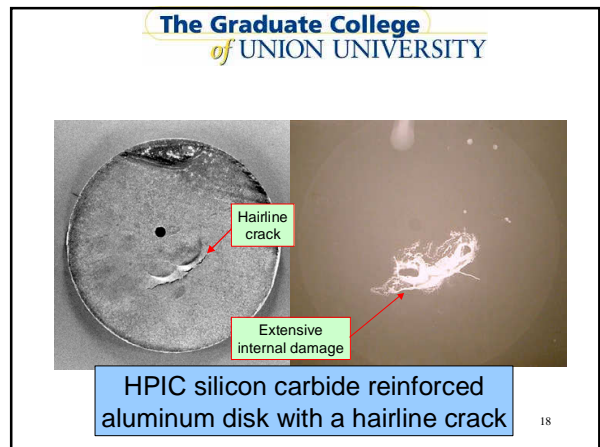
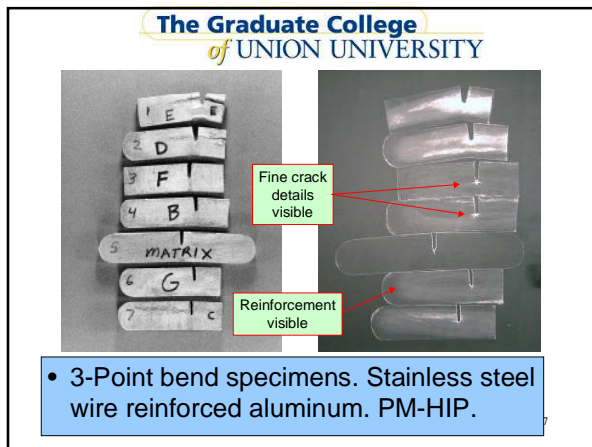
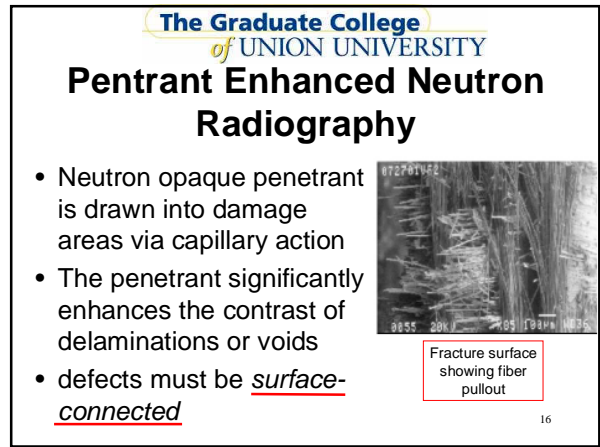
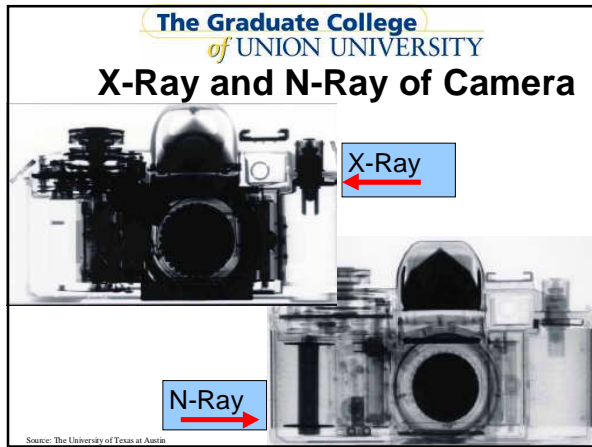
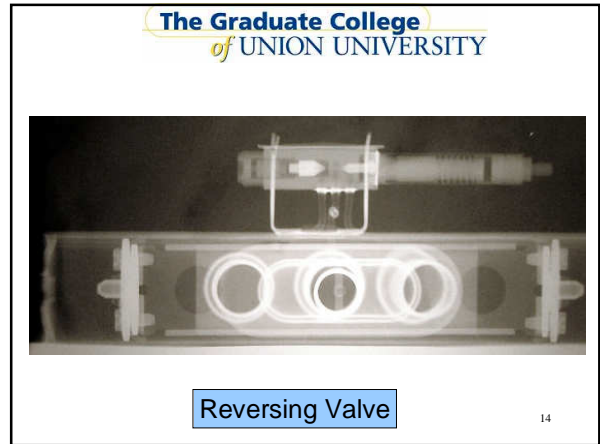
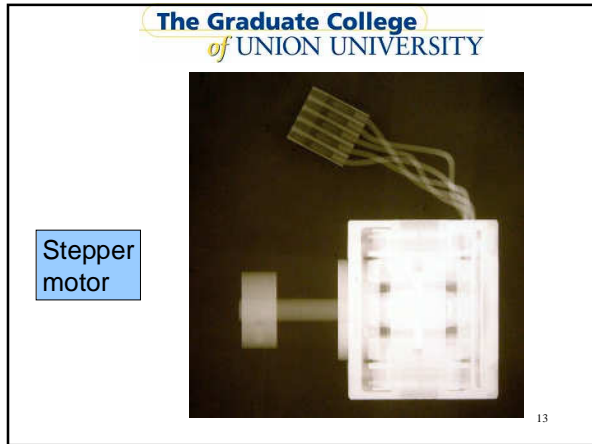
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Water Faucet

Small Plant and Flowers Behind one inch of lead



Summary

- Neutron radiography effectively complements photon (X-ray, gamma-ray) radiography
- Plastics, water, oil, etc. are visible inside steel, aluminum, brass, lead, etc.
- Static (film), penetrant enhanced, and radioscopy are established methods

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