Intelligent damage mitigation for BWR nuclear reactors

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ABSTRACT: This paper deals with light water reactor, particularly BWR type nuclear power plants, similar to Fukushima Dai-ichi Nuclear Power Plant with reactors equally vulnerable to core-melt accidents. It first reiterates the observations and assertions made by Shinozuka (Shinozuka 2012) to recognize that the core-melt is the most critical damage event that must be mitigated by aggressive mitigation procedures if it cannot be prevented. In this regard, it is noteworthy to observe that U.S. Nuclear Energy Institute (NEI) recently introduced a procedure FLEX (NEI 2012) for emergency preparedness. This paper however proposes a different procedure as promoted by Shinozuka earlier (Shinozuka 2012) which is now named "Direct Core Cooling System" (DCCS). DCCS is developed making use of mobile closed-circuit water chilling system in such a way that pumps, a part of this system, are (1) directly connected by pipes to the core, (2) while minimizing their connections with any other reactor components. (1) and (2) above indicate the care that must be exercised not to get trapped by 3 pitfalls related to such connections. Any one of these pitfalls if trapped can compromise effectiveness of DCCS. The mobile water chilling system is originally introduced to similar line of research by Cheung (Cheung 1991 & 2012). The cooling action by DCCS takes place as soon as intelligent sensors in the sense of engineering cybernetics detect initial sign of core-melt, and contain the core-melt leading it to a cold shut down.

1 INRODUCTION

After the bitter catastrophe experienced following the failure of Fukushima Dai-ichi Nuclear Power Plant, the world is faced with a difficult decision to make: whether or not to accept continued operation of existing nuclear power plants including those of BWR vintage similar to Fukushima Dai-ichi Plant with reactors equally vulnerable to core-melt accidents. Discussion for pros or cons on this issue will never end. However it is realistic to recognize that some of these plants will continue to operate. These plants are expected to continue to reliably generate substantial CO2 free electric power to help sustain regional, national and eventually worldwide economic activity. At the same time, however, it is prudent to consider potential core-melt accident in these plants and develop procedure to prevent or mitigate the disasters resulting from the core-melt accidents. The most important among these disasters is radioactive contamination of various forms that can disperse air and waterborne over wide regional areas for a long period of duration. The waterborne dispersion can take place through underground paths possibly contaminating rivers, the sea around the plants. In the case of Fukushima Plant event, even two years, after the event, there still are hundreds of thousands of evacuees and the displaced due to Fukushima Plant event still remain far away from their homes because of real or perceived health risk of radioactive contamination. This widely dispersive nature of the radioactive contamination implies that even the nationwide closure of nuclear power plants may not guarantee complete avoidance of radioactive contamination because the contamination originated elsewhere can visit the nation by air, water, and sea borne dispersions. It is particularly for this reason that this paper considers the core-melt as a critical nuclear power plant damage that must be prevented or aggressively mitigated. For this purpose, this paper introduces a system DCCS (Direct Core Cooling System). Currently the design strategy for nuclear power plants against natural and manmade hazards is to demonstrate analytically and experimentally that the plant is safe against extremely devastatingly hazardous but extremely rare events of natural and manmade origin. Unfortunately this strategy does not consider direct protection of the reactor core. Furthermore, this strategy is highly vulnerable to 3 pitfalls associated with current power plant design. DCCS does provide the desired protection "independent" of the state of damage, if any,