Abstract

In case of a severe accident in a NPP fission products are released from the degraded fuel and may reach the environment if their confinement is lost and/or bypassed. Given the high radio-toxic nature of nuclear aerosols for environment and population, their unrestricted release should be absolutely avoided.

One particular situation is the core meltdown sequence with steam generator tube rupture (SGTR). The containment bypass turns this sequence into an indispensable scenario to model when assessing PWR risk. As a result, a significant database on the aerosol behavior in the secondary side of the steam generator (SG) has been developed within the international projects EU-SGTR, ARTIST and ARTIST-2. The role played by the break stage is particularly significant since it might be responsible for a good fraction of the total mass retained and for the shift of the particle size distribution towards smaller diameters. This awoke the interest in the effect of variables such as the particle nature, the breach type (size and shape) and the tubes vibration on the particle retention within the breach stage of a dry steam generator. Those aspects have been experimentally investigated in the first part of this thesis.

Two experimental campaigns, CAAT2 and SET, were conducted in order to explore the potential influence of the particle nature on their retention. Moreover, the effect of the breach size and shape has been investigated in the CAAT2 campaign while the SET experiments were devoted to the tube vibration characterization and the effect of the vibration on the particle retention. The tests conducted highlighted several key insights: the strong effect of particle nature in the secondary side capability to scrub the particle-laden gas; the confirmation of the high retention efficiency when using compact particles and the significant one when using agglomerates; the similarities between guillotine and fish-mouth breaches in terms of efficiency, but their noticeable different deposition patterns; and the secondary effect of the breach size. Finally, the tube vibration is not as significant as the particle nature effect on the net deposition.

The second part of the thesis is focused on the fraction of particles susceptible of leaving the containment in case of a severe accident regardless of the SGTR sequence. Accidents like Fukushima highlighted the importance of relying on efficient mitigation systems capable of reducing any release to the environment as much as possible. Although many reactors worldwide had installed filtered containment venting systems (FCVS) the interest in FCVS and even other mitigation systems has become of outstanding importance in nuclear safety. This is the frame of the PASSAM project in which an experimental sound database is being built to explore potential enhancement of existing source term mitigation devices and demonstrate the ability of innovative systems to achieve even larger source term attenuation. As a matter of fact, particle agglomeration processes via the propagation of acoustic vibrations through a gas could be applied for a better decontamination. High-intensity acoustic fields applied to an aerosol induce interaction effects among suspended particles, giving rise to successive collisions and agglomerations, resulting in larger particles that can be more easily removed or precipitated.

The mitigative system acoustic agglomerator was built-up and tested in the AAA experimental campaign. The tests were conducted under a constant ultrasonic field with aerosols of different nature and size with different gas mass flow rates. The results pointed out two main insights: the small acoustic-agglomeration effect and the key effect of the gas mass flow rate and the aggregation state of the former particles in the agglomeration process. This research is the first approximation on the application of the ultrasonic chamber as an innovative system for the source term mitigation. However, a broader experimental database is needed for proper assessment of this technology.

In summary, this thesis is based on two experimental initiatives, one investigating aerosol retention and the parameters that influence it (in particular, the particle nature, breach type and tube vibration) in the secondary side of a dried-out SG and the other on acoustic enhancement of aerosol agglomeration. The results of the vibrational and acoustic-agglomeration aspects of this work comprise particularly novel contributions to the nuclear-safety field.