WET CLEANING INVESTIGATIONS

by

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Presented by
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The simplest and perhaps the most common type of wet collector is the centrifugal scrubber in which air or gas is introduced tangentially or is given a rotating motion by deflecting vanes after entering the scrubbing chambers. Spray nozzles are usually located on an axial water main to spray radially outward, although they may be placed at the scrubber wall so as to spray tangentially in the direction of air flow.

A simple wet cyclone scrubber with a tangential inlet was constructed from 55 gallon oil drums and provision made for introducing hydraulic and pneumatic spray nozzles at different locations in the cyclone body, Figure 1. Basic performance data were obtained with a finely divided talc dust having a median size by count of less than one micron.

1. Effect of wet operation.

Weight efficiency was determined for wet and dry operation over a wide range of dust loadings. The results obtained were approximately straight lines on log-log paper, Figure 2.

Efficiency of the collector when operated wet ranged from 78% at a loading of 0.03 grains per cubic foot to 94% at 18 grains per cubic foot. Efficiency of the collector when operated dry varied from 46% at a loading of 0.5 grains per cubic foot to 75% at 10 grains per cubic foot. The wet runs were made with a water rate of 6 gallons per 1000 cubic foot of air using two 400 psi hydraulic nozzles. It is apparent that the dust loading is important in the performance of this type of device.

Since the slopes of the "Efficiency-Loading" curves are nearly equal, the relative effect of water is nearly constant in terms of reduction of effluent loading. The dry effluent is 2.8 times that obtained for the wet unit at a loading of 0.1 grains per cubic foot and 3.6 times at a loading of 10.0 grains per cubic foot. In terms of relative performance the effect of the sprays is slightly greater at higher loadings. This indicates, as predicted from theory, that there are a greater number of possible collisions as the number of dust particles increases. With dry operation an increase in efficiency with loading can be attributed to greater probable collision and subsequent agglomeration between particles. The rise in efficiency under wet conditions is a result of the increased collisions between particles and droplets.

2. Effect of wetting the cyclone walls.

Since many wet centrifugal dust collectors use only wetted walls or baffle plates as a means of increasing dust retention, the relative efficiency of the cyclone when dry and with walls wetted by means of a circular drip tube located around the upper edge of the cyclone body was investigated. The wetted wall tests were made with a water rate of 4.5 gallons per 1000 cubic feet and loadings about 1 grain per cubic foot. At low entry velocities wet and dry efficiencies were substantially equal (Figure 3) but at 4000 feet per minute entry velocity the difference was small but significant, indicating that even with small particles there is a dynamic equilibrium in dry cyclones between deposition on the walls by centrifugal force and re-entrainment by (1) rebound and (2) eddy formation at irregularities on the collector surfaces. The differences between dry and wetted wall operation would doubtlessly be greater if there were larger particles (i.e. more nearly in the usual particle size range for equipment of this nature) in the test dust.

From these tests it was concluded that the wetted wall surfaces accounted for only a small part of the increased efficiency noted when the cyclone was operated with high pressure sprays located at the inlet.

3. Effect of entry velocity.

The efficiency of a centrifugal collector is a function of entry velocity, i.e. higher entry velocities give higher efficiencies (as well as greater power requirements). A series of runs, wet and dry, was made to study the effect of velocity on efficiency. For the wet runs the water rate was 8 gallons per thousand cubic feet of air. The maintenance of constant water rate per volume of air was accomplished by maintaining constant water pressure but varying the number of nozzles in order to be certain that droplet characteristics would not change. For all these runs dust loading was approximately 1 grain per cubic foot of air.

Both wet and dry efficiency increased with increasing entry velocity (Figure 4), although the increase was more apparent on the dry than the wet runs. Relatively, dry efficiency improved at twice the rate of wet over the range tested. Other results indicate that when the wet cyclone is operating in a lower region of the efficiency curve, wet efficiency increases with increased inlet velocity in the same manner as dry efficiency.

4. Effect of water rate variation.

One of the basic considerations in the study of any wet collector is the amount of water required to give satisfactory performance. Figure 5 shows a series of tests using 2, 3, and 4 high pressure nozzles to study the effect of water rate variation. Dust loading was held close to 1 grain per cubic foot and an entry velocity of 3500 feet per minute was maintained during all of these tests. The portion of the curve between 0 and 4 gallons per 1000 cubic feet of air has been shown with a dotted line to indicate its expected position. The optimum water rate for use in the collector can be selected from curves of-this type. As the water rate is increased above 6 gallons per 1000 cubic feet of air the curve rapidly approaches an asymptote indicating that further increases in water rate do little or nothing to enhance the performance of the collector and only serve to increase the power requirements as well as contribute to waste water disposal problems.

Figure 6 shows the effect of water rate and inlet velocity on scrubber efficiency for low pressure hydraulic nozzles located near the cyclone entry at right angles to air flow. Efficiency increased with increasing nozzle pressure (i.e. water rate). This was also true for the high pressure nozzles.

Efficiency with the nozzles in place but the water turned off was 52% at an entry velocity of 3900 feet per minute. This is considerably below the dry efficiency of the cyclone when tested with no spray nozzles installed. The wet efficiency of the cyclone at 8 psi is also less than the dry efficiency of the empty cyclone. This peculiar result is probably due to the entry vane effect of the nozzles placed in the path of the incoming air. This is in agreement with studies on conventional cyclones which show that entry vanes decrease the velocity of the spinning gases in the cyclone body.

5. Effect of spray droplet size.

The effect of spray droplet size was investigated with coarse spray, low pressure hydraulic nozzles and fine-spray pneumatic nozzles operating at the same total water rate (Figure 7). The coarse spray gave higher efficiencies for the same entry velocity and dust loadings, indicating that the fine hydraulic nozzle spray droplets were too small to sweep or penetrate the area involved in front of the inlet (instead they were carried away with the air stream). The coarse flooding nozzle spray droplets were large enough to penetrate the air stream and reach the outer cyclone wall; but in comparison with high pressure sprays (dust collection efficiency approximately 90%) too few droplets were formed for effective dust removal. As a matter of interest, it may be noted that wet efficiency with the fine spray pneumatic nozzles was not appreciably superior to efficiency using an empty, dry cyclone although it was higher than dry efficiency with the spray nozzles in place.

6. Location of sprays.

Effect of nozzle location on wet cyclone performance for a low pressure pneumatic spray is summarized in Table I. The nozzles noted in the first item in the table were placed one foot above the inlet and directed downwards in an attempt to direct the spray toward the wall where the dust concentration is highest. Efficiency and resistance were both low. Efficiency was increased 16% by placing the nozzles at right angles to the inlet but resistance also increased (test 2). When the nozzles were placed countercurrent to flow in the cyclone inlet duct (test 3) efficiency increased another 11% and the resistance of the system doubled.

From this table it may be seen that highest efficiencies (and resistances) occurred with the nozzles placed in the inlet duct. With two nozzles placed countercurrent to flow, a water rate of 14.5 gallons per 1000 cubic feet of air and a water pressure of 50 psi, an efficiency of 84.7% was obtained (test 4). This compares favorably with 90% obtained with 400 psi nozzles at the same inlet velocity, but cyclone resistance with nozzles in the entry duct was about an inch higher and water rate 6 gallons per 1000 cubic feet greater. With low pressure nozzles, however, pumping requirements are less and water can be recirculated with less danger of plugging the nozzle orifice than with the high pressure ones.

Several runs were made with 1/8 inch mesh Saran screens inserted in the inlet duct downstream of a nozzle spraying concurrently (test 7). The screens were included to break up large water droplets and spread the water by surface tension effects. The insertion of two screens increased efficiency 8% (from 72 to 80.2%, test 6) but also resulted in a somewhat greater resistance. Water rate was relatively low (7 gallons per 1000 cubic feet) and there was no accumulation of material on the screens.

The design of the experimental scrubber studied is not a practical one since it has an unnecessarily high resistance. This particular design was chosen primarily for convenience and ease in construction and was purposely underdesigned in order to give low efficiency so that the effect of the addition of sprays, etc. would be readily apparent. Other investigations have indicated those factors which produce low energy loss in cyclone collectors and when the present studies of wet collection demonstrate the optimum methods of applying a scrubbing fluid, a practical, low-loss, high-efficiency scrubber will be constructed and tested.

TABLE I

Effect of Nozzle Position on Wet Cyclone Performance

Test No.	No. Nozzles	Position	Water Pressure psi	Water Rate gals/1000CF	Cyclone Resistance " H_2O	Dust Loading grains/CF	Efficiency % by weight
1	3	Directed down at inlet near entry wall	25.5	15.9	2.6	1.17	54.8
2	3	Right angles at inlet	25.5	15.9	4.6	1.09	70.9
3	3	Countercurrent to flow in inlet duct	25	15.3	9.2	1.00	82.0
4	2	Countercurrent to flow in inlet duct	50	14.5	9.5	1.11	84.7
5	1	Countercurrent to flow in inlet duct	45	7.0	---	1.09	76.3
6	1	Concurrent with flow in inlet duct	45	7.0	---	1.22	72.0
7	1	Concurrent in inlet duct followed by 2 Saran screens supported by a coarse wire screen	45	7.0	---	0.951	80.2

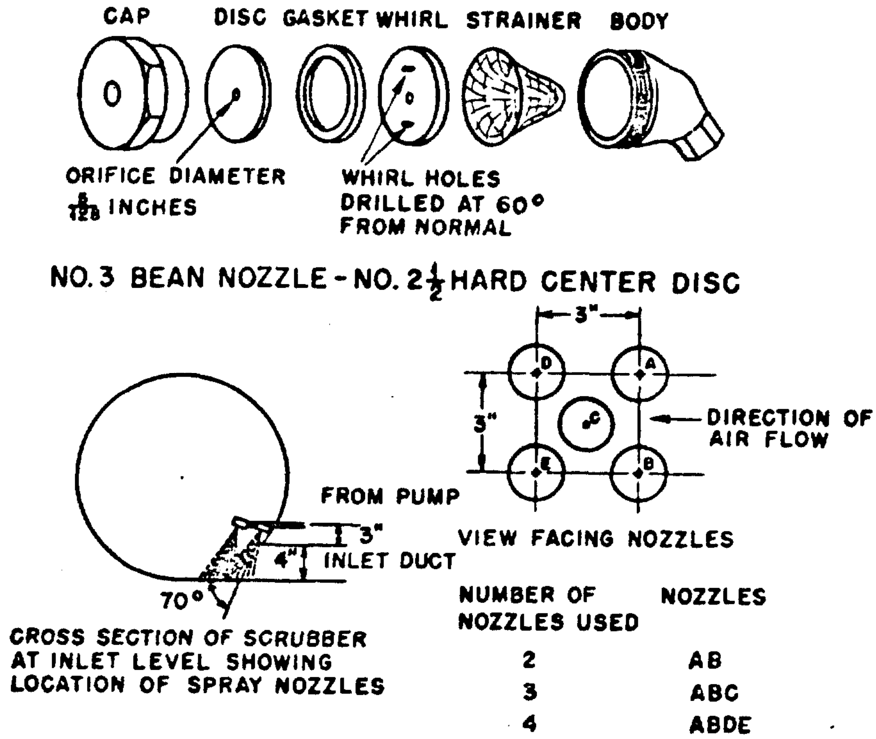

Fig. 1—Arrangement of spray nozzles.

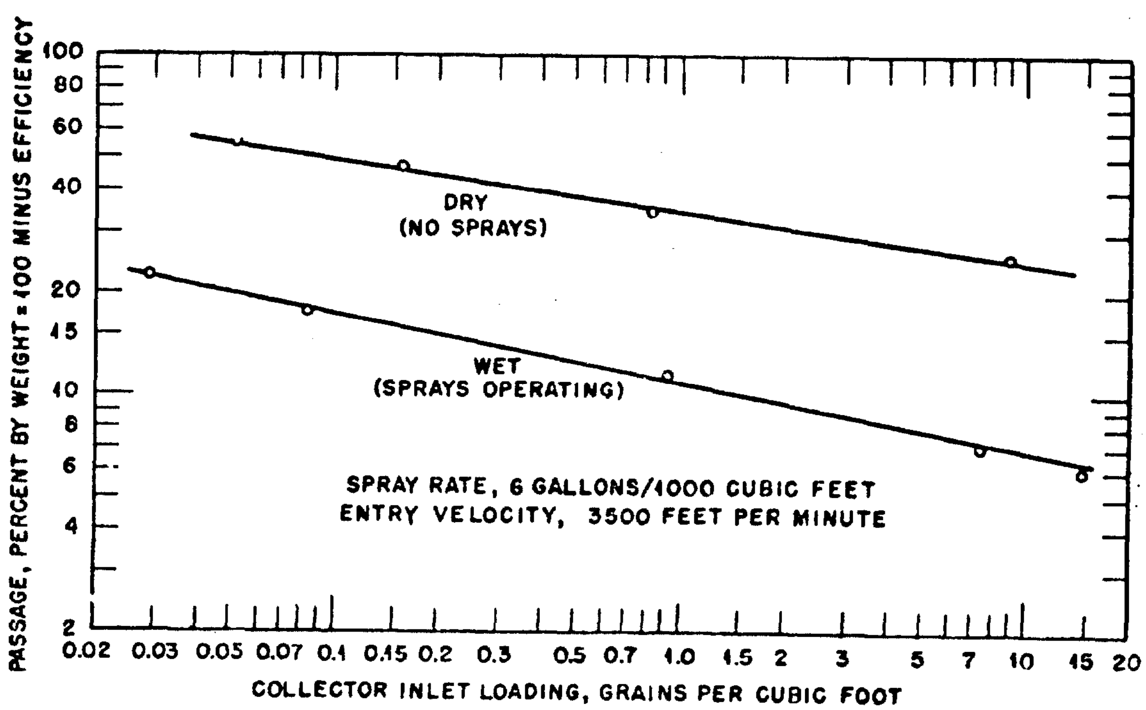

Fig. 2—Effect on efficiency of inlet dust loading.

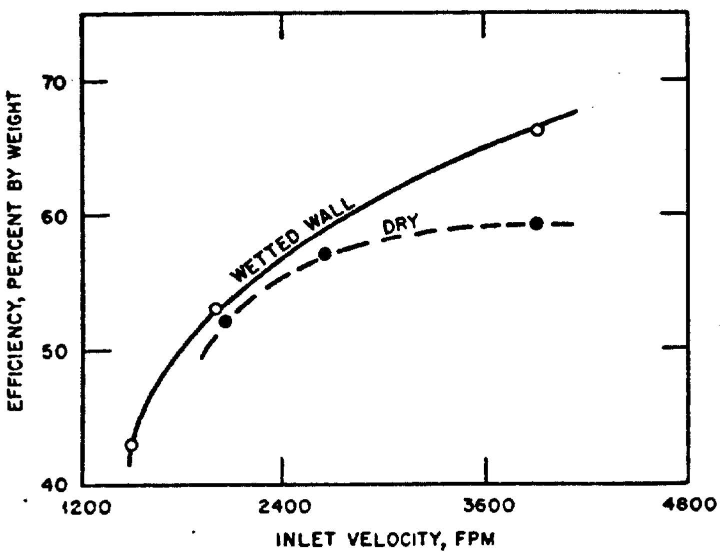

Fig. 3 — Efficiency of cyclone with wetted walls.

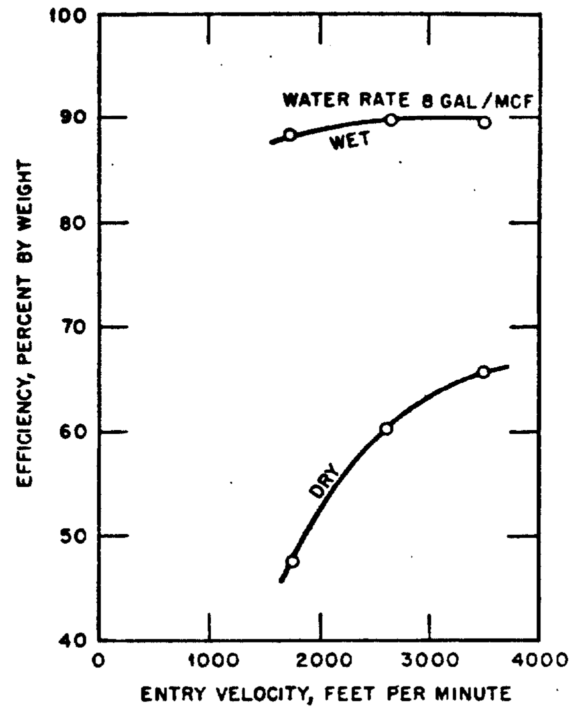

Fig. 4 — Effect of entry velocity on efficiency.

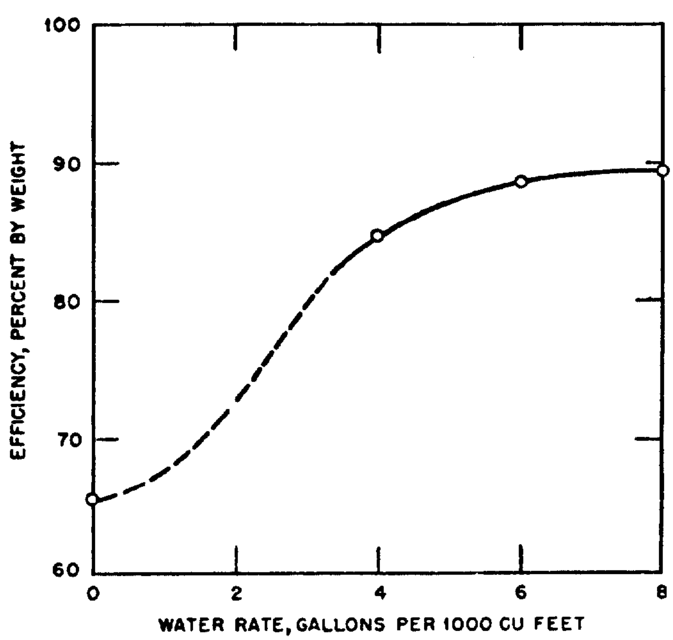

Fig. 5 — Effect of water rate on efficiency.

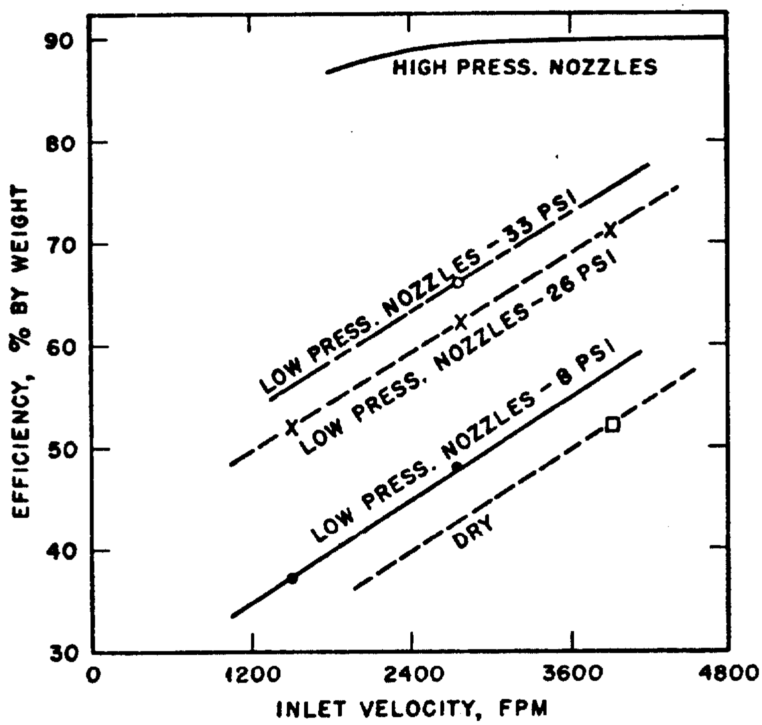

Fig. 6—Performance with low pressure hydraulic nozzles.

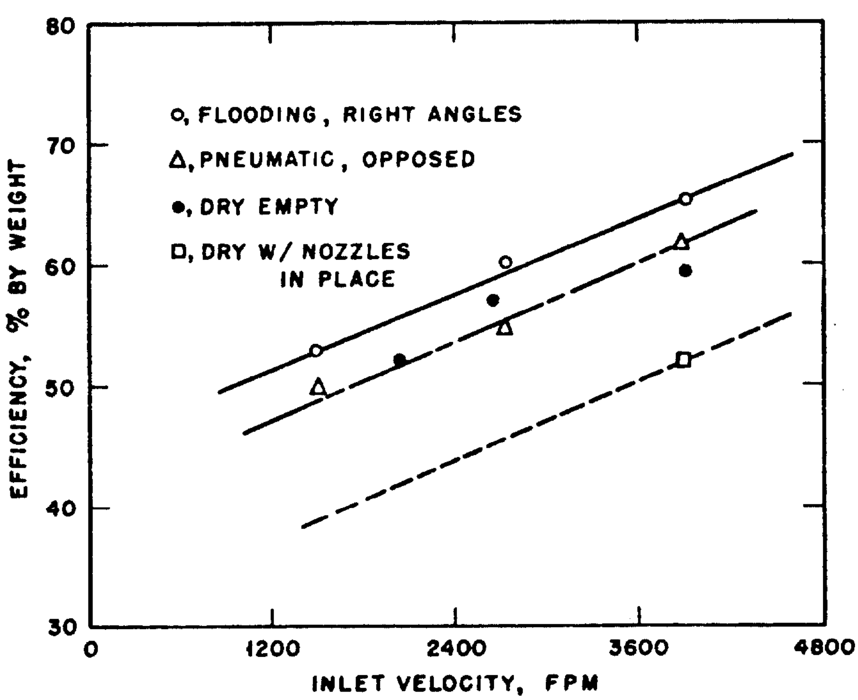

Fig. 7—Effect of size of spray droplets.