# MECHANICAL ASSESSMENT CRITERIA OF SPENT FUEL ASSEMBLIES BASKET DESIGN

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# OUTLINE

Function And Structure Of Baskets

What Has To Be Verified

Method Of Assessment

Load Assumptions

Experimental Investigations

Mechanical Analyses

# FUNCTION AND STRUCTURE OF BASKETS

Designed for:

Fuel assemblies BWR and PWR

Fuel assemblies from research or test reactors

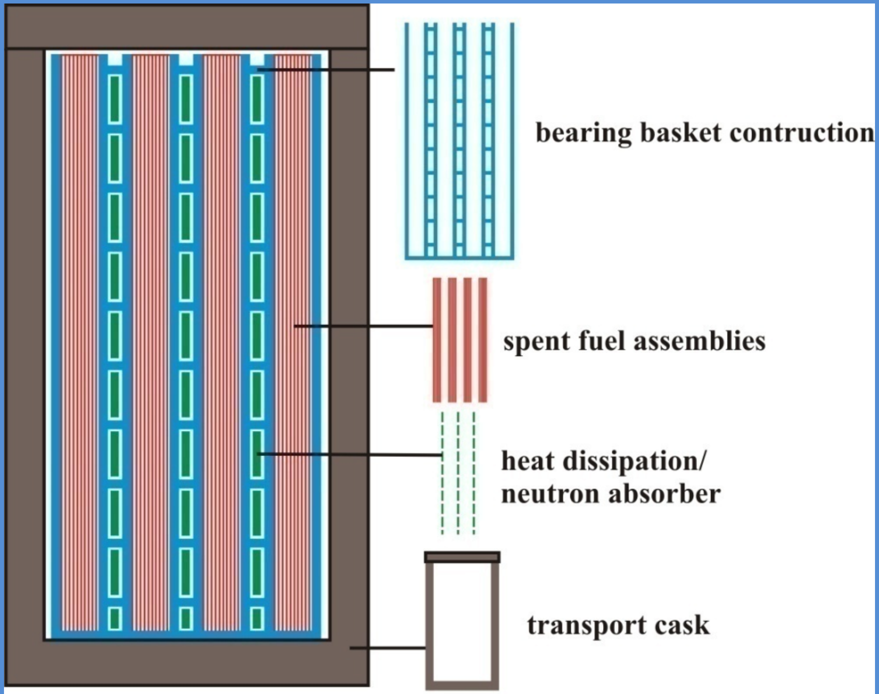
Broken fuel rods or sections of fuel rods

Nuclear Power Plant BIBLIS (GERMANY)

Model Of Fuel Assembly

Transport Cask CASTOR V/19 with basket
source : GNS (GERMANY)

# FUNCTION AND STRUCTURE OF BASKETS




construction of basket
(shematic diagram)

**Bearing Basket Construction**

- metal sheets made of steel or aluminum
- sheets and plates are screwed or welded
- compartments for fuel assemblies

**Heat Dissipation**

- additional aluminum or copper sheets

**Neutron Absorber**

- for neutron absorber used boron alloys

**Damping Components**

- minimize loads e.g. onto lid system

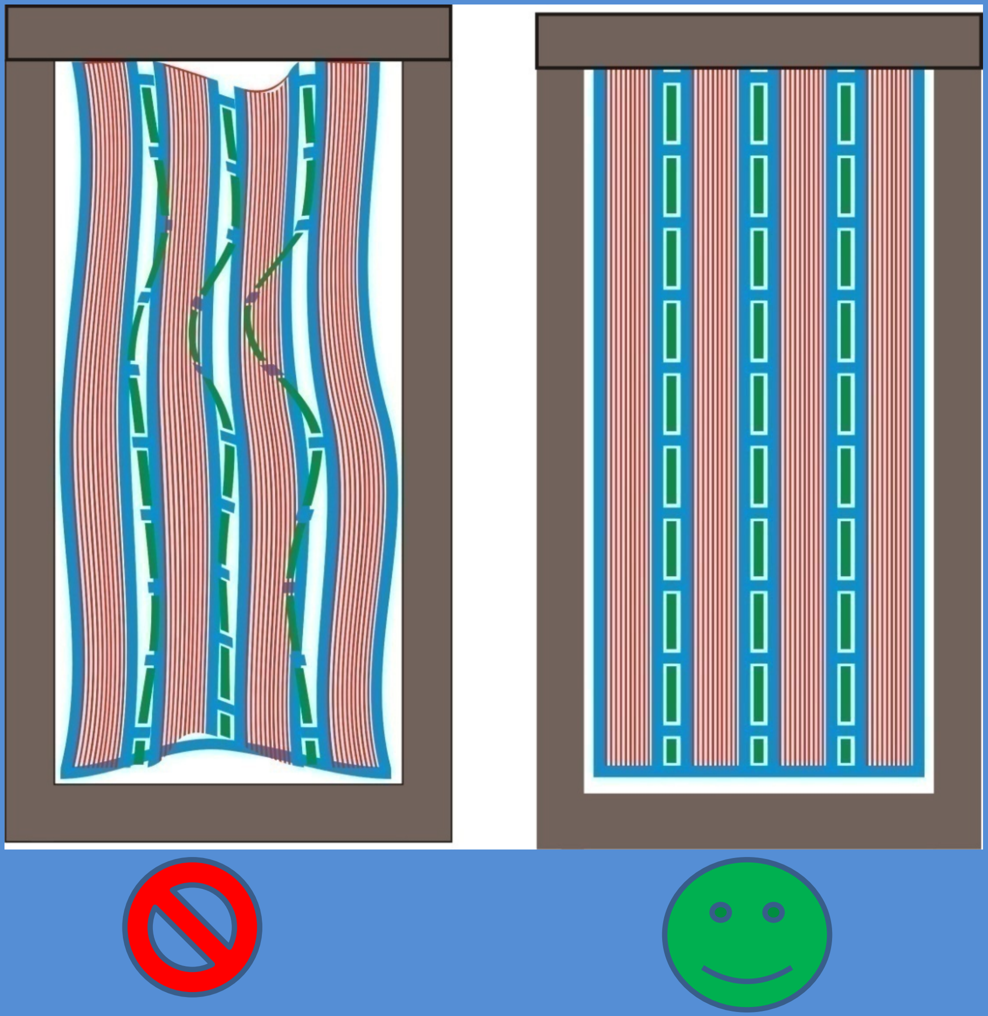
**Corrosion properties**

- due to underwater loading

**Radiation Resistance**

- basket materials

# FUNCTION AND STRUCTURE OF BASKETS



**the main function of baskets**

**exact position of spent fuel assemblies**

**within the cask**

**under**

**Routine, Normal and Accident Conditions**

# WHAT HAS TO BE VERIFIED?

| | Obective | Criteria |
|---|---|---|
| **Mechanical and Thermal-Mechanical Analysis** | structural integrity | no damage of load-bearing components |
| | permanent deformations | correlation with boundary conditions for the criticality safety analysis |
| | gap closing | correlation with boundary conditions for the criticality safety analysis, heat dissipation |
| | safe handling in nuclear power plants | compliance with requirements of KTA 3905 |
| | leak tightness of separate containment systems | correlation with activity release |
| **Thermal-Analysis** | safe heat dissipation | maximum permissible temperatures of the cask components and the content |
| | determination of temperatures for dimensioning | correlation with strength values in mechanical analyses |
| **Quality Assurance** | quality assurance for manufacturing and operation | compliance with requirements of BAM-GGR 011 |

# METHOD OF ASSESSMENT

**TS-R-1 par. 701**

- **test of prototype or specimens**
- **reference to satisfactory demonstrations for sufficiently similar structure**
- **tests with models of appropriate scale, material investigation**
- **analytical and numerical calculation methods**

**Safety Analysis Report (SAR)**

Experience in assessment of SAR shows, that a **combination** of these methods is usually applied.

# LOAD ASSUMPTIONS

**Based on IAEA transport condition according TS-R-1**

## RCT

### mechanical

specific values of accelerations are listed in table IV.1 in TS-G-1.1

special load assumptions for load attachment points for the handling in German nuclear power plants (KTA 3905)

### thermal

decay heat of radioactive content

ambient temperature : -40°C up to 38°C

## NCT & ACT

### mechanical

depend on cask design and have to be determined in each specific case
For example a combined approach is often used in calculations:

- definition of inertia forces based on the calculation of impact deceleration values by analytical methods
- structural calculation performed by quasi-static methods, dynamical effects have to be considered as well (e.g. multiple-mass effect)
- dynamical effects captured by drop test or component investigation

### thermal

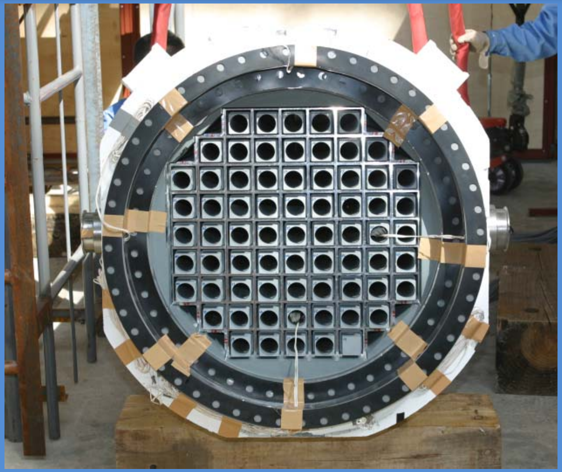
decay heat of radioactive content

ambient temperature NCT: -40°C up to 38°C
ACT: 800°C, 30 minutes
ACT: 800°C, 60 minutes (Typ C package)

# EXPERIMENTAL INVESTIGATIONS

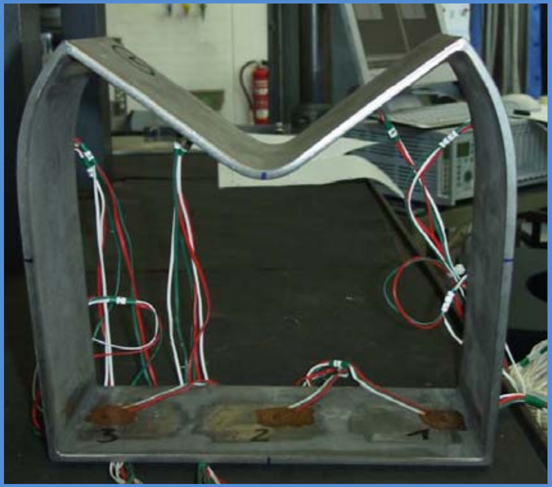
## Categories of experimental investigations

### test of prototypes or models



**scaled model and basket**
drop test program carried out at the BAM drop test facility; drop test model were designed and manufactured by Mitsubishi Heavy Industries, Ltd.

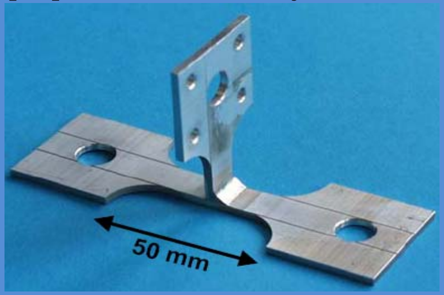
### component tests



**component tests with compartment for spent fuel assembly**
investigation of bending behavior;
test series designed and carried out by
GNS Gesellschaft für Nuklear Service mbH

### material tests

**tensile specimen**
material testing is carried out to get appropriate values of material properties for the analysis.




**investigations of T-joints**
source GNS and Frauenhofer IWM
Böhme.W et al.: Werkstoffprüfung (2007)

# MECHANICAL ANALYSES

### Categories of mechanical analyses

analysis of the structural integrity for load-bearing elements (stress or limit analysis, brittle fracture),

stability analysis and

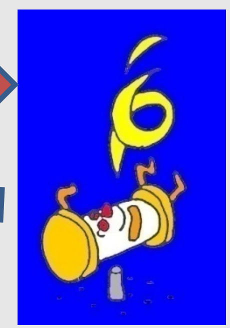
deformation analysis

### Analyses have to consider the combination of conditions of transport


source by Nuclear Cargo + Service GmbH

**Routine Conditions of Transport**

**Normal Conditions of Transport**



**Accident Conditions of Transport**

# STABILITY ANALYSIS

**basket design is made up often as a slender structure**

**therefore stability analysis has to be performed**

buckling loads for simple structure can be found by analytical approaches

complex structure elements are often calculated by FEM

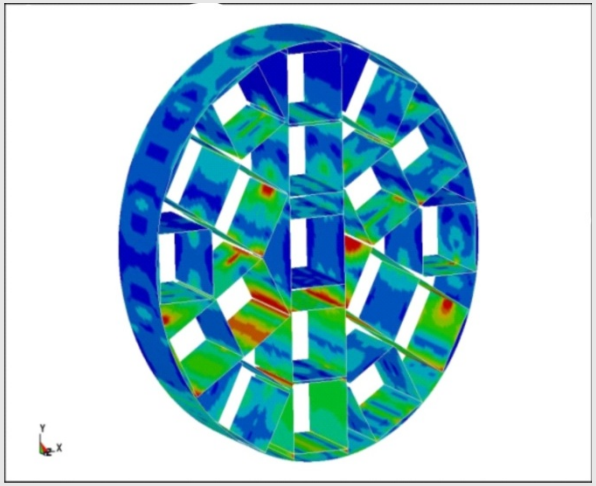
- model with no imperfections by linear-elastic analysis
- model with imperfections with elastic-ideal-plastic analysis

imperfect forms and amplitudes for example can be taken from German standard DIN 18800

for load assumptions the inertia loads of content and basket as well as thermal-mechanical loads are used

# STRESS AND LIMIT ANALYSES

If the materials of load-bearing structure of basket show **sufficient ductility**, the demonstration of **structural integrity** can be carried out on basis of appropriate German standards **like KTA 3201.02**



example of limit analysis with FEM created by GNS Gesellschaft für Nuklear Service mbH

## analysis concept in dependence on KTA 3201.2

Different loading levels and assessment criteria determined in KTA 3201.2 can be used for classification of loading cases of RCT, NCT and ACT.

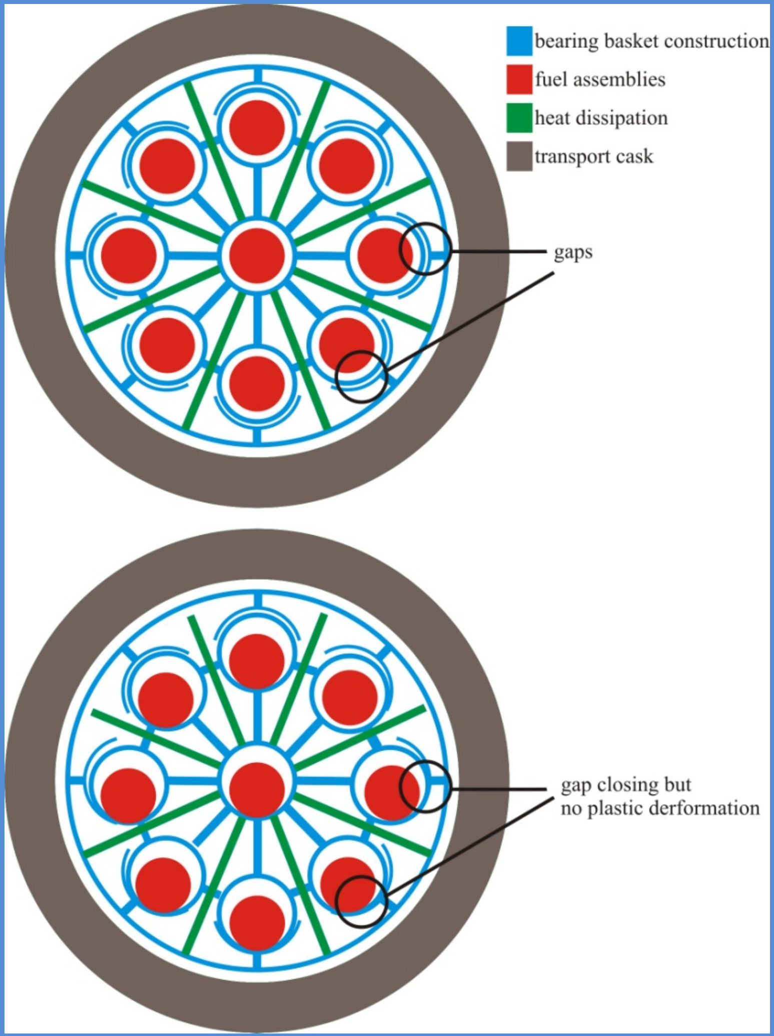
The design stress intensity factor $S_m$ is used for stress limitation in linear elastic stress analysis and for the definition of fictitious yield stress in case of limit analysis.

The $S_m$ value has to be obtained from strength properties of materials and service temperature of components .

For RCT it should be demonstrated by means of linear-elastic stress analysis that no plastic deformations occur.

The level of mechanical loads under NCT and ACT is in general too high for a linear stress analysis, the demonstration of structural integrity can be carried out by limit analysis.

# DEFORMATION ANALYSES




Geometric boundary conditions in criticality safety analysis base on the possible permanent deformations of the basket.

Complex FEA but also analytical approaches can be applied.

- E.g. for vertical drop orientation and simple cross section can be carried out by analytical calculation.

Results:

- approach of single compartment to each other or to the geometric centre of the entire construction
- permanent deformations of single sheets

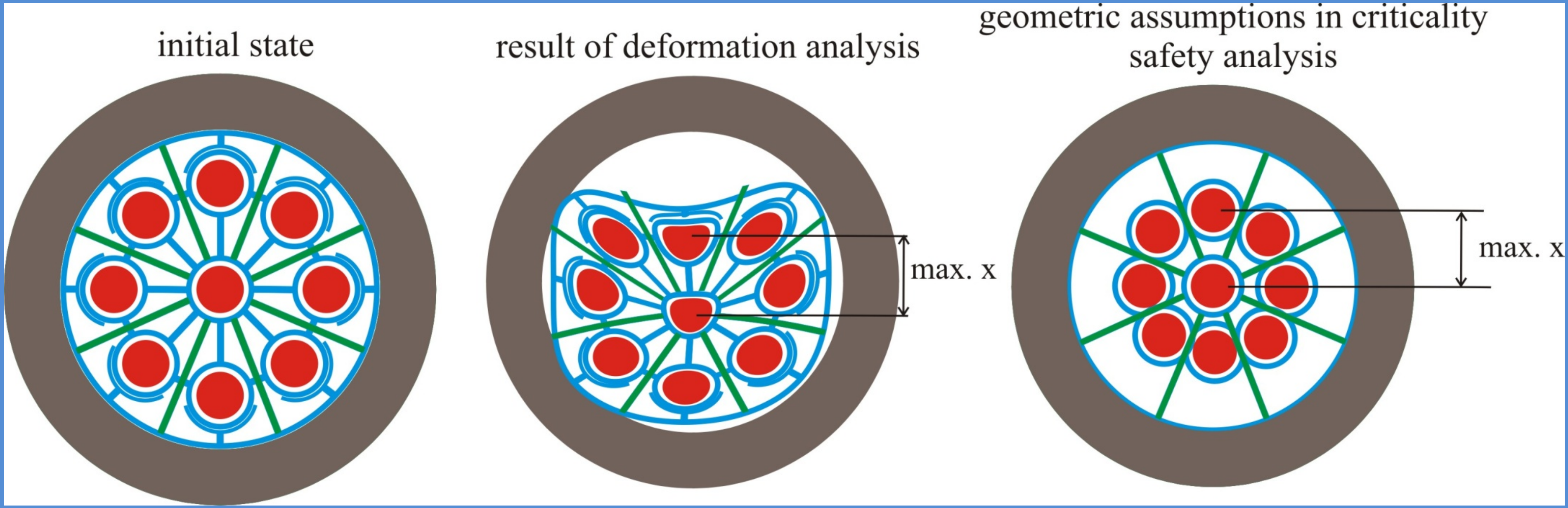
The investigation of possible gap closing in the basket structure under specific loading situations is an additional objective of the analysis Shell elements are usually applied for modeling of slim and slender basket constructions in FEA.

Attention should be paid to correct definition of parameters of contact pairs and boundary conditions. It should be noted that imperfections based upon fabrication tolerances are an influencing parameter for FE calculations.

# DEFORMATION ANALYSES

A reasonable criteria or parameters have to be defined for comparison between results of deformation analysis and geometric assumption in criticality safety analysis.

An example for such a parameters is the radial approach for all box sections to the centre of the basket. In this case the maximum computed value of the approach can be conservatively considered for all construction.



# CONCLUSIONS

The dimensioning of baskets is very complex because the requirements in consideration of the construction are very high. Routine normal and accident conditions of transport have to be considered. Solutions can be achieved by tests or calculations.

In this presentation I tried to give some examples especially to solve mechanical problems by different kinds of calculation.

**Thank you for your attention**