FIELD STUDIES OF COMMERCIAL DUST COLLECTOR PERFORMANCE

by

Richard Dennis, Melvin W. First, and Leslie Silverman

Presented by
Richard Dennis

1. Objective and Methods

Field testing of commercial dust collectors provides information covering a wider range of aerosols and operating conditions than can be investigated conveniently in the laboratory. In addition, the effects upon efficiency and resistance of average plant maintenance and normal deterioration of equipment under typical industrial applications can be observed.

Results of our studies of commercial cloth collectors (utilizing bag shaking or the reverse jet cleaning principle) and dry mechanical and inertial types have been reported previously (1) (2). Tests have since been made on representative models of two-stage, low voltage electrostatic precipitators and on a variety of wet collectors embodying a fairly representative group of the many designs now available.

Sampling and analytical procedures followed closely the methods and principles described at length in our Annual Report for 1950-1951 (1). High volume sampling with type S pleated filters and low volume sampling with molecular filters were used for determining weight collection efficiency and particle size distribution, respectively, when dealing with low dust loadings (i.e. $<$0.1 grain per cubic foot of air), and our stack sampler with paper or all-glass thimbles (for high temperature gases) was used for higher dust concentrations. Impinger tubes were used where excessive moisture caused filter plugging.

2. Test Results

a. Electrostatic precipitators. Operating principle and general construction of all models tested are basically identical. An adequate description may be found on page 42 of the Handbook on Air Cleaning (3). Ionizing wires maintained at a positive potential of 12 to 13.5 KV preceded collecting plates charged to 6 or 6.5 KV. Plate depth in the direction of air flow varied from 10 to 12 inches and the spacing between the alternately charged and grounded collecting plates was approximately 3/8 inch.

Collectors from three different manufacturers (Westinghouse "Precipitron", American Air Filter "Electromatic", and Trion "Electric Air Filter") were tested. The units differed in methods employed to clean the plates, the use of adhesive coatings and the location and construction of auxiliary filters. After-filters were employed in all units to guard against power failers, blow-off of accumulated dust and to eliminate carry-over during cleaning.

Table I is a summary of our test data. No significant performance variations were observed among the three models studied but efficiency varied inversely with flow rate as shown by tests 1, 2, 3, and 5, 6, 7. Other factors beside air flow rate may have influenced these results since they represent six different collectors, but so far as could be determined they were all operating properly at the time of the tests. Manufacturers rate these units as 90 per cent efficient at 350 FPM and 85 per cent at 400 FPM by the NBS discoloration test (4). The relationship between "blackness" and weight efficiency tests is not easily determined but our results seem to indicate that weight efficiency is a more severe test of the air cleaning effectiveness of these precipitators.

Because of improper location of return air ducts there was considerable variation in air velocity over the face of some of these units (in some instances maximum velocities nearly twice average were observed). Maldistribution of air tends to overload some sections of the collector and permits little or no air to reach other locations. This undoubtedly lowers efficiency. Flow resistance of these units is so low, i.e. 0.05 to 0.10 inches water gage, that there is little tendency for air to straighten and enter into all sections and special straightening devices should be employed upstream of the precipitator for this purpose when air distribution is abnormal. In the field it was not possible to determine quantitatively what part poor air flow distribution plays in lowering the efficiency of these units.

Tests 4a and 4b of Table I indicate greater efficiency for adhesive-coated plates although power pack fluctuations may have exaggerated the apparent advantage of the sticky plates.

b. Wet collectors. The units tested may be divided into two main catagories; (1) mechanical-centrifugal scrubbers in which dust collector and air exhauster are incorporated into a single unit, i.e. type W Rotoclone (American Air Filter Company) and Hydro Volute Scrubber (Buffalo Forge Company) and (2) inertial types in which the dust laden air is caused to flow over or around wetted baffles and vanes which impart a spinning motion to the gases. Both types of wet collectors are described and illustrated in the Handbook on Air Cleaning (3, p.26).

Both mechanical-centrifugal scrubbers employed an involute scroll as a pre-cleaner. For the type W Rotoclone, sprays are used in both pre-cleaner and impeller sections, while in the Hydro Volute Scrubber, sprays were used in the entry to the pre-cleaner section and in the droplet eliminator section to keep the bent plates washed clean. Nozzle pressures of 80 to 90 psi are used in the type W Rotoclone and 5 to 15 psi in the Hydro Volute Scrubber. Table II lists the results of tests on these two wet scrubbers. Five type W Rotoclones (capacity 5,000 to 10,000 CFM) gave weight efficiencies ranging from 97.2 to 99.6 per cent on foundry dusts having mass median diameters of 40 to 47 microns. Inlet loadings ranged from 0.75 to 7.29 grains per cubic foot. A 1,000 CFM Hydro Volute Scrubber gave 97.8 per cent efficiency on a re-suspended flyash with a mass median of 16 microns and a loading of 1.35

grains per cubic foot. As the equipment gets larger, inertial forces tend to decrease and give lower efficiencies, but these results are a good indication of the useful range of this type of equipment, i.e. efficiency 95 per cent or better on particles greater than 10 to 15 microns for units ranging in capacity from 1000 to 10,000 CFM. Because of the dual role of the impeller it cannot be designed for maximum aerodynamic efficiency and power requirements for units of this type are high.

Table III lists the results of tests on a variety of inertial wet collectors. Type N Rotoclones employing a water curtain and abrupt changes in direction to capture dust appear to be approximately as efficient as the mechanical-centrifugal type when applied to similar dust (i.e. 37 to 140 micron mass median diameter). (Had dust loadings been more nearly like those found in the type W Rotoclone tests, efficiency probably would have been somewhat improved). These units are not suitable for dusts one micron in size (MMD) or less as shown by Test 2b, Table III, but have about the same useful range as the mechanical-centrifugal types and may have somewhat less air flow resistance.

A 3,500 CFM Air Tumbler unit (wetted-wall spiral tube of four turns) removed 76 per cent of Al_2O_3 dust having a MMD of 25 microns, (Test 3). Air flow resistance was 1.9 inches water gage. With maximum gas flow (unit is rated up to 5,000 CFM) resistance would double (approximately) and efficiency might increase somewhat.

Five different impingement type scrubbers were tested. All have tangential entries (to produce a cyclonic air motion) plus guide vanes and impingement plates wetted by low-pressure water sprays. Efficiency ranged from 73 to 96.8 per cent, increasing with increase in size of dust and decrease in size of scrubber. Only the smaller units (1000 to 3000 CFM) appeared to be as efficient as the mechanical-centrifugal types.

A Buffalo Forge Company high-pressure-spray tower is representative of several such designs now available commercially. Their distinguishing feature and principal cleaning mechanism is multiple rows of 300 to 500 psi water sprays. Test 9, Table III, indicates that a 2,000 CFM tower removes 75 per cent of a dust having a mass median diameter of 0.9 microns. It is not possible to compare these results with those discussed above since the particle size is so different but it may be concluded that this type of scrubber will do at least as well on dust of a comparable size. Air flow resistance is low but the cost of pumping 400 psi water is a significant factor. High pressure nozzles are easily plugged and scrubbing liquor cannot be recirculated. A comparison of temperature reduction of hot gases passing through a low-pressure spray Ducon collector (2 gpm per 1,000 CFM at 20 psi) and a high-pressure spray Buffalo tower (3 gpm per 1,000 CFM at 400 psi) is as follows: from 230° to 120°F for the Ducon and from 329° to 72°F for the high pressure nozzle Buffalo unit, indicating that high pressure sprays may have some advantages where intimate contact between air and water is desired.

REFERENCES

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TABLE I—PERFORMANCE OF LOW-VOLTAGE ELECTROSTATIC PRECIPITATORS WITH ATMOSPHERIC DUST

Manufacturer	Test[1] and Unit[6]	Method[2] of plate Cleaning and Coating	DUST DESCRIPTION: Inlet: Loading[3] Grains per 1000 cu. ft.	Inlet: Median Size Microns: Count	Inlet: Median Size Microns: Mass.	Outlet: Loading[4] Grains per 1000 cu. ft.	Outlet: Median Size Microns: Count	Outlet: Median Size Microns: Mass.	Air Flow Rate (S.T.P.)[5] cfm	Face Velocity (Average) fpm	Per cent Air Recirculated (Estimated)	Collection Efficiency by Weight per cent
Westinghouse	1 (A)	Manual	0.0254	0.44	0.90	0.00638	0.39	0.48	21,900	780	50	74.9
	2 (A)	Washing	0.0302	0.44	0.85	0.00803	0.40	0.46	27,150	565	50	76.4
	3 (A)	and	0.031	---	---	0.0034	---	---	15,700	154	65	89.4
	4_a(A)[8]	Water	0.0224			0.011			15,700	253[7]	50	50.9
	4_b(A)	Soluble Adhesive	0.061	0.45	0.74	0.0221	0.39	0.47	15,700	253[7]	50	63.7
AAF	5 (B)	Automatic	0.0584	0.44	0.54	0.0171	0.42	0.47	22,000	389	50	70.8
	6 (B)	Cleaning	0.0632	0.45	0.52	0.0058	0.42	0.48	4,580	255	50	90.9
	7 (C)	by Oil Dipping	0.0307	0.43	0.58	0.00107	0.39	0.48	7,370	140	50	96.6
Trion	8 (D)	Built-in	0.0302	0.51	0.63	0.0032	0.46	0.56	1,800	322	45	89.5
	9 (D)	Water Sprays No Adhesive Coating	0.00902	0.42	0.62	0.00228	0.41	0.51	2,200	297[7]	90	74.7

[1]Cell voltages: ionizer 12 - 13.5 Kv, plate 6 - 6.5 Kv.
[2]Total plate depth = 12 in. (Westinghouse); 10 in. (AAF); and 10.75 in. (Trion).
[3]Outside air in units 1 through 4 pre-cleaned with coarse Fiberglas filters.
[4]Loading refers to concentration downstream of coarse metal fiber after filters (integral parts of units 5-9).
[5]S.T.P. = 70 deg. F., 760 mm. Hg.
[6]Letters in parenthesis indicate different designs: (A,D) fixed vertical plates; (B) moving vertical plates, 2 rev. per 24 hrs.; (C) moving horizontal plates, 2 rev. per 24 hrs.
[7]Voltage fluctuation during tests. Arcing in unit 4, low plate current in unit 9.
[8]No adhesive on plate.

Note: Pressure losses across all units varied from 0.05 to 0.1 in. water.

TABLE II—PERFORMANCE DATA FOR MECHANICAL - CENTRIFUGAL WET COLLECTORS

			DUST DESCRIPTION											
			Inlet			Outlet								
			Loading Grains per Cu. Ft.	Median Size Microns		Loading Grains per Cu. Ft.	Median Size Microns							
Type Unit	Test No.	Operation		Mass	Count		Mass	Count	Air Flow Rate (S.T.P.) cfm	Water Flow Rate gpm	Entry Velocity fpm	Pressure Loss. In. Water	Collection Efficiency by Weight Per cent	Overall Unit Dimensions. Feet L × W × H
Type W Rotoclone	1	Castings	5.07	47	9.5	0.022	7.2	1.7	10,400	9	3,750	3.2	99.6	8.8 × 8.0 × 15.3
	2	Cleaning	0.75	40	10.5	0.0052	6.7	2.1	4,150	9	1,490	4.4	99.3	8.8 × 8.0 × 15.3
	3	by Metal	5.98	47	5.4	0.045	6.0	1.0	10,000	14	2,500	3.0	99.2	10.2 × 9.6 × 17.8
	4	Shot and	7.29	43	1.1	0.029	2.7	0.6	5,220	7.5	2,830	3.3	99.6	7.0 × 6.6 × 13.2
	5	Sandblast, & Tumbling	1.12	45	---	0.031	--	--	5,440	7.5	3,060	4.2	97.2	7.0 × 6.6 × 13.2
Hydro Volute Scrubber	6	Flyash	1.35	15	4.0	0.030			1,000	6.5	2,800	5.1	97.8	3 × 2.5 × 8

TABLE III—PERFORMANCE DATA FOR INERTIAL AND CYCLONIC WET COLLECTORS

			DUST DESCRIPTION											
			Inlet			Outlet								
			Loading Grains per Cu. Ft.	Median Size Microns		Loading Grains per Cu. Ft.	Median Size Microns		Air Flow Rate (S.T.P.) cfm	Water Flow Rate gpm	Entry Velocity fpm	Pressure Loss. In. Water.	Collection Efficiency by Weight Per cent	Overall Unit Dimensions Feet L × W × H
Type	Test	Operation		Mass	Count		Mass	Count						
Type N Rotoclone	1	Foundry Tumbling	0.28	140	10.1	0.0025	9.0	2.4	10,100	3.2	3,370	2.6	99.1	8.2 × 8.1 × 16
	2a	Machine Shop—Grinding	0.0114	37	21	0.001	7.8	4.4	28,000	2.2	2,800	2.9	91.2	19.6 × 8.1 × 18
	2b	Machine Shop General Air	0.0056	1.0[1]	0.6	0.002	---	---	28,000	2.2	2,800	2.9	64.5	19.6 × 8.1 × 18
Air Tumbler	3	Steam Drying Al_2O_3	0.525	25	1.0	0.126	10.7	0.9	3,350 (176–140°)[2]	0.3	3,350	1.9	76.0	9 × 3 × 8.5 Diam. × H
Schneible	4a	SiC	0.076	20	7.6	0.0024	5.0	3.1	895 (142–88°)[2]	4.5	1,350	0.7	96.8	3 × 13
	4b		0.127	---	---	0.0066			1,900	4.5	2,880	3.2	94.8	3 × 13
Ducon	5	Stone and Sand Drying	5.8	4.3	1.7	1.5	1.2	0.6	9,200 (230–120°)[2]	20	1,300	2.5	74.0	6 × 16.7
	6	Banbury Mixer	0.0052	---	---	0.00077			16,600	16	3,200	5.2	85.2	5.3 × 13.5
Warren Bros.	7	Sand and Stone Drying	3.6	4.3	1.7	0.3	1.2	0.59	3,200	10	2,050	--	92.0	3 × 10.5
	8		6.4	---	---	1.7	---	---	10,000 (275–145°)[2]	12	2,000	--	73.0	4.5 × 18
Buffalo Forge Company	9	Ferro-Silicon Furnace Fume 90% Amorphous Silica	0.972	0.89	.35	0.243	0.82	0.31	2,800 (329–72°)[2]	10	4,000	1.1	75.0	4 × 16

[1]Estimated Size - Machining Operations Suspended During Test.
[2]Inlet and Outlet Air Temperature, deg. F.