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Design Safety Limits for Transients in a Metal Fuelled Reactor

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To provide rapid growth and faster deployment of fast breeder reactors in future, metal fuelled reactors are planned. The Design safety limits (DSL) for normal and anticipated transient events are arrived at for a typical 500 MWe metal fuelled reactor, which is addressed in this paper.
All the design basis events occurring during the lifetime of the components concerned are classified into four categories based on the frequency of occurrences. The design approach followed in determining the DSL limits for clad is that the pin is deemed to have failed if Cumulative Damage Fraction (CDF), based on creep rupture data under operating pressure & temperature conditions, reaches 1.0. This CDF limit is applied uniformly across all the categories, viz., CDF of 0.25 is to be respected for each of the category –1, 2 & 3 event and the rest 0.25 is allocated for SA during handling & in internal storage. In order to estimate the temperature limits for clad, the time of transient events for which the clad has to withstand the given temperature is considered as 30 minutes for category-2 event and 2 minutes for catergory-3 events which is based on the occurrence of events.
The failure mode in a metal fuel pin is primarily due to swelling, fission gas pressure loading and due to the thinning of clad (because of eutectic formation between fuel and clad at high temperature). In order to arrive at the temperature limits, the temperature dependent liquid penetration rate into the cladding and hence the thinning effect are considered along with the end-of life fission gas pressure loading on the clad. The creep rupture properties of T91 are taken from RCC-MR code after accommodating for irradiation effects.
Based on the analysis, for category-2 event, the clad inside hotspot temperature is limited to 993 K and for catergory-3 events, it is restricted to 1043 K and category-4 event, it is restricted to 1243 K. Similarly, the limits for fuel and coolant are also arrived at. These limits will be fine tuned based on the out-pile and in-pile experiments planned in the future.

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