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Study of iodine removal efficiency in self-priming venturi scrubber

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ABSTRACT

Venturi scrubber is used in filtered vented containment system of nuclear power plants to remove the gaseous pollutants from contaminated gas during severe accidents. In this research, an experimental and theoretical investigation has been carried out to study the iodine removal efficiency in a self-priming venturi scrubber. The aqueous solution is prepared by adding weight percentage of sodium hydroxide 0.5% and sodium thiosulphate 0.2% in scrubbing water to increase the absorbance of inorganic iodine (I_2) from the contaminated gas during emission. The iodine removal efficiency is investigated at various gas and liquid flow rates, and iodine inlet concentrations. The iodine removal efficiency is measured experimentally by measuring the inlet and outlet concentration of iodine at sampling ports. The petite droplets are formed in a venturi scrubber to absorb the iodine through the mass transfer phenomenon. A mathematical model for mass transfer based on a gas liquid interface is employed for the verification of experimental results. The contact time between iodine and scrubbing solution depends on the total volumetric flow of gas and liquid, and volume of throat and diffuser of the venturi scrubber. Sauter mean diameter is calculated from the Nukiyama and Tanasawa correlation. Steinberger and Treybal's correlation is used to measure the mass transfer coefficient for the gas phase. The results calculated from the model under predict the experimental data.

1. Introduction

Gas absorption process is defined as the transfer of a gaseous pollutant from a gas phase to a liquid phase. This process is used in wet scrubbers such as venturi scrubber to remove the gaseous contaminants from a gas stream. Gas absorption process is a mass transfer phenomenon in which mass transfer of gaseous contaminants has been taken place from gas phase into liquid phase due to the concentration differences between these two phases (Cheremisinoff, 1977).

In the severe accident in Nuclear Power Plant (NPP), the fission products are released from the molten core into the containment. Among many of the radioactive fission products released during an accident, the radioactive iodine I-131 is a major constituent who have the significant impact on the environment and human health (World Health Organization, 2011). Radioactive iodine I-131 has a short half-life of 8 days. It accumulates in the thyroid gland of human body and increases the risk of thyroid cancer. It is exposed in a body of human by drinking contaminated water or milk, and breathing the contaminated air (Winteringham, 1989).

Filtered vented containment system (FVCS) has been suggested to mitigate the effect of the severe accidents in a NPP. This system is installed for: protection against excessive pressure buildup, removal of aerosol, iodine, and organic compounds, safe release of hydrogen, and removal of decay heat (AREVA INC, 2011). Filtered vented containment system (FVCS) comprising of venturi scrubbers and metallic fiber filter is installed in the NPP (Rust et al., 1995) as shown in Fig. 1. When high gas velocity passes through the throat of a venturi scrubber, provides suction of liquid due to low pressure. The liquid entered into the venturi scrubber due to static pressure of gas and hydrostatic head of liquid in scrubber unit. This liquid is disintegrated into tiny droplets and travelled along with gas. These tiny droplets interact with radioactive iodine gas and remove it by the absorption process. The absorbed iodine in droplets is collected in scrubber unit and clean gas exits through vent stack.

The goal of conducting this research work is to study the iodine removal efficiency in a self-priming venturi scrubber. For this purpose, experimental and theoretical approach is used to study the removal efficiency of iodine. The results obtained from them are explained and compared.

The research article is organized as follows: Section 2 highlights the previous work related to experimentation and modeling for absorption of gas in a venturi scrubber: Section 3 explains the mathematical model developed for removal efficiency of iodine: Section 4 illuminates the experimental facility: Section 5 discusses

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Nomenclature

C	concentration (mg/m^3)
r	radius (m)
t	time (s)
k	mass transfer coefficient (m^{-1})
V	volume (m^3)
v	velocity (m s^{-1})
Sh	Sherwood number (dimensionless)
Re	Reynolds number (dimensionless)
Sc	Schmidt number (dimensionless)
d	diameter (m)
D	diffusion coefficient (m^2 s^{-1})
ρ	density (kg m^{-3})
σ	surface tension (N m^{-1})
Q	volumetric flow rate (m^3/h)
μ	viscosity (N s m^{-2})
V'	geometry volume (m^3)
E	efficiency

Subscripts

d	droplet
r	relative
l	liquid
g	gas
re	removal efficiency
in	iodine
out	outlet
i	interface
T	throat
D	diffuser

experimental and theoretical results: Section 6 concludes the conducted research work for iodine removal efficiency of iodine in a self-priming venturi scrubber.

2. Previous work

Ravindram and Pyla (1985) proposed a mathematical model for the absorption of gaseous pollutants in a venturi scrubber. The pollutants were absorbed by irreversible chemical reaction between gaseous pollutant and alkaline solution. It was assumed that the throat was covered with fine, spherical and uniform size of droplets. The reaction took place in throat and diffuser section. The gas phase resistance was ignored. The model was validated experimentally by demonstrating the absorption of SO_2 and CO_2 in 0.6 M NaOH solution. The model satisfied well with the experimental results.

Hills (1995) suggested the solutions for mass transfer in a venturi scrubber with different boundary conditions. The solutions were based on first-order chemical reaction. The boundary conditions were: surface concentration constant, absorption from a limited volume of a gas, external mass transfer resistance with constant bulk gas concentration, gas-phase mass-transfer resistance and finite gas volume, and infinitely rapid reaction. The results obtained from these boundary conditions were compared against with the experimental data of Ravindram and Pyla (1985) and found serious disagreement.

Talaie et al. (1997) proposed a three-dimensional model for SO_2 removal efficiency in a venturi scrubber by water and alkaline solution. The three-dimensional model was based on non-uniform concentration dispersion of droplet. The model was verified against the experimental data of Johnstone, Wen and Fan.

Gamisans et al. (2002) experimentally studied the absorption of SO_2 and NH_3 in NaOH and H_2SO_4 in an ejector venturi scrubber. The performance of the scrubber was analyzed at different absorbing liquid and gas flow rates, and pollutant concentrations. Response surface methodology (RSM) was used to determine the optimal factors which can affect the absorption process in an ejector venturi scrubber. The various configurations of venturi scrubber were

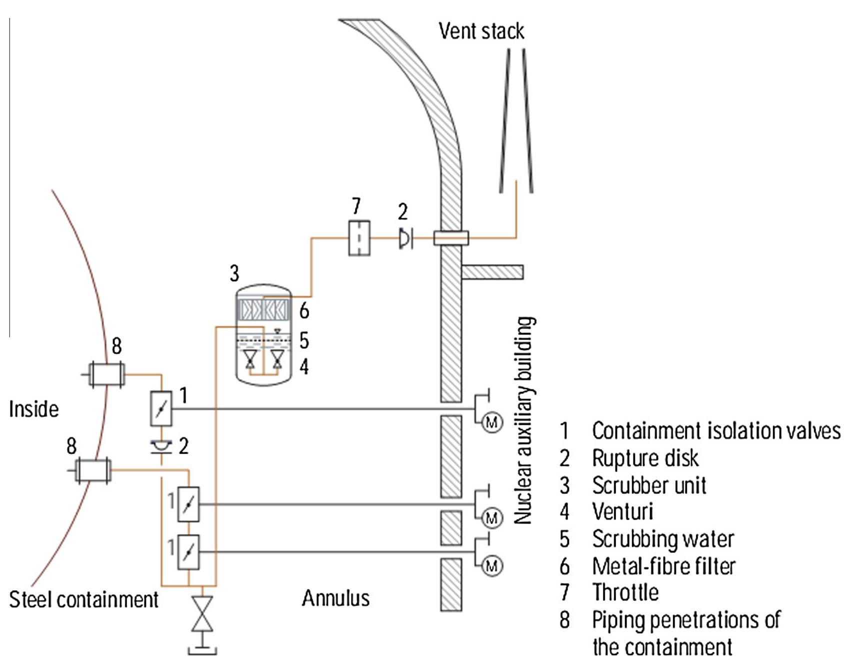

Fig. 1. Gosgen filtered vented containment system (Kernkraftwerk Gosgen-Daniken AG, 1999).