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Experiments on aerosol removal by high-pressure water spray

Ada del Corno [a], Sonia Morandi [a], Flavio Parozzi [a,*], Lucio Araneo [b,c], Francesco Casella [b]

[a] RSE, Power Generation Technologies and Materials Dept, via Rubattino 54, I-20134 Milano, Italy
[b] Politecnico di Milano, Department of Energy, via Lambruschini 4A, I-20156 Milano, Italy
[c] CNR-IENI, via Cozzi 53, I-20125 Milano, Italy

HIGHLIGHTS

- Experimental research to measure the efficiency of high-pressure sprays in capturing aerosols if applied to a filtered containment venting system in case of severe accident.
- Cloud of monodispersed SiO_2 particles with sizes 0.5 or 1.0 μm and initial concentration in the range 2–90 mg/m^3.
- Carried out in a chamber 0.5 × 1.0 m and 1.5 m high, with transparent walls equipped with a high pressure water spray with single nozzle.
- Respect to low-pressure sprays, removal efficiency turned out significant: the half-life for 1 μm particles with a removal high-pressure spray system is orders of magnitude shorter than that with a low-pressure sprays system.

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ABSTRACT

An experimental research was managed in the framework of the PASSAM European Project to measure the efficiency of high-pressure sprays in capturing aerosols when applied to a filtered containment venting system in case of severe accident.

The campaign was carried out in a purposely built facility composed by a scrubbing chamber 0.5 × 1.0 m and 1.5 m high, with transparent walls to permit the complete view of the aerosol removal process, where the aerosol was injected to form a cloud of specific particle concentration. The chamber was equipped with a high pressure water spray system with a single nozzle placed on its top.

The test matrix consisted in the combination of water pressure injections, in the range 50–130 bar, on a cloud of monodispersed SiO_2 particles with sizes 0.5 or 1.0 μm and initial concentration ranging between 2 and 99 mg/m^3. The spray was kept running for 2 min and the efficiency of the removal was evaluated, along the test time, using an optical particle sizer.

With respect to low-pressure sprays, the removal efficiency turned out much more significant: the half-life for 1 μm particles with a removal high-pressure spray system is orders of magnitude shorter than that with a low-pressure spray system.

The highest removal rate was detected with 1 μm particles at the highest water injection pressure, mainly because of the high concentration of droplets with high velocity, while lower removal was measured for 0.5 μm particles. No influence of the initial aerosol concentration was observed for both particle sizes.

1. Introduction

The PASSAM project (Passive and Active Systems on Severe Accident source term Mitigation) started in 2013 as part of the 7th Framework Programme of the European Commission to improve the understanding of radionuclide trapping techniques, under severe accident conditions, in order to reduce potential releases of airborne radioactive species to the environment through a filtered containment system.

The project is of R&D experimental nature, aiming at exploring potential enhancement of existing source term mitigation devices and demonstrating the ability of innovative systems to achieve significant source term attenuation. This four years research is coordinated by the French IRSN (Institut de Radioprotection et de Sûreté

* Corresponding author.
E-mail addresses: delcorno@rse-web.it (A. del Corno), morandi@rse-web.it (S. Morandi), parozzi@rse-web.it (F. Parozzi), lucio.araneo@polimi.it (L. Araneo), francesco2.casella@mail.polimi.it (F. Casella).

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Nucléaire) and involves nine partners from six European countries having a strong experience on severe accidents (Albiol et al., 2013).

In this context, a work package has been coordinated by the Italian RSE (Ricerca sul Sistema Energetico) to evaluate the efficiency of high pressure sprays in removing suspended particles, investigating the physical phenomena that can permit the development of mechanistic models, not facility-dependent, to be implemented in accident analysis codes.

Indeed, water low pressure sprays are widely adopted in LWRs (Light Water Reactors) as engineered safety systems. In addition to their function of preventing overpressurization of the containment in the case of DBAs (Design Basis Accidents), sprays are also considered capable of removing radioactive aerosols from the containment atmosphere in the case of severe accidents.

High-pressure sprays could have a removal efficiency much higher than that of a water spray operating under the same conditions at low pressure. In fact, droplets generated by high pressure sprays have a smaller diameter and a higher speed than those generated by spray at low pressure. That implies larger contact surface, higher turbulence, higher relative velocity between droplets and aerosol particles, thus increasing the particle collection efficiency for aerosols below 1 μm (Powers and Burson, 1993).

The work here presented, then, reports the first results of the experimental campaign carried out with a lab-scale facility, not plant-dependent, focused on studying the capability of high pressure sprays to remove airborne micronic particles.

2. Experimental apparatus

2.1. Overview of the facility SCRUPOS

The SCRUPOS facility (SCRUbbing by POol and Spray) was built at the laboratories of RSE in Milano. The facility, schematized in Fig. 1, simply consists in a chamber 0.5 × 1 m and 1.5 m high, having a stainless steel structure and glass walls.

The aerosol is injected at the bottom. The air flow coming from a compressed air line is separated into two lines: a flow meter/regulator maintains constant the flow going to the particles dispenser in the first line, a flow meter/regulator allows to change the air flow rate in the second line. The two lines are rejoined before the injection into the chamber, thus obtaining a variable total air flow rate. The pipes are made with transparent material for monitoring the possible particle deposition upstream the injection into the chamber. An extraction system on the chamber top allows to discharge the aerosol that has not been removed by the scrubbing process.

2.2. Aerosol generation system

The solid aerosol is generated with a Topas SAG 410 dust dispenser. Here, preformed particles are filled and, with a scraper and a moving belt, are dosed. The aerodynamic forces, generated in the ejector, disperse and fragment the powder to form the aerosol. The resulting particle number concentration of the output aerosol can be easily adjusted by setting the feeding belt speed over a wide range. A further adjustment of the particle concentration can be obtained by varying the air flow rate.

2.3. Particle measurement

Measurements of the solid particles concentration and of their size distribution are performed with the TSI Optical Particle Sizer 3330, that uses the single particle counting technology.

An aerosol sample flow is continuously sucked from the test chamber with a pump and, after a dilution, it goes to the measurement region of the instrument. Here, the flow crosses a laser beam,

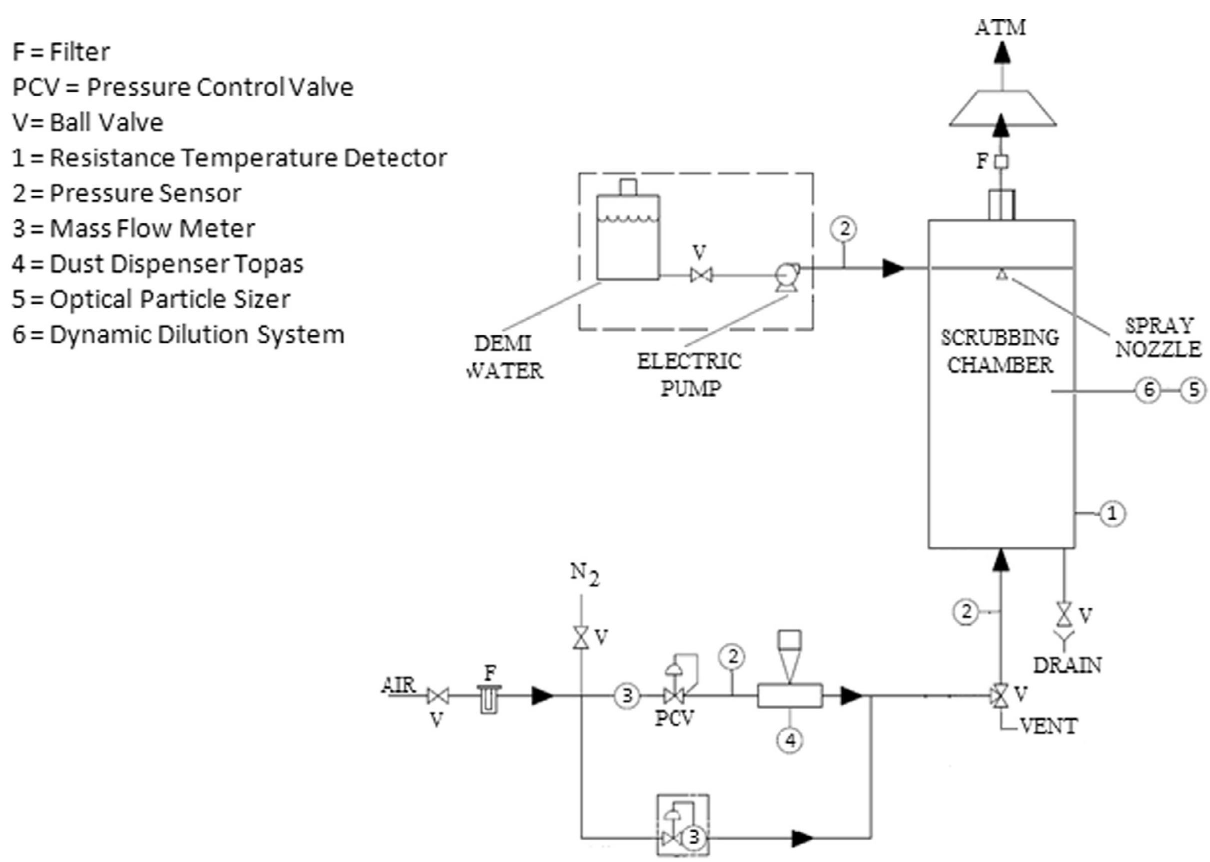

Fig. 1. Scheme of the SCRUPOS facility.