Centrifugal Filtration System for Severe Accident Source Term Treatment

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1. Introduction

1-1 Background

❖Reactor containment may lose its structural integrity due to over-pressurization during a severe accident

❖For preventing the dispersion of these uncontrolled radioactive releases to the environment, several ways to capture or mitigate these radioactive source term releases are under investigation at KAIST.

❖Example: air curtain, a chemical spray, and a suction arm

❖Treatment of the radioactive material captured by these systems would be required, before releasing to environment

1-2 Current filtration system in nuclear industry

❖Sand — Multi-venture scrubber

❖High efficiency particulate arresting (HEPA) — Charcoal

❖Combinations of the above

1-3 Purpose of the Research

❖Develop the conceptual design of a filtration system that can be used to process airborne severe accident source term.

2.Conceptual design

2-1 Conceptual model

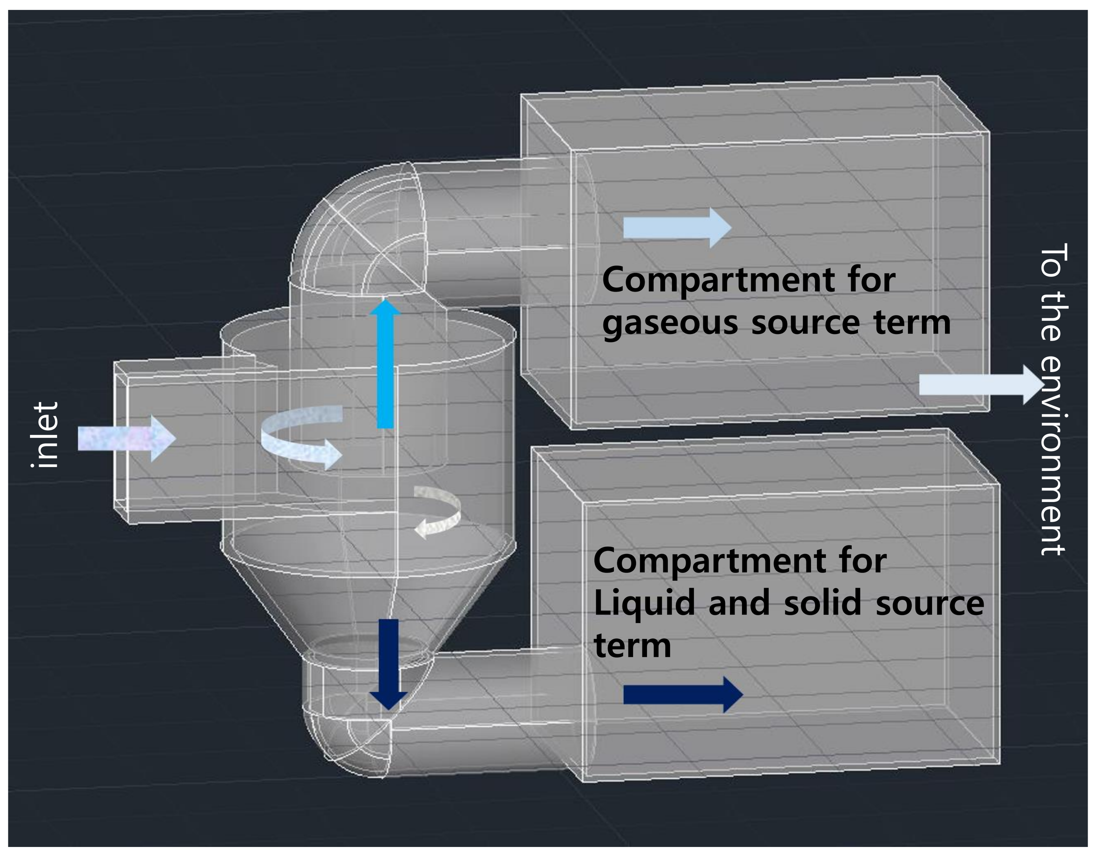


Figure 1: conceptual design and work flow

2-2 Source term analysis

The simplest categorization of the material to be treated, that could be released from a nuclear power plant, is the mixture of noble gases, gaseous iodine, cesium particulate and other particulate.
In this simulation, the source term is presented as:

Fluid phase: air (containing gaseous iodine); **Particle:** CsI

2-3 Filtration technology and absorbents:

❖ Centrifuge:
- a) Currently not used in nuclear industry
- b) Flexible in dimension and widely used in industry
- c) Can act as a pre-filter

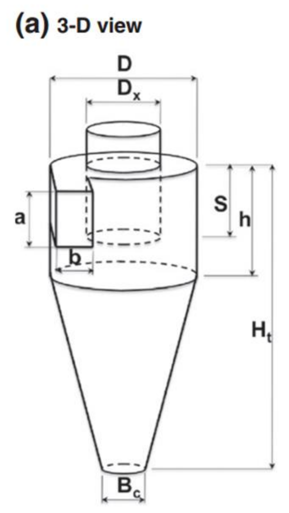
❖ TEDA Charcoal for gaseous source term
- a) Impregnated with TEDA (tri-ethylene-di-amine)
- b) Concern: Humidity control & temperature

❖ Water containing NaOH and $Na_2S_2O_3$
- a) Widely used in wet scrubber of filtered containment venting system(FCVS) in nuclear field

2-4 Geometery

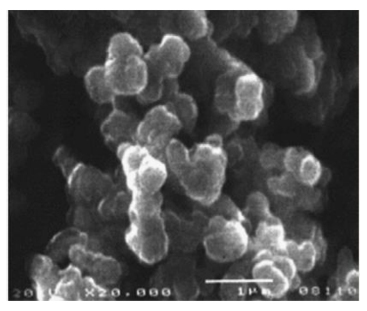
❖ A typical staimand cyclone design parameters, D=1m

Cyclone	a/D	b/D	Dx/D	Ht/D	h/D	S/D	Bc/D
Stairmand design	0.5	0.2	0.5	4	1.5	0.5	0.375



❖ Particle size and distribution

The SEM images of aerosols from an impactor plate in the circuit of the Phébus FPT0 test shows an agglomerated structure of particles typically in the range 0.1–0.5 mm
Particle density: 0.1g-100g/m3
--Normal distribution



2-5 Turbulent model

❖ LES model for gas phase
-- High Reynolds number flow

❖ Paticle forces
--ErgunWenYu Drag model
-- suitable for all particulate volume fractions up to the closed packed condition;

3. Simulation results

3-1 Simulation

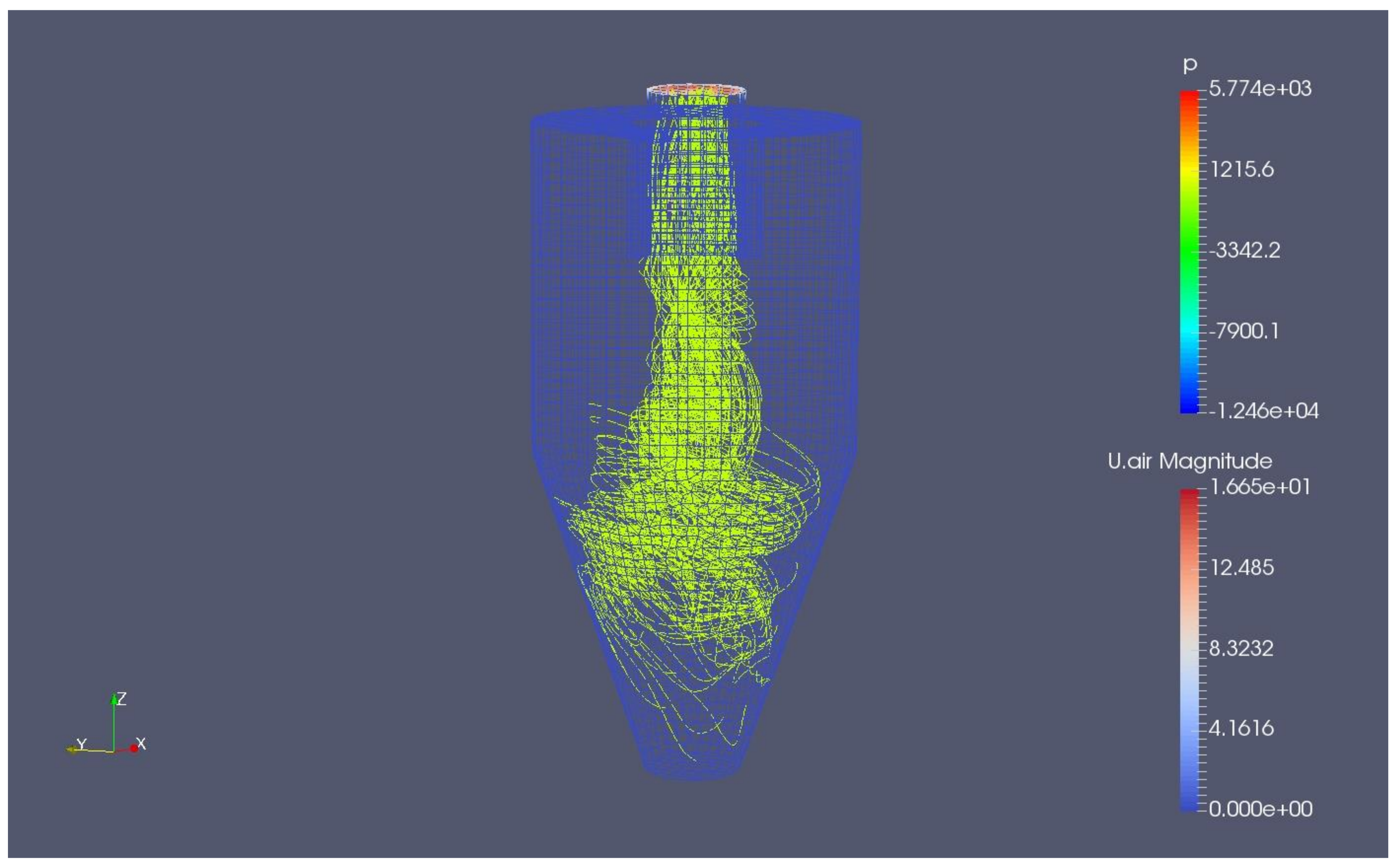


Figure 2: Simulation of the cyclone separation

3-2 Cutoff diameter

The particle diameter corresponding to 50% collection efficiency

$D_{p50} = 3\sqrt{\frac{\mu b}{2\pi \rho_p U_i C N_t}}$ * $D_{p50} =$ 590mm

U_i : gas velocity at the inlet; t : residence time t, t=V/Q

ρ_p : particle density; μ : air dynamic viscosity;

C : slip correction factor of the particle corresponding to D_{p50}.

N_t : number of turns, Nt= tUi/πD V : volume of the cyclone

Q : volumetric flow rate, Q= a*b*Ui

4. Conclusion

4-1 Summary

❖The current centrifuge can be used as a pre-filter to separated the gaseous compartment and particle.

❖Because the particle size is relatively small, the current separation efficiency is not ideal.

4-2 Future work

❖Cyclone efficiency analysis for different inlet velocity and pressure.

❖Optimization of the cyclone design.

❖Analysis of the absorbent and filter part.

Reference

- Centrifugal Separator and Filter Arrangement Having a Centrifugal Separator of Said Type ,US 20140298761 A1
- Calculation of release of radioactive materials in gaseous and liquid effluents from pressurized water reactors, NUREG-0017, rev.1
- Status report on filtered containment venting, NEA/CSNI/R(2014)7
- Filtered containment venting systems at Swiss NPPs and KKL in particular
- William C. Hinds, Aerosol technology, 2nd edition, 1999
- Luke S. Lebel, Markus H, Piro et al., Concept for a cyclonic spray scrubber as a fission product removal system for filtered containment venting, Nuclear Engineering and Design 297 (2016) 60-71
- Dmitry Bogdanov, Sergey Poniaev, Numerical simulation of turbulent flow in a cyclone separator, Journal of Physics: Conference Series 572 (2014) 012056

- Centrifugal Separator and Filter Arrangement Having a Centrifugal Separator of Said Type ,US 20140298761 A1
- Calculation of release of radioactive materials in gaseous and liquid effluents from pressurized water reactors, NUREG-0017, rev.1