Transactions of the Korean Nuclear Society Autumn Meeting
Pyeongchang, Korea, October 30-31, 2014

A conceptual study of the filtration equipment arrangement in CFVS system

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1. Introduction

Containment Filtered Venting System (CFVS) is installed in nuclear power plant to protect the integrity of containment against the over pressurization and removal of fission product which are aerosol, vapor and gaseous forms release from the fuel into the containment. CFVS comprise of venture scrubber, water pool and metal fiber filter which is shown in Fig. 1.

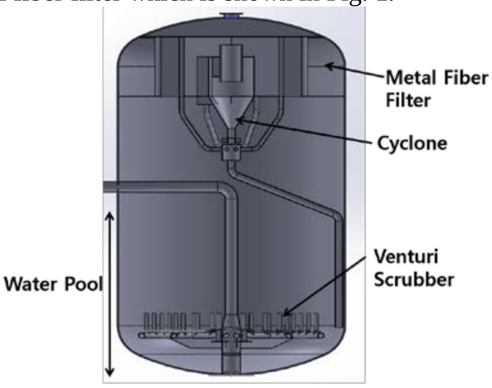


Fig. 1 Containment Filtered Venting System

CFVS has filtering process in two step. In step one, the multi-venturi scrubber for removing aerosol. The venting gas entering the venturi scrubber is injected into a pool of water via a small number of nozzles. As the vent gas passes through the throat, the incoming gas flow develops a suction that causes scrubbing water to be entrained with it. Due to the large difference between the velocity of the scrubbing water droplet and gas velocity, aerosols are removed. So the maximum gas velocity of throat is to affect the performance is an important factor in the venturi scrubber.

The venting flow gas are distributed to each of the venture scrubber through the distribution pipes which is shown in Fig. 2. For this reason, composition of distribution pipe and location of scrubber is important, because read to a flow rate different in each venture scrubber.

Fig.2 Schematic diagram of venturi scrubber assembly.

In step two, the metal filter combination additionally equipped with metal fibers and cyclone device. The gas exiting from the pool venturi section contains small amounts of penetrating aerosols as well as small scrubbing water droplets. In case that water droplet moves to metal filter unseparated, filtering performance is rapidly declined. Cyclone is used to prevent the water droplets on the metal filter, separating the droplet including radioactivity which is passed through scrubber by centrifugal force.

Therefore separating droplet phase in cyclone is the important thing in aerosol filtering phases although radioactive is not separated.

In this study, we found a conceptual design alternative for CFVS performance increasing by reviewing the optimal composition of cyclone and optimal design of distribution pipe with numerical analysis.

2. Scrubber arrangement

2.1 Analysis Model

Fig.3 shows design of CFVS's distribution assembly for venture scrubber. Distribution assembly is composed of main pipe, header, distribution pipe, venturi scrubber nozzles. Table 1 is described for design of distribution assembly. To compare outlet flow rate impact from scrubber nozzle, a difference of the number of distribution pipe and nozzle.

The venting flow condition is the flow rate 20kg/s and temperature is 200 ℃ on steam. Distribution pipe is modeled only for one because the periodic axially. Inlet condition is flow rate which is divided number of scrubber, analysis was performed using the ANSYS CFX 14.5.

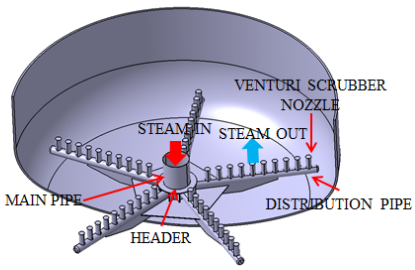


Fig. 3 Geometric depiction of distribution pipe for CFVS

Table I: Problem Description

Case	Num. of Nozzle / Distribution pipe [ea]	Dia. Of Distribution pipe [mm]	Dia. Of Header [mm]	Distance (Nozzle to Nozzle) [mm]
1	10 / 5	114.3	406	192
2	5 / 10	89.1	558.8	384
3	6 / 8	165.2	609.6	320
4	7 / 7	101.6	500	275
5	8 / 6	165.2	450	240

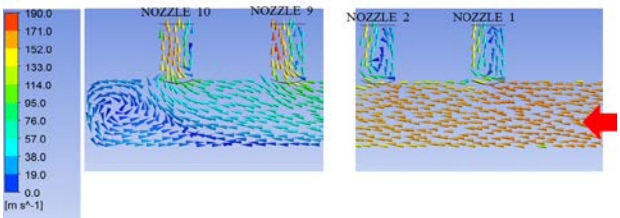
2.2 Analysis result and arrange alternative

Table 2 shows the flow rate in each entrance of nozzle. Such as case 1, the less number of distribution pipe and the more number of nozzle, flow uniformity has decrease in nozzle. In case that diameter of distribution pipe is small, recycle area of exit of nozzle which is close to nozzle entrance increases so that flow uniformity will be decreased due to a velocity increasing in part of entrance. Fig. 4 shows velocity vector on case 1 and case 3. Entrance velocity of cas1 is faster than case 3, confirm that nozzle1's recycle area is bigger.

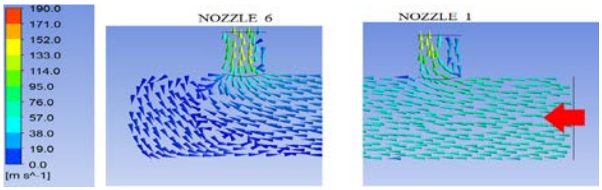
Therefore, if a diameter and number of distribution pipe is increased, such as case 3 & 5, flow uniformity is high in nozzle part.

Table Ⅱ: Mass flow rate for nozzle(kg/s)

Case	Nozzle location									
	1 (inside)	2	3	4	5	6	7	8	9	10 (outside)
1	0.14	0.18	0.23	0.28	0.35	0.42	0.50	0.57	0.62	0.70
	Different massflow ratio (max/min) : 5									
2	0.20	0.28	0.39	0.51	0.60					
	Different velocity ratio (max/min) : 3									
3	0.33	0.37	0.4	0.44	0.47	0.49				
	Different massflow ratio (max/min) : 1.5									
4	0.18	0.23	0.30	0.40	0.50	0.57	0.66			
	Different massflow ratio (max/min) : 3.7									
5	0.30	0.33	0.36	0.40	0.43	0.48	0.50	0.52		
	Different massflow ratio (max/min) : 1.7									



(a) case 1



(b) case 3

Fig. 4 Velocity vector

3. Cyclone arrangement

3.1 Analysis Model

Fig.5 shows shape of CFVS's cyclone. It is separated into a droplet by using the centrifugal force on the cyclone that radioactive aerosol containing water droplets are passed through a scrubber. A conceptual design for the optimal placement of cyclone can be applied middle and side arrangement in pressure vessel. For performance analysis of cyclone were compared average flow rate of 6 for cyclone in middle and side arrangement.

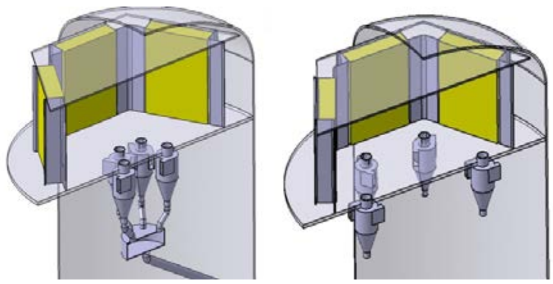


Fig. 5 Middle and Side Cyclone

3.2 Analysis result and arrange alternative

Table 3 shows flow rate 6 cyclone. In case of middle location, largest flow rate is 3, 4 cyclone and less flow rate is 1 cyclone. In case of side location, largest flow rate is 4, 5 cyclone and less flow rate is 3, 6 cyclone. However, the variation in the flow rate of each location is less than 2% of the total flow rate. Also, the difference between the average flow rates for each location also appears to less than 2%. Therefore, Flow rate of side and middle location is little difference that can be ignore. So cyclone arrangement is determined to consider production process.

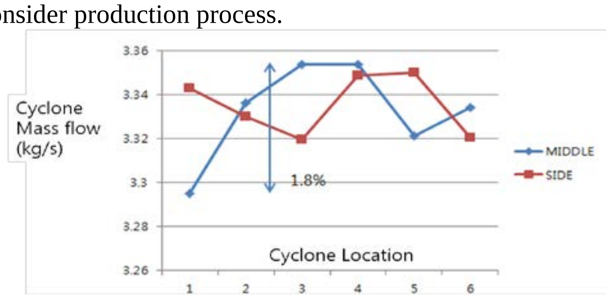


Fig. 6 Differences of flow rate in cyclone location

Table Ⅲ: Mass flow rate for Cyclone (kg/s)

Case	Cyclone location						
Middle	1	2	3	4	5	6	Ave.(kg/s)
	3.29	3.34	3.35	3.35	3.32	3.33	3.33
Side	1	2	3	4	5	6	Ave.(kg/s)
	3.34	3.33	3.32	3.35	3.35	3.32	3.34

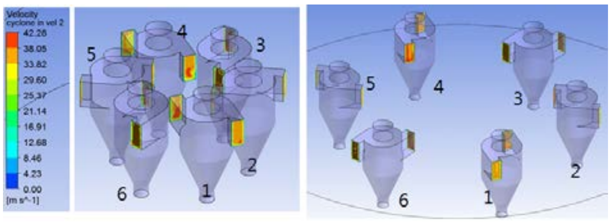


Fig. 7 Middle and Side Cyclone

4. Conclusions

Numerical analysis was performed with the relationship between the distributions of the flow to the nozzle arrangement in accordance with the size of the distribution pipes, so that the optimal performance of the scrubber can be installed in CFVS. As a result, a high filtration efficiency of the scrubber in the case of case 3 which the number and distribution pipes diameter increased.

Also, in case of cyclone, flow rate of side and middle location is little difference that can be ignore. So cyclone arrangement is determined to consider production process.

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[1] AREVA., 2011, “Filtered Containment Venting System,” AREVA INC., Coporate Headqurters One Bethesda Center, Maryland 20814

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