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Conf-720823--18

WATER SPRAY HEAT EXCHANGERS
FOR HEPA PROTECTION IN ACCIDENTS

(Heat Removal Requirements and the Effect
of Smoke and Water on HEPA Filters)

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INTRODUCTION

The smoke and heat from fire occurring within a radiochemical processing facility must be vented through the buildings' high efficiency particulate air (HEPA) filtration system, as shown in Figure 1. This filtration system must continue to function under fire conditions, even though smoke can plug the filters and heat can damage them¹.

In order to maintain the integrity of the building and its filtration system, a device is needed which will both abate the smoke and exchange the heat from the exhausting air.

Such a device, consisting of a water-cooled heat exchanger, has been described in an earlier paper². In order to design this device, some prediction of the inlet air temperatures are necessary. In addition, the effectiveness of smoke removal should be determined.

¹Burchsted, C. A., Fuller, A. B., "Design, Construction, and Testing of High-Efficiency Air Filtration System for Nuclear Applications", ORNL-NSIC-65, USAEC.

²Domning, W. E., "Design of Filter Plenum Heat Exchangers", CONF 710401, USAEC.

Figure 1 .Schematic Representation of Building Ventilation System.

EXPERIMENTAL RESULTS

Tests have been run to simulate the effect of fire with full-size gloveboxes³. Figure 2 shows a typical scene during these tests.

Figure 3 shows the temperature of the glovebox ventilation air during a fire. The reason for the different rates of rise is that the air flow varied between tests. Figure 4 shows the temperature of the air surrounding the burning glovebox. The step in these curves are due to sprinkler discharge.

Using temperatures of 1600°F for the glovebox ventilation air and 1000°F for the air surrounding the glovebox, calculations have been made which show that for a credible glovebox fire, the bulk temperature of the air entering the filtration system will be 226°F.

Two experiments were performed in the fire test facility at Rocky Flats⁴ to study the effects of water and smoke on filters.

³Domning, W. E., Woodard, R. W., "Glovebox Fire Tests", RFP-1557, Dow Chemical U.S.A., 1969.

⁴Domning, W. E., "New Fire Protection Systems for Filter Plenums", CONF 700816, USAEC.

Figure 2 Glovebox Fire Test

Figure 3 Air Temperatures Within Glovebox

Figure 4 External Temperature of Glovebox

The experimental arrangement for the initial test of this series is shown in Figure 5. The inlet duct was fitted with a 2 x 2 foot deflector located eight inches from the end of the duct as shown in Figure 6.

The test consisted of building a wood and paper fire in the incinerator and adjusting the air flow to 5400 CFM. The water flow was activated when the filter face temperature reached 70°C. Table I and Figure 7 contain the data obtained in this test.

The nozzle used for the fire test was a Viking Model A2-120°. The total gallonage of water delivered was 790 which yields a water density of 12 gallons per minute or 0.25 gallons per minute per square foot of filter area.

The air flow through each filter was measured with an Alnor Velometer and the results of these measurements are summarized in Figure 8. The flows are expressed in cubic feet per minute, uncorrected for altitude or temperature; however, the temperature was the same (4.5°C) when all the measurements were taken. The row (Figure 8) marked "CFM Dry" was the air flow established through a new set of filters. The row

Figure 5 Plenum Configuration

1-2-6

TABLE I

Smoke And Countercurrent Water Spray

<u>Time</u> <u>(Min. - Sec.)</u>	<u>Pressure Drop</u> <u>Across Filters</u> <u>(Inches of Water)</u>
0	0.29
2:20	0.26
8:00	0.5
16:00	0.36
26:00	0.48
32:00	0.52
38:00	0.52
54:00	0.52
60:00	0.52

Figure 7 Inlet and Outlet Air Temperatures

FILTER NO.
CFM DRY
CFM WET
CFM DRIED

FILTER NO.
CFM DRY
CFM WET
CFM DRIED

FILTER NO.
CFM DRY
CFM WET
CFM DRIED

FILTER NO.
CFM DRY
CFM WET
CFM DRIED

1 440 320 400	2 480 300 320	3 540 320 360
4 400 280 320	5 400 340 420	6 440 260 336
7 440 300 380	8 460 280 380	9 440 280 320
10 420 300 340	11 420 300 300	12 400 360 320

Figure 8
AIR FLOW RATES

"CFM Wet" was the air flow measured after the experiment was performed and the filters were wet from the carried-over spray. The remaining row shows the air flow existing after 14 hours of air-drying at 5400 CFM.

Twelve new filters were used for these tests and a DOP (polydisperse) in-place test showed the installation to be 93 percent effective. Immediately after the test, the filters were in-place tested and found to be 97 percent efficient. The reason for the increase could be that a crack between the filter frames and plenum ceiling was located and patched. Three of the filters were individually DOP tested for efficiency. The data for these tests are tabulated in Table II. The filter numbers refer to location indicated by an upstream view of the filter frame as shown in Figure 8.

TABLE II

Filter Efficiency After Fire Test

<u>Filter No.</u>	<u>DOP Efficiency</u>
1	99.996
5	99.998
2	99.998

Inspection of the interior of the plenum showed that fire residue, ash, soot, and smoke particles were deposited on the plenum walls at the point of impingement of the water spray. No damage to the media was noted either by visual or DOP inspection. Figure 9 has been constructed from data of Table I and Figure 3 to show the relationship between pressure drop and flow for the 12-filter bank in the plenum.

An experiment was performed by spraying water directly upon twelve clean, 24" x 24" x 11 7/8" HEPA filters from a Viking A-2 sprinkler positioned three feet from the filters at a rate of 0.25 gallons per minute per square feet of filter face. During this experiment, the fan inlet valve remained at a constant setting and the pressure drop was allowed to vary.

Since the fire was not used in this experiment, there was no effect from smoke on the change in pressure drop. The data are presented in Table III and show the increase in pressure drop, due to the water spray, to be 0.18 of water for the 30.5 minutes of spray.

Figure 9. Pressure Drop - Flow Correlation

- O CLEAN FILTER
- X SOILED FILTER
- WET AND CLOGGED FILTER

TABLE III

Water Spray Data

<u>Time</u> <u>(Minutes)</u>	<u>Pressure Drop</u> <u>Across Filter Bank</u> <u>(Inches of Water)</u>
1.0	0.27
2.0	0.29
3.0	0.29
6.0	0.31
9.0	0.34
12.0	0.36
15.0	0.38
18.0	0.40
21.0	0.41
24.0	0.42
27	0.43
30.5	0.44

Figure 9 and Table III have been used to construct Figure 10 which shows the relationship between flow through a filter and time of exposure to water.

Figure 10 Water Pugging of HEPA Filters

DISCUSSION

With restricted air exhaust^t, a glovebox fire fueled by Plexiglas and rubber gloves will reject the greater proportion of its heat to the surrounding module air. The predicted bulk air temperature of 226°F assumes that perfect mixing of the module air occurs. This would not be the case, however, and it might be possible for 1000°F air to impinge upon some of the overhead areas of the module. Design of the filter plenum heat exchanger should use an inlet temperature between these numbers.⁷ The average flow through the dry filters was 440 CFM per filter at a pressure drop of 0.29 inches of water. After 60 minutes of the paper and cardboard fire, the pressure drop had increased to 0.52 inches of water. The average air flow rate at this time was 303.3 CFM per filter. The filters were dried and the average flow rate became 349.6 CFM per filter, and the pressure drop had decreased to 0.37 inches of water.

By subtraction, the pressure drop due to smoke plugging became 0.08 inches of water, and that due to water, 0.15 inches of water.

These data show that smoke plugging from a fire to be less an effect than water plugging as determined from the pressure drop across the filters.

Referring to Table I, the system was run one minute and 30 seconds before the water was turned on. However, smoke was entering the system for this period of time. Unfortunately, the pressure drop was not recorded at the time the water spray was activated, but 50 seconds later, the pressure drop with the water spray going had decreased. Therefore, it may be safe to assume that the initial rate for smoke plugging is small.

In the second filter plenum experiment, the pressure drop increase of 0.18 inches of water is of the same order of magnitude when compared with the pressure drop of 0.15 inches of water reported in the first experiment. In the first experiment, the water spray was counter-current to the air flow for one hour and in this experiment, it was co-current to the air stream for one-half hour. However, when the pressure drop time relationship (Tables I and III) are compared at the 30 minute time, a similar pressure drop is obtained; 0.50 inches of water versus 0.44 inches of water.

That the pressure drop did not rise after 32 minutes as shown by the data of Table I suggests that the filters had become saturated with water. The smoke was being scrubbed from the air stream.

A water-cooled heat exchanger used to protect a HEPA filter system should be designed to handle an incoming air temperature of 1600°F from glovebox exhaust, and air in the 1000-3000°F range from rooms.

At half-rated air velocities, smoke is scrubbed at a sufficient rate to prevent a serious rise in pressure drop through ~~than~~ filters. In the experiments reported, water spray was shown to have a greater effect on plugging than smoke.

Figure 2 Glovebox Fire Test