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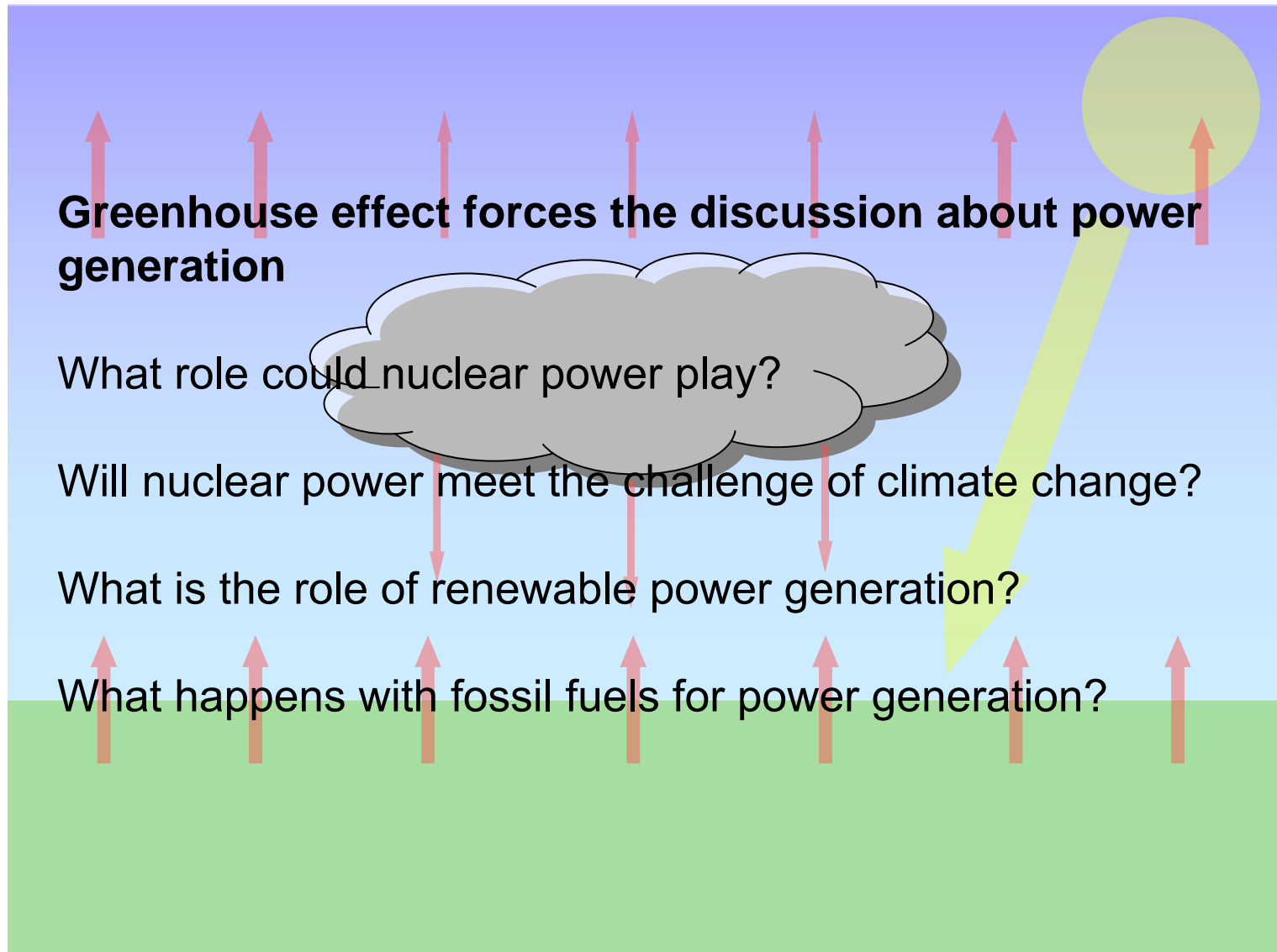
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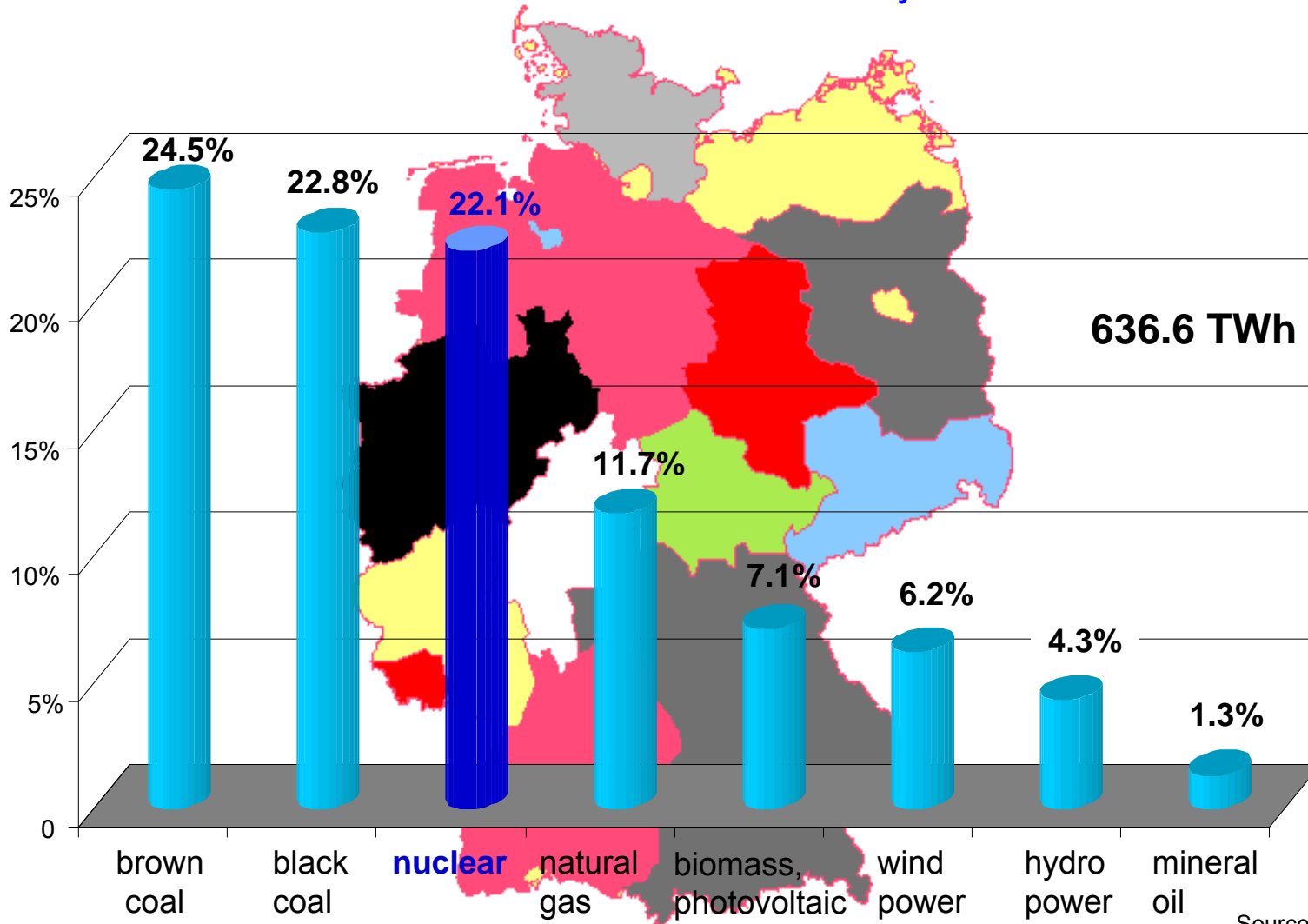
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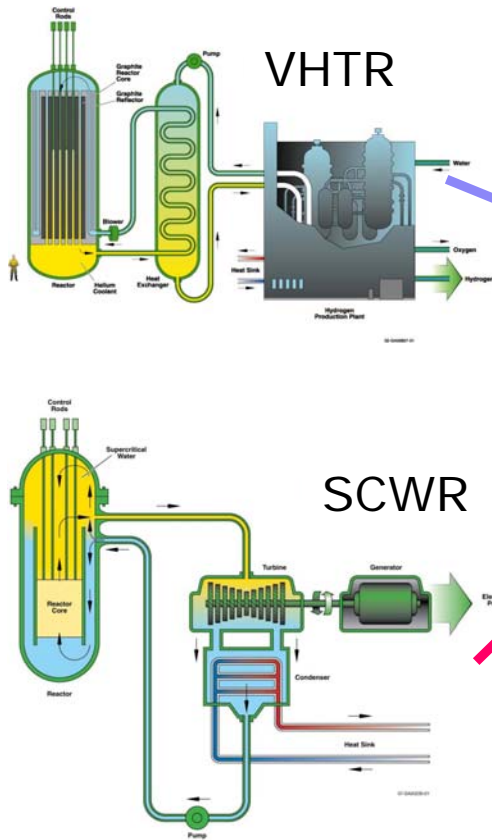
Discussion about Greenhouse Effect

- Atmospheric concentrations of some of the gases responsible for the greenhouse effect, e.g. water vapour, carbon dioxide and methane are increasing due to human activity. Most of the world's climate scientists believe this causes global warming. Over one-third of human-induced greenhouse gases come from the burning of fossil fuel to generate electricity.
- When reducing greenhouse gases, other **alternative energies like hydrogen, wind and photovoltaic** are potential sources for electricity production. Unfortunately, these energies are currently not powerful enough to satisfy the electricity needs of industrial countries. Nuclear power plants, unlike fossil fuel, do not generate greenhouse gas emission.
- The **Kyoto Protocol** (United Nations, 1998), a legally binding agreement for industrialized countries to reduce their emission of greenhouse gases, requires the realisation of fixed values for greenhouse gas emission.

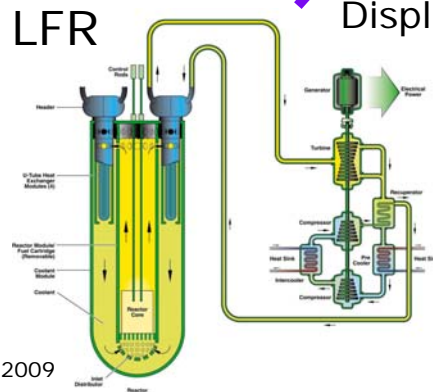
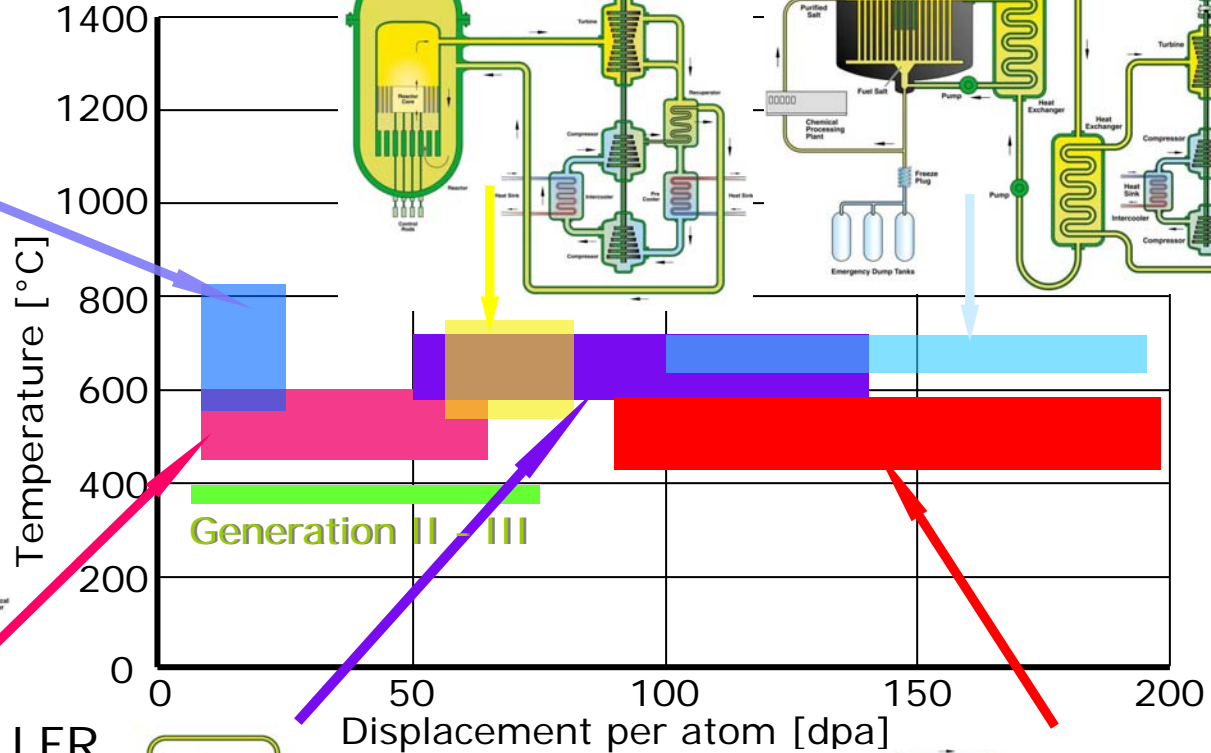


In most industrialized countries there is still an energy mix - the proportional relationship between all used energy sources –

MSR Molten Salt Reactor;
GFR Gas Cooled Fast Reactor

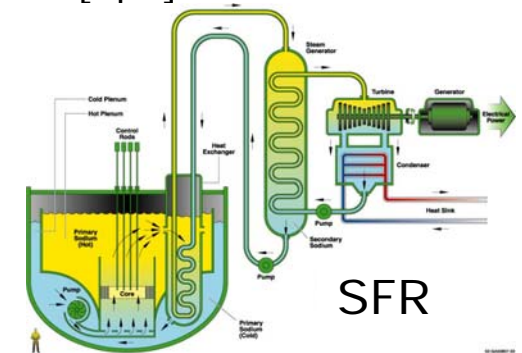


VHTR Very High Temperature Reactor;
SCWR Supercritical Water Cooled Reactor



LFR

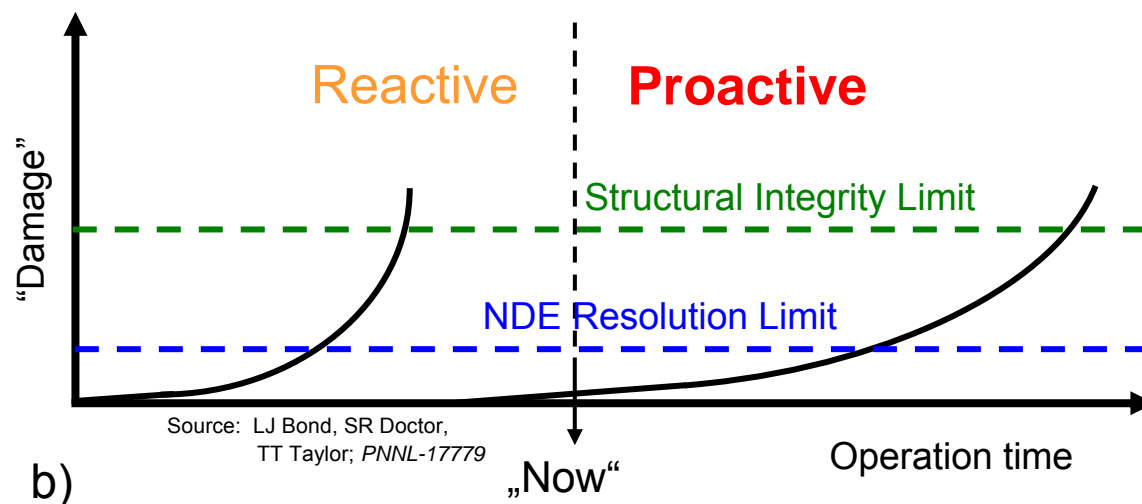
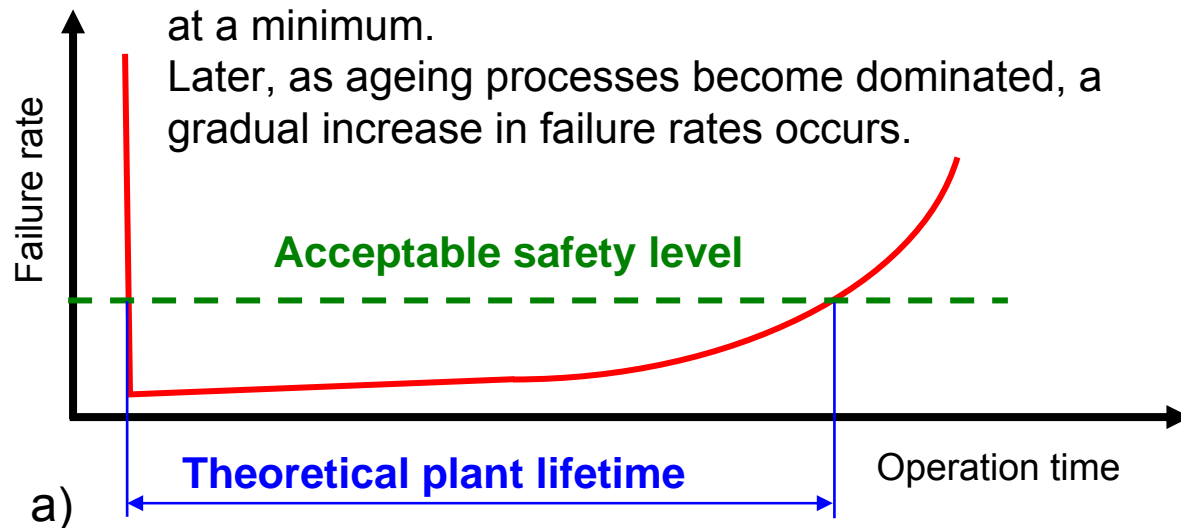
LFR Lead Cooled Fast Reactor;
SFR Sodium Cooled Fast Reactor;



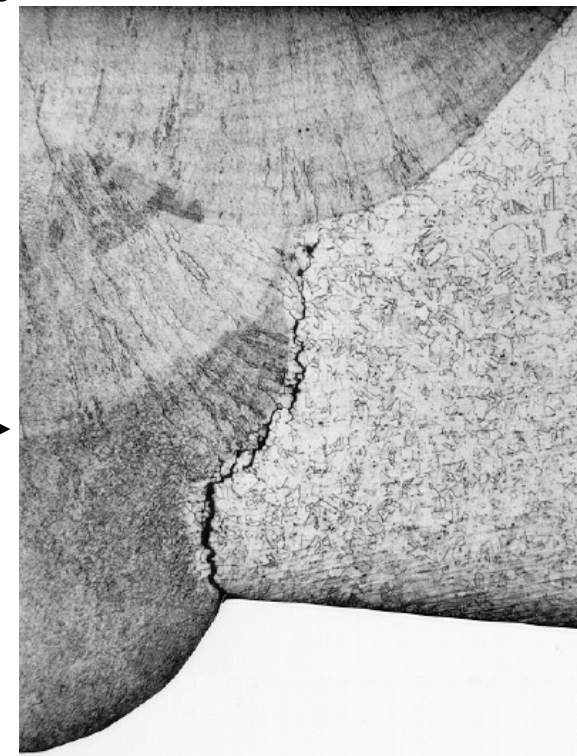
SFR

Source: **MRS BULLETIN** - VOLUME 34-JANUARY 2009

Failure rates are generally high after plant starts.
During the 'middle age' of a plant, problems tend to be
at a minimum.
Later, as ageing processes become dominated, a
gradual increase in failure rates occurs.

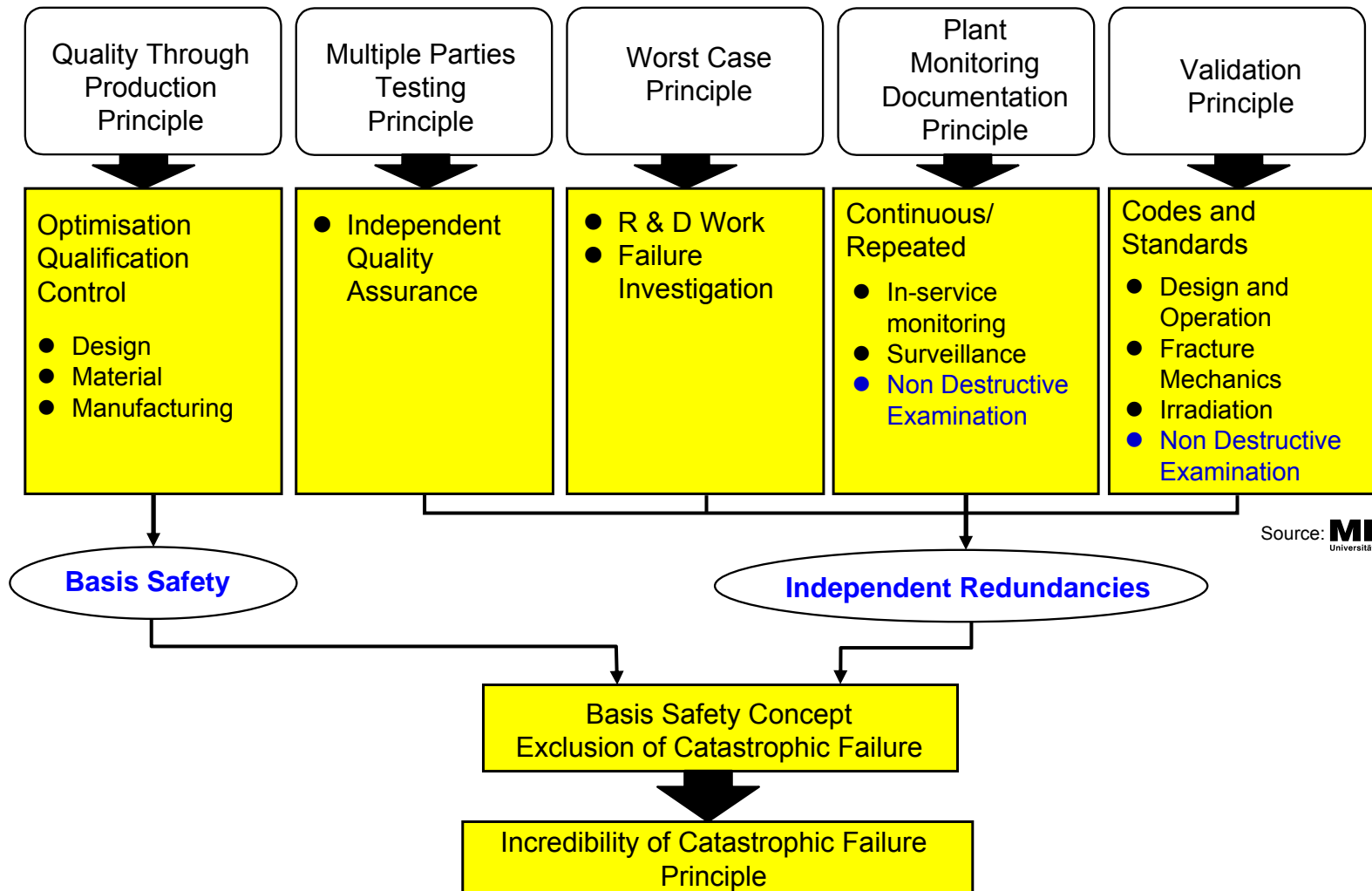


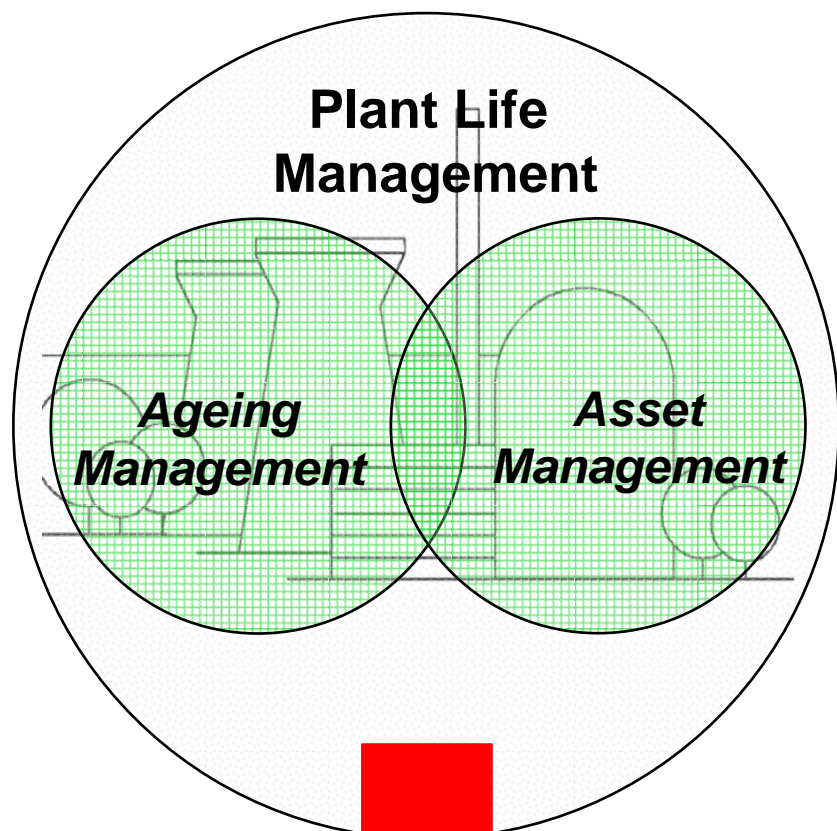
Source: LJ Bond, SR Doctor,
TT Taylor; PNNL-17779



Intergranular stress
corrosion cracking (ISCC)
produced during operation

- Requirements will provide the pressure-retaining boundary with a basic safety that will preclude any catastrophic failure of a plant component as a result of manufacturing defects (the „**quality through production**“ principle)
- The basic safety of a component depends on the following features:
 - High-grade material properties, in particular ductility
 - Conservative limitation of stresses
 - Prevention of stress peaks by way of optimized design and construction
 - Assurance of the application of optimized manufacturing and testing technologies
 - Knowledge and assessment of fault conditions, if any
 - Consideration of the operating medium





PLIM is defined as an integration of ageing management and economic planning to optimize operation, maintenance, to maintain an acceptable level of performance and safety, and to maximise return of investment.

Ageing Management in Germany

- *Ageing Management is integrated into the Quality Management System from the very beginning*
- *Conceptual ageing, technological ageing or physical ageing always considered for permanent up-grading and back fitting of plant's components, systems and structures*
- *Regular ageing management status reports to be supplied to the Regulator, as required by a recommendation of the Reactor Safety Commission since 2004*

Source:  AREVA



Plant Life Extension

Three aging mechanisms are essential during plant life:

- **physical aging**: through loads and environment conditions (*fatigue, corrosion, neutron embrittlement etc.*)
- **technological aging**: through change of knowledge
- **conceptional aging**: through change of requirements or specifications

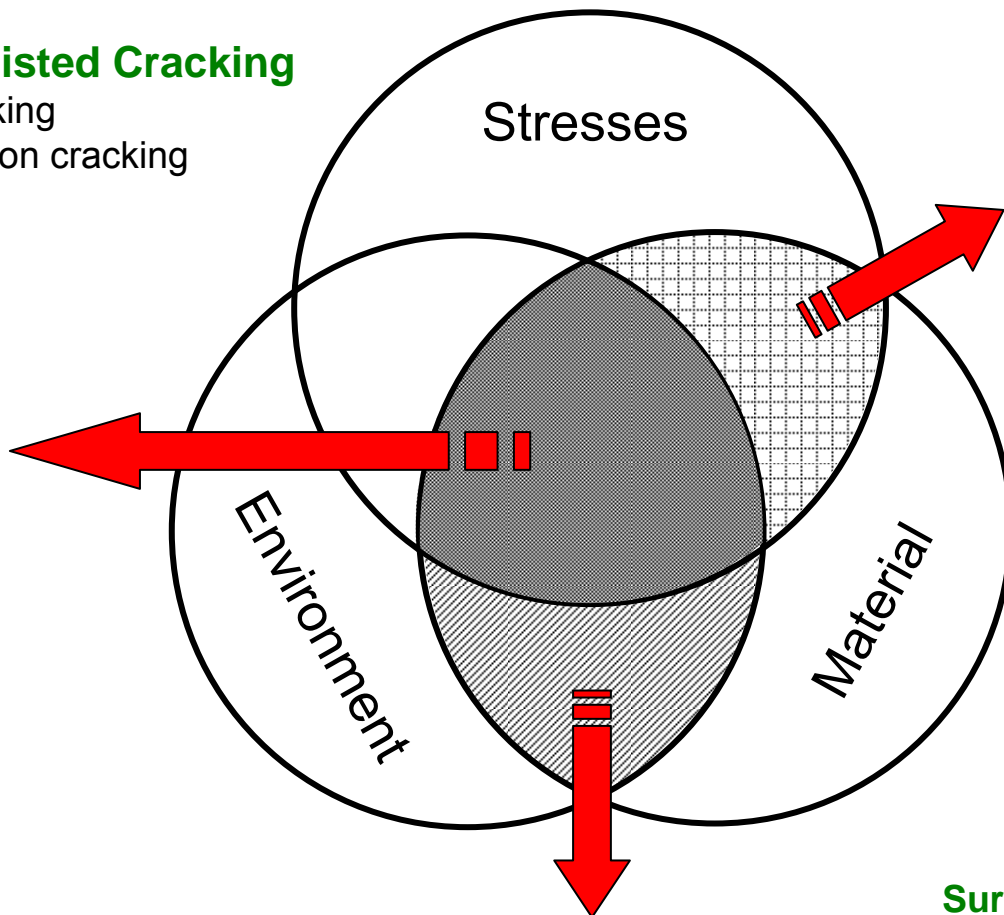
Therefore, ageing management refers to all organisational and technical changes put into place by the utility to counteract important safety related ageing phenomena. The main goal of ageing management is the acquisition and evaluation of ageing mechanism data and a systematic damage prevention.

Environmental Assisted Cracking

- Stress corrosion cracking
- Strain induced corrosion cracking
- Corrosion fatigue



- Unfavourable state of material
- Local stresses
- Unfavourable (local) environment



- Mechanical and thermal loads
- Material degradation caused by operation



Plastic Deformation

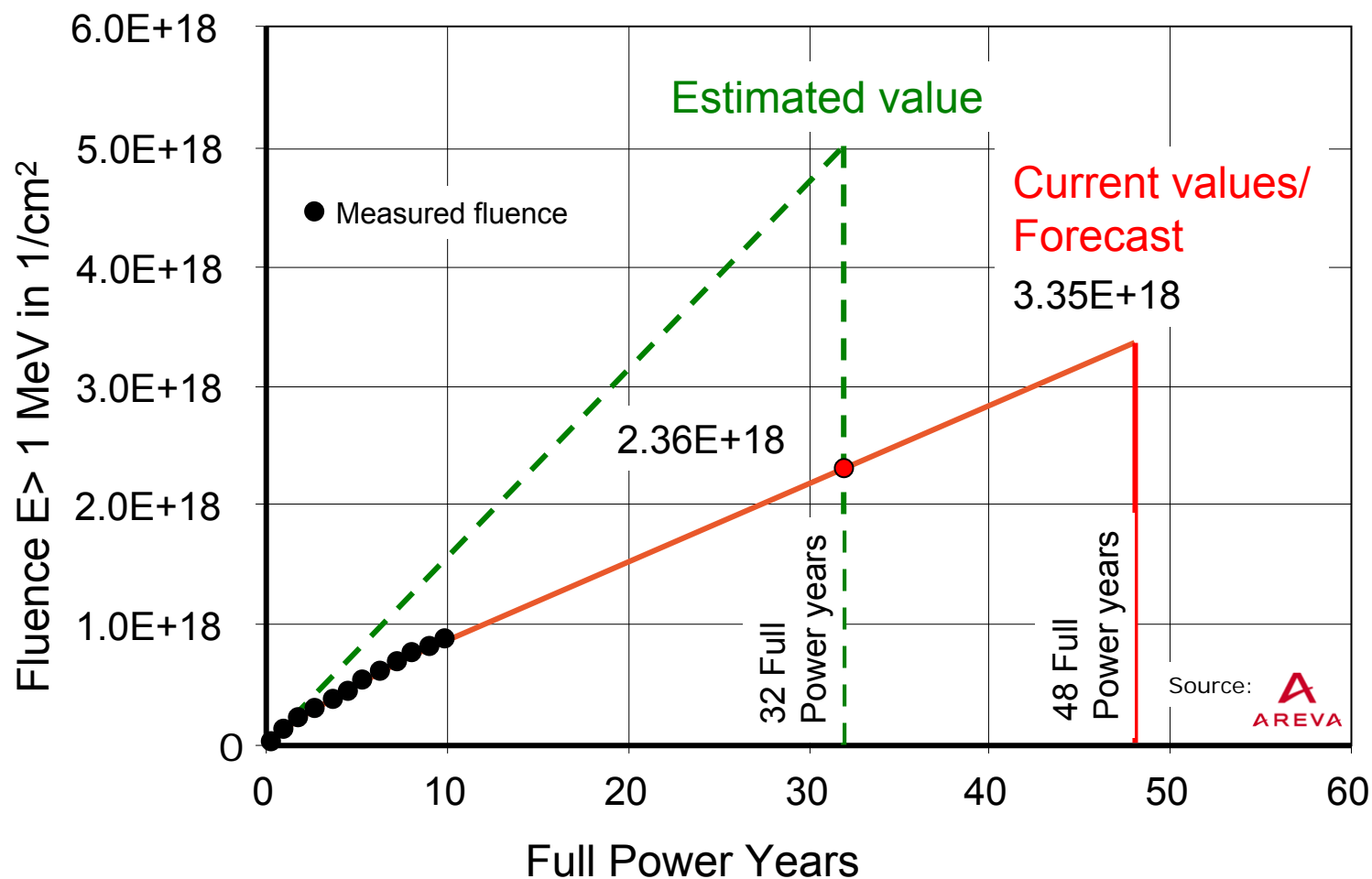
- Deformation
- Ratcheting (cycle creep) fatigue

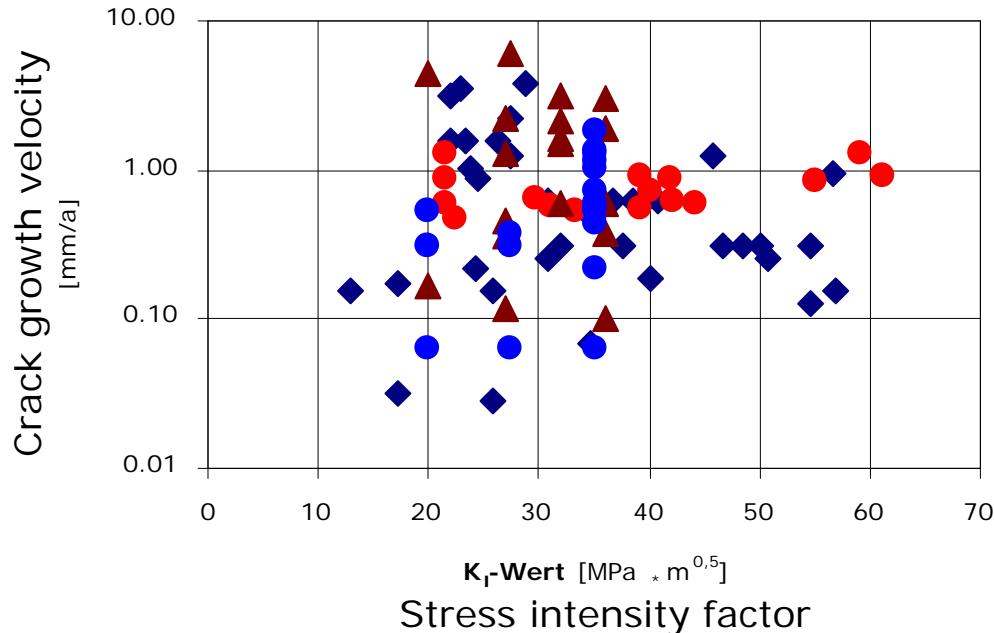
- Material not resistant
- Electrochemical attack



- Surface corrosion
- Pitting
- Selective corrosion
- Erosion corrosion

Ageing mechanism: Neutron embrittlement of the reactor pressure vessel especially in the core area due to increasing neutron fluence with increasing lifetime





Corrosion assisted Crack Growth in Austenitic steel

Result:

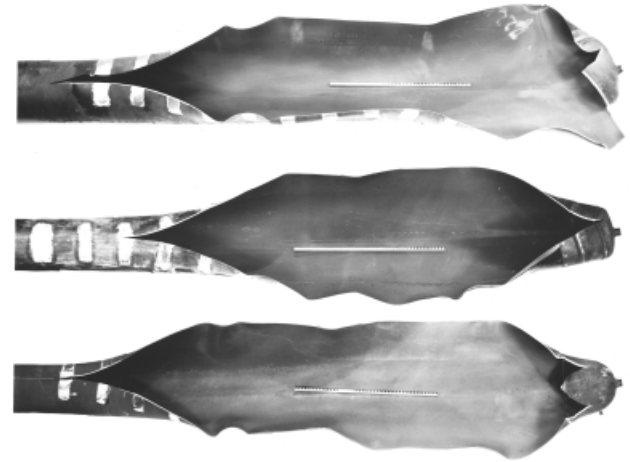
Influence of the different solvents with different concentration to the specimens **without external loading**

Forecast:

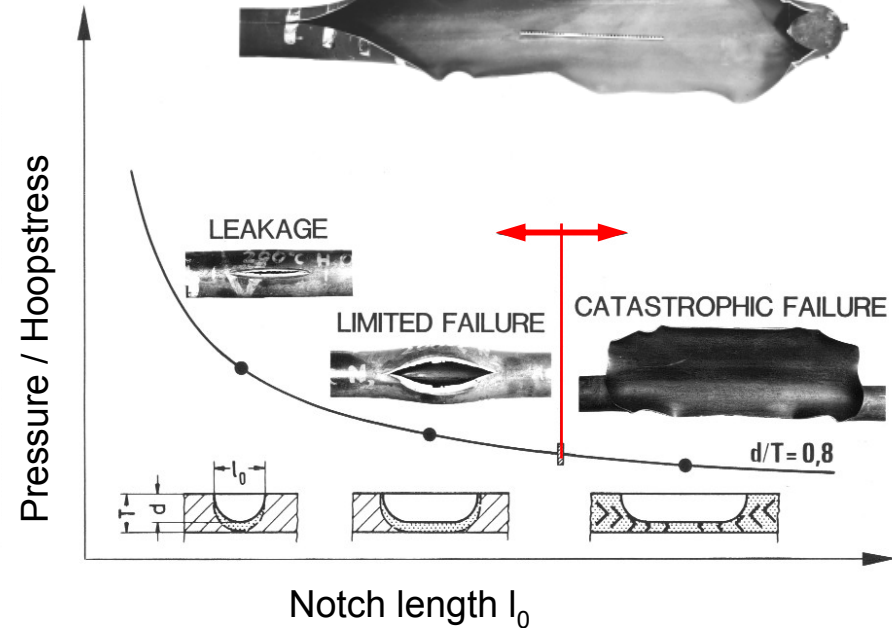
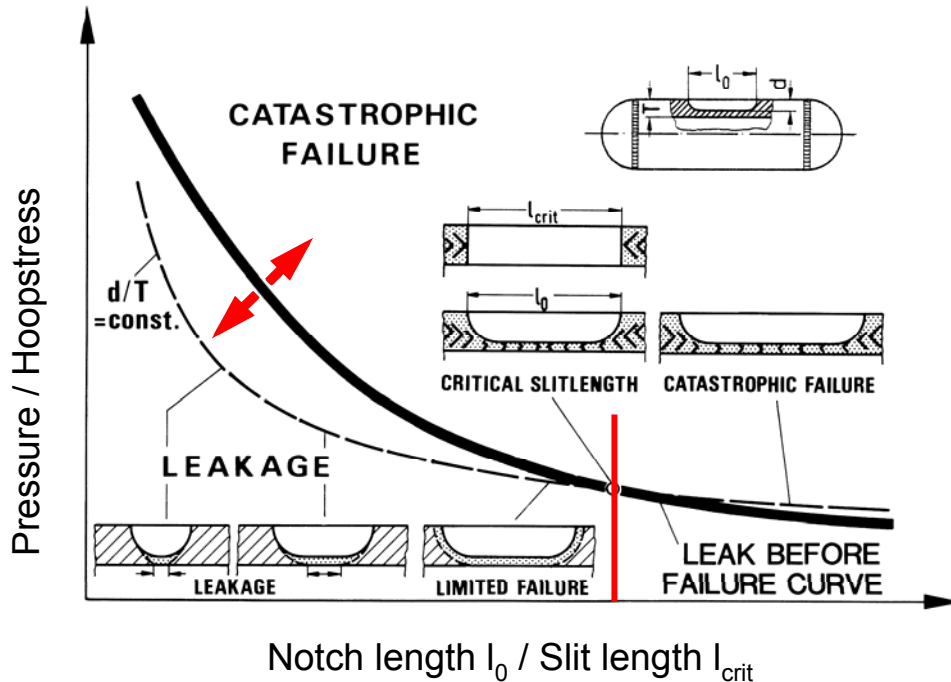
Influence of the solvents by **different external loading quasi static and dynamic**

- For austenitic stainless steels intergranular stress corrosion cracking (IGSCC) is a major concern in some environments.
- Crack growth velocity data for stabilized and non-stabilized austenitic stainless steels in oxygenated high-temperature water.
- The evaluation of the measured data shows no clear dependence of crack growth velocity and stress intensity.
- The arithmetic mean value of all data points is 0.95 mm/a and a median value of 0.6 mm/a can be determined.

Burst tests of longitudinal cracked feed water pipes



Leak before break behavior of axial defects

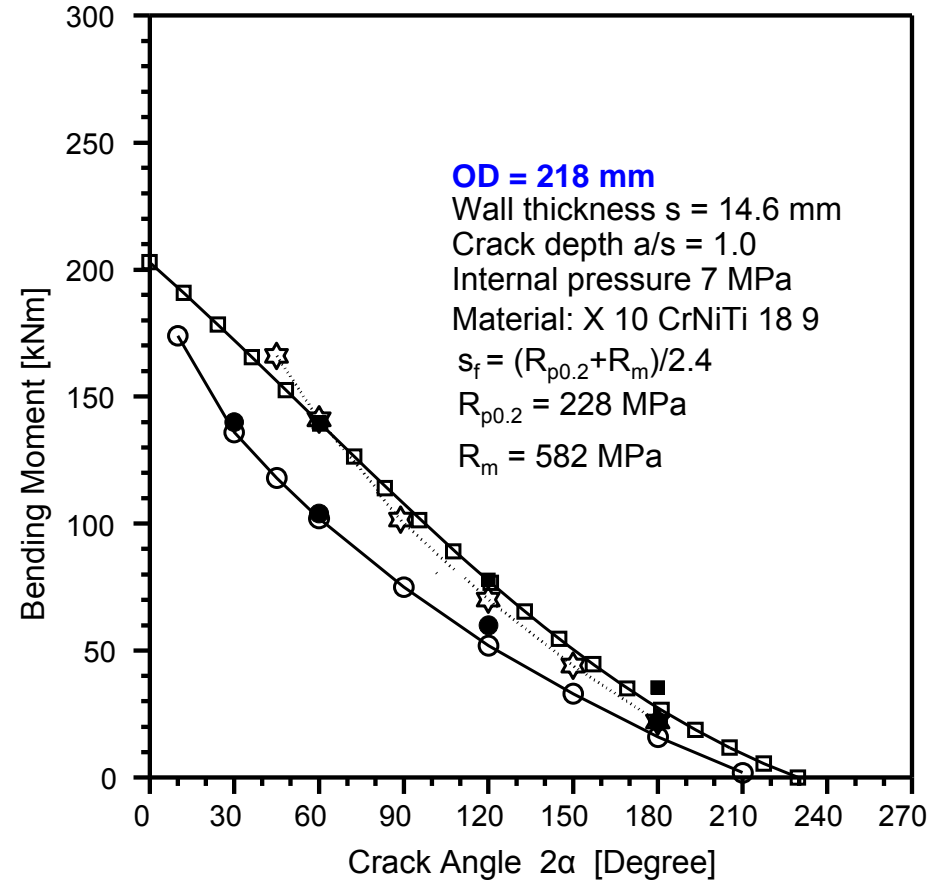
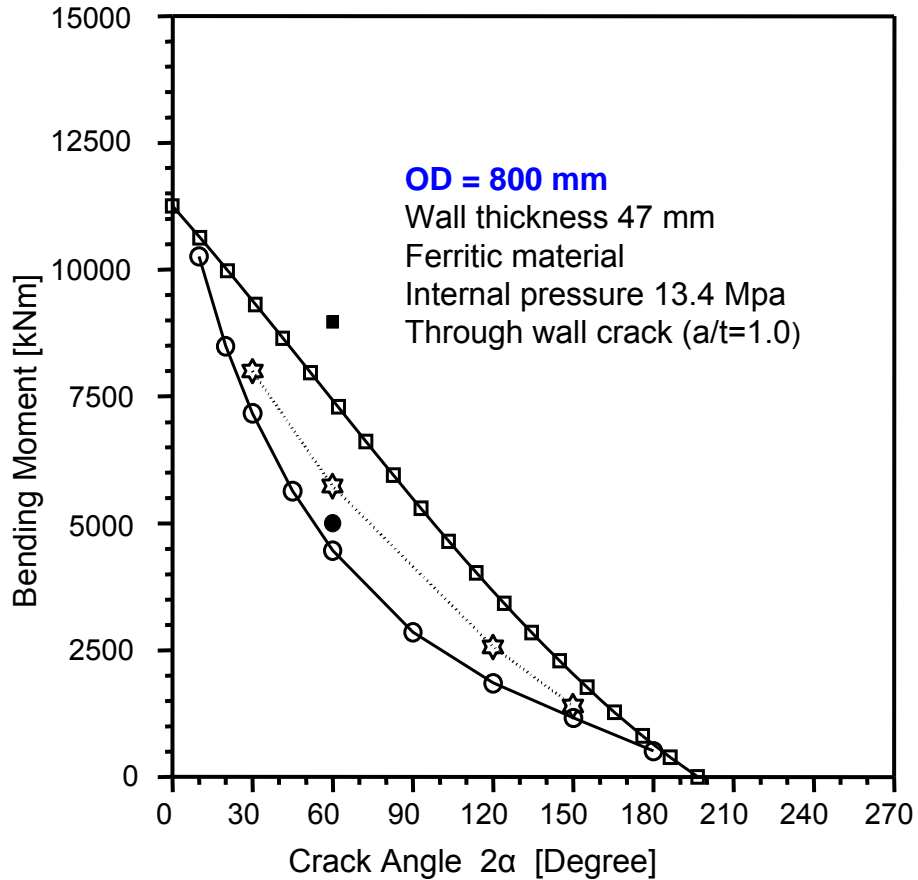


Source: **MPA**
Universität Stuttgart

Experimental verification by pipe tests

Research work at MPA Universität Stuttgart
Sponsored by the Federal Ministry of Education and Research (BMBF)

Load Bearing Capacity of Ferritic and Austenitic Pipes

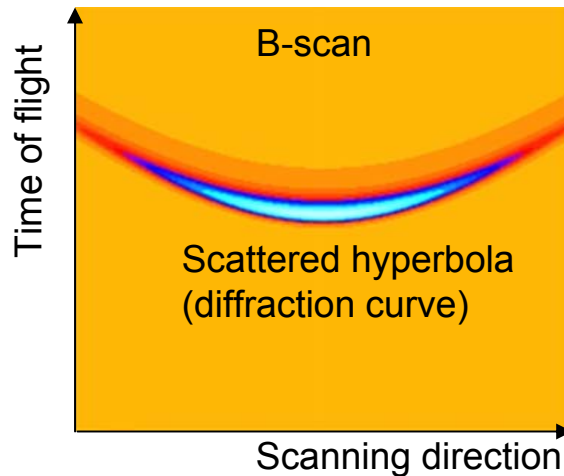


Experimental verification
by pipe tests

- Experimental crack initiation
- Experimental maximum load
- Plastic limit load
- Initiation R6
- ☆ Instability R6

Source: **MPA**
Universität Stuttgart

Diffraction Tomography or Synthetic Aperture Focusing Technique (SAFT) is a solution of inverse problems regarding diffraction phenomena's of scattered signals.

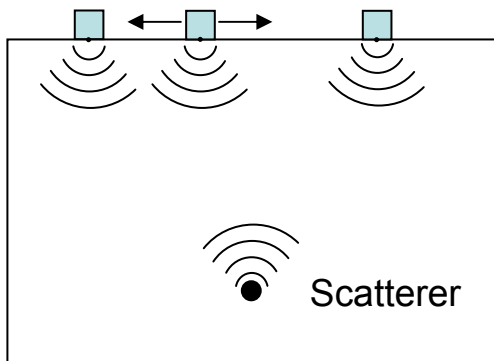


SAFT principle:

Under the assumption that an arbitrary scatterer can be described by a number of independent point sources a reconstruction method can be developed: discretisation of the reconstruction area and calculation of the scattered hyperbola for every pixel coordinate (x', y', z') with the known material sound velocity. Integration of the scalar measured data $\Phi(x, y, z)$ along the hyperbola and storage the integration result in the corresponding pixel.

$$o(x', y', z') = \iint_{S_M} \Phi \left(x, y, d, t = t_0 + \frac{\sqrt{(x_t - x')^2 + (z_t - z')^2}}{c} + \frac{\sqrt{(x - x')^2 + (z - z')^2}}{c} \right) dx dy$$

Transmitter/Receiver



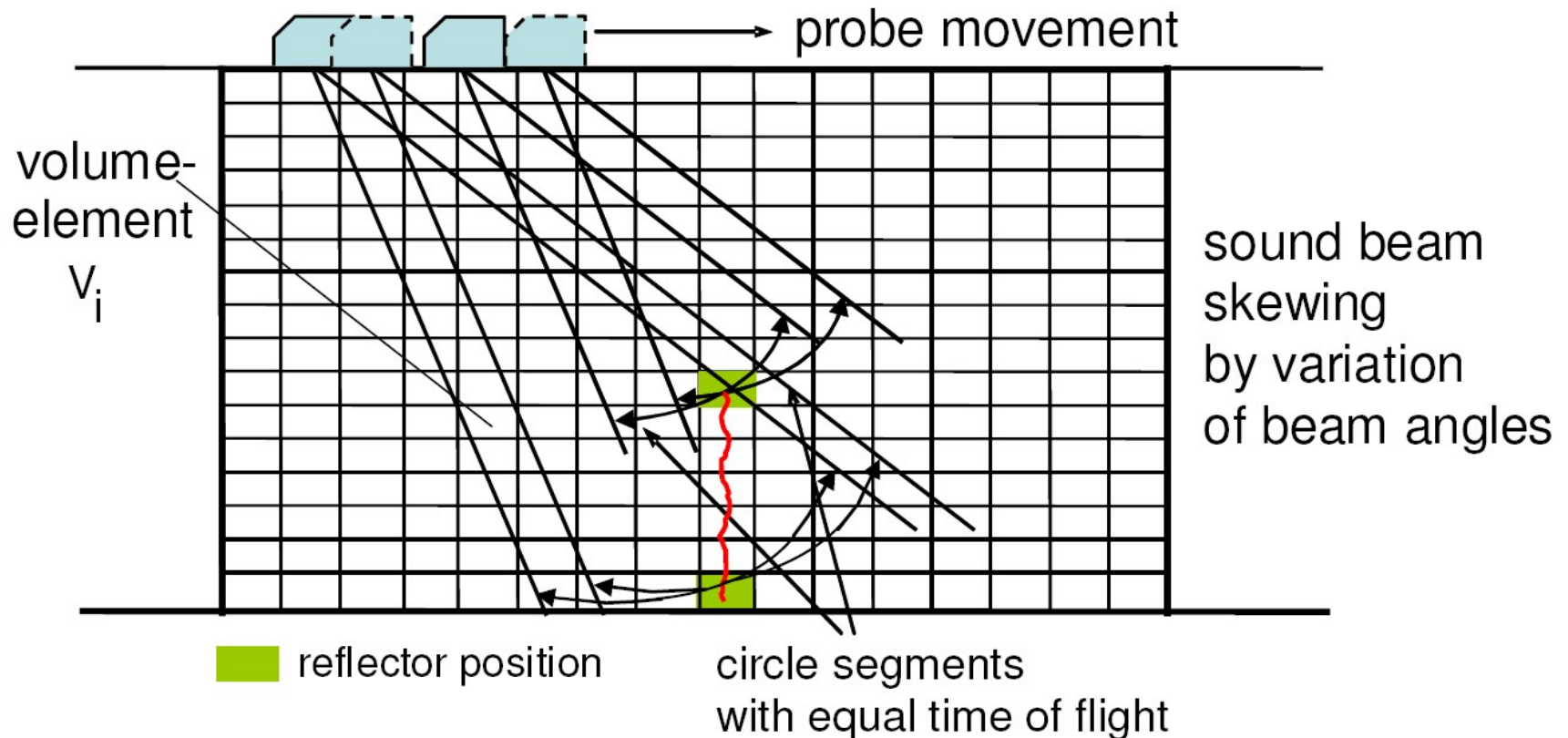
For monostatic measurements i.e. Transmitter and Receiver are not separated the Reconstruction Formula is given by:

$$o(x', y', z') = \iint_{S_M} \Phi \left(x, y, d, t = t_0 + 2 \frac{\sqrt{(x - x')^2 + (y - y')^2 + (z - z')^2}}{c} \right) dx dy$$

Advantage of the SAFT method using phased array UT technology

- Sound beam skewing** → increasing the beam spread angle
- increasing defect information
- increasing resolution
- increasing examination reliability

phased array probe

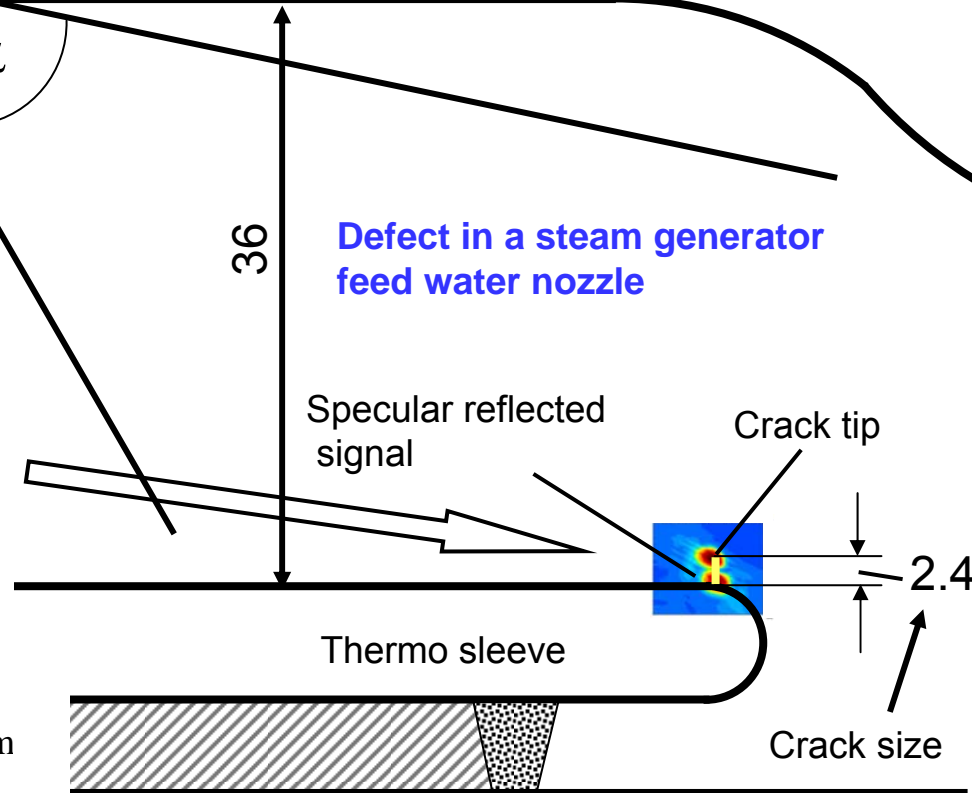
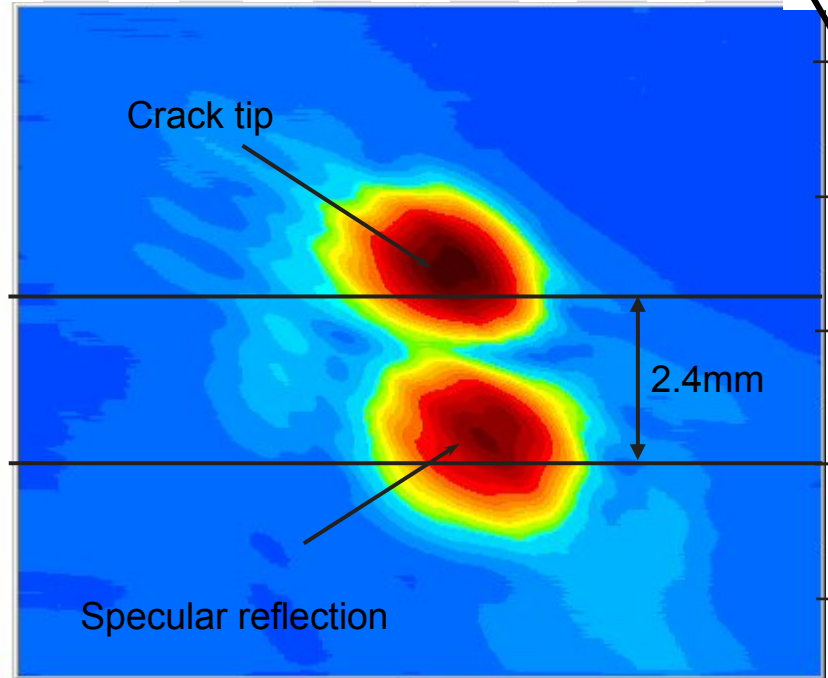


Phased Array Probe

$\Delta\alpha=30^\circ; \alpha_{\min}=30^\circ; \alpha_{\max}=60^\circ, \text{ step width } 5^\circ$

Carbon Steel

-8 -6 -4 -2 0 2 mm $\Delta\alpha$



Defect in a steam generator feed water nozzle

Without further knowledge, perhaps with additional phase information of the signals, a-priory information or information from other nondestructive testing techniques the evaluation will be ambiguous, because the pattern of the images look almost the same if amplitude information were negligible.

- Ageing of material properties of mechanical components will change from the very beginning of plant operation.
- Ageing is a continuous time-related loss of material quality caused by the operating conditions due to different kind of damage mechanisms.
- This circumstances are considered in ageing management, a part of the plant life management by the use of independent redundancies, such as monitoring, non-destructive examination, failure investigations, codes etc.
- Prevention of damage mechanisms and their influence on the components integrity from the beginning of plant operation is essential for management and the assumption for lifetime extension.
- Monitoring and continual improvement by R&D work on possible influences are in accordance with the German **Basis Safety Concept** (BSC).
- The BSC has an overall strategy starting with the quality through production principle: the basis safety. Therefore, the newer German plants fulfil the requirement for lifetime extension although phasing out still exists.