Preliminary Design of Molecular Sieve for Removing Organic Iodide in Containment Filtered Venting System

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1. Introduction

In the event of nuclear power plant (NPP) severe accident, the nuclear reactor containment might suffer damage resulting from overpressure caused by decay heat. In order to prevent this containment damage, containment venting has been considered as one of effective methods. However, since vented gases contain radioactive fission products, they should be filtered to be released to environment. Generally, containment filtered venting system (CFVS) is installed on NPP to achieve this aim. [1] Even though great amount of efforts have been devoted to developing the CFVS using various filtering methods, the decontaminant factor (DF) for radioactive gaseous iodide is still unsatisfactory while DFs for radioactive aerosols and elemental iodine are very high.

In this paper, to increase the DF for gaseous iodine species, especially organic iodide, molecular sieve filled by silver exchanged zeolites is proposed and designed preliminarily. Its aerodynamic analysis is also performed and presented.

2. Design of Molecular Sieve

The silver exchanged zeolites, well-known adsorbent materials for removing gaseous iodine species, do show high DFs for both elemental iodine and organic iodide, typically ranging from 10^3 to 10^5, under the right operation conditions. Since high humidity can decrease the DF for organic iodide by orders of magnitude, a molecular sieve filled by these zeolites is generally installed downstream of throttling device. [2] Therefore, its operation pressure is near-atmosphere and super-heated steam is injected into the molecular sieve.

In the process of molecular sieve design, a key point is to predict or calculate an adsorption capacity of silver exchanged zeolites for organic iodide. Because this parameter is related to linear velocity of organic iodide as well as residence time of organic iodide inside zeolites. The adsorption capacity is generally increased according to increase of the residence time and decrease of the linear velocity. To determine the adsorption capacity of silver exchanged zeolites, organic iodide removal tests shown in Fig. 1 were performed. Atmosphere pressure was given as operation pressure while test temperature and velocity of organic iodide were imposed as 150°C and 0.1m/s, respectively. From these tests, 17mg/g of adsorption capacity was obtained when the residence time was 0.3 second. On the other hand, the value was 81mg/g in the case of 1 second. According to the CFVS inlet and outlet pipes' sizes and opening pressure of CFVS, the volumetric flow rate toward molecular sieve is changed. Therefore in this design, volumetric flow rate ranging from 6 m^3/s to 20 m^3/s was considered. And we conventionally assumed that the total vented organic iodide during CFVS operation was 5kg. At least 295kg of silver exchanged zeolites should be filled in molecular sieve using the zeolites that has 17mg/g of adsorption capacity.

Table I shows the design parameters of molecular sieve at 6, 8 and 20 m^3/s of volumetric flow rate, respectively. Deep-bed type was chosen for molecular sieve type, 10 beds were used in the molecular sieve and 1,620kg of zeolites were filled in the 10 bed evenly. In this case, the safety factor which is a ratio of real loading and minimum required masses is 5.5 (1,620kg /295kg). If this molecular sieve is used for 20m^3/s of volumetric flow rate, the residence time is only 0.09 sec. Since the adsorption capacity of silver exchanged zeolites will be lower than 17mg/g in this case, the safety factor will be also smaller. If >3.09mg/g of adsorption capacity can be obtained, the safety factor could be larger than 1.

In order to verify effectiveness of the molecular sieve, the aerodynamic analysis of the molecular sieve was performed by using CFDesign code. From this analysis, it is verified that the 10 beds in the molecular sieve functioned well. The aerodynamic analysis with various volumetric flow rates are shown in Fig. 2.

Table I. Design Parameters of Molecular Sieve with Ten Beds.

Design Parameters				Unit
Height	1200			mm
Length	1500			mm
Depth	100			mm
Number of Beds	10			#
Volume	1.8			m^3
Total Adsorbents	1620			kg
Area	18			m2
Design Volumetric Flow Rate	6	8	20	m^3/s
Linear Velocity	0.33	0.44	1.11	m/s

Residence Time	0.3	0.225	0.09	sec
Safety Factor	5.5	<5.5	<5.5	-

3. Conclusions

In order to increase the DF for gaseous organic iodide, deep-bed type molecular sieve was proposed and designed preliminarily. Total 1,620kg of silver exchanged zeolites were filled evenly in 10 beds of the molecular sieve. And its safety factor was up to 5.5 at 6m^3/s of design volumetric flow rate. And through the aerodynamic analysis, its effectiveness was verified.

It is worthy to make a couple of points. The safety factor in the case of 20m^3/s will be smaller than the counterpart of the standard case (6m^3/s). However, if the adsorption capacity of the zeolites is larger than 3.09mg/g when the residence time is 0.09 second, the designed molecular sieve can be used at 20m3/s of volumetric flow rate. This designed molecular sieve has wide operation flow rate. Therefore, further iodine removal tests with various residence times, especially 0.09 sec, should be performed.

On the other hand, the primary disadvantage of the silver exchanged zeolites is the high cost of silver. Therefore, even though the safety factor will be larger according to the increase of the number of beds, the optimum loading should be determined. The removal efficiency for organic iodide should be considered as well as economical aspects in the design of molecular sieve.

ACKNOLEGEMENTS

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REFERENCES

[1] Safety Inspection Group, "Domestic NPP Safety Inspection Result Report", KINS/AR-916, Korea Institute of Nuclear Safety, 2011.
[2] D. R. Haefner and T. J. Tranter, "Methods of Gas Phase Capture of Iodine from Fuel Reprocessing Off-Gas : A Literature Survey," Idaho National Laboratory, INL/EXT-07-12299, 2007.
[3] CFDesign in Autodesk Simulation.

Test Facility | Test Section

Figure 1. Organic Iodide Removal Test Facility and Test Section.

Volumetric Flow Rate	6 m^3/s	8m^3/s	20m^3/s

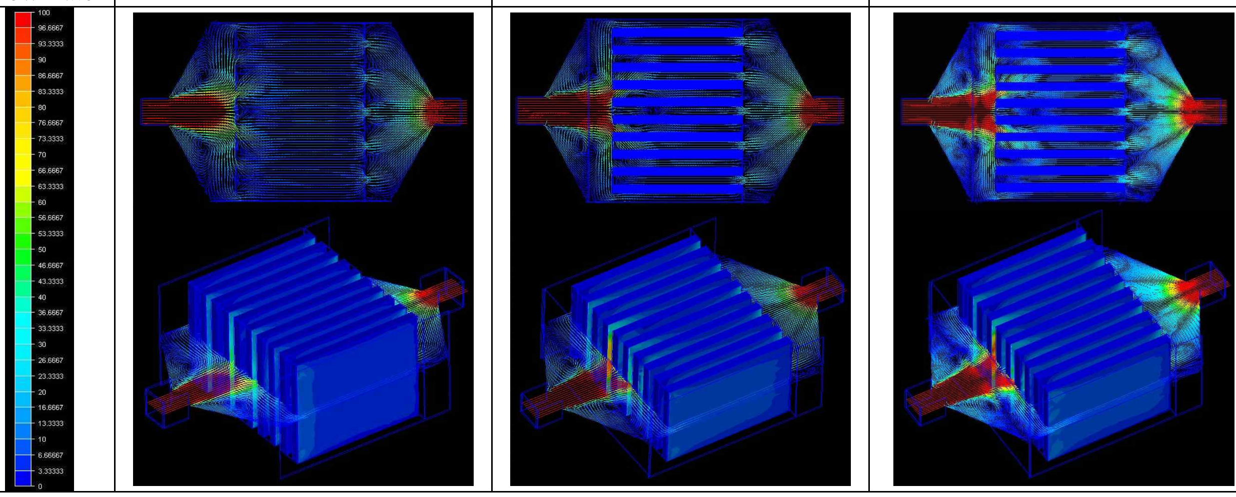

Figure 2. Aerodynamic Analysis of Molecular Sieve with Ten Beds by CFDesign.