Contribution of IRSN R&D to reducing the risks of airborne pollutants dispersion during the dismantling of nuclear facilities

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Contribution of IRSN R&D to Reducing the Risks of Airborne Pollutants Dispersion during the Dismantling of Nuclear Facilities – 23099

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ABSTRACT

This paper presents a general overview of IRSN research activities for assessing and reducing the risks of airborne dispersion of radioactive contamination during the dismantling operations of nuclear facilities. Four main topic areas are addressed: aerosol source term, contamination transfers, behavior of containment equipment and contamination metrology. Firstly, the various experimental and numerical means involved are presented.

INTRODUCTION

The dismantling operations of a nuclear facility can be generally broken down into five major steps:
- inventory, then evacuate the radioactive substances and waste still present in the facility at the end of the operating phase,
- decontaminate, then dismantle the equipment of the processes implemented,
- clean up the building rooms with a view to their decommissioning or the demolition of the facility,
- treat, package and eliminate the waste produced,
- provide environmental monitoring of the deconstructed site.

During these five stages, nuclear licensees seek to optimize operations in terms of cost, schedule and volumes of waste to be eliminated, while taking care to minimize the impact on workers, the public and the environment. In the current context where dismantling operations still remain isolated and sporadic on a very wide variety of facilities, a significant need for new industrial technologies is emerging, in particular to respond to the expected increase in these activities. This increase leads to new questions from the IRSN units in charge of safety assessment. Among these, the risk of dispersion of radioactive substances (in gaseous or particulate form) constitutes a major risk, present during the five dismantling stages. It is all the more significant with regard to worker's radiation protection since, compared to the operating phase, the radiological risks decrease for the environment, but increase for the workers, due to the nature of the operations to be carried out.

Thus the licensees' measures for worker survey and for containment/ventilation of rooms and site airlocks are topics particularly assessed by IRSN. This is how the units in charge of safety assessment expressed specific R&D needs on the metrology of airborne contamination, airflow transfers or protective equipment such as:
- the performance of monitors used to monitor working environments on dismantling sites,
- the performance of the capture processes implemented during the dismantling operations,
- the efficiency of the containment provided by the site airlocks,
- the evaluation of the transfer of contamination in the near field of the emission source or inside the rooms,
- the characterization of ventilation networks, which are constantly modified during the dismantling operations,
- the performance of the personal protective equipment (PPE) of the operators.

Furthermore, since the dismantling operations aim, among other things, to dismantle equipment and clean up contaminated surfaces, increased risks of dispersion and fire are to be feared because of the techniques

used (cutting by tools creating materials suspension or hot spots). These risks are therefore the subject of a specific assessment by IRSN, which leads to the identification of R&D needs on the suspension of contamination and on protective equipment such as:
- the suspension of particles during metal cutting or concrete bush hammering operations, during the movement of operators, during incidents or accidents (falling objects, fire, etc.),
- the efficiency of filter protection devices against incandescent particles,
- the behavior of the pre-filtration devices as well as that of the HEPA filters.

In addition, the particular context of the dismantling of the damaged Fukushima Daiichi reactors has led IRSN to participate since 2016, in collaboration with the CEA and ONET Technologies, in several projects relating to the characterization of the aerosols produced during the laser or mechanical cutting of the corium, as well as to the limitation of their dispersion.

Finally the specific issue of waste management, and more particularly the conditions of storage or disposal of the packages produced during the dismantling operations, also lead IRSN to assess the measures taken by the licensees. For example, the lack of availability of a disposal route for particular waste leads some licensees to design new storage facilities, raising questions from the units in charge of safety assessment, in particular on the behavior packaging such as the performance of the metal filters used on the waste containers.

As a result, assessing the risks inherent in dismantling operations requires the development of knowledge in the areas of characterization of aerosol source term, transfer of pollutants, behavior of equipment as well as the associated metrology. Important elements of knowledge are notably provided by research work carried out at the Airborne pollutants and Containment Dispersion Department of IRSN (located in Saclay, France). Most of this work is led according to a stage-approach based on experimental and numerical studies: a phenomenological approach with analytical experiments to provide elements of understanding of the physical mechanisms involved, a semi analytical approach for the study of representative scenarios, and an industrial approach on real equipment.

The aim of this paper is to present a general overview of IRSN research work on aerosol source term, contamination transfer, behavior of containment equipment and contamination metrology, as well as its main findings. Firstly, the various experimental and numerical means involved are presented.

EXPERIMENTAL AND NUMERICAL MEANS

The Airborne pollutants and Containment Dispersion Department conducts experimental and numerical research programs dealing with pollutants emission, transfer and containment in nuclear facilities, both in normal and accident conditions. The experimental activities are based on more than fifteen facilities grouped into three experimental platforms: MARIN (Metrology of Aerosol, Resuspension, In-situ and Nuclear diagnostics), MISTRAL (Means for Investigating Species Transfers, Airflows and Leakage) and BOREE (Benches fOr Resistance of Equipment and Effluent purification). Five of these facilities are more particularly related to the evaluation of the risk of airborne dispersion during dismantling operations: CAPIMIF, DISCO, TOSQAN, EPICEA and MASSALE. CAPIMIF (Fig. 1a) is used to characterize the source emissions of mechanical (grinder) and thermal (plasma torch) cutting processes and to study the behavior of safety equipment (spark arrestors, prefilters, HEPA filters). DISCO (Fig. 1b) allows to measure the aerosol suspension factor due to the fall of contaminated powders, liquids or objects. The 7 m^3 TOSQAN facility (Fig. 1c) can be used to study phenomena associated with aerosol pool or spray scrubbing. MASSALE (Fig. 1d) is a 100 m^3 ventilated enclosure that may contain a depressurized airlock to study the risks of pollutant leakage through openings. Finally, ICARE (Fig. 1e) is a test bench designed to generate radioactive aerosols (AMAD from 0.1 to 10 µm and volume activities up to 200 $Bq.m^{-3}$) for the calibration of radiation protection instruments or environmental monitors.

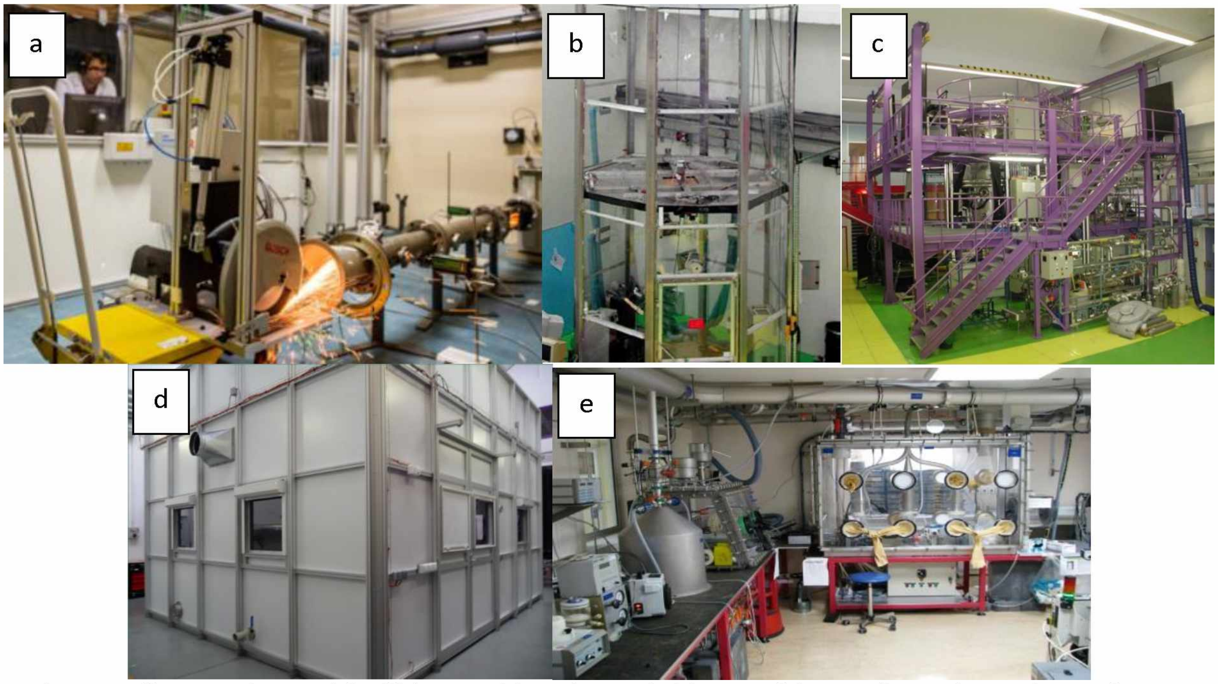

Fig. 1. IRSN experimental facilities used in R&D activities on airborne dispersion and containment during dismantling operations

Associated to these experimental facilities, IRSN also relies on simulation tools (CFD and zonal codes) to predict the contamination transfers inside a facility, from the emission source of contaminant to the potential release into the environment. Thus IRSN has implemented several models related to aerosol physics in CFD codes (ANSYS CFX®, CALIF^{3}S [1]) to predict local values of volume and surface concentrations of aerosols in any geometry (ventilated room or enclosure, ventilation duct, sampling line…). First, an aerosol transport and deposition model was developed, based on a simplified eulerian approach [2]. This model was then improved by implementing an aerosol agglomeration model based on a DQMOM approach [3] and a resuspension model based on the Rock'n'Roll approach [4]. Finally IRSN added a model of aerosol collection by spray droplets to evaluate the efficiency of aerosol scavenging by spraying [5]. Some examples of CFD simulations are presented later in the article.

IRSN has also developed the zonal SYLVIA code [6] which makes it possible to simulate the behavior of an industrial ventilation network in degraded or accidental mode, in terms of evolution of pressures, flow rates and pollutant concentration. The modelling principle is to break the ventilation network down into a series of nodes and branches (Fig. 2): a node represents a pressure, temperature and uniform pollutant concentration zone and a branch represents any connection between two nodes comprising an item of equipment in the network (filter, duct, etc.). Aerosol deposition models in rooms, straight ducts and bends are also available. As mentioned later, this software can be used, for example, to evaluate the different modifications planned on a ventilation network during the dismantling of a facility and to analyze any associated risks.

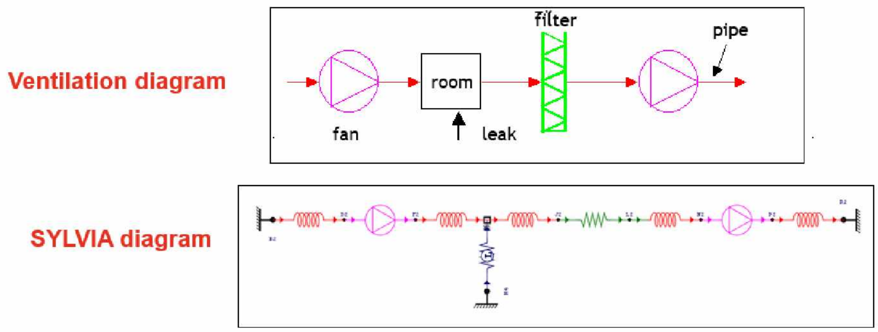

Fig. 2. Principle of modelling a ventilation network with the SYLVIA code

R&D ON AEROSOL SOURCE TERM

The dismantling operations of the process equipment used in nuclear facilities, and the clean-up operations of the building rooms, are generally accompanied by a significant production of particles. Licensees use different means aimed at containing these particles (source capture, ventilated airlock, etc.) but the consequences of a failure must be evaluated. This evaluation requires the estimation of the quantities of substances likely to be dispersed and, first of all, the determination of the aerosol source term inherent in each industrial process used.

Cutting of Materials by Different Tools

In the 1980s and 1990s, IRSN carried out several research projects aimed at characterizing the production of particles emitted by different materials cutting (cutting of steel plates by plasma torch, reciprocating saw, chainsaw, arc saw…) [7-9]. This work has made it possible to determine the suspension coefficients of particles produced during different industrial situations and to elaborate summary sheets in a database called BADIMIS which is developed by IRSN and continuously enriched. More recently, experiments of laser Nd:YAG cutting in air and underwater were performed on steel samples of different thicknesses in the DELIA facility operated by the CEA [10]. Aerosol produced were characterized by IRSN in terms of mass concentration, particle size distribution and morphology in the exhaust line of the facility, designed and qualified by IRSN (Fig. 3). It was shown that an important part of these aerosol particles are submicronic and in the form of aggregates of nanometer primary particles.

The same experimental means were used this year as part of the H2020 European project LD_SAFE (Laser Dismantling Environmental and Safety Assessment). The global objective of this project is to validate the laser cutting technology of the most challenging components of power nuclear reactors (reactor pressure vessel and internals) in air and underwater. In this context, detailed data on aerosols characteristics were acquired by IRSN during laser cutting trials for various stainless steels and various cutting conditions such as underwater, non-underwater in dry or humid condition, with assist gas with air and nitrogen (Fig. 4).

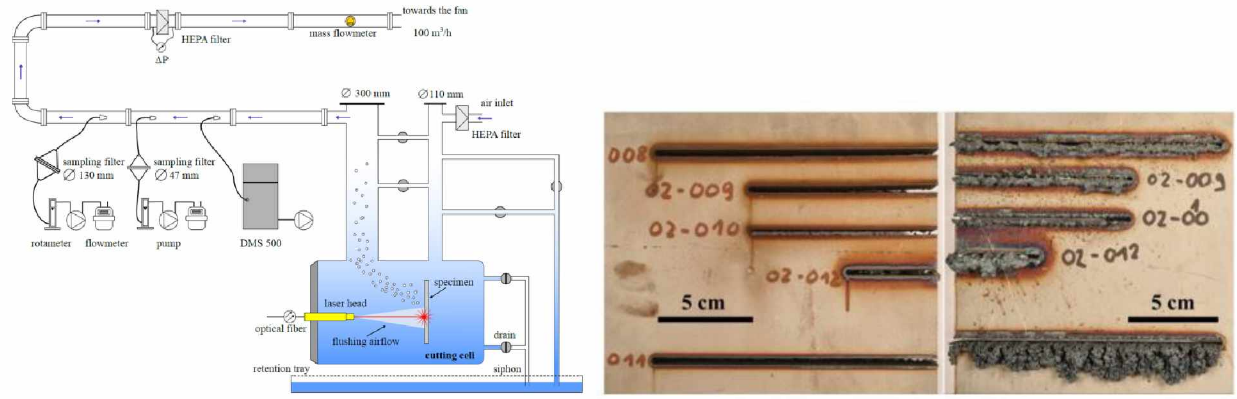

Fig.3. (left) Sketch of the DELIA facility and its aerosol sampling line; (right) Example of a 20 mm thick steel sample with various laser cuts [10]

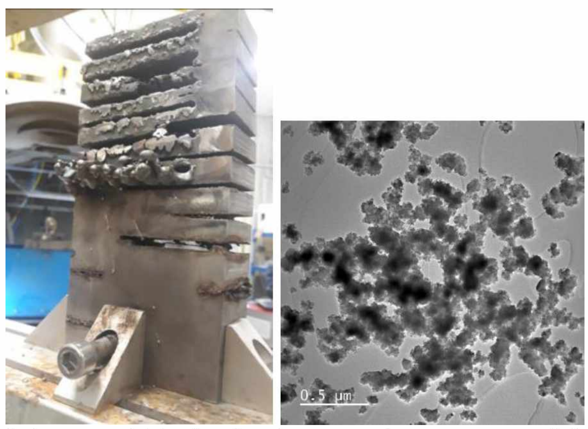

Fig. 4: (left) Example of stainless steel block after laser cuttings, as part of the LD-SAFE project; (right) Example of submicronic particles produced during underwater laser cutting with air assist gas

These experimental means have also been used as part of several projects related to the retrieval of the corium of the damaged reactors of Fukushima, which are described below and in a companion paper [11].

<u>Retrievial of the Damaged Reactors of Fukushima</u>

One of the important challenges for the decommissioning of the damaged reactors of the Fukushima Daiichi (1 F) Nuclear Power Plant is the fuel debris (corium) retrieval. Several R&D projects have been launched and subsidized by the Japanese government since 2016 to study and prepare operations for this retrieval. First a French consortium (ONET Technologies, CEA, and IRSN) has been selected to implement R&D related to the laser cutting of 1 F fuel debris and related to dust collection technologies. This research focuses on the assessment of the production of secondary emissions generated by the laser cutting technique for air and underwater conditions with inactive fuel debris simulants, designed and manufactured by the CEA, for in-vessel and ex-vessel configurations. Experiments were performed in the DELIA facility and the aerosol were characterized by IRSN in the exhaust line as explained before [12-13]. Significant differences were observed between the aerosol particles generated from in-vessel and ex-vessel simulants (Fig. 5), which may have a significant impact on particle transport and deposition mechanisms as well as mitigation strategies such as filtration or spraying.

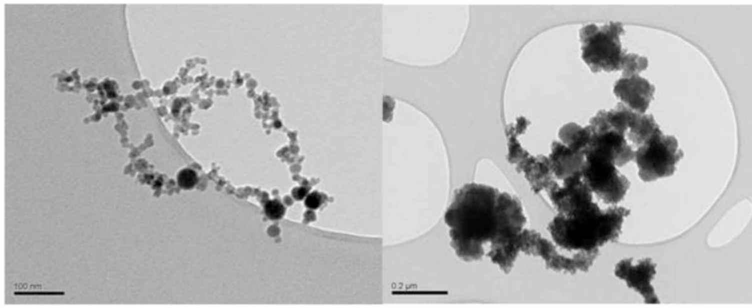

Fig. 5. Visualization by Transmission Electron Microscopy of aerosol produced during the laser cutting of ex-vessel simulant (left) and in-vessel simulant (right) [13]

Following this study, other experiments were performed on the characterization of the aerosol source term during the cutting of corium simulants with a grinder and a plasma torch, on the CAPIMIF facility of IRSN (Fig. 6). Finally, as part of the URASOL project, the consortium ONET Technologies/CEA/IRSN recently characterized the aerosols generated during the thermal (furnace) and the mechanical (core boring) processing of prototypic fuel debris simulant containing major fuel components (depleted uranium / fission products) [14]. These experiments were carried out on the PLINIUS platform of the CEA.

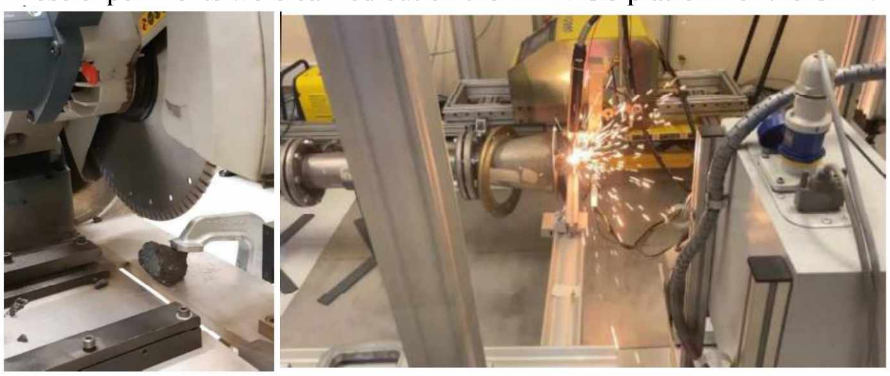

Fig. 6. Cutting of corium simulant with a grinder (left) and a plasma torch (right) in CAPIMIF

Concrete Bush-Hammering Operations

Throughout the operation of nuclear plants and laboratories, their concrete structures can be activated by the neutron flux, or their surfaces may become contaminated by accidental contact with fission products. Thus the concrete structures of nuclear facilities must be cleaned up so that the waste resulting from the dismantling operations meets the criterion of very low-level waste. Available data in literature about the risk of resuspension of particulate matter throughout remediation operations is very limited. Hence IRSN launched a dedicated experimental study on particle airborne release fraction during concrete scarifying operations, by quantifying the total amount of emitted aerosol [15]. Several milling operations were performed on a standard non-radioactive concrete slab in a confined experimental chamber (operated by the CSTB – Centre Scientifique et Technique du Bâtiment) using an industrial scarifying machine (Fig. 7). Experiments reveal a significant production of fine particles and the airborne release factor was quantified with and without a vacuum suction device intended to confine the dust production close to the source.

Fig. 7. Experiment of scarifying operations of a concrete slab using a manually propelled industrial milling machine [15]

Walking of Operators on a Contaminated Floor

Among the various possible sources of atmospheric contamination within the facilities, the suspension of particles due to the walking of operators on contaminated soil, during dismantling operations or post-accident interventions, constitutes a topic of increasing interest. Assessing the risks of radiological exposure of workers and the relevance of the means of protection implemented requires jointly estimating the rate of suspension of the particles when walking as well as the transport of the particles induced by the movement of the operators. Research work carried out in collaboration with EDF (Electricité de France) has made it possible to provide the first elements of knowledge regarding the suspension of aerosols linked to walking, by simulating, using a CFD approach, the effect of the pose and lifting of a shoe at ground. At the same time, walking experiments in a ventilated room made it possible to measure suspension rates as a function of the characteristic walking, particle and soil parameters.

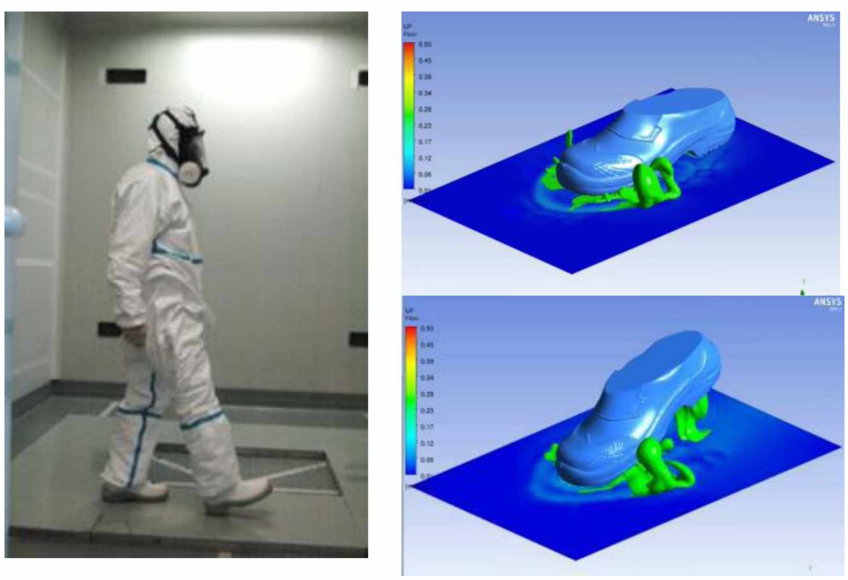

Fig.8. (left) Experiment of aerosol resuspension during operator walking; (right) CFD simulation results of aerosol resuspension when putting down and lifting a shoe on the ground

R&D ON CONTAMINATION TRANSFERS

Efficiency of the Containment Provided by the Site Airlocks

During nuclear dismantling or maintenance operations, a dynamic confinement is applied to depressurized enclosures (airlocks) to prevent the leakage of pollutants outside these enclosures. To guarantee an efficient dynamic confinement, the ISO 16647 standard recommends maintaining a constant value for inward inflow velocity near each nominal or accidental opening, depending on the level of radioactive pollution hazard. Nevertheless, under certain conditions (internal air flows produced during clean-up or dismantling processes), flow inversions near the opening can occur and lead to gaseous pollutant leakage. In order to precise these conditions and to quantify the amount of the contamination backflow on airlock walls (tears, piercing, burns), IRSN conducted an experimental and numerical research program. Experiments were performed on a small size ventilated enclosure equipped with a controlled rectangular opening on its frontal and several configurations of internal jet perturbation (counter-current or parietal turbulent jet flow in competition with the mean directional opening flow) were investigated by using gas and particulate tracing techniques, as well as laser flow visualization [16]. Results showed that a new relevant criterion based on the aeraulic conditions at the opening should be taken into account to ensure an efficient containment. In parallel, CFD numerical simulations were carried with a turbulent hybrid (RANS-LES) model, showing the ability of this kind of modelling to qualitatively predict the flow inversions and to quantify the backflow phenomenon close to the opening (Fig. 9).
This work is currently continuing on a full-scale airlock with flexible vinyl walls installed in the MASSALE enclosure (Fig. 10). Various operating sequences will be studied (opening/closure of the personal and material airlock doors, internal jets, exhaust fan stop and resume, shocks and vibrations on a wall…). More details are given in a companion paper [17].

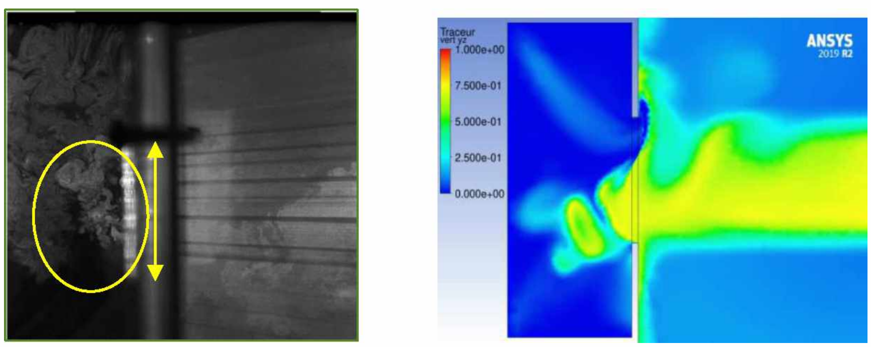

Fig.9. Illustration of pollutant leakage through an opening of a depressurized enclosure, induced by an internal counter-jet: (left) Experimental visualization; (right) CFD simulation results

Fig. 10. Flexible airlock installed in the MASSALE enclosure

Performance of the Capture or Mitigation Means Implemented during Dismantling Operations

As mentioned before, IRSN has been involved for some years with CEA and ONET Technologies in projects funded by the Japanese government (METI). These projects aim at evaluating a strategy for the retrieval of fuel debris fell over the floor of Fukushima Daiichi reactor pedestal. However an important issue regarding aerosols dispersion and potential release into the environment is present around this well-proven technology and must be under control. Thus, after providing quantitative data on the source term of aerosols from laser cutting of fuel debris simulants, IRSN simulated the aerosol transport and deposition inside the reactor pedestal due to the airflows coming from the laser cutting head (Fig. 11, left) and assessed the efficiency of sprays to help mitigating the dispersed aerosols [5] [18] (Fig. 11, right).

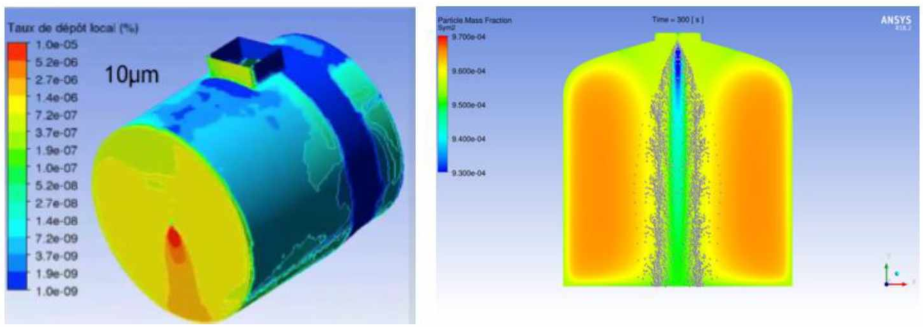

Fig.11. Examples of CFD simulation results: (left) Deposition of 10 µm aerosol on the pedestal of the damaged reactors of Fukushima Daiichi; (right) Aerosol scavenging by spraying droplets in TOSQAN facility [18]

Characterization of Evolving Ventilation Networks and Induced Contamination Transfers

The dismantling and deconstruction of a nuclear facility lead to significant modifications to the ventilation networks (closing/removal of ventilation ducts, stopping of fans or modifications to operating points, etc.) and civil engineering (addition/removal of partitions, door or hopper openings). Temporary ventilation networks are also implemented (creation for example of ventilated airlocks, with filtered discharge of the air extracted inside a room or in the ducts of existing networks). All of these modifications can induce a risk of undesirable transfer of radioactive substances which can be assessed with the SYLVIA code. Based on a model of the initial state of a facility ventilation network (Fig. 12, left), it is possible to simulate each of the dismantling stages envisaged by the licensee and to analyze any associated risks (inversion of the pressures between rooms, reversal of the direction of air flow in ducts, etc.).
Furthermore the gradual shutdown of ventilation as the dismantling operations progress tends to increase the influence of the wind effects on airflow transfers within the facility being dismantled. The TIVANO research program conducted at IRSN has demonstrated the ability of SYLVIA to predict airflow transfers related to the wind in a situation of partial or total ventilation [19], but also that of CFD simulations to predict the pressure coefficients induced by the wind on the network connections with the outside (building facades, chimney) (Fig. 12, right) [20].

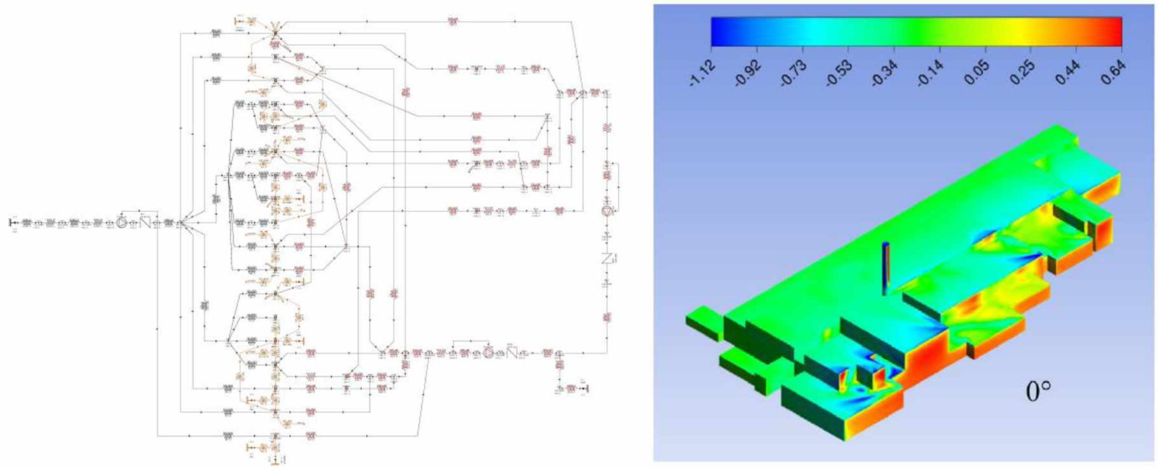

Fig. 12. (left) Example of modeling a ventilation network with the SYLVIA code; (right) Wind pressure coefficients predicted by CFD simulation on the same facility [20]

R&D ON BEHAVIOR OF CONTAINMENT EQUIPMENT

Characterization of Incandescent Particles and Protection of HEPA Filters

The use of mechanical or thermal cutting tools during decommissioning operations generates a lot of incandescent particles that may represent a deterioration risk of the containment barriers (HEPA filters) associated with a potential fire hazard. Therefore IRSN launched, in partnership with EDF, a research program whose objectives are on the one hand to determine the characteristics (temperature, diameter and velocity) of the incandescent particles produced by a cut-off grinder or a plasma torch, and on the other hand to evaluate the performance of different spark arrestors. Experiments were performed in the CAPIMIF facility.

For the first part of the program dealing with mechanical cutting by a grinder [21], particle velocity was measured with a high-speed camera using the particle tracking velocimetry (PTV) technique, and an adaptation of a commercial monochromatic pyrometer allowed the temperature of the particles to be measured. Fig. 13 presents the measuring section, an example of visualization of particles and filter fiber deterioration without any spark arrestor. It was shown that a particle velocity around 10 m/s and a temperature up to 1500 K are sufficient to damage the filter and greatly reduce its decontamination factor. Therefore the second part of the program consisted in studying the ability of commercial spark arrestors to protect filters from being affected by particles produced not only by a grinder but also a plasma torch cutting [22]. Three models of spark arrestors and two models of HEPA H14 filters (a double dihedral and a half-cell) were studied (Fig. 14). Efficiency of each spark arrestor was evaluated by measuring the decontamination factor of the filters before and after each cutting operation, according to the Annex C of the NF EN ISO 16170, by using a soda-fluorescein aerosol with a mass median diameter of 0.15 µm. In particular, it was shown that plasma torch cutting leads to greater clogging of the filters and greater reduction of their decontamination factor compared to grinder cutting.

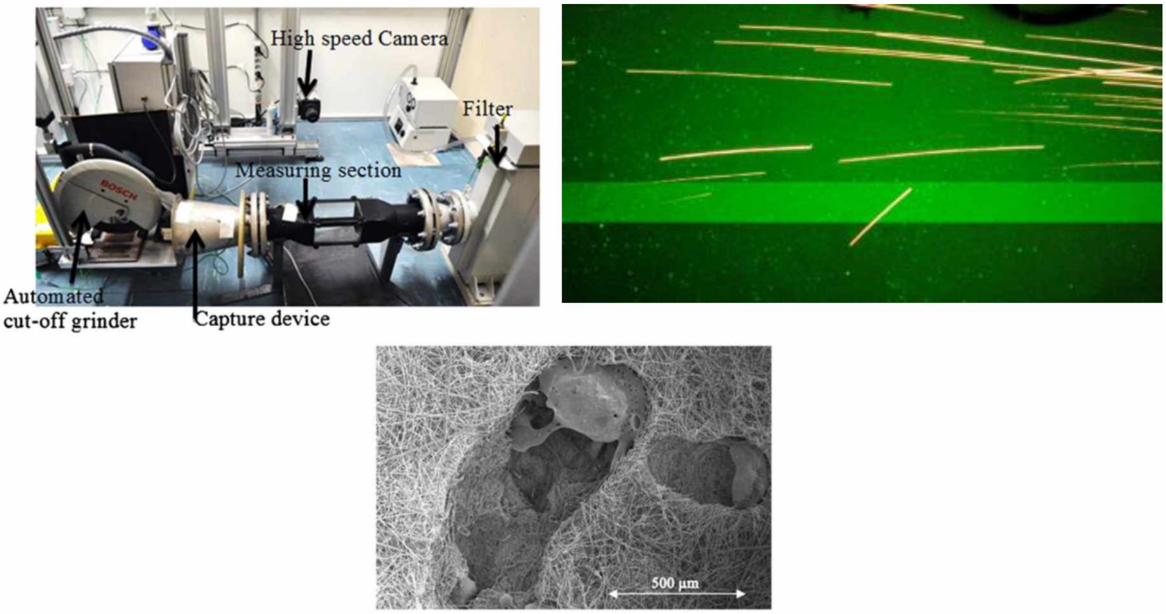

Fig. 13. (left) The CAPIMIF facility with the measuring section of incandescent particles; (right) High-speed camera visualization of incandescent particle trails; (bottom) SEM visualization of particles on a sampling filter at 0.6 m from the source [21]

Fig. 14. (left) Three models of spark arrestors tested; (right) Two models of filters tested [22]

In parallel of this research work on the risk of HEPA filter degradation by incandescent particles produced by cutting operations, IRSN has been conducting for many years research on HEPA filter performance, in terms of filtration efficiency and clogging. Until now, this work has mainly been carried out with regard to the fire risk and has resulted in the development of a phenomenological model for predicting the clogging of a HEPA filter [23]. It is planned to evaluate the relevance of this model regarding a bimodal aerosol, which is commonly produced during thermal cutting operations (laser, plasma torch…).

Metallic Filters Fitted to Waste Packages

Some solid waste is packaged in bulk in stainless steel containers whose welded lids are equipped with metallic filters allowing the evacuation of the gases produced by radiolysis (hydrogen…) while preventing the dispersion of radioactive substances outside. The IRSN units in charge of safety assessments are currently questioning the ability of such a filtration system to constitute an effective containment barrier and the risk of accumulation of hydrogen in the event of filter clogging. In order to provide quantitative elements, an experimental program will be soon carried out to study the performances of the filters in terms of efficiency, clogging and gas permeability.

PPE Performance

The use of Personal Protective Equipment (ventilated or non-ventilated clothing, respiratory protection devices) is essential to carry out certain dismantling operations likely to present a risk for an operator, both radiological and conventional. The performance of this equipment, in particular in terms of protection factors, is verified under laboratory conditions by approved bodies, according to normative reference systems, and is subject to certification procedures. Thus IRSN has been carrying out for many years performance tests on several types of PPE (clothing, gloves, etc.) and is also notified by the public authorities for the UE certification of protective equipment against radioactive contamination. Nevertheless the question arises of the actual performance of certain equipment under conditions of use or in specific environments, such as those that may be encountered during dismantling operations (impact of the use of cutting processes, impact of heavy dust, high humidity or high temperature, etc.). In particular, IRSN was recently asked by the French General Directorate of Labor (DGT) to co-pilot a study aimed at evaluating the protection factors assigned to ventilated-pressurized clothing likely to be used in asbestos removal sites, following the reduction by a factor of 10 of the occupational exposure limit for asbestos fibers.

R&D ON CONTAMINATION METROLOGY

Performance of the Continuous Air Monitoring Systems (CAMs)

IRSN is involved in research program aimed at characterizing the behavior of Air Monitors Systems (CAMs) ensuring continuous and real-time monitoring of atmospheric radioactive contamination in the nuclear facilities. These monitors sample ambient aerosols on a HEPA filter and continuously measure the deposited activity. However particular conditions (dust, humidity, temperature, etc.) observed in some dismantling sites are at the origin of an increasing number of false alarms. Indeed, apart from the standardized conditions of the IEC standards (International Electrotechnical Commission), the responses of aerosol monitors are not characterized.
Firstly, research work was led in collaboration with EDF on the effect of coarse non-radioactive aerosols on the CAM response (Fig. 15) [24]. Results showed a positive correlation of the background of the natural radon progenies (especially ^{218}Po) with the aerosol mass sampled by the CAM. Il was also highlighted that the background could not be considered as proportional to radon progenies as it is currently used, and that the mass accumulation of particles sampled is not the only parameter that impacts the behavior of the CAM: it depends also on the aerosol size distribution.
This work, which made it possible to determine the origin of the degradation energy spectra generating false alarms of CAMs, will be continued with new test conditions standards in atypical situations to suggest in the short term to improve the current IEC standards.

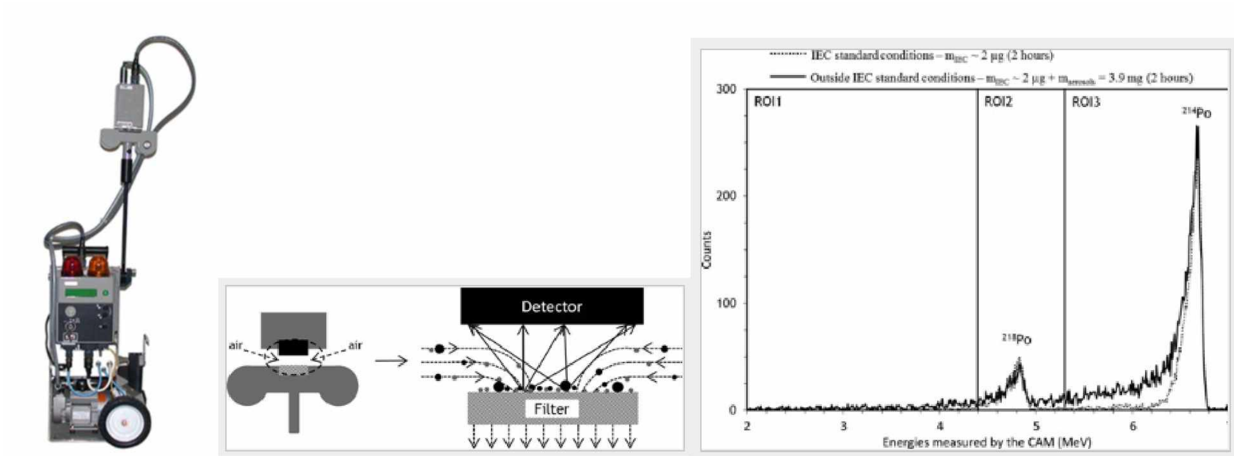

Fig. 15. (left) CAM used for the study on the impact of the coarse indoor non-radioactive aerosols on the background radon progenies' compensation; (middle) Illustration of the deposition of natural radioactive and non-radioactive particles on the filter of the sampling head; (right) Energy spectra measured by the CAM under IEC standard condition (in black dots) and under simulated dismantling site conditions (in full black line) [24]

CONCLUSIONS

This paper addresses the various research programs carried out at IRSN for several years to improve knowledge on the risks of airborne pollutants dispersion associated to the dismantling of nuclear facilities, with a view to assessing the safety of the operations while ensuring the best radiation protection of workers. These programs rely on experimental facilities and numerical simulation tools allowing to characterize and quantify particle emission sources (including incandescent particles), to predict contamination transfers inside the facility and to assess the performance of containment equipment (spark arrestors, HEPA filters, PPE…) and the performance of contamination monitors. Faced with the considerable increase of dismantling sites in the years to come, new knowledge needs on these topics will undoubtedly emerge, far beyond the prospects already envisaged.

REFERENCES

1. A Software Components Library for the Computation of Reactive Turbulent Flows, CALIF^{3}S, https://gforge.irsn.fr/gf/project/isis
2. Nerisson, P., Simonin, O., Ricciardi, L., Douce, A., Fazileabasse, J., Improved CFD transport and boundary conditions models for low-inertia particles (2011) Computers and Fluids, 40 (1), pp. 79-91
3. Gélain, T., Porcheron, E., Chagnot, C., Doyen, I., Journeau, C., Roulet, D., Development and validation of an agglomeration model for CFD simulations of aerosol dispersion in the frame of Fukushima fuel debris retrieval (2021) Journal of Nuclear Science and Technology, 58 (6), pp. 690-703
4. Gélain, T., Gensdarmes, F., Peillon, S., Ricciardi, L., CFD modelling of particle resuspension in a toroidal geometry resulting from airflows during a loss of vacuum accident (LOVA) (2020) Fusion Engineering and Design, 151, art. no. 111386
5. Gélain, T., Porcheron E., Leblois, Y., Doyen, I., Journeau, C., Delalez R., Roulet, D., On the assessment of the risk of aerosol dispersion during laser cutting operations of fuel debris int the 1F2 reactor pedestal and the intended strategies in terms of mitigation means, Proceedings of FDR2022, International Topical Workshop on Fukushima Decommissioning Research, Oct 14-16, 2022. Naraha, Fukushima, Japan

6. Plumecocq, W., Audouin, L., Joret, J.P., Pretrel, H., Numerical method for determining water droplets size distributions of spray nozzles using a two-zone model (2017) Nuclear Engineering and Design, 324, pp. 67-77
7. Grandjean, J.P., Pilot, G., Evaluation of Various Cutting Techniques Suitable for the Dismantling of Nuclear Components: Final Report Volume 17919 de EUR / European Commission Nuclear science and technology Office for Official Publications of the European Communities, 1998
8. Pilot, G. (2008) Assessment of the airborne release coefficient during cutting operations in the frame dismantling studies. ICONE 16-48405, pp. 827–834.
9. Pilot, G., Fauvel, S., Gosse, X., de Dinechin, G., Vernhet, D. (2008) Measurement of secondary emissions during laser cutting of steel equipments. Nucl. Eng. Des. 238: 2124–2134.
10. Peillon, S., Fauvel, S., Chagnot, C., Gensdarmes, F., Aerosol characterization and particle scrubbing efficiency of underwater operations during laser cutting of steel components for dismantling of nuclear facilities (2017) Aerosol and Air Quality Research, 17, pp. 1363-1373
11. Porcheron E., Leblois Y., Gélain T., Doyen I., Journeau C., Delalez R., Roulet D., How to evaluate and reduce the risks of dissemination of radioactive aerosols during fuel debris retrieval operations at Fukushima Daiichi, WM2023 Conference, Phoenix, Arizona
12. Dazon, C., Porcheron, E., Journeau, C., Suteau, C., Chagnot, C., Doyen, I., Excoffier, E., Roulet, D., Characterization of chemical composition and particle size distribution of aerosols released during laser cutting of fuel debris simulants (2020) Journal of Environmental Chemical Engineering, 8 (4), art. no. 103872
13. Porcheron, E., Dazon, C., Gélain, T., Chagnot, C., Doyen, I., Journeau, C., Excoffier, E., Roulet, D., Fukushima Daiichi fuel debris retrieval: results of aerosol characterization during laser cutting of non-radioactive corium simulants (2021) Journal of Nuclear Science and Technology, 58 (1), pp. 87-99
14. Porcheron, E., Leblois, Y., Bouland, A, Journeau, C., Suteau, C., Delacroix, J., Molina, D, Berlemont, R., Lallot, Y, Roulet, D., Tsubota, Y., Ikeda-Ohno, A., Particle Generation Test Using Simulated Uranium Containing Debris: The URASOL project in the framework of Fukushima Daiichi dismantling (2021) International Conference on Decommissioning Challenges: Industrial Reality, Lessons Learned and Prospects (DEM 2021), Avignon, France
15. Sow, M., Leblois, Y., Bodiot, C., Motzkus, C., Ritoux, S., Gensdarmes, F., Aerosol release fraction by concrete scarifying operations and its implications on the dismantling of nuclear facilities (2020) Journal of Hazardous Materials, 400, art. no. 123077
16. Rida, Z., Kaissoun, S., Prevost, C., Gelain, T., Climent, E., Experimental study of backflow air leakage through an opening from a depressurized enclosure (2022) Journal of Nuclear Science and Technology, 59 (6), pp. 792-806
17. Prevost, C., Rida, Z., Gelain, T., Climent, E., Evaluation of the relevant criteria to ensure the efficiency of the dynamic containment of flexible site airlocks during dismantling operations, submitted to WM2023 Conference, Phoenix
18. Porcheron, E., Leblois, Y., Gelain, T., Chagnot, C., Journeau, C., Roulet, D., Assessment of Spray and Pool Scrubbing Efficiencies for Means of Mitigation Against Aerosol Dispersion in the Context of Fuel Debris Retrieval at Fukushima Daiichi: Part I/II (2022) Journal of Nuclear Engineering and Radiation Science, 8 (3), art. no. 031701/031702
19. Le Roux, N., Faure, X., Inard, C., Soares, S., Ricciardi, L., Reduced-scale study of wind influence on mean airflows inside buildings equipped with ventilation systems (2012) Building and Environment, 58, pp. 231-244
20. Ricciardi, L., Gélain, T., Soares, S., Experimental and numerical characterization of wind-induced pressure coefficients on nuclear buildings and chimney exhausts (2015) Nuclear Engineering and Design, 292, art. no. 8359, pp. 248-260
21. Marchal, P., Porcheron, E., Grehan, G., Lafanechere, L., Walter, J., Gelain, T., Characterization of incandescent particles emitted by a cut-off grinder during decommissioning operations for evaluating filter degradation (2015) Journal of Nuclear Engineering and Radiation Science, 1 (2), art. no. 021005
22. Bourrous, S., Barrault, M., Brunisso, A., Ricciardi, L., Characterization of the degradation of HEPA

filters protected by different spark arrestors for various cutting means and cutting conditions, submitted to Journal of Nuclear Engineering and Radiation Science

23. Bourrous, S., Bouilloux, L., Ouf, F.-X., Lemaitre, P., Nerisson, P., Thomas, D., Appert-Collin, J.C., Measurement and modeling of pressure drop of HEPA filters clogged with ultrafine particles (2016) Powder Technology, 289, pp. 109-117
24. Hoarau, G., Dougniaux, G., Gensdarmes, F., Cassette, P., Ranchoux, G., Impact of the Coarse Indoor Non-radioactive Aerosols on the Background Radon Progenies' Compensation of a Continuous Air Monitor (2022) Health Physics, 122 (5), pp. 563-574