Progress in Understanding Key Aerosol Issues

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Summary

The 6th FWP SARNET project launched a set of studies to enhance understanding and predictability of relevant-risk scenarios where uncertainties related to aerosol phenomena were still significant: retention in complex structures, such as steam generator by-pass SGTR sequences or cracks in concrete walls of an over-pressurised containment, and primary circuit deposit remobilization, either as vapours (revaporisation) or aerosols (resuspension). This paper summarizes the major advances achieved.

Progress has been made on aerosol scrubbing in complex structures. Models based on empirical data (ARISG) and improvements to previous codes (SPARC) have been proposed, respectively, for dry and wet aerosol retention, but, further development and validation remains, as was noted during the ARTIST international project and potential successors. New CFD models for particle-turbulence interactions have been developed based on random walk stochastic treatments and have shown promise in accurately describing particle deposition rates in complex geometries. Aerosol transport in containment concrete cracks is fairly well understood, with several models developed but validation was limited. Extension of such validation against prototypic data will be feasible through an ongoing joint experimental program in the CEA COLIMA facility under the 6th Framework PLINIUS platform.

Primary deposit revaporisation has been experimentally demonstrated on samples from the Phebus-FP project. Data review has pinpointed variables affecting the process, particularly temperature. Available models have been satisfactorily used to interpret separate effect tests, but performing integral experiments, where revaporisation is likely combined with other processes, still pose a difficult challenge. Further experimental data as well as modelling efforts seem to be necessary to get a full understanding. Resuspension, sometimes referred to as mechanical remobilization, has been recently addressed in SARNET and although a set of models were already available in the literature (i.e., Rock'n Roll model, CESAR, ECART), further work is needed to extend current capabilities to multi-layer deposits and to produce simplified, but sufficiently accurate, models. A major remaining uncertainty is the particle-to-particle/wall adhesion and its dependence on microscale roughness. Data from the previous EU STORM project have been retrieved and further experiments designed for code validation are being used to benchmark the models.

A. INTRODUCTION

Aerosol phenomena during postulated severe accidents have been extensively investigated worldwide (Ref. [1]). As a result, a reasonable understanding has been achieved and current models in integral and system safety codes can be considered mature enough, their interface with thermal-hydraulics playing a key role in their accuracy. Nevertheless, a PIRT assessment in the 5th FWP EURSAFE project highlighted some remaining issues that needed further investigation (Ref. [2]). These are: retention in complex structures, such as steam generator tube rupture (SGTR) sequences resulting in containment by-pass, leakage through cracks in concrete walls of an over-pressurised containment, and primary circuit deposit remobilization, either as vapours (revaporisation) or aerosols (resuspension). The PIRT noted the potential or these processes to increase the source term (except for SGTR studies) and the absence of proper models in source term evaluation codes.

Consequently, the 6th FWP SARNET project launched a set of studies to enhance the understanding and predictability of scenarios where those phenomena could play a role (Ref. [3]). This paper summarizes the progress achieved. Additionally, as in other SARNET areas, one of the most significant outcomes has been database pooling. Several databases have been made available in a structured way. As an example, data from ARTIST (Ref. [4]) and PECA/SGTR (Ref. [5]) have been extensively used in the SGTR research (data from PSAERO and HORIZON data being also available –Ref. [6]). Likewise, data from old experimental programmes, like STORM (Ref. [7]), have been recovered and are now available to the SARNET resuspension community. Finally, as will be referred to below, new experimental data have been produced in the SARNET investigation of aerosols. All these data have been uploaded through the SARNET ACT (Advanced Communication Tool) in IED (Implementation of the Experimental Database).

This paper summarizes the progress achieved in understanding and modelling of those scenarios where aerosol phenomena could result either in a reduction (i.e., SGTR by-pass sequences and cracked concrete containments) or in an increase (i.e., revaporization and resuspension) of the potential source term to environment. The paper has been structured accordingly.

B. RETENTION IN COMPLEX STRUCTURES

B.1 SGTR sequences

Postulated severe accident SGTR sequences are a dominant contribution to the overall public risk. Despite being very unlikely, the potential consequences of a direct path for fission products from the primary coolant system to the environment turn these scenarios into a relevant issue for nuclear safety research. The potential retention within the secondary side of a failed steam generator during a SGTR severe accident sequence was seen as one of the largest uncertainties in the analyses reported in NUREG-1150 (Ref. [8]). Consistently, and given the present absence of a comprehensive database or specific model for the retention in the secondary side of the failed steam generator, Probabilistic Risk Assessments (PRA's) usually give no credit to any potential decontamination within the secondary side of a steam generator. Nonetheless, it has been experimentally demonstrated that some retention should be expected and that it would be highly dependent upon governing thermal-hydraulic conditions and the location and size of the break. Particularly, the presence of water in the secondary side appears to be a key factor, since a substantial fraction of particles carried by gas might be scrubbed by the water. Furthermore, even if no water is present, gas interaction with internal structures (i.e., tubes, support plates, separator, etc.) could result in some fission product and aerosol retention (Ref. [6]).

The specific objectives set out for the SARNET-SGTR investigation were to enhance further understanding of available SGTR data and to critically assess available models and codes. The research has been focused on aerosol retention near the tube breach under two boundary conditions: dry and flooded secondary side of the steam generator. Additionally, improvements in 3D particle tracking modelling have been achieved with direct application to in-tube deposition.

In the case of a dry scenario, the EU-SGTR project indicated that fluid flow pattern across the tube bundle played a key role in the aerosol deposition profiles on tube surfaces. Three-D computational analyses with the FLUENT 6.2 code have allowed insights into the jet evolution within the bundle (Ref. [9]). By assuming that the gas behaves as a compressible fluid and adopting the *k-ω* model to describe turbulence, the tube nearby has been modelled following the Best Practices Guidelines (BPSs) recommended for CFD applications to the nuclear safety issues. Figure 1 shows how the FLUENT predictions matched the main deposition areas found experimentally; in particular, the deposit on the broken tube over the breach has been shown to be due to a secondary recirculation loop set up at the inner side of the quasi-parabolic jet trajectory.

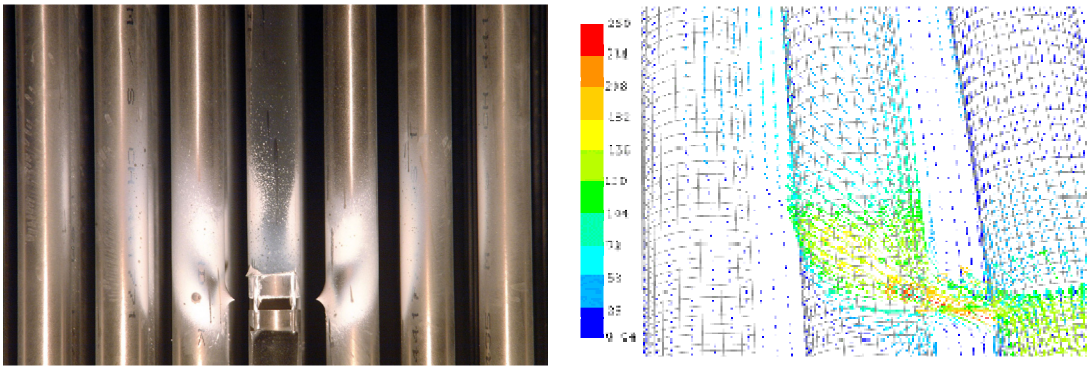


Figure 1. EU-SGTR results comparison to FLUENT 6.2 velocity predictions

The fundamentals and approximations of the ARISG model revealed major shortcomings and limitations when compared to data, as shown in Figure 2 (Ref. [10]). It was especially emphasized the need of considering key phenomena that hinder net aerosol retention. Examples are resuspension, erosion, bouncing and particle fragmentation. No less important, it was acknowledged that the jet aerodynamic description across the bundle should be well understood and properly encapsulated in a simple ARISG-like 1D model, which would eventually be implemented in integral severe accident codes like ASTEC [38].

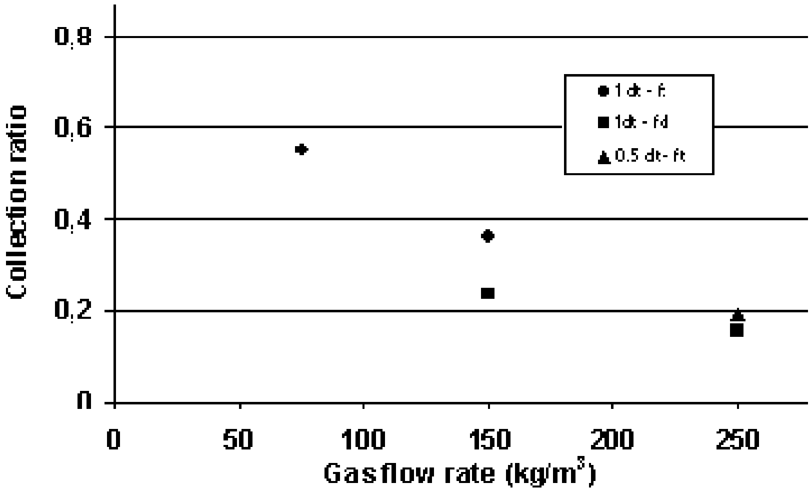


Figure 2. Measured-to-predicted collection ratio as a function of gas flow rate (**dt** – **t**ube **d**iameter; **ft** – breach in **f**ront of the neighbour **t**ube; **fd** – breach oriented **f**acing a **d**iagonal of the tube bundle)

The ARTIST experiments of the EU-SGTR project showed that particle scrubbing by a flooded secondary side leads to very large decontamination factors, even with a relatively small amount of water (Ref. [4]). State of the art codes, like those of the SPARC family, however, predict DF's that deviate significantly from experiments in cases where the aerosol source term is deeply submerged. Such deviations have been mainly attributed to limitations of bubble characterization and hydrodynamic description in codes. No less important, the individual addition of particle removal mechanisms at the gas-liquid interface can be questioned for large particles.

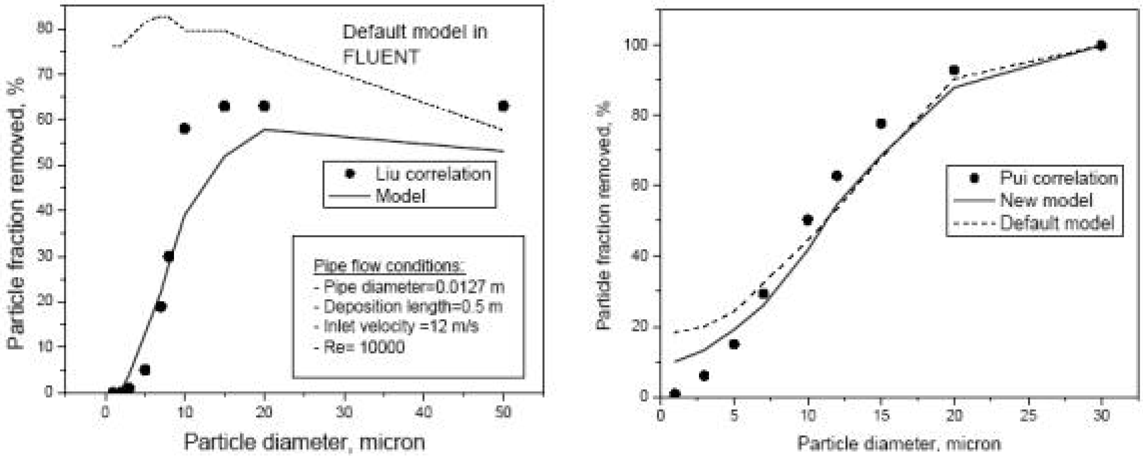
At the injection zone, droplet entrainment has an outstanding significance, particularly under the anticipated jet regimes (i.e. $We>10^5$) characteristic of SGTR sequences. The original Epstein model (Ref. [11]) has been refined to account for the relative motion of gas and droplets of different sizes. New expressions for the entrainment coefficient (Ref. [12]) and the collection efficiency (Ref. [13]) have been implemented in a modified way to consider the droplet-droplet hydrodynamic interaction and screening. At the plume region, the bubble-pool interaction is very complex due essentially to turbulence and flow confinement characteristic of these scenarios. This has been intended to get into the modelling (Ref. [14]) and it has resulted into a high sensitivity of DF estimates to bubble size distribution. The results achieved with this refined model and the reference SPARC-b/98 code are compared to data in Table I. As noted, although new model estimates get notably closer to measurements than the reference ones, they still deviate significantly from the experimental values.

Table I. DF data-predictions comparisons of EU-ARTIST experiments

Tests	Main features	Submergence	Decontamination Factors (DF)		
			Data	Reference DF (SPARC-B/98)	New DF
EU-SGTR A02	• Steam • Hot pool • Medium flow rate	1.3	50-100	3.8	352

EU-SGTR A03	• Non-condensables • Cold pool • Low flow rate	Dry 1.2 2.3 3.6	4.88 124 1251 5739	- 3.87 5. 7.8	- 37 54 60
EU-SGTR A04	• Steam • Hot pool • Low flow rate	Dry 1.33 2.55 3.80	4.6 482 1081 514	- 4.54 6.15 7.27	- 248 928 2395

Before reaching the secondary side of either a dry or flooded steam generator, , particles would be transported along pipes and broken tubes, so that they should undergo some retention. The flow regime inside the broken tube during SGTR sequences is highly turbulent. Given turbulence anisotropy, Lagrangian particle dispersion modelling, which assumes turbulence isotropy gives erroneous predictions of particle deposition rates on walls, even in simple geometries. The stochastic particle tracking model in FLUENT 6.2 has been modified to include a better treatment of particle-turbulence interactions close to walls, where anisotropic effects are significant (Ref. [15]). The new model has been tested against correlations for particle removal rates in turbulent pipe flow and 90° bends from the SOPHAEROS module [32] developed by IRSN for the ASTEC V1.3 code. Comparison with experimental data from scenarios with a noticeable 3D velocity has resulted in much better agreement with the data than that of the default model (Figure 3).



(a) (b)

Figure 3. In-tube (a) and at-bends deposition vs. particle diameter

B.2 Aerosols in cracks

Under severe accident conditions, a fraction of in-containment gases and aerosol particles could escape containment through cracks and/or failed seals, even if a catastrophic containment failure does not occur. Traditional safety analyses assumed that the aerosol release rates are identical to the gas leak rates, even if narrow leak paths can trap airborne particles significantly. This conservative assumption is far from reality: a certain fraction of particles is expected to get removed from the carrier gas onto the bounding walls. Nevertheless, as any particle filtration would mean a less conservative source term estimate, a research program was set up within SARNET to develope new theoretical models that overcome shortcomings of previous works in the open literature and to validate them against available experimental data. This target has required to designing and conducting experimental activities under conditions as representative as feasible to anticipated scenarios. The models produced could be easily implemented in the ASTEC code.

Previous work had been done on the particle transport through narrow passages (Ref. [16]). Most of the experimental studies were performed with small leaks and capillaries having diameters ranging from a few microns to a few millimeters, with pressure differences up to several bars. Large scale experiments were also performed during the ‘60s in the USA. Using a one-fifth linear scale model of a typical 1000 MWe PWR, a series of aerosol leakage tests with artificial pathways gave a decontamination factor of 15 for iodine and 100 for cesium in dry conditions, and almost complete retention in wet conditions. Other large scale experiments were performed in Japan on actual containment penetrations of a BWR plant using dry CsI aerosol particles: those experiments indicated decontamination factors between 10 and 1000. However, even if a number of theoretical studies were conducted, no specific models were developed to calculate the source term associated to the radioactive aerosol escaping the cracks.

An Eulerian model has been developed at “Demokritos” Research Centre to calculate deposition through cracks, as well as plug formation (Ref. [17]). The model is based on the numerical solution of the aerosol transport equation, considered in one-dimensional form along the flow path. This model assumes that aerosol transport is almost steady-state and that plug formation is uniform over the duct circumference. The particle deposition velocity is determined by considering brownian diffusion and gravitational settling. In case of turbulent flow, the mechanisms of turbulent diffusion and eddy impaction are also included. Encouraging results have been obtained by comparing the predictions of this model with measurements reported in literature and IRSN experimental results (Figure 4). Note that, in addition to separate effect test data (Ref. [18]), the prediction from parameterized global correlations used by IRSN is also included (as reported in Ref. [18]).

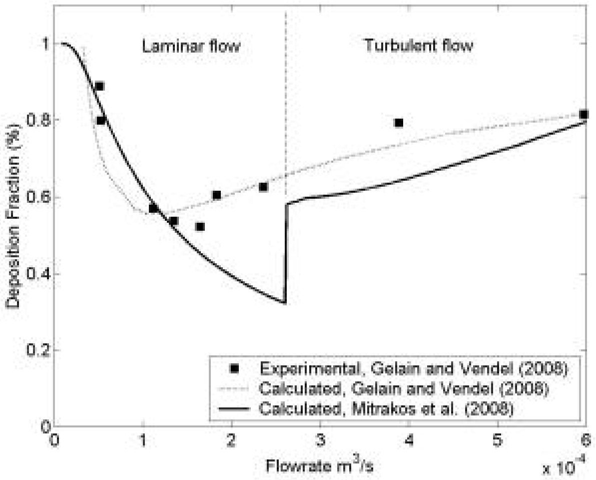


Figure 4. Penetration fraction vs. in-tube velocity (data-predictions comparison for 1.1 μm particles)

Alternatively, a Lagrangian approach similar to the one used in pool scrubbing codes, has been developed accounting basically for the same aerosol depletion mechanisms. Its response consistency has been tested by comparing its estimates to those from an Eulerian code (i.e., ECART) under anticipated conditions in a 1000 MWe PWR. In both cases, the scoping calculations demonstrated indicated a very high retention potential. The major advantage of the Lagrangian approach is shortening computer time.

An experimental campaign is being conducted at the COLIMA facility of the PLINIUS Platform (Ref. [19]). The aerosols will be produced from a piece of corium heated up to 2000-3000 K. The cracked samples, made of representative limestone concrete, will be accommodated to the COLIMA facility as shown in Figure 5. They are well characterized, so that the crack pathway is known. A picture of one of the samples to be used is displayed in figure 5. The test series as well as its interpretation have started recently and are still in progress.

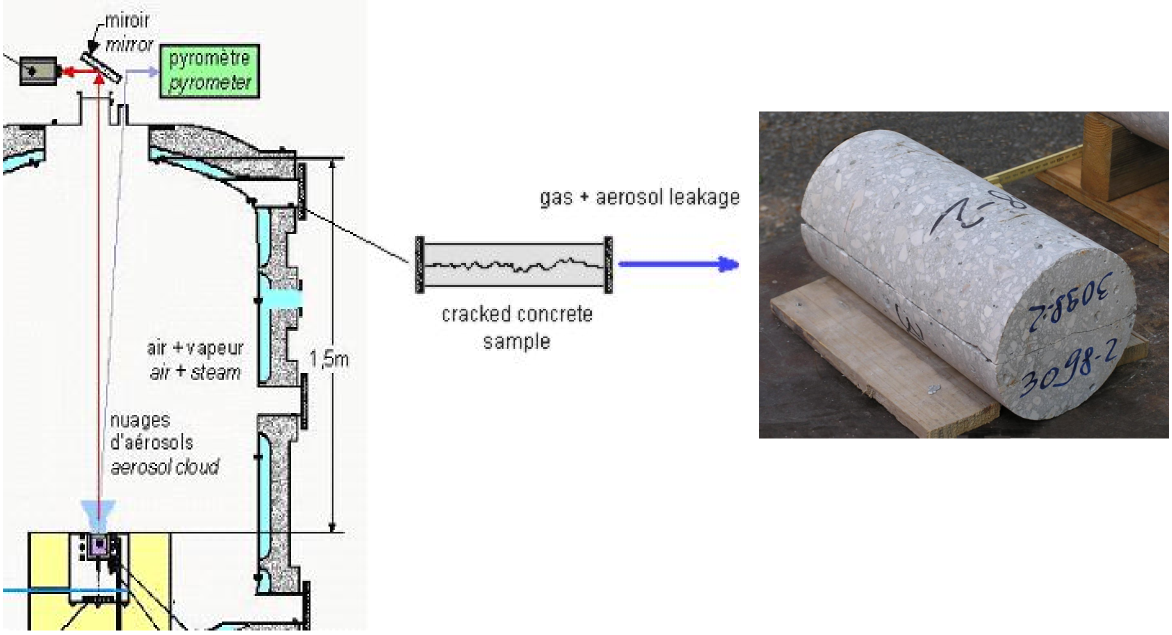


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Figure 5. Schematic of the COLIMA facility and a view of the crack sample

C. REMOBILIZATION OF PRIMARY DEPOSITS

Retention of radionuclides both in the Reactor Coolant System (RCS) and in the containment depends on deposition and remobilisation processes. Whereas deposition mechanisms are currently considered to be adequately known, the significance of remobilisation has not been clearly established (Ref. [20]).

C.1 Resuspension

Mechanical resuspension in RCS is considered to be especially significant in by-pass sequences, like SGTR, because then it may add directly to the source term. Resuspension in the primary circuit can take place due to core quenching by delayed intervention of ECCS (Emergency Core Cooling System), core slump into the pool of water remaining in the vessel bottom or fast depressurization of RCS (Ref. [21]). Resuspension is also known to take place in fast turbulent gas flow, even if the flow rate remains constant. Resuspension in the containment may be significant in terms of safety consequences if it takes place during or after containment failure. Dry aerosols deposited in the containment could be resuspended because of hydrogen deflagration, steam explosion or fast depressurization due to containment failure or venting (Ref. [21]). Both experimental and theoretical studies have been carried out in the past, so that several resuspension models for it are already available in the literature (Ref. [22]).

Hence, the goals of the resuspension research carried out under the SARNET framework have been: to bring disparate studies together, to validate the existing resuspension models and to integrate the models into source term evaluation codes.

Two sets of separate effect tests have been designed and carried out especially for code validation purposes (Refs. [4,23]). Both studies featured well defined particle sizes and online measurement techniques for deposition and resuspension. Experiments focused especially on dry resuspension of multilayer deposition in a turbulent internal tube flow for which previous experimental data was scarce. In addition, information on ongoing resuspension experiments in other applications (i.e., fusion devices and coal-fired power plants) was also given some attention (Refs. [24,25]).

The PSAERO experiments (Ref. [23]) paid particular attention to the relative importance of deposition mechanisms on the deposit resuspension. A straight, 1.1 meter long glass tube, placed horizontally in a constant gas flow was used. The inner diameter of the tube was 13 mm. The evolution of deposits was monitored online by a set of eight sequentially placed LED – photo diode pairs. The aerosol used in the experiments was a dense polydisperse pre-fabricated nickel powder with approximately spherical shape. The aerodynamic mass median diameter (AMMD) of the particles ranged from 1.9 to 2.5 µm. Three deposition mechanisms were explored: sedimentation (1 test), turbulent impaction (6 tests) and electrophoresis (5 tests). After the deposition phase the gas flow rate was increased stepwise and the amount of deposit remaining in the tube was measured. From that information the resuspension into a pure gas stream could be calculated.

Some relevant observations may be highlighted from these tests:

- In some cases resuspension was observed to occur as large agglomerates, which re-deposited rapidly back to the surface by gravitational settling.
- Particles deposited either by turbulent impaction or by electrophoresis adhered to the wall much more strongly than particles deposited by settling.
- The size of deposited particles seemed to be the parameter defining the adhesion strength rather than the deposition mechanism (Figure 5)
- Simultaneous deposition and resuspension took place even in laminar flow. As a result, the adhesion of particles remaining on the wall increased with time spent in the flow.
- Particles adhesion force distribution seemed to become flatter due to resuspension. Therefore, the relative importance of this largely unknown distribution seemed to decrease with continuing resuspension. At high flow velocities resuspension rates depended primarily on the gas flow.

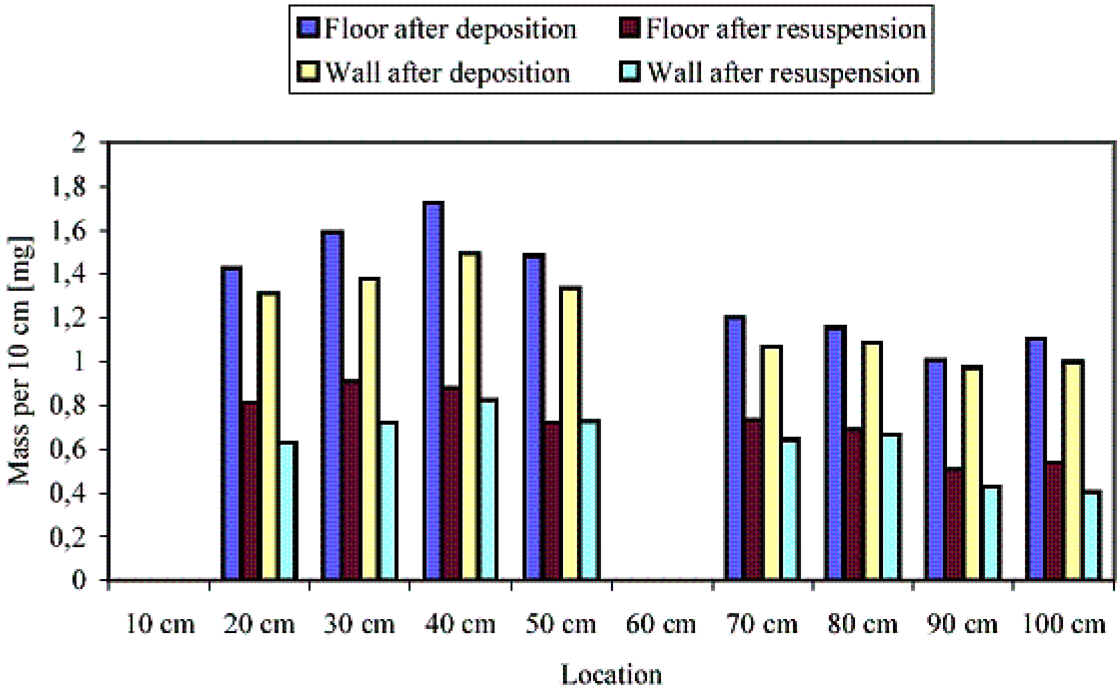


Figure 6. Linear mass concentration vs. length (electro-deposit in turbulent flow)

In-tube resuspension was studied by conducting 15 separate effect tests (Ref. [4]) described in Table II. All the tests were carried out under steady turbulent gas flow. These experiments constituted phase I of the ARTIST programme, which has been dedicated to studying aerosol retention in steam generator tube rupture (SGTR) incidents.

Table II. In-tube retention test matrix (Ref. [26]).

Aerosol	Tube configuration	D_{ae} [µm]	Flow [kg/h]	P(in) [bar]	C(in) [mg/Nm^3]
SiO_2 spherical	No bend, 9m	0.7	300	3.8	0.03
	Small bend, 18m*	0.7	235	3.8	0.05
	Intermediate bend, 18m	0.7	235	4.1	0.03
	Intermediate bend, 18m	1.4	235	4.1	0.1
	Intermediate bend, 18m	1.4	235	4.1	60
Latex, spherical	Small bend, 18m*	0.4	235	4.0	0.01
TiO_2 agglomerates (Nanophase, Degussa)	No bend, 9m	2 - 5	300	3.8	120
	No bend, 5.3m	2 - 5	360	3.6	120
	No bend, 5.3m condensation	2 - 4	245	3.2	120
	Small bend, 18m*	2 - 5	235	4.0	130
	Intermediate bend, 18m	2 - 5	235	4.2	110

* Two tests

The major observations derived from these experiments were the following:

- In-pipe retention can cause pressure increases up to a certain level at which the deposit get flushed.
- Particle size and material are very important parameters, strongly affecting resuspension in turbulent flow. Retention of smaller silica particles was very high, whereas almost all larger silica particles were resuspended when the particle mass concentration was low. With higher mass concentration retention of larger silica particles increased indicating balance between deposition and resuspension velocities. Retention of TiO_2 agglomerates was always very low. There were evidences that TiO_2 agglomerates broke up to much smaller particles.

Additionally, analytical studies have begun on two main directions. On one side, the so-called rock 'n' roll model (Ref. [27]) is being enabled to deal with multi-layer deposits; this renewed version is planned to be implemented into the SOPHAEROS code. On the other, validation activities based on the above PSAERO tests as well as on the previous STORM programme (Ref. [28]) are being undertaken; at the moment the potential participating codes are ECART (Ref. [29]), APROS (Ref. [30]) and SOPHAEROS (Ref. [31]).

C.2 Revaporisation

Revaporisation was recognised as a dominant risk phenomenon since it could substantially increase the source term by remobilising fission products such as Cs and I in the late phase of a severe accident (Ref. [2]]. Multiple factors affect the process, from the conditions during the deposition phase (i.e., gas and surfaces temperatures, gas composition, etc.) to those during the volatilization, like sudden temperature or gas flow rate changes (both capable of reducing the vapour concentration under saturation which would act as a revaporization trigger). Given such a complexity, the main objective of the work was to get a sound understanding of fission product revaporisation, particularly that of Cs, from an extensive experimental database, so that a robust modelling approach can be developed (Ref. [32]).

A good deal of experimental data demonstrates the feasibility of revaporization. Initial radiotracer testing carried had showed that the CsOH & CsI deposits revaporised under flowing steam above 400°C - 500°C. Further testing showed that mixed radioactive fission product deposits had a similar behaviour to the simple deposits (Ref. [33]). These experiments were conducted with samples taken from the vertical line above the PHEBUS-FP bundle during the FPT1 test and submitted to a hot flowing steam with temperatures up to 1000 ºC. An example of the experimental data available can be seen in Figure 7, where the behavior of samples from the FPT1 and FPT4 tests may be observed. Cs revaporisation commences at 550°C and is rapid until 750°C. Total revaporisation is very high on the flat metallic substrate of FPT1 (approx. 95%) but is still significant (60%) from ceramics (FPT4). From irradiated CANDU fuel samples, it was confirmed that various fission product deposits on structural materials could revaporize under various atmospheres (Ref. [34]). Coupons of Zircaloy-4, Zr-2.5Nb, different types of stainless steels and Inconel-600 were exposed to a gas stream of different compositions (air, steam, or steam diluted with Ar) downstream from the fuel to form the deposit. The coupons with the deposit were then heated up to 700ºC for 1800s and several isotopes were detected in the releases (^{134}Cs, ^{137}Cs and ^{129m}Te, with ^{103}Ru and ^{106}Ru and Ag^{110m}).

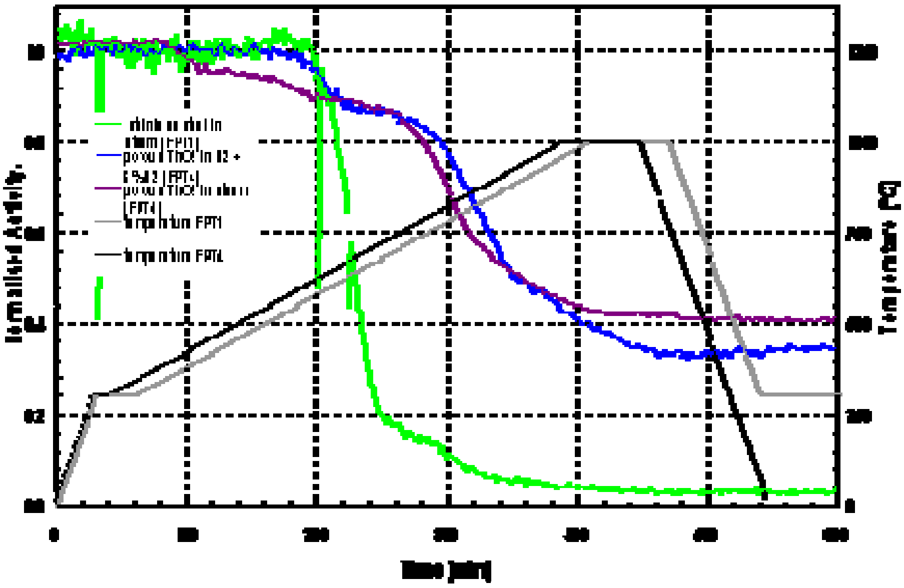


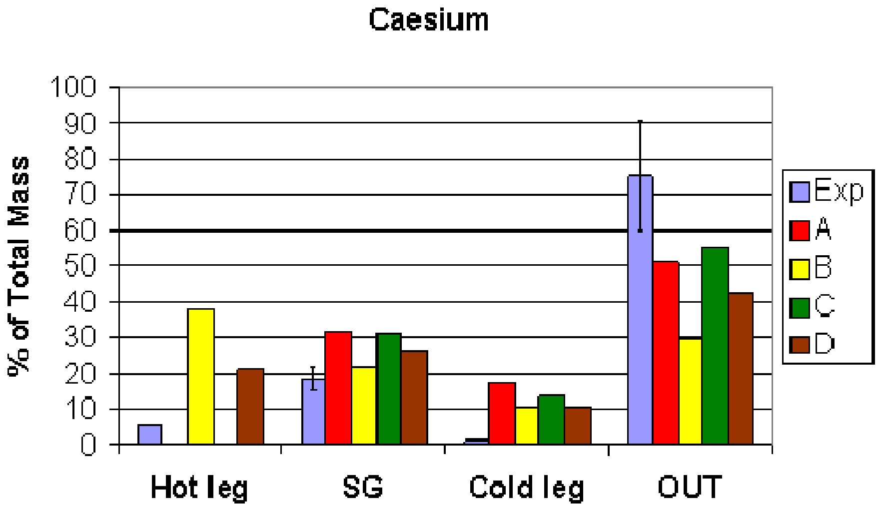
Figure 7. Cs-137 revaporisation from PHEBUS FPT1 and FPT4 deposits

In addition to the data coming from separate effect tests, the PHEBUS-FP tests provided substantial understanding (Refs. [35,36]) of aerosol revaporization processes, such as the fact that this could happen under oxidizing as well as reducing atmospheres or that fission products other than Cs could well revaporize to varying extents (eg., Mo). These findings allowed specific observations from the PHEBUS experiments to be interpreted, e.g., the burst of Cs activity aerosol on the FPT1 bundle shutdown and also the downstream motion of Cs-137 in the primary circuit on the reactor shutdown on the low steam FPT2 test.

All these experimental results are planned to be complemented by high surface temperature chemistry tests to be conducted in an “ad-hoc” facility. These, together with those from the CHIP program [37] (focused on the gas phase chemistry of fission products), will assist to better understand the revaporisation process.

As for modelling, the SOPHAEROS code and the Material Data Base within the ASTEC v1.3 code (Ref. [38) have been validated against the PHEBUS-FPT1 data. A relatively good agreement with measurements has been found for CsI. The experimentally observed vaporisation is slightly slower in the final phase, after temperature rises beyond 700°C, than predicted by the models, implying that the calculated CsOH vaporisation rate was too fast, but discrepancies of about two orders of magnitude in CsOH vapour pressure from three different sources were noted. SOPHAEROS predicts that, after evaporation, a fraction of CsOH changes into the dimer form ($[Cs(OH)]_2$), but this cannot justify the differences noted. Other species such as Cs_2MoO_4 were also predicted to be quantitatively formed (2:1 - 3:1, with respect to CsOH) in most of the FPT1 samples.

The APROS SA code (Ref. [30]) has also been compared to the PHEBUS-FPT1. The scenario simulation was done according to guidelines supplied in the ISP-46 benchmark (Ref. [39]) and the comparisons set in terms of deposits at different circuit locations, as observed in Figure 8. The deposited material was predicted to be totally removed from the hot leg surfaces when the revaporisation model was turned on (cases A & C), which fits the experimental results best.



Cases	**A**	**B**	**C**	**D**
Revap.	Yes	No	Yes	No
Settling	Yes	Yes	No	No

Figure 8. Distribution of caesium in FPT1 and in APROS SA calculations.

D. CONCLUSIONS

In previous sections the major results achieved within the 6th FWP SARNET project concerning aerosol behaviour in specific scenarios in which a better understanding and predictability could result either in a reduction (i.e., SGTR by-pass sequences and cracked concrete containments) or in an increase (i.e., resuspension and revaporization) of the potential source term to environment, have been reviewed. From them a set of overall conclusions can be drawn as follows:

- The data gathered in projects out of SARNET, like ARTIST and EU-SGTR, together with their analysis, have allowed relevant insights to be obtained concerning retention at different locations and conditions (i.e., in-tube, dry break-stage and flooded-bundle) during SGTR meltdown sequences. As a consequence, models have been refined and a better consistency with data has been managed. Nonetheless, in order to develop a consistent methodology to quantify retention in the steam generator under SGTR severe accident conditions, further experimental data and analytical efforts are needed. Through this additional effort new predictive models would be developed, refined and/or linked to others (if already developed) and, no less important, the overall predictive strategy could be validated.
- Modelling of aerosol behaviour in cracks has progressed as much as feasible. Different types of models, from Eulerian to Lagrangian, and correlations have been produced and their performance against the available data base seems consistent. However, their application in safety studies would require a more extensive validation against representative experimental data. To overcome this shortcoming to some extent an experimental campaign has been initiated at the COLIMA facility of the PLINIUS platform within the 6th FWP SARNET project.
- Data obtained within the SARNET project (i.e., PSAERO) as well as outside the project (i.e. ARTIST), have allowed key variables of resuspension to be identified, such as particle size, nature, flow velocity and acceleration, etc. This information together with the retrieved STORM data are the basis to enable the Rock'n Roll model to tackle multilayer deposits and for the validation of this (to be included in the SOPHAEROS code) and other models encapsulated in ECART and APROS. Even though further experimental data may be needed in the future, the main issue still open in the area seems to be the validation of existing models.
- Even though integral data have shown the potential of primary system deposit revaporization and some separate-effect tests have already been carried out and

successfully modelled, the challenge in this area is double: to extend the limited database with revaporization tests using representative samples (PHEBUS-FP deposits, for example) and to bring predictions closer to observations in integral experiments, where consistency so far is not so good.

In summary, the SARNET project has managed to step forward in the still open aerosol issues. Nevertheless, their closure will require additional man-power in the coming years essentially to reliably validate models and encapsulate them in nuclear safety codes.

Acknowledgements

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