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Fuel Retrieval and Management of Fuel Element Debris

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Summary from Co-chairs

Session Theme

Nuclear accidents involving core meltdown have not been so rare. While the first occurred in early fifties, it is reported that about 20 have occurred worldwide in military and commercial reactors. The more recent and major accidents are

1. Three Mile Island, USA in 1979: Approximately half the core was melted, and flowed to the bottom of the reactor pressure vessel however the pressure vessel remained intact and contained the damaged fuel.
2. Chernobyl, former USSR in 1984: Explosive release of radioactive material occurred. About 6 tons of fuel was dispersed as air-borne particles. Most of the core was damaged or melted.
3. Fukushima, Japan 2011: Three units suffered melt down. In unit 1 almost all the fuel assemblies melted and accumulated at the bottom of the vessel. It is reported that the vessel failed and the molten corium has penetrated the concrete. In the units 2 and 3, partial melting of cores has occurred.

In several of these cases, fuel retrieval and management activities have been carried out. The experience and insights gained from these activities will be extremely useful for planning and execution of similar activities in future if ever they are needed. The purpose of this session was to exchange this experience and also to share the lessons learned. This is of particularly important, at this juncture, when planning and preparation for retrieval of damaged cores in Fukushima NPP is in progress.

Papers presented in the session

In all, five papers were presented in the session. While three of them dealt with retrieval of damaged fuel, the remaining two covered management of damaged fuel after removal. The paper by R. Green, USA described in detail the post accident defueling of TMI unit 2. S. Szucsan of Hungary described removal of damaged fuel assemblies from the cleaning vessel at Paks NPP and its transfer for safe storage in the spent fuel pool of the NPP. In another paper, C.Negin of USA highlighted the challenges for removal of damaged fuel based on the TMI experience.

In the other two papers on management of damaged fuel, while S. Bourg of France very systematically brought out the options available for management, Burakov of Russia provided details of material studies carried out for characterization of "lava" and hot particles from Chernobyl's damaged core.

Some of these authors were actually involved in these activities and hence spoke from personal experience in great detail.

Last hour of the session was devoted to discussion on specific issues related to the theme of the session.

Key observations, issues and comments

Based on the presentations and discussions that followed in the session following observations, concerns and issues are brought out.

1. Irradiated fuel is extremely radioactive and chemically complex in nature. During and after an accident its safe containment is a major concern. It needs to be kept subcritical and cooled continuously. (In light water reactors the fuel is not in the most critical configuration; unlike heavy water reactors) After meltdown its exact configuration and composition is not known. Consequently any intervention has the potential risk of re-criticality due to change in configuration. The molten core is also an enormous source of radioactivity containing trans-uranium elements and fission products. Some of these radio-nuclides have very long half life. Hence any attempts of intervention or retrieval, even after a long time, have to be carried out remotely and carefully.
2. Each core melt down accident is different. The differences come from the type and composition of fuel, the quantity of fuel in the core, cladding and other structural materials and moderator (e.g. graphite) in the core, the extent to which the accident has progressed, the intervention measures used during the mitigation of the accident (for example, use of sea water, sand, lead boric acid etc). These differences will make each retrieval method different and specific to the conditions for that accident
3. In the overall scenario of recovery from an accident, fuel retrieval and management has very little impact on remediation measures for the off-site areas. However, successful retrieval of fuel and its storage or disposal at a safe place away from the NPP site will have positive impact on the on the affected community.
4. In case of TMI, retrieval of fuel was taken up after 5 years and completed in about 10 years. In case of Fukushima also, as per the current plans, retrieval of molten cores is proposed to begin in 10 years. In several other accident cases no action regarding retrieval has been taken for decades. The decision when to take up retrieval of fuel will depend on specific situation. However some factors that need to be considered are
    a. Safety of the molten core i.e. possibility of recriticality, radiological conditions,
    b. Stability of the structures supporting/ containing the accidented core
    c. Other factors such as possibility of accelerated corrosion or self disintegration of the lava as observed in some cases

Important lessons from the experience

Though each case of retrieval and management of fuel debris is substantially different, following important lessons can be learnt

- Characterization of core is essential before planning any retrieval/intervention
- Hostile conditions require remote handling technologies and tooling.
- Tools need to be simple, reliable and adaptable to provide flexibility in the face of surprises. They should also be easy to decontaminate

- Adequate shielding, ventilation and lighting is essential for safety and convenience of workers
- Full scale mock-ups are essential for testing of tools, validation of processes and training of workers.
- Appropriate containers are needed for transfer, storage and shipping in case it is planned
- After retrieval the fuel debris could be stored on site, shipped for offs-site storage or processed for long term storage/disposal
- In- situ storage or entombment could also be an option in some cases.

Recommendations

Considerable experience has been gained around the world in the area of retrieval and management fuel debris after an accident. Collecting and documenting this experience will not only be useful for Fukushima but is essential for knowledge preservation.