Iodine Removal in Self- Priming Venturi Scrubber

Jawaria Ahad[*1], Amjad Farooq[1], Masroor Ahmad[1], Khalid Waheed[1], Naseem Ifran[1], Waseem Siddique[2], Kamran Rasheed Qureshi[2],
[1] Department of Nuclear Engineering, Pakistan Institute of Engineering and Applied Sciences, Pakistan
[2] Department of Mechanical Engineering, Pakistan Institute of Engineering and Applied Sciences, Pakistan
jawariahad@gmail.com

Abstract
Nuclear power plants are a reliable and clean source of energy. After occurrence of major nuclear accidents like Fukushima, a special nuclear safety system was developed for power plants named as Filtered containment venting system (FCVS). The objective of this system was to control over- pressurization to maintain integrity of structure and restrict the radioactivity from spreading out into environment in case of an accident. In the list of radioactive products, iodine is a major hazardous radioactive product that can cause thyroid cancer in case it gets released into environment. Iodine removal is very crucial for safety of people and environment. So, an indigenous lab scale setup of this system was built at PIEAS to conduct research on iodine removal. A venturi scrubber containing a solution of 0.2% sodium thiosulphate and 0.5% sodium hydroxide was used in the setup. The throat velocity of venturi was varied to see its effect on removal efficiency of iodine. It was observed that the removal efficiency increased with increasing throat velocity. Overall, maximum removal efficiency of 99.47 % was obtained which fulfilled the required for FCVS.

Keywords
Environment Safety, Venturi Scrubber, Iodine Removal, Hydrodynamics, Nuclear Mitigation System

Introduction

Nuclear Power Plants play a very significant role in fulfilling the energy requirement of our country. Nuclear power plants are designed very articulately after performing a series of safety analysis. Several redundant and diverse systems along with wide safety margin are present with power plants. After three major accidents that are Three Mile Island, Chernobyl and Fukushima, it was felt that a special passive safety system should be present in all nuclear power plants as well. Its sole purpose should be to control over- pressurization by releasing part of containment air and removal of radioactive products from this incoming air[1]. This system should not in any case make the accident situation worst. This system gets activated when the containment pressure gets beyond the set point in case of an accident when other safety systems fail to keep the pressure under control. In this scenario, hot steam along with other gases at a constant flowrate from containment is led through a rupture disc (passive activation) or isolation valves (manual activation) to control over-pressurization [2]. This steam coming from containment contains radioactive materials. Radioactive gaseous Iodine is one of the most hazardous product present in this steam. If it gets released into the environment, it can cause thyroid cancer among other disasters. It is very important to conduct in depth research on removal of iodine to keep the environment and people safe [3].
Different scrubbers including nozzles, spargers and venturi scrubbers are used in FCVS for removal of iodine. The most commonly used scrubbers are venturi scrubbers because of their

high efficiency. A self- priming venturi consists of a column filled with solution along with a venturi. There are three parts of venturi including converging section, throat and diverging section. The air- gas mixture is added via converging section which is conical in shape that converges into a smaller diameter throat section [4]. The mixture is then passed onto throat section which contains 8 orifices. The pressure of gas mixture gets very low here compared to outside the throat. So, the solution gets sucked into these orifices due to pressure difference and reacts with mixture. Then comes the diverging section which is also conical in shape but here the size diverges from smaller to bigger diameter. The pressure gets recovered in this section. Then, the mixture moves onto the column from venturi and at the exit of column, the output sample is taken. In another method called forced feed method, a source like a pump is provided to inject water into the throat of venturi scrubber [5, 6].

Material and Methods

Schematic diagram of the setup used in this research is shown in Figure 1. It consists of compressor to simulate the hot and highly compressed air coming from the containment in case of an accident. This compressed air is then moved onto a moisture separator where all the moisture from this air is removed. A rotameter is then used to regulate and measure the flow rate. Air is then heated by a heater to a temperature of 110^{o}C. This temperature is achieved to keep the iodine in gaseous form because its sublimation temperature is 85^{o}C. Otherwise, it would get deposit in the line. Iodine is then injected via an injection pump into this heated line. It gets converted into gaseous form and this air- gas mixture moves on towards the scrubbing column. The inlet sample is taken here. The scrubbing column contains a solution of 0.2% sodium thiosulphate and 0.5% sodium hydroxide. The mixture enters the venturi scrubber, mass transfer takes place and iodine gets retained. The outlet sample is taken from the outlet of column. Sampling is done by using a trap solution of KOH which is later analysed by UV- VIS spectroscopy. The dimensions of venturi are shown in Figure 2.

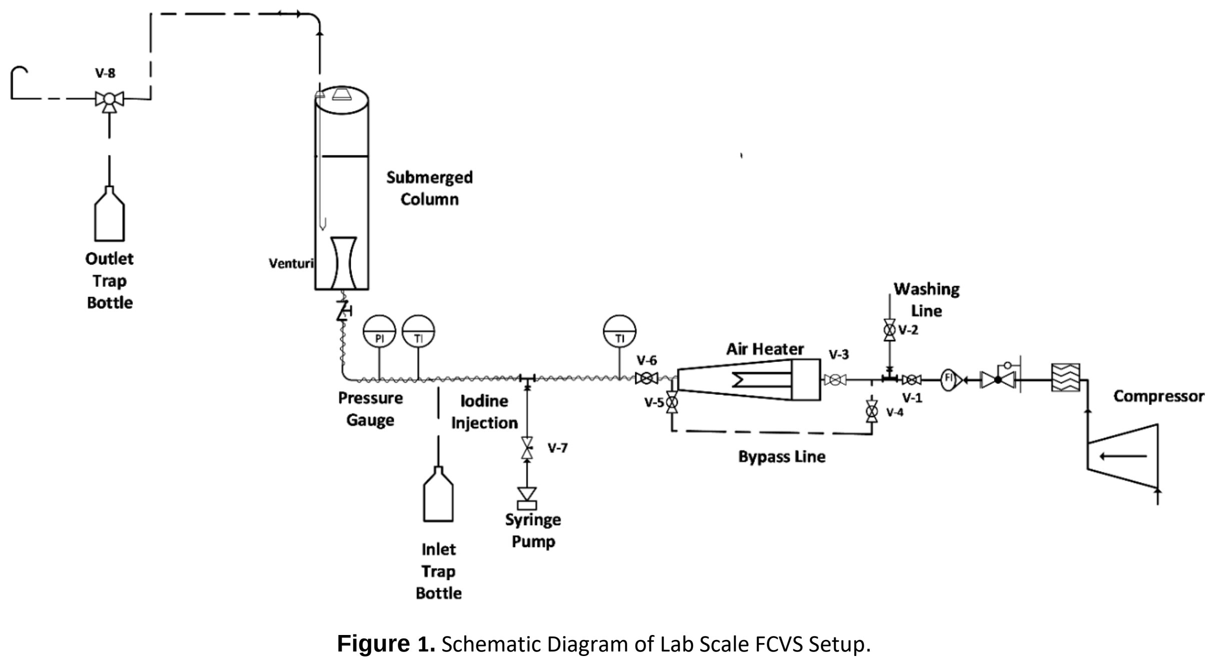

Figure 1. Schematic Diagram of Lab Scale FCVS Setup.

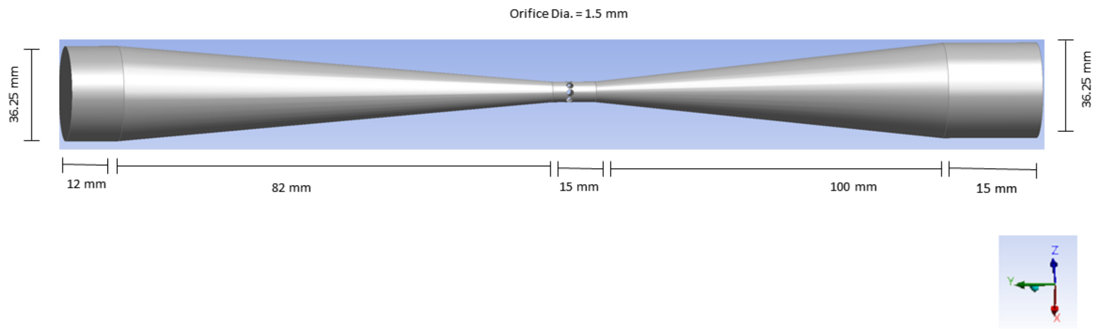

Figure 2. Dimensions of Venturi

Results and Discussion

The throat velocity of venturi is varied to see its effect on the removal efficiency of iodine. The graph is shown in Figure 3. Results show that the removal efficiency of iodine increases with increase in throat velocity. Maximum mass transfer and iodine removal takes place at throat region. The pressure of mixture gets very low in the throat section, and this sucks the water into throat via orifices. Water gets transformed into droplets via inertial impaction. The mixture interacts with droplets and due to concentration difference iodine gets trapped inside droplets and gets retained. The pressure starts to recover in the diverging section, but some mass transfer takes place here as well. When the gas leaves venturi and enters the column, it gets transformed into bubbles. The iodine gets out of the bubbles due to concentration difference, reacts with the chemical solution and gets retained.

When the throat velocity is increased, more negative pressure gets created at the throat, more water gets sucked into the throat and contact between liquid and gas increases. As a result, mass transfer rate increases, and more iodine gets retained.

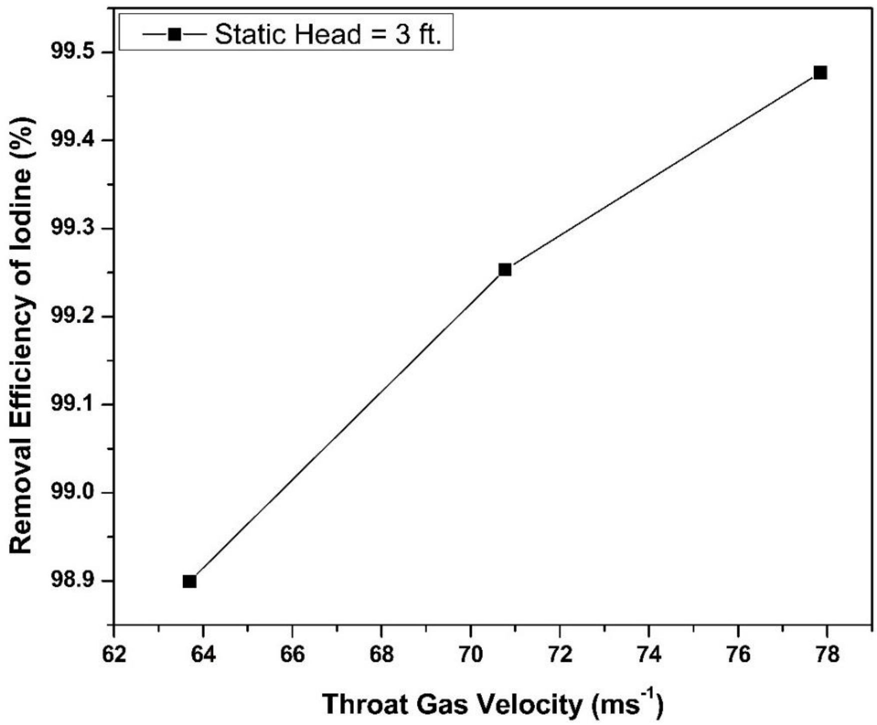

Figure 3. Graph of Throat Gas Velocity and Removal Efficiency of Iodine

Conclusion

- Iodine removal efficiency increases with increase in throat gas velocity.
- We can get required efficiency by optimization of throat gas velocity.
- A maximum removal efficiency of 99.47 % was obtained which is above the requirement for FCVS.

Acknowledgments

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