# Wet Over Pressure Test of Radial Flow Filters

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## Abstract

ASME AG-1 Code on Nuclear Air and Gas Treatment requires that Type 1 radial flow filters must under go a resistance to pressure test. The wet over pressure test for radial flow filters presents significant difficulties to ensure uniform and appropriate challenge of the medium. Using the same methods as for axial flow filters can result in ununiformed spray of water that does not thoroughly challenge all of the filter medium. Development of testing infrastructure and methods for improvement of the wet over pressure is necessary to ensure accurate qualification of ASME AG-1 section FK 2000 cfm radial flow HEPA filters.

## Performance Specifications for FK-5140 Resistance to Pressure

The filter shall be tested for resistance to pressure on a machine capable of testing in accordance with Table FK-5000-4 shown in Table 1 below.

- Prior to being tested for resistance to pressure, the filter shall be conditioned at atmospheric pressure for 24 hr min. in a chamber at 95°F ± 5°F (35°C ± 3°C) and a relative humidity of 95% ± 5%.
- After being conditioned, the filters shall withstand the airflow and water spray environment listed in Table FK-5000-4 without rupture of the filter media.
- The Type 1 filter shall be installed in the test stand with the filter configured 90 deg from the positions shown in Fig. FK-4100-1 through Fig. FK-4100-4 with the filter in the horizontal orientation and with the filter inlet facing the airflow stream so that the airflow enters the filter inlet along the centerline of the filter inlet.
- Within 15 min. after completion of the pressure test and while still wet, the filter shall meet the requirement of FK-5120 at 20% airflow.

| TABLE FK-5000-4 | |
|---|---|
| TEST CONDITIONS AND REQUIREMENTS | |
| Test Conditions | Test Requirements |
| Temperature | 95°F ± 5°F (35°C ± 3°C) |
| Relative humidity | 95 ± 5% |
| Rate of airborne water droplets flowing toward the filter [See Note (1)] | 1 ± 0.25 lb/min per 1000 ft3/min (0.45 ± 0.1 kg/ min per 1700 m3/hr |
| Pressure differential across filter | 10.0 ± 0.2 in. water (2.5 kPa) |
| Time to reach pressure | 0.5 min, maximum |
| Time duration at sustained differential pressure | 1 hr, minimum |
| Airflow | That required for producing the above pressure differential |

NOTE: (1) Rate of airborne water droplets flowing toward the filter is defined as the rate of water flowing through the spray orifice less the fallout and drainage from the air duct walls between points of location of the spray orifice and one inch before the face of the filter.

## Test Set Up

Figures 1-4 show the plumbing system used for water spray onto the filter.

- The pump shown in Figure 1 was connected to a large reservoir of filtered water to ensure the water was not contaminated.
- The speed controller shown in Figure 2 was used to control the pump to produce a flow rate of 0.25 gal/min.
- The flow rate was measured using the rotameter shown in Figure 4.

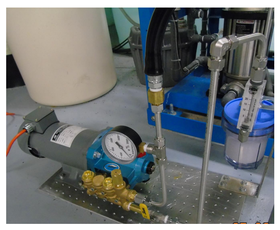

Fig. 1 Pump, Filter, and Rotameter

Fig. 2 Pump Speed Controller

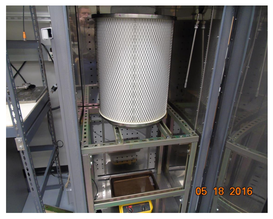


Fig. 3 Filter in Oven for 24 hour conditioning.

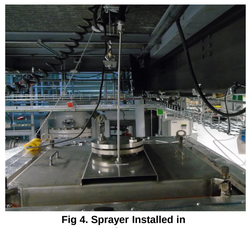

Fig 4. Sprayer Installed in Housing Door

## Design of Test Stand

During characterization testing, multiple nozzle variations were used to achieve a uniform distribution of water to the entire filter media. The single nozzle sprayer shown in figure 5 was tested first, followed by the four nozzle sprayer shown in figure 6 and six nozzle sprayer shown in figure 7. The six nozzle sprayer was selected for use because it resulted in the most uniform distribution. Blue dye was added to the water and sprayed into the filter to observe the distribution of liquid on the media. The blue dye spray is shown in Figures 8-12.

Fig. 5. Single Sprayer

Fig. 6. Four Nozzle Sprayer

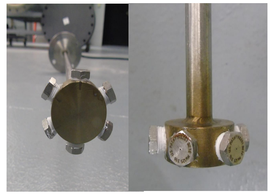

Fig. 7. Six Nozzle Sprayer

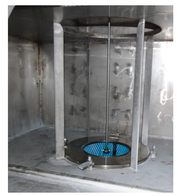

Fig. 8. Sprayer Located at Filter Inlet

Fig. 9. Pre Sprayed Filter.

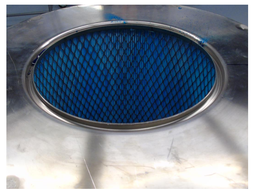

Fig. 10. Inside Filter Post Spray with Blue Dye

Fig. 11. Outside of filter Pre Spray

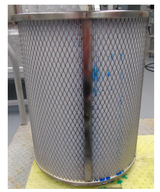

Fig. 12. Outside of filter post test.

For characterization of differential pressure measurements the total filter dP and filter media dP a probe was used to measure the dP from the side of the housing walls and compared to that of a probe
at several locations including at the filter inlet and below the filter inlet for a filter cap with the filter pack removed as well as for a assembled filter. The testing set up is shown in Figures 13 and 14.The test results are shown in Figure 15.


Fig 13. Differential pressure probe


Fig 14. dP measurement on housing wall and dP probe.

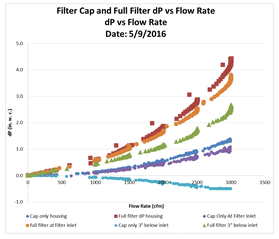


Fig 15. Evaluation of effect of filter inlet on total filter differential pressure.

## Pre Testing Results

Prior to performing the wet over pressure test, a resistance to airflow test was performed.

- The differential pressure was recorded from 400 cfm to 2000 cfm in increments of 400 cfm.

The initial filtering efficiency test was performed at 100% and 20% of rated flow (2000 cfm) in accordance with ASME AG-1 Section FK-5120.

- Aerosol concentration and sizing data was collected using a TSI Laser Aerosol Spectrometer (LAS).
- Dioctyl phthalate (DOP) was used as the challenge aerosol during the filtering efficiency test.

Results from the initial filter efficiency tests are shown in figures 16 and 17 and Table 2. The resistance to air flow curve prior to the wet over pressure test is shown in Figure 14.

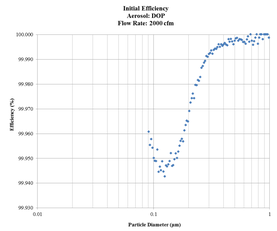


Fig 16. Pre Test FE at 2000 cfm

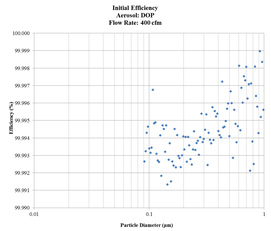


Fig 17. Pre Test FE at 400 cfm

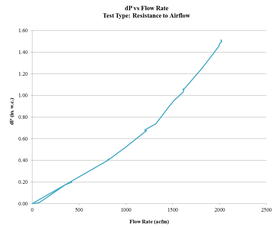


Fig 18. Pre Test resistance to air flow

## Testing Methods

Prior to wet over pressure testing the filter was conditioned in accordance with ASME AG-1 Section FK-5140. The filter was conditioned using an oven and a hot plate with a pan of water for 24 hours at 95° F and 95% RH.
The filter was challenged for one hour at 10 in. w. c. differential pressure at 95°F and 95% RH. The following steps were performed in the testing of the filter.

- The test stand was pre conditioned to approximately 98°F and 93% RH at 2000 cfm.
- After pre conditioning the filter was installed as quickly as possible in order to maintain elevated conditions inside the test stand.
- The spray nozzle and housing door were installed immediately following the filter.
- The test stand fan, sprayer, and steam were turned on simultaneously.
- The test stand was set to automatically regulate the flow rate required to maintain 10 in. w. c. differential pressure across the filter.
- The filter was challenged at required conditions for one hour.

## Results

Figures 19 and 20 show testing conditions vs time. Figure 21 shows differential pressure vs flow rate during the wet over pressure test. This data was collected using the data acquisition system in tabular form and reduced to plots.

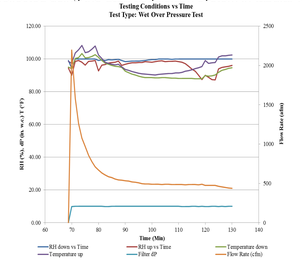


Fig 19. Wet Over Pressure Test Conditions

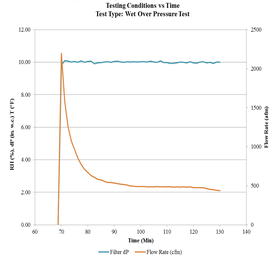


Fig 20. Wet Over Pressure Test Conditions

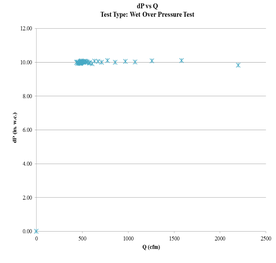


Fig 21. Wet Over Pressure dP vs Q

After the filter is tested for one hour at the required conditions, a final filtering efficiency test was performed at 20% of rated flow beginning 10 minutes after the end of the wet over pressure test with the filter is still wet in accordance with ASME AG-1 Section FK-5120. The results of the final efficiency test are shown in Figure 22 and Table 2.

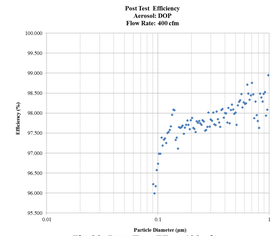


Fig 22. Post Test FE at 400 cfm

**Table 2. LAS Filter Efficiency Results**

| Flow Rate | FE (%) at 0.3 µm | MPPS (µm) |
|---|---|---|
| Initial 2000 cfm | 99.991 | 0.125 |
| Initial 400 cfm | 99.993 | 0.145 |
| Post Test 400 cfm | 97.607 | 0.093 |

Pleat collapse and multiple ruptures in the filter media were visible after the filter was removed. After testing photographs are taken of any damage or deformation to the filter. Damage to the filter media is shown in Figures 23-24.

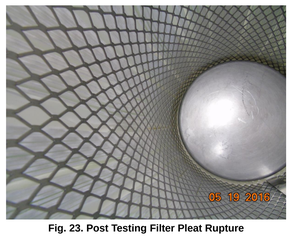


Fig. 23. Post Testing Filter Pleat Rupture

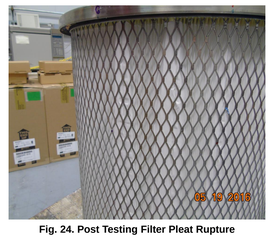


Fig. 24. Post Testing Filter Pleat Rupture

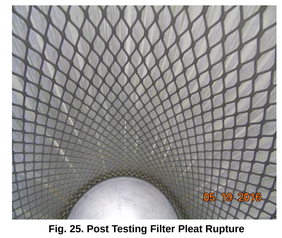


Fig. 25. Post Testing Filter Pleat Rupture

## Acknowledgment

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## References

1.American Society of Mechanical Engineers (ASME), Code on Nuclear Air and Gas Treatment (ASME AG-1). [Standard]. New York: ASEM, (2013).