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SEVERE ACCIDENT RESEARCH

Where Have We Been?
Where are we?
Where do we need to go?

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Where Have We Been?

Approximate Time	Studies	Important Phenomena
1975	Reactor Safety Study	Steam explosions, MCCI.
1979	Post TMI-2 Analyses	Hydrogen generation and combustion.
1985	Tube Rupture Events	RCS natural circulation.
1988	Individual Plant Examinations (IPEs)	DCH, MCCI, Mark I Liner and fission product revaporization.
1995	Severe Accident Management Guidelines	Incorporation of the above understanding into accident response.
1998	ALWRs and Evolving Designs	Incorporation of the above understanding into the design.

<u>Where Are We?</u>

1. Research on steam explosions and the α mode failure enabled the NRC to assess the importance of this phenomenon through the Steam Explosion Review Group (SERG). It was concluded that in-vessel steam explosions were far less likely to challenge containment integrity than the 10^{-2} value used in the RSS.

Where Are We?

2. Studies on hydrogen deflagration and detonation demonstrated that:
   - containment could be inerted with N_2,
   - igniters can be used to locally burn the hydrogen present and prevent accumulation to high concentrations,
   - approximately half an atmosphere of steam in the containment atmosphere will inert a mixture of any concentration,
   - turbulence caused by containment sprays can increase the burning rate from a trivial value to essentially an adiabatic burn as long as the system is not inert,
   - in non-inerted containment systems it is difficult to accumulate to very high concentrations due to the small ignition energies needed.

Where Are We?

3. Studies on the thermal challenges to a Mark I containment liner following a postulated RPV failure show that the combination of energy transfer to the drywell floor, water in the drywell and the liner wall itself would cause crust formation of the debris. This would limit the energy transfer to the liner sufficient to prevent early failure.

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4. Multiple scale experiments on DCH have illustrated that the pressurization from such events would be limited by the containment geometry. Scaling evaluations of the test results applied to large dry and subatmospheric containments show that virtually all systems are sufficiently robust to contain such events.

Where Are We?

5. Initial MCCI experiments were performed in the absence of an overlying water layer. These showed that the ablation rate could be represented by relatively straightforward models. These can be used to evaluate the shortest interval before the containment integrity could be challenged due to overpressurization or basemat melt-through.

   Subsequent experiments with an overlying water layer show these to be very difficult experiments. Those performed to date show that some, but not all, of the decay power is transferred to the water. Most importantly these show that the water is very effective in scrubbing fission products released during the MCCI.

<u>Where Are We?</u>

6. Analyses and experiments have demonstrated that deposited fission products can heatup the surface sufficiently to revaporize the radioactive material. Severe accident evaluations need to include this potential for continued mobility.

<u>Where Are We?</u>

7. Experiments and analyses on natural circulation flows generated by the high temperatures of a core damage event illustrate that these flows could transport high temperature gases to the steam generator tubes for PWR designs with inverted U-tube generators. Integral evaluations show that a key element in this transport is the energy transfer to the hot leg as well as the mixing of hotter and cooler gases in the SG inlet plenum. Rupture of the hot leg due to material creep would limit the energy transport as would intentional depressurization of the RCS by operator action. (Hot leg creep rupture tends to precede other failures due to material creep.)

Where Are We?

8. Emergency Operator Procedures (EOPs) and Severe Accident Management Guidelines (SAMGs) have incorporated the extensive severe accident research into the plant specific implementation of these tools considering (a) the spectrum of potential accident states and (b) the available instrumentation for the operators.

Where Are We?

9. ALWR and evolving design have incorporated this extensive research into their design through:
   - passive cooling systems (RCS and containment),
   - enhanced depressurization capabilities,
   - external cooling of the RPV lower plenum and the cylindrical part of the vessel, and
   - dedicated cooling capabilities for core debris in containment.

Where Do We Need To Go?

1. With the increasing needs for power, we need to continue improving best estimate type of analyses to more accurately represent margins.
2. Improved diagnostic tools will help decision makers response appropriately during an accident. This will minimize confusion and maximize the influence of actions taken.
3. Need to be continually vigilant that the EOPs and SAMGs are consistent with the current understanding of severe accident progression.
4. Continue investigating long term debris cooling conditions for both in-vessel and ex-vessel.

Where Do We Need To Go?

5. Continue to investigate the chemical forms of fission products that could be formed, both in-vessel and ex-vessel, and how this could influence the airborne fission products in the containment atmosphere and possible releases.
6. Most importantly, we need to be vigilant in documenting and using (benchmarks) the extensive severe accident data base that has been developed. Moreover, we need to be vigilant in educating new engineers and scientists on the results of key experimental studies and industrial experience and what these mean in terms of reactor system design and operation.