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THE FACILITATION OF CRITICALITY SAFETY ASSESSMENTS FOR FUEL ASSEMBLIES

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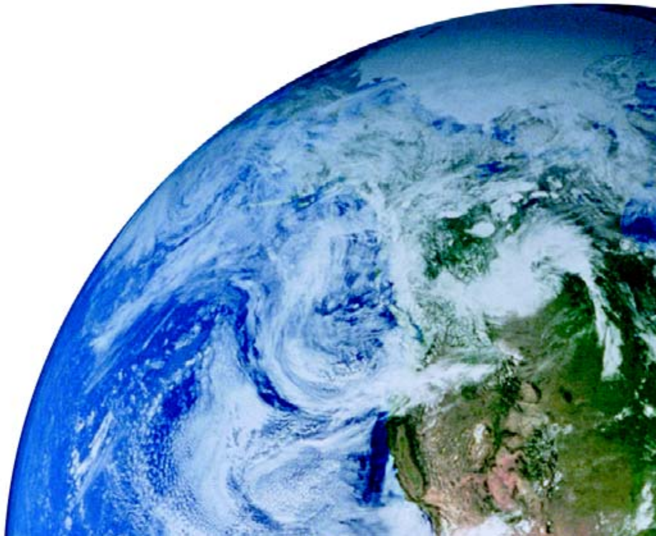

INTRODUCTION

- The application of the TS-R-1 to a criticality safety case may not be straight-forward:
  - can be issues because of data uncertainties
  - may not be clear how best to represent certain aspects of the packaging or fissile contents.
- Major issues are usually concerned with modelling the hypothetical accident conditions, that is: representing state of the package (ie packaging + fissile contents) following the sequence of impact, fire and water immersion.
- The physical consequences of these accidents are usually impossible to predict and model exactly (eg fuel assembly impact damage).
- Therefore for both normal and accident conditions, assumptions need to be made in order to model the state of the package and these must bound reality without being unduly conservative.

INTRODUCTION cont'd

- Unfortunately, the payload of a package can be sensitive to differences in modelling assumptions.
- This can be very important when a minimum payload is required in order to enable operations at a plant to proceed efficiently.
- Given the number of organisations involved in obtaining a full international approval technical, the complexities of criticality assessment and the inconsistencies in assumptions and methodologies, it is not surprising that obtaining a full set of approvals can be lengthy.

WNTI CRITICALITY ASSESSMENT TASK FORCE

- To alleviate some of these difficulties, the WNTI has established a working group of criticality experts from its member companies to explore ways to ease the preparation of criticality safety cases.
- Past experience has shown that using working groups is an efficient way of identifying potential issues, collating relevant knowledge and experience and formulating solutions.
- Specifically the WNTI wishes to:
  - identify ways to facilitate consistency in assessments
  - reduce the effort and shorten the time involved in obtaining approvals.

WNTI CRITICALITY ASSESSMENT TASK FORCE

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- The working method has been for members to submit methodologies and data to the Task Force for consideration.
- Only methodologies that had been accepted by a Competent Authority were reviewed.
- The study aims to identify the major generic factors which must be addressed in the preparation of safety cases by applicants and the assessment by Competent Authorities.
- Not the intention of the working group to prescribe methodologies and data. These matters will depend on the circumstances relating to a particular application.

WNTI CRITICALITY ASSESSMENT TASK FORCE cont'd

Recent work by the WNTI working group has considered topics which are often important to a criticality safety case for new and spent fuel elements, namely:

- Enrichment mapping
- Water ingress
- Burn-up credit
- Deformation of Internal Components
- Safety Margins and Criteria

ENRICHMENT MAPPING

- The fissile content of a fuel assembly may vary radially or axially.
- Discussions with member organisations showed that three approaches to criticality modelling are commonly employed and accepted by Competent Authorities:
  - Actual mapping
  - Average value
  - Maximum value
- All three methods should be acceptable as the basis of a criticality assessment –
- Pros and cons discussed below.

ENRICHMENT MAPPING cont'd

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Actual mapping

- Modelling complexity can be increased over the other approaches, though most criticality codes have special features to simplify the effort needed to represent the pin map.
- Because there is no excess conservatism in this approach, a reduction of the manufacturing cost for the packaging and its basket and/or an increase in payload may be obtained over the other methods. No justification is required for this option because there are no potentially optimistic approximations.
- However consideration needs to be to damaged fuel assemblies; often a bounding enrichment is used to represent displaced fuel pins and fuel debris.

ENRICHMENT MAPPING cont'd

Average value

- All of the fuel pins in the assembly are assumed to have an enrichment based on the average.
- In general, averaging over the fuel assembly will <u>not</u> be a conservative process because the fission rate in regions of high flux can be under-represented. However, this difficulty can easily be remedied by using an "offset" to the average; that is using a value a little larger than the mean.
- Clearly, preliminary work would be needed to establish a suitable enrichment value.
- The advantage of this approach is that the criticality modelling work can be simplified.
- The disadvantage is that the conservatism introduced may result in a reduced payload. Again consideration needs to be given to the means of representing a damaged fuel assembly.

ENRICHMENT MAPPING cont'd

Maximum enrichment

- Using the maximum enrichment to model all of the fuel pins in an assembly is the simplest approach.
- Fuel debris and pin displacement accident conditions also modelled at the maximum enrichment.
- No justification is required because this is clearly a conservative assumption. However, there could be significant penalty in terms of package payload.
- Maybe very conservative with penalty for payload.

WATER INGRESS

- Except for packages with special features, the individual package needs to be explicitly considered in a criticality assessment.
- Member companies were canvassed for the issues that Competent Authorities had shown concerns about:
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WATER INGRESS

Assuming no water ingress

- In order to make a claim for this, multiple water barriers of a high standard must be present in the package. (Residual water, for example from wet fuel assemblies, would need consideration).
- This is not a commonly used assessment route, but package approvals have been given on this basis; these required a high degree of quality control on the production and maintenance of the packagings.

WATER INGRESS cont'd

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Differential flooding or leakage

- The packaging configuration with the greatest neutron multiplication factor does not necessarily occur with complete flooding.
- Intermediates states, such as can occur with partial or differential flooding, or where void spaces are filled with water mists, can prove more reactive.
- The review showed a variety of approaches with some applications assessing all void spaces and others just the main ones.
- In general spaces in the packaging that need consideration include the: Flask cavity, Fuel assembly compartments (including the spaces within the fuel assembly) and Neutron flux traps. There may be other spaces that need to be assessed.

SAFETY CRITERIA

- A criticality safety criterion is always required. For assessments based on the results of modeling with Monte-Carlo criticality codes (nowadays the norm), the general form of the criticality safety criterion is:

$$K + n.\sigma \leq 1 - \Delta Km - \Delta Ku$$

- where: K is the estimate of the neutron multiplication factor produced by the criticality computer code, σ represents the associated standard error associated with the estimate of K and n is a number chosen to give the required statistical confidence.
- Of the remaining factors: ΔKm is the required margin of sub-criticality and ΔKu is an allowance for calculational biases and uncertainties.
- Discussions within the WNTI group revealed some small, but potentially significant, differences. In particular it was found that:

SAFETY CRITERIA cont'd

- **ΔKm** - is a value set by agreement between the applicant and the Competent Authority and is subjective, effectively representing an attitude to criticality risk. For the same fissile materials, some package approvals are based on a value of 0.05 some on 0.02 and others in between. Some approvals use one value for normal conditions and another for accident conditions; whilst others use the same value throughout.
- **n** – This is also a subjective value. Sometimes n = 3 is used; more often the value used is = 2. Using a value of n=3 rather than n= 2, effectively increases the value of K by a $\Delta K = \sigma$.

SAFETY CRITERIA cont'd

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- **ΔKu.** The treatment of biases and uncertainties is also governed by judgment (always to some extent) and showed the largest range of approaches.
- In some applications, statistical errors were simply added together, in others all of the errors (including σ) were added in quadrature.
- Some assessments were not statistically consistent.
- Some applications used professional judgment for setting nuclear data error terms, whereas others used sophisticated techniques based on sensitivity analysis.
- These differences seem quite small, but they can have a significant effect on K, and therefore on payload, particularly in systems which are close to the safety criterion.

CONCLUDING REMARKS

- Criticality safety assessments for transport packages frequently rely on complex inter-disciplinary safety justifications.
- It is perhaps not surprising that often they need a lot of high level-effort from both applicants and regulators.
- It's also not surprising that there may be inconsistencies in the approaches preferred by the applicants and the various Competent Authorities involved in the approval process.
- Protracted discussions and rework are not uncommon, resulting in high costs for all and delays in the transport.

CONCLUDING REMARKS cont'd

- The World Nuclear Transport Institute considers that these difficulties could be alleviated by a more efficient approach to criticality safety case preparation; that is by encouraging the use of internationally consistent methodologies, data and assumptions.
- A first step in this process is to understand the range of differences in the approach to transport criticality assessments.
- A working group, established by the WNTI, has been busy reviewing the various approaches that have been successfully employed by the member organization in gaining package approvals.
- This paper summarises some of the recent findings by the group in this respect, in the assessment of new and spent fuel.