PERFORMANCE OF REVERSE JET CLOTH FILTERS

by

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A detailed description of the experimental reverse-jet filter used in this study appeared in a previous report (1) with resistance and efficiency data for clean wool felt bags filtering room air.

During the past year investigations have been conducted with a variety of test aerosols. Loadings ranging from 0.001 to 10 grains per cubic foot and air flow rates up to 25 cfm per square foot of filter cloth have been employed to determine the performance of (a) reverse jet construction, size, flow rate and per cent operating time; (b) filter bag diameter; and (c) types of filter media (i.e. resin- and silicone-treated and untreated felt bags).

a. Effect of reverse jet cleaning on performance.

Resistance and dust retention are influenced by (a) the amount of reverse jet air (b) speed of traverse of the reverse jet and (c) design of the slot. Since resistance and retention are also determined by filtration rate and dust loading, the effect of the reverse jet was investigated over a wide range of loadings and flows.

(1) Percent of time reverse jet operates.

Reverse jet action may be controlled by a pressure switch which turns on when the bag reaches a pre-set resistance and stops when the pressure differential falls below this value. The percentage of time the reverse jet is in operation can be varied to a considerable degree by setting appropriate "on" and "off" limits into the filter resistance-actuated switch. When the reverse jet sweeps only a fraction of the entire filter surface during each cycle that section of felt becomes too clean and dust retention is lowered. Rapid, short cycling of the reverse jet mechanism is also poor from the standpoint of mechanical wear. Air flow rate and nature and concentration of the dust being filtered will determine the minimum and maximum resistance range over which filter operation is feasible.

The minimum resistance at which a reverse jet filter will operate for a particular aerosol and filtration rate may be determined by continuous reverse jet cleaning. Intermittent operation is possible with greater resistances and the smaller the fraction of reverse jet "on" time, the higher the resistance range will be. This is illustrated in Figure 1 which represents the behavior of untreated wool felt when filtering 1 grain per cubic foot of vaporized silica (mass median diameter = 0.6 microns) at a rate of 10 cfm per square foot of cloth. Velocity of the reverse jet was 4000 fpm and a constant pressure differential of one inch of water gage (i.e. between "off" and "on" switch positions) was maintained when the pressure settings on the reverse jet switch were changed. The right curve boundary represents the pressure at which the reverse jet starts and the left the pressure at which it stops. For these conditions the lowest operating resistance is 5.2 inches of water gage with 100% reverse jet operation and resistance increases exponentially as the per cent of reverse jet time is reduced.

The choice of continuous or intermittent operation of the reverse jet is a matter of convenience and economics. For specific situations the cost of increased maintenance and replacement which would accompany continuous or high reverse jet operational rates must be balanced by the cost of sufficient additional filter capacity to permit intermittent cleaning.

The cleaning action of the reverse jet affects collection efficiency by removing some of the material which accumulates on the dust side of the filter cloth. The effect on retentivity of disturbing the "filter cake" is shown in Table I. The absolute amount of penetration is considerably influenced by the properties of the aerosol (i.e. particle size, shape, concentration, etc.) but, in general, maximum efficiency is associated with minimum reverse jet cleaning. For well plugged filters and dust loadings between 0.1 and 10 grains per cubic foot of air the differences in the weight of material penetrating are small but a significant trend is present.

(2) Effect on performance of reverse jet air velocity.

Resistance is affected by the amount of reverse jet air as well as by the frequency of application. The quantity of reverse jet air may be noted in terms of total volume, volume per inch of slot length or as average slot velocity. For a reverse jet mechanism of constant size, speed and operational "on" time, increases in reverse jet air volume result in decreased resistance as illustrated in Figure 2. When filtering flyash (MMD = 16 microns) resistance is considerably below that for vaporized silica (MMD = 0.6 microns) although this factor can only be quantitated approximately as different filtration velocities and loadings were employed for each series of tests. In spite of a wide diversity of loadings, flow rates and aerosols, the curves relating filter resistance to reverse jet air flow have a similar slope and within the limits of our observations resistance is inversely proportional to reverse jet air flow and tends to become asymptotic to some jet air volume at one extreme (i.e. as the reverse flow is increased a point will be reached where substantial increases in jet air volume produce only a negligible decrease in filter resistance) and to some pressure at the other extreme (i.e. as the resistance of the filter increases a point is reached where substantial decreases in jet air volume produce only a negligible increase in filter resistance).

Table II shows that when either air volume or jet velocity is held constant an increase in the width of the reverse jet slot produces a decrease in filter resistance. This indicates that cleaning action is related to intensity of the jet (lower resistance with higher velocity) and to the total length of time during which the reverse jet cleans each section of cloth (lower resistance with longer treatment time).

Table III shows that increasing reverse jet velocity produces lower resistance (as noted above) but also results in a higher effluent dust concentration. With flyash, a doubling of the reverse jet volume produced a tripling of the effluent concentration.

(3) Effect of linear speed of travel of reverse jet.

Local overcleaning is likely to occur when speed of travel is too low while high speeds result in insufficient removal of dust accumulation. In both cases high resistances will result. Between these extremes, increases in jet travel speed produce slight decreases in resistance. For example, when filtering an aerosol containing 0.5 grains of vaporized silica per cubic foot of air resistance decreased from 5.5 to 5.2 to 4.6 inches of water gage as jet travel speed increased from 18 to 31 to 52 fpm, respectively.

b. Effect of inlet dust loading.

Filter resistance increases with dust load, the rate of increase is exponential with loading. The slope of the resistance-loading curves range between 0.1 and 0.3 for the dusts tested in our laboratory. Variations in filtration rate, jet velocity, etc., change the displacement of these curves but not their shape. Figure 3 shows typical results for three different aerosols. It may be noted that for loadings above 4 to 5 grains per cubic foot of air, increases in loading produce little change in overall resistance when the reverse jet operates continuously.

Outlet loadings of 10^{-5} to 10^{-3} were found for inlet loadings ranging from 0.001 to 10 grains per cubic foot. Although higher inlet loadings were found to be associated with increased effluent concentrations, the relative rate of increase of dust in the outlet air is slow and a net increase in weight retained does occur. These tests, as well as others previously reported (1), indicate that effluent loading appears independent of inlet loading when the entering dust load is greater than approximately 0.1 grain per cubic foot.

c. Effect of filtration rate.

Over the range of flow rates investigated (7 to 31.4 cfm per square foot of filter cloth) there was a direct linear relationship between resistance and air rate indicating that flow through the felt bag and accumulated dust layer is in the laminar range. In order to keep the thickness of the filter cake constant, dust was fed at the same rate (i.e. grains per minute) regardless of air flow. In this way the amount of dust reaching the filter was maintained constant.

Higher velocities through the medium (in the range of 10 to 25 cfm per square foot) cause higher effluent concentrations. Doubling the velocity from 10 to 20 cfm per square foot, caused a 10 times increase in penetration in a typical case. Data on the retention of atmospheric dust with changes in air rate indicate that this same relationship also holds for light dust loadings.

d. Effect of filter size.

From comparative tests made on 18 inch diameter felt filters and 6 inch diameter bags of the same material it was concluded that three 6 inch bags have substantially the same resistance, retention and capacity as a single 18 inch diameter bag of equal length.

e. Effect of filter cloth treatment.

Tests with treated and untreated wool bags indicated that a silicone impregnated felt (designated "HCE") has a higher resistance (3.5 inches of water gage) but yields higher efficiency (99.997%) than the same wool, untreated (i.e. 2.8 inches of water gage and 99.93% efficiency). Tests were conducted over a twelve hour period on well-plugged filter cloths using Cottrell precipitated flyash at inlet loadings of 3.8 to 3.9 grains per cubic foot of air. Another type of felt cloth, treated to produce a resin coating on the wool fibers, was intermediate between "untreated" and "HCE Treated" in both resistance and efficiency at equal capacity.

REFERENCES

(1) First, M. W., et al., Performance of Reverse Jet Cloth Filters, "USAEC Report No. NYO-1581, Waste Disposal", Boston, Harvard School of Public Health. (1952).

TABLE I

EFFECT ON COLLECTION EFFICIENCY OF REVERSE JET OPERATION TIME

Air Flow Rate cfm/sq.ft.	Test Dust	Filter Resistance - in. w.g. Start	Stop	Average	Reverse Jet Velocity fpm	Dust Loading Grains/1000 cu.ft. in	out	Reverse Jet Operation Time %	Dust Penetration % by weight
24.2	Atmospheric Dust	---	---	1.48	----	.0022	.00020	0	6.6
23.8	Atmospheric Dust	---	---	1.40	2200	.0022	.00030	100	12.6
11.5	Talc	5.6	4.8	----	1620	140	.00025	45	0.0019
11.5	Talc	---	---	4.72	1620	160	.00125	100	0.0078
10.0	Vaporized Silica	8.0	7.1	----	4000	1070	.001	10	0.00093
10.0	Vaporized Silica	---	---	5.1	4000	1260	.018	100	0.0014
9.5	Fly Ash	2.4	1.7	----	4200	1120	1.0	7	0.023
10.0	Fly Ash	---	---	1.06	4200	1240	0.25	100	0.082

TABLE II

EFFECT ON FILTER RESISTANCE OF REVERSE JET SLOT WIDTH

Slot Width in.	Reverse Jet Air Volume cfm	Reverse Jet Air Velocity fpm	Filter Resistance in. w.g.	Ratio of Reverse Jet Air To Filtration Volume
0.030	74	7200	5.7	0.36
0.030	42	4000	9.0	0.20
0.046	69	4000	5.8	0.35
0.055	74	4000	5.1	0.36
0.055	42	2300	6.3	0.20

TABLE III

EFFECT ON FILTER EFFICIENCY OF REVERSE JET AIR VELOCITY

Reverse Jet Velocity fpm	Dust Loading Grains per cubic foot		Penetration Percent by weight
	in	out	
4250	11.9	.00136	0.0114
3200	13.4	.000607	0.0046
2100	11.2	.000437	0.0039

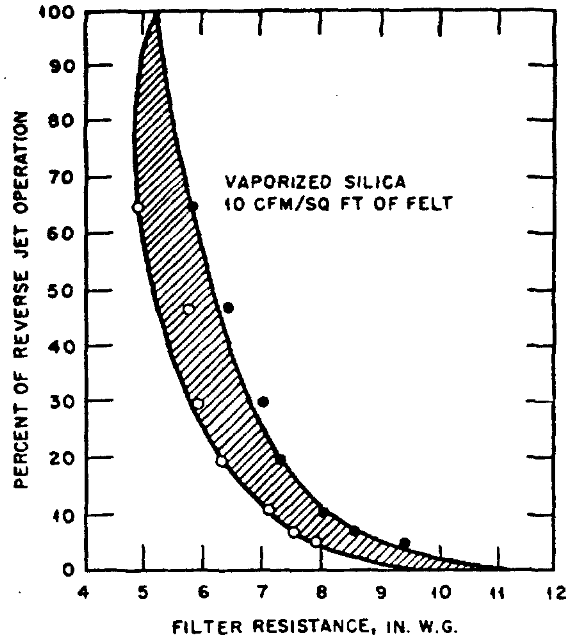

Fig. 1—Effect on filter resistance of reverse jet operation time.

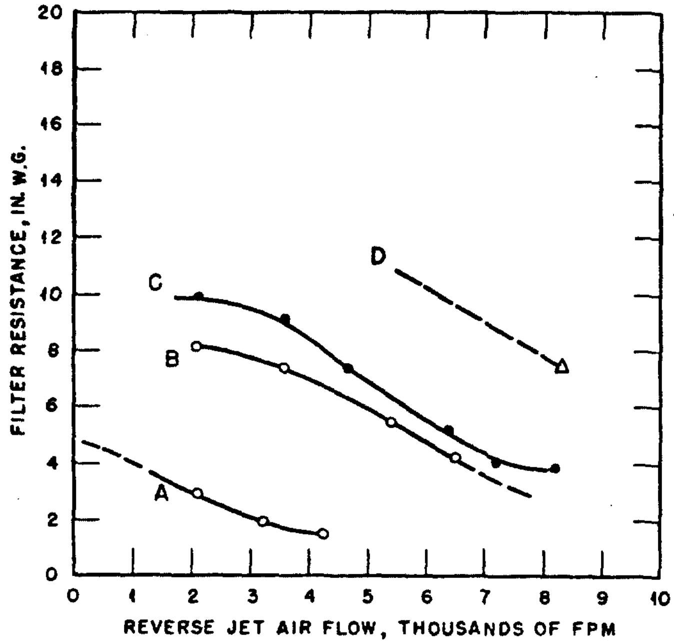

Fig. 2—Effect on resistance of reverse jet air velocity.

Curve no.	Test Dust	Filtration velocity	Reverse jet slot width
A	Fly ash	10 fpm	0.055 in.
B	Silica	10 fpm	0.055 in.
C	Silica	15 fpm	0.030 in.
D	Silica	15 fpm	0.055 in.

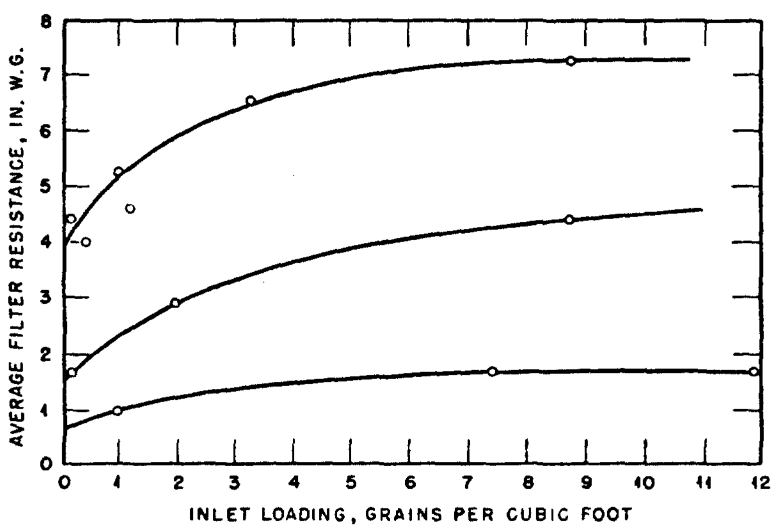

Fig. 3—Effect on resistance of inlet dust concentrations.

Dust	Air rate cfm/sq. ft.	Reverse jet velocity fpm	% time reverse jet operates
Silica	10	8,000	100
Talc	8	2,000	100
Fly ash	10	4,250	100