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A Study on Replacement of HEPA Filter In-place Leak Test Challenge Agent from DOP to PAO in NPP

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1. Introduction

Atmosphere cleanup system of nuclear power plants is a gas waste treatment system to minimize the leakage of radioactive materials produced during normal operation and accidents. The HEPA(High Efficiency Particulate Air) filter in this system has the major role to filter the particulate radioactive materials. The leak test method of HEPA filter conforms to the Reg. Guide 1.140 and Reg. Guide 1.52 of USNRC, which were both revised in 2001. The revisions include the permission of alternative challenging aerosol agents besides DOP (dioctyl phthalate) for HEPA filter in-place leak test. US DOE is demanding to stop using DOP since DOP was suspected as a carcinogen. Currently, industries other than nuclear power plants mostly use PAO (polyalpha olefin) as HEPA filter leak test challenge aerosol agent. Due to Reg. Guide 1.140(Rev.2) and 1.52(Rev.2), only DOP has been allowed to be used in nuclear power plants. As a result, nuclear power plant workers have been exposed to mental and physical risks whenever there is HEPA filter in-place leak test. In this paper, the leak test results using DOP and PAO are compared to verify that DOP can be replaced with non-carcinogenic PAO for HEPA filter leak test in nuclear power plants.

2. Methods and Results

2.1 Materials and apparatus

For HEPA filter challenge aerosol ATI DOP and ATI PAO-4 were used. Both are commercial products from ATI. A scaled-down simulator was built to simulate ESF ACS in YGN #5,6 for experiments[1]. An artificial bypass lines were installed upstream and downstream of the HEPA filter bank to compare the capacity for knowing the leak of DOP and PAO.

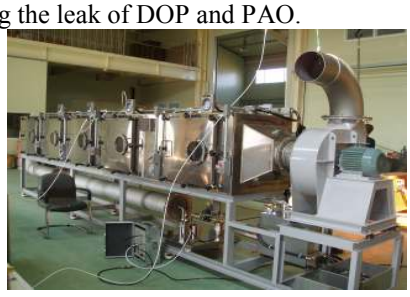

Fig. 1. Nuclear Power Plant ESF ACS simulator

Aerosol generators for in-place leak tests were NUCON's SN-5 (slit nozzle type) for simulator and DG-F for on-site tests respectively. NUCON's aerosol detector (Model F-1000-DD) was used for both tests as a photometer.

The final on-site test was performed on TSC(Technical Support Center) Makeup ACU in YGN #6, which consist of moisture separator bank, medium filter bank, pre-HEPA filter bank, charcoal adsorber bank, post-HEPA filter bank, and a fan. The rated flow rate of the system is 6,000 CFM.

2.2 Requirement of HEPA filter challenge aerosol

Alternative challenge agents may be used to perform in-place leak testing of HEPA filters when their selection is based on the following.

1. The challenge aerosol has the approximate light scattering droplet size specified in Article TA-1130 of ASME AG-1-1997.
2. The challenge aerosol has the same in-place leak test results as DOP.
3. The challenge aerosol has a similar lower detection limit, sensitivity, and precision as DOP.
4. The challenge aerosol causes no degradation of the HEPA filter or the other ESF air cleaning system components under test conditions.
5. The challenge aerosol is listed in the Environmental Protection Agency's "Toxic Substance Control Act" (TSCA) inventory for commercial use.

One of the best materials to satisfy above requirement is PAO. It is studied intensively by many researchers such as US army Chemical Research and NUCON. [2,3,4,5] There is also a case to perform leak test with PAO in Korea[6]. Therefore, this study is focused on the requirements 1 and 2.

The accumulated size distribution of the HEPA filter challenge aerosol should be $< 0.4\ \mu m$ 20%, $< 0.7\ \mu m$ 50%, and $< 3.0\ \mu m$ 99% in diameter.

2.3 Comparison of DOP and PAO aerosol size

The size of aerosol was measured by a laser particle counter (model: MetOne-2400). The result shows that the size distribution conforms to the ASME AG-1 and KEPIC MH-TA 1130.

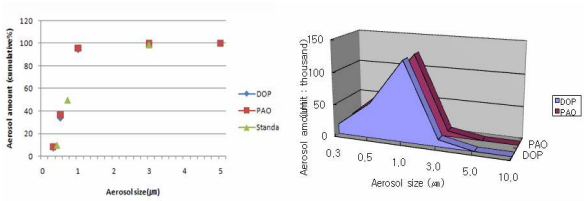

Fig. 2. Comparison of DOP and PAO aerosol size distribution

2.3 Comparison of leak test with DOP and PAO on the simulator

The concentration of PAO aerosol was 2.0~2.5 ㎍/ℓ higher than that of DOP aerosol at the same pressure. Temporary bypass line was installed between upstream and downstream of HEPA filter to create leak through the filter. A valve was on the bypass line to control the leak rate. The change of the leak rate was measured at DOP and PAO aerosol generation pressure of 25, 35, and 45 psig. The result showed that the leak rate difference between DOP and PAO was the same at 0.00006 ~ 0.0014% in average regardless of the aerosol generation pressure. It implies that there is no real problem to replace DOP with PAO considering that the criterion to determine the HEPA filter leakage is 0.05%.

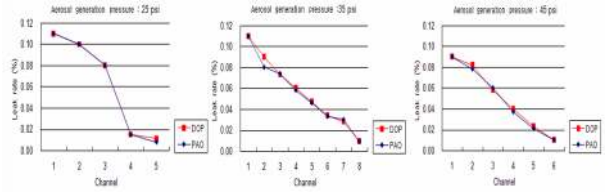

Fig. 3. Comparison of leak rate in the simulator at various pressure (25, 35, and 45 psig)

2.4 Comparison of on-site leak tests with DOP and PAO

Since the simulator is a scaled-down equipment with single unit of HEPA filter and a cold type aerosol generator (slit nozzle type) was used for the test, on-site leak tests were performed on a system having higher flow rate with hot type generator to confirm that the test result can be applied to all HEPA filters in NPPs. As shown in Table 1, DOP and PAO demonstrated the same tendency whether there was leak in the HEPA filter or not.

Table I: Leak rate of TSC Makeup ACU(DOP vs PAO)

test	filter	challenge	Average leak rate	Measured value
1	post HEPA filter	DOP	0.090	0.090
				0.090
		PAO	0.070	0.070
				0.070
				0.070
2	pre HEPA filter	DOP	0.125	0.100
				0.100
				0.140
				0.160
		PAO	0.098	0.100
				0.100
				0.090
				0.100
3	pre HEPA filter	PAO	0.025	0.025
				0.024
		DOP	0.028	0.030
				0.026
4	pre HEPA filter	PAO	0.014	0.014
				-
		DOP	0.013	0.015
				0.011

3. Conclusions

To find the possibility of replacing DOP with an alternative challenging agent, HEPA filter in-place leak tests were performed with DOP and PAO on the NPP ESF ASC simulator and an on-site system at YGN. A bypass line was installed on the simulator to compare the capacity for knowing the leak of DOP and PAO. Since a cold type aerosol generator was used on the simulator, on-site application tests were performed on TSC Makeup ACU in YGN #6 with hot type aerosol generator. The tests results on the simulator and the on-site system both confirm that PAO is a good candidate to replace DOP.

4. Acknowledgement

The authors appreciate KHNP YGN III for the support to allow the on-site tests on TSC Makeup ACU in YGN #6. We also give thanks to KINS Radiation & Waste Safety Evaluation Department, who attended the on-site tests, and to Korean Filter Testing Laboratory, who undertook the third party verification.

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