A Review of Core Catchers for Advanced Reactors

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A REVIEW OF CORE CATCHERS FOR ADVANCED NUCLEAR REACTORS

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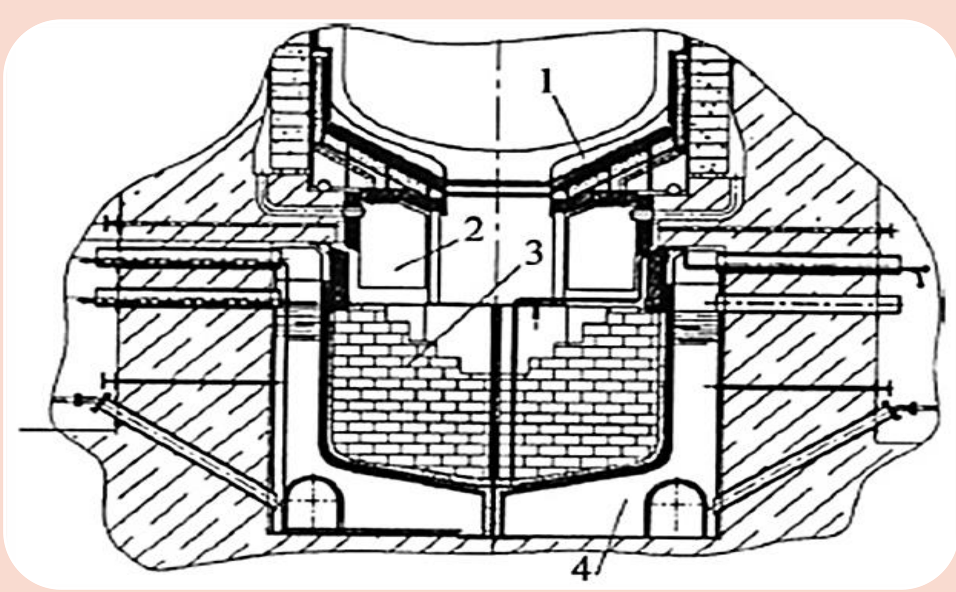
BACKGROUND

- Core melting during severe accident scenario is one of the major concerns due to its radioactivity, chemical reactivity and temperature.
- Coolability and stabilization of corium are the major objectives for severe accident management in nuclear reactors to prevent failure of reactor pressure vessel.
- Severe Accident with Colt Meltdown can be initiated by
  - LOCA + Loss of Emergency Cooling System
  - Extended SBO
- As a counter-measure for the severe accident leading to core meltdown, the implementation of a core-catcher device in existing and future types of nuclear power plants is envisaged. Such a core-catcher has to securely enclose the melt and guarantee long-term heat removal and thereby preserve the containment integrity.

DESIGN OBJECTIVE	CORE CATCHER	Relocation of the solid and liquid parts of the melt, core fragments and structural materials of the reactor i.e. Corium
		Maximum transfer of heat removal from the molten corium to cooling water
		Limiting the spreading of the molten materials beyond the boundary of the design
		Maintain the sub-critical conditions of the corium during the severe accident management
		Minimize the gases products, such as hydrogen, release to prevent the increase of pressure in the containment and avoid the steam explosion scenarios
		Limiting the stress to a permissible level on the structural materials
		Minimize the intervention from the operational staff
		Able to cool the molten corium for a long period of time and should be able to protect the structural materials from destruction during this period
	SACRIFICIAL MATERIAL	To reduce the temperature level in the final melt by endothermic interaction between the corium melt and the sacrificial material.
		To reduce the specific volumetric heat release and the heat flow rate over the melt boundaries due to melting of sacrificial material in the corium.
		Due to a change in the density of the oxide component an inverse stratification of the oxide and metallic layers occurs, with the upward re-location of the oxide layer.
		To exclude second criticality of the mixture due to high absorbing properties of the sacrificial material (addition of neutron poison)
		The release of gases and aerosols is reduced.

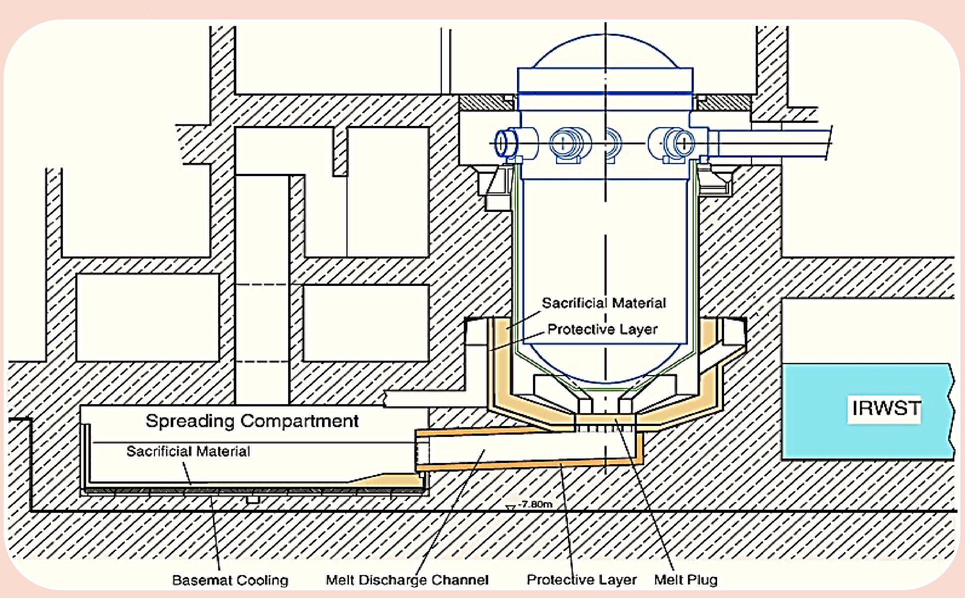
TYPES OF CORE CATCHERS



1. The ex-vessel corium catcher for VVER consisted of a big crucible located in the reactor pit beneath the RPV.

2. In case of a RPV failure, the corium will be collected in the crucible which is cooled externally by flooding of the reactor pit by passive water injection.

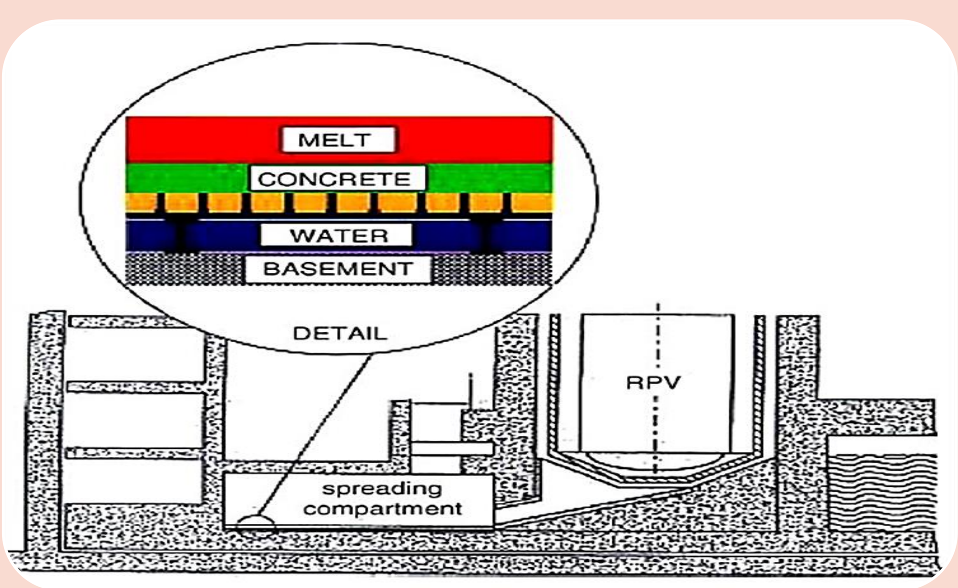
3. The crucible is partly filled with sacrificial material (a mixture of sintered iron oxide and alumina) which melts and mixes with the corium, reducing the power density in the melt and yielding heat fluxes at the surface of the crucible below the critical heat flux which can be removed by the external cooling



1. The corium melt is collected in the reactor pit, conditioned with sacrificial concrete and subsequently spread onto a large surface of a special compartment in order to obtain a thin layer that can be cooled by addition of water from the top.

2. In MCCI analysis, which was validated by appropriate experiments, illustrated that for the given sacrificial concrete thickness of 50 cm, the lower head of the RPV will always fail long before the end of the retention period.

3. The concrete cover of the plug is an integral part of the sacrificial layer of the pit. The gate will therefore be contacted by the melt when the axial erosion approaches the level.



1. After erosion of a sacrificial concrete layer, the melt is passively flooded from the bottom by injection of coolant water.

2. The water is forced up through the melt, the resulting evaporation process of the coolant water breaks up the melt and creates a porously solidified structure from which the heat is easily removed.

3. The porous melt is expected to solidify within less than 1 h from onset of flooding, and continuous boiling removes the decay heat from the permanently flooded corium bed.

CONCLUSIONS

- **Core Catchers are Proprietary**
  - **Core Catchers are divided in two categories depending on the location of its placement, viz., In-vessel (placed in side the Reactor Pressure Vessel) and Ex-vessel (placed in side the containment but outside the Reactor Pressure Vessel).**
  - **Although bottom flooding is an effective strategy to ensure melt coolability, there is a possibility of rapid containment pressurisation due to prompt quenching of melt and associated steam formation. Hence, the strategy of top flooding and side indirect cooling of core catcher can be incorporated.**
  - **Sacrificial Material is completely soluble in molten corium.**
  - **Combination of Iron Oxide and Aluminium Oxide is most suitable material for Sacrificial Material.**
  - **Use of Sacrificial Material will prevent the metal water reaction and generation of non-condensable gases, hence depressurization of the containment.**
  - **The phenomenology of melt inversion will lead to entrapment of the radioactive nuclides in core catcher it, this ensuring the safety of the environment.**

SHORTCOMINGS

- **Mechanism of Interaction of Corium With Sacrificial Material**
  - **Understanding the phenomenology of thermal ablation of oxidic sacrificial material with the molten corium and kinetics of chemical interactions**
  - **Understanding the phenomena of melt inversion during operation of core catcher**
- **Spreading of Melt In The Core Catcher**
  - **Understanding the spreading and distribution of flux at various locations of core catcher and Optimization of the arrangement of the bricks based on the understanding**