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DUSTS USED FOR TESTING AIR CLEANER EFFICIENCY

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Various agencies in the last ten years have made tests of the dust separation efficiency of air cleaners designed to protect automobile and truck engines against dust entering by way of the carbureter. Very wide differences between results reported by different persons testing the same cleaner, and in a few cases at different times by the same person for the same cleaner, have suggested a study of the reasons for the differences.

As difference in the character of the dusts used was assumed to be probably the largest single factor producing differences in the results, the work here reported was confined to that phase. The dusts compared were secured from a number of sources. Besides four different kinds of fuller's earth (a material frequently used for air cleaner testing), three other dusts used by air cleaner manufacturers (one European) were obtained. In addition to these were samples of cement, of various screened dusts, and of the "No. 1 standard" used in 1922 and the "No. 3 standard" used since 1925 in the air cleaner work at the Experiment Station at Davis, California.

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SCREEN TESTS

Some of the dusts were compared by use of a Tyler Ro-Tap machine and Tyler standard wire sieves having 100, 200, 250, 270, 300, and 325 meshes per inch and corresponding aperture widths 140, 74, 61, 53, 46, and 43 microns respectively. Marked differences were observed, but the results obtained did not show with sufficient clearness how the different dusts would perform when used to test air cleaner efficiency. Hence a more satisfactory method of comparison (later described) was devised and used.

The dust that floats around for minutes and sometimes for hours after a motor vehicle goes by on an earth road constitutes the great bulk of what an air cleaner in service must handle. It varies from less than one micron to about seven microns in diameter. Being of colloidal fineness it tends to flocculate or collect in flakes and balls when gathered in quantity, and agitated, as when placed in a sifting machine. Figure 1 shows this tendency. The dust shown is what

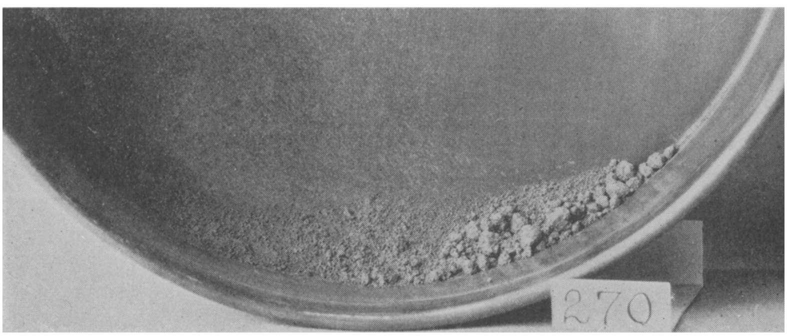


Fig. 1. Screen test of No. 3 dust. Very fine dust tends to flocculate or ball up when collected and agitated. One-hour shaking in Ro-Tap machine left this dust as shown on a 270-mesh screen. A few strokes with a soft brush sent it through this and all the other screens, including the 325-mesh-per-inch, almost without residue.

remained on the 270-mesh-per-inch screen after a sample of fine dust had been shaken for one hour at 153 strokes per minute in a Tyler Ro-Tap machine. Yet this dust went through not only the 270-mesh but also the 300 and 325 practically without residue when the work of the Ro-Tap was supplemented by hand use of a soft, dry, varnish brush. This dust sample was 25 grams of the "No. 3 standard" (table 1).

Quite different results were obtained when the same sifting and brushing processes were applied to the test dust used by Air Cleaner Manufacturing Company A, item 4 of the table. Figure 2 shows the parts of the sample that remained on the several screens and that part which passed through all and was found in the bottom pan. As will be noted, all the material except that in the bottom pan was too coarse to show any flocculation.

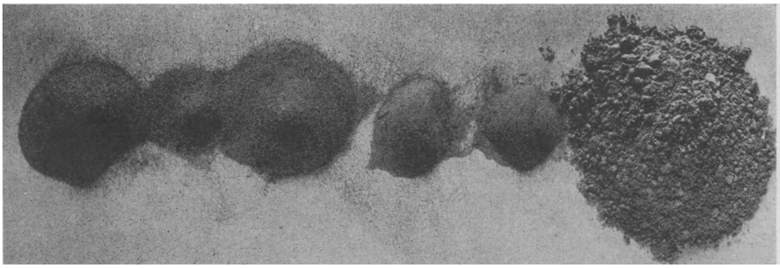


Fig. 2. Screen test of dust "Air Cleaner Manufacturing Company A." Residue left on 200, 250, 270, 300, and 325-mesh-per-inch screens and what passed 325-mesh, left to right respectively, after being shaken one hour in Ro-Tap machine and brushed. No tendency to flocculate except in that on the extreme right.

SETTLING AND FLOATING TESTS

To enable the making of direct numerical comparisons, a settling test was devised in which 25-gram samples of dust were brushed into an air stream going through a 6-inch by 30-foot pipe line, figure 3. The pipe line was made up of 15 lengths of ordinary 6-inch stovepipe, the joints being pushed closely together and the slight gap at the seams covered by weighted pieces of eiderdown blanketing. Air flow was maintained through the pipe at the rate of 15 cu. ft. per minute, the equivalent average velocity being 1.28 ft. per second or 0.87 m.p.h. The dust sample was placed in the tube shown at the right in figure 4 and pushed slowly against a bristle brush revolved in a housing opening into the head of the pipe line. Figure 5 shows the construction of the brush and housing. These served to blow the air through the pipe and to brush the dust sample out into fine division in the air stream. The bristles on the cylindrical surface were made long so as to sweep out the housing thoroughly, while those on the flat end were short and stiff to prevent their swinging out because of centrifugal forces and so leaving between their tips and the end of the dust tube

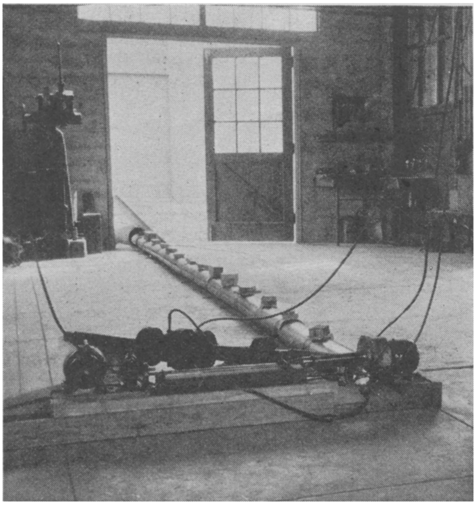


Fig. 3. Apparatus for comparing dusts used for testing efficiency of air cleaners. A 25-gram sample of each dust was sent into a 6-inch by 30-foot horizontal pipe line through which air passed at 15 cubic feet per minute (a speed of 0.87 miles per hour). The dust that settled in the pipe was weighed, and what escaped to the outside air was calculated. Results are shown in table 1 and in figures 6 and 7.

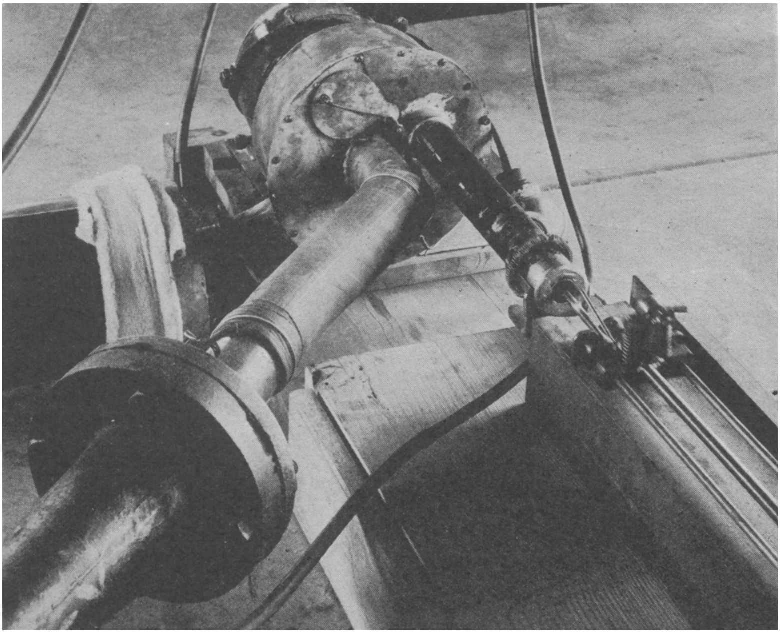


Fig. 4. Head of pipe line and dust feeding mechanism. The plunger in the tube on the right pushed the dust sample slowly against the bristle brush which revolved in the housing. The brush acted as a centrifugal air pump and brushed out the dust into a fine cloud.

a gap which would have permitted portions to fall as chunks into the air stream instead of being brushed out into fine division. The discharge end was screened against wind by use of a 4-foot length of 8-inch pipe open at both ends, from the far end of which a vacuum cleaner drew the dusty air to prevent its being recirculated. In the bead near the end of each length of pipe was placed a sheet-metal baffle one inch high and curved at the bottom to fit the pipe, to prevent bits of sand being rolled along after being sent out by the revolving brush. The rate of feeding was 25 grams in about fifteen minutes.

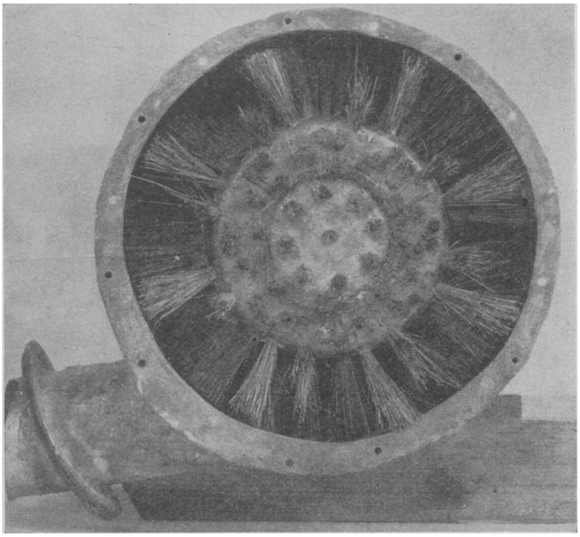
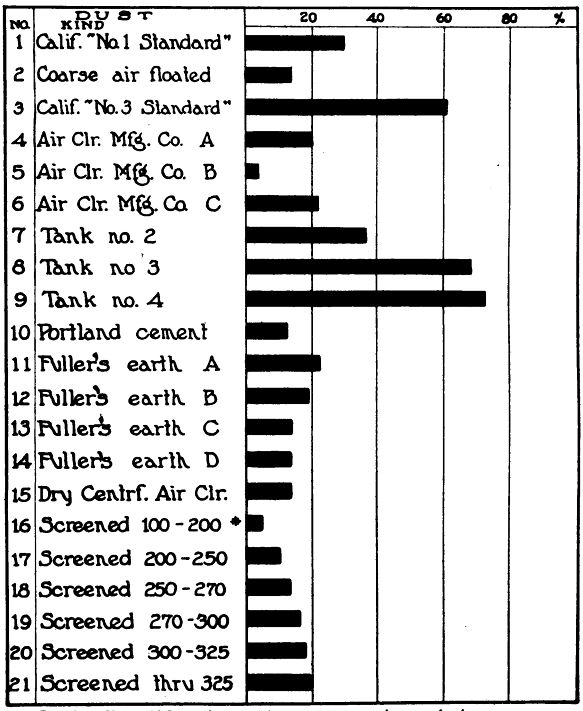


Fig. 5. Close-up of brush and housing. The long bristles on the curved surface of the wheel sweep out the housing. The use of short, stiff bristles on the flat end surface prevents the brush tips from swinging out by centrifugal force and leaving a gap between the brush and the end of the dust tube through which chunks of dust might fall and not be properly comminuted.

After the dust was all in, the brush was left to run for five minutes. Then the dust left in the brush housing and in the short adapter by which the housing was fitted to the pipe line, and that in each length of pipe, were removed and weighed separately.

Figure 6 shows characteristic differences in the settling of five dusts, three coarse and two fine. The coarsest showed less than 4 per cent floating through the pipe line and escaping to the outside air and more than 95 per cent settling in the brush housing and adapter and the first four feet of the pipe line. This was a sandy material used by a European manufacturer in testing air cleaners. The next, ''Air

Cleaner Manufacturing Company C,'' showed 11 per cent floating through. It was a sample of ''Aunt Jemima's Pancake Flour,'' a material reported as being used for test purposes by one American air cleaner manufacturer. The third (No. 4 of table 1 and fig. 7) is an earth dust ''obtained from Michigan State Road No. 33, passed through 200-mesh screen.'' (The aperture width of 200-mesh screen is 74 microns.)



* *Passing thru 100 and caught on 200 mesh per inch*

Fig. 6. Settling characteristics of coarse and of fine dusts. Ninety-six per cent of the coarsest dust (that used by a foreign air cleaner manufacturer) settled in the brush housing and adapter (designated at *O* pipe) and in the first two pipe lengths. Similarly, 35 per cent of ''No. 3 standard'' settled. However, note that the finer the dust the greater the amount that settled in the housing and adapter. Molecular and electrostatic forces produce more marked effects on very fine particles.

It showed 20 per cent floating through. The ''No. 3 standard,'' which has been used in the testing work at the Experiment Station at Davis, California, since 1925, had 61 per cent passing through. This dust was made by settling air-floated earth dusts in four tanks connected in series. That caught in the first tank was discarded, and that in the other three was mixed to make the ''Standard.'' A sample from tank 4 of the series had 72 per cent floating through. It is interesting to note that the finer the dust the larger the portion that adhered to the brush housing and settled in the short adapter (indicated by pipe length No. O in figure 6). This may result from the fact that electrostatic and molecular forces show their effects more markedly on very small particles. Turbulence caused by the abrupt change in diameter of section ($2\frac{1}{16}$ inches to 6 inches) between the brush housing and the pipe line may have contributed also.

TABLE 1

SETTLING AND FLOTATION PROPERTIES OF DUSTS USED FOR TESTING THE EFFICIENCY OF AIR CLEANERS

Dust		Number of tests	Per cent of total sample	
No.	Kind		Settling in pipe	Floating through to air†
1	Calif. "No. 1 standard"	7	70	30
2	Coarse air-floated	3	86	14
3	Calif. "No. 3 standard"	4	39	61
4	Air Cleaner Mfg. Co., A	2	80	20
5	Air Cleaner Mfg. Co., B	1	96	4
6	Air Cleaner Mfg. Co., C	1	89	11
7	Tank No. 2	1	64	36
8	Tank No. 3	1	32	68
9	Tank No. 4	1	28	72
10	Portland cement	2	88	12
11	Fuller's earth, A	1	78	22
12	Fuller's earth, B	1	81	19
13	Fuller's earth, C	1	86	14
14	Fuller's earth, D	1	86	14
15	Dust caught by dry centrifugal air cleaner	2	86	14
16	Screened 100–200*	3	95	5
17	Screened 200–250	1	90	10
18	Screened 250–270	6	87	13
19	Screened 270–300	4	83	17
20	Screened 300–325	3	82	18
21	Screened through 325	5	81	19

* Passed through 100 and caught on 200-mesh-per-inch screen after 15 minutes in Tyler Ro-Tap machine. Numbers 16 to 21 inclusive were made from dust No. 2 above. Sifting of road dust not air-floated would give dusts that would settle still more rapidly.

† Calculated.

COMPARISON OF DUSTS

Table 1 and figure 7 give comparative data of settling and flotation tests on twenty-one materials representative of about the range of what is being used in testing air cleaner efficiency. The data given in the last column of the table and graphically in figure 7 are believed to be a close measure of the difficulty that the average dry centrifugal type air cleaner would encounter in separating the several materials.

It is understood, of course, that other types of cleaners may be affected but slightly or in some cases not at all by the character of the dust.

The first item in table 1 is the "No. 1 standard" dust[2] used by the author in 1922 in testing air cleaners designed for tractors. It is probably very like the average dust that is encountered by the smaller tractors (30 hp. and smaller) in California fields. For the large

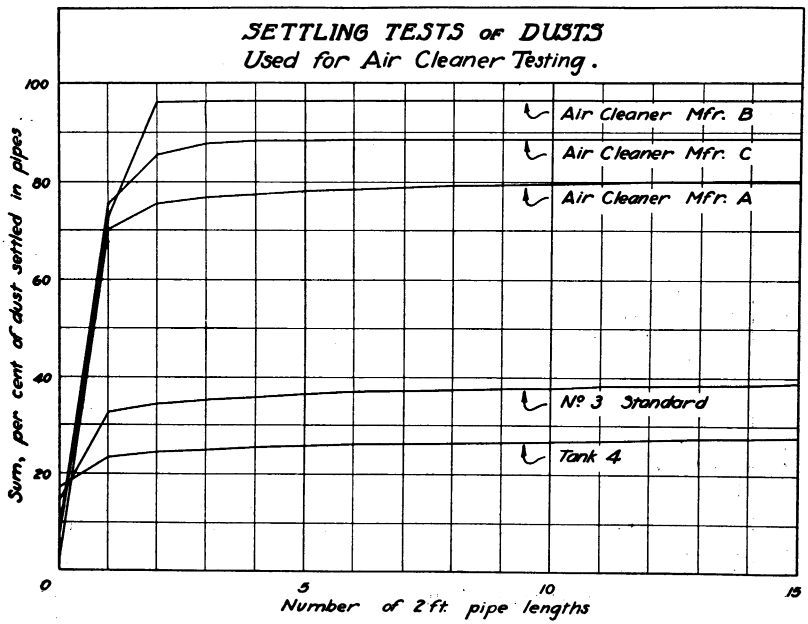


Fig. 7. Floatability of dusts for testing air cleaners. The lengths of the lines show the "floatability," that is, the per cent of each sample that floated through the pipe line. They also represent the relative difficulty a dry centrifugal air cleaner would have in separating these dusts. No. 15 is a sample taken from two collecting-type dry centrifugals used in California and shows the character of the dust they were able to handle.

tractors that have their carbureter inlets 7 or 8 feet above ground and for the average automobile in California it is probable that the "No. 3 standard" is more nearly representative. This dust would be duplicated very nearly if ten or more soils representative of California (or of the United States) were air-floated in the machine of figure 9 at the air speed indicated (less than 1 foot per minute) and the settled fine dusts were mixed. The dust of item No. 2 is the result of using a much higher air speed in a machine similar to that of figure 9.

[2] Hoffman, A. H. Efficiency of dust separation in air cleaners for internal combustion engines. Agric. Engineering 4:89–116, figs. 1–24. 1923.

VARIATIONS IN RESULTS OBTAINED

The motor used to drive the bristle brush of the dust-feeding mechanism (figs. 3 and 4) was a series-wound, commutator type alternating current motor. The speed of motors of this type is markedly affected by voltage variations of the power line and by changes in the load. At the beginning of the test series the brush wheel and its housing were new; and, though the device was run empty for several hours before the first test, there was still considerable friction load. In later tests the motor speed had noticeably increased, it being found necessary to decrease the area of the air inlet in order to keep the rate of air flow down to the normal. The maximum range of speed observed was from about 2400 to 4200 r.p.m. Probably the rather

TABLE 2

SETTLING AND FLOTATION TESTS; DUST, "NO. 3 STANDARD"

Serial No. of test	Dust left in pipes, per cent	Dust escaping, per cent	Relative humidity, per cent	Air temperature, degrees Fahr.	Barometer reading, inches mercury
1*	37	63	56.5	65.0	30.120
8	41	59	43.0	79.0	30.130
28	41	59	39.0	79.5	30.239
39	38	62	32.5	77.5	29.937

* The samples used in tests Nos. 1 and 8 had 3 per cent moisture. Those of tests Nos. 28 and 39 were practically moisture-free.

TABLE 3

SETTLING AND FLOTATION TESTS; DUST NO. 2 OF TABLE 1, COARSE AIR FLOATED, MOISTURE, 3 PER CENT

Serial No. of test	Dust left in pipes, per cent	Dust escaping, per cent	Relative humidity, per cent	Air temperature, degrees Fahr.	Barometer reading, inches mercury
34	86	14	17	77	30.081
35	88	12	58	61	30.115
38	85	15	27	78	30.000

large variations found in the results of different tests on the same kind of dust resulted from variations in brush speed. A synchronous motor, or at least one having similar constant speed characteristics, should be used for this purpose.

Table 2 gives the data taken in the four tests made on the No. 3 standard dust. The values given are uncorrected for the changes in moisture content of the dust that occurred during the testing and weighing. The samples in tests Nos. 1 and 8 had approximately 3 per cent moisture. The samples in Nos. 28 and 39 had been dried for two hours at 220° F at atmospheric pressure and were nearly moisture-free. Table 3 shows the variation for a coarse dust, No. 2 of table 1.

HOW FINE SHOULD THE TEST DUST BE?

Seven years' experience shows that dust for testing air cleaner efficiency must be exceedingly fine to give results upon which dependance may safely be placed. Many times automobiles equipped with dry centrifugal type air cleaners that showed good efficiency when tested with coarse dusts like numbers 4 and 6 of table 1 have shown excessively rapid engine wear when used in such regions as the Imperial Valley, California, or around Pendleton, Oregon. The

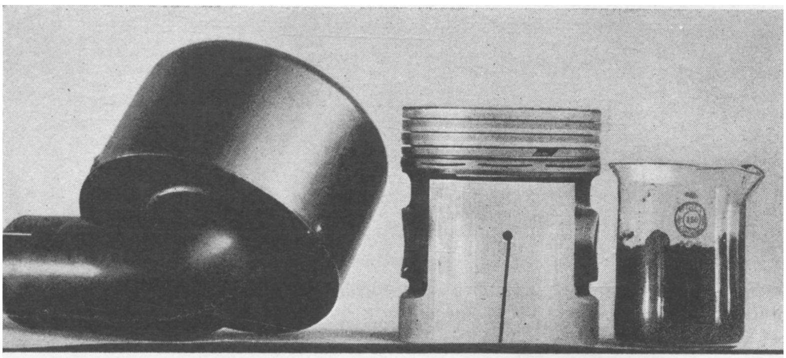


Fig. 8. Dry centrifugals do not protect adequately. Air cleaner from 1928 "Standard Six" in service of California Highway Commission; piston removed after three months, 3478 miles use, and replaced by .015-inch oversize; dust (99.48 grams dry) removed from carbureter and connecting tubes after 100 miles use. Note clearance between rings and ring grooves.

material shown in figure 8 is of a typical case of severe dust conditions and illustrates the inability of a dry centrifugal cleaner to afford satisfactory protection. The air cleaner and piston shown are from a 1928 "Standard Six" in the service of the California Highway Commission. It was a new machine and had been used three months and run 3478 miles to and from a road construction camp near Oroville when it was found necessary to rebore the cylinders and put in .015-inch over-size pistons. The dry centrifugal type air cleaner, regular equipment on this machine, was replaced by a self-washing oily filter type, and the machine was returned to the service. The reports indicate no further trouble in the succeeding twelve months' use.

As further evidence of the inability of dry centrifugal type air cleaners to afford adequate protection against dust and undue wear, the data given in table 4 of solid impurities (other than carbon) removed by crankcase oil filters may be cited. At the milage readings and dates specified the oil filters were removed and carefully cut open,

TABLE 4

SOLIDS TAKEN OUT BY ENGINE CRANKCASE OIL FILTERS*

Car No. 1, Buick 27-20 coach used at Davis, California, and vicinity.
Oil: Penzoil heavy, drained at 779 and at 8,344 miles.
Filter: AC, B-1.
Air cleaner: AC dry centrifugal (regular equipment).

Car No. 2, Buick 28-26S club coupe used at Davis, California, and vicinity.
Oil: Pennzoil extra medium, drained at about each 1,000 miles.
Filter: AC, B-1.
Air cleaner: Bowden, oily pasteboard type.

Car No. 3, Buick 28-20 coach used at Davis, California, and 10,000 miles transcontinental.
Oil: Pennzoil extra medium, drained at 600, 1,817, 7,000, 12,000 and 20,876 miles.
Filter: AC, B-1.
Air cleaner: Bowden, oily pasteboard type.

Car No. 4, Dodge Victory Six, 1928 sedan, used at Davis, California, and vicinity.
Oil: Valvoline medium, drained at 250 and at 9,500 miles.
Filter: Purolator SA-2.
Air cleaner: Bowden, oily pasteboard type.

Car No.	Test No.	Filter installed		Filter removed		Use, miles	Total ash, grams	Ash per 1,000 miles, grams
		Date	Odometer reading	Date	Odometer reading			
1	27	Oct. 15, 1927	0	Feb. 25, 1929	8,344	8,344	34.7	4.16
	107	Feb. 25, 1929	8,344	Oct. 15, 1929	13,782	5,438	24.1	4.43
				Totals and weighted average..		*13,782*	*58.8*	*4.26*
2	15	Oct. 15, 1927	0	April 23, 1928	5,000	5,000	14.4	2.88
	84	April 23, 1928	5,000	Sept. 6, 1929	16,043	11,043	17.3	1.57
				Totals and weighted average..		*16,043*	*31.7*	*1.97*
3	16	Oct. 27, 1927	0	April 18, 1928	1,851	1,851	14.5	7.84
	22	April 19, 1928	1,851	July 26, 1928	12,728	10,877	15.4	1.41
	161	Jan. 26, 1928	12,728	Jan. 29, 1930	20,876	8,148	13.2	1.62
				Totals and weighted average..		*20,876*	*43.1*	*2.03*
4	7	1928	0	Feb. 19, 1929	3,081	3,081	10.7	3.47
	62	Feb. 19, 1929	3,081	May 22, 1929	6,224	3,142	3.7	1.18
	111	May 22, 1929	6,224	Oct. 18, 1929	12,470	6,246	10.5	1.68
				Totals and weighted average..		*12,470*	*24.9*	*2.00*

* Chemical determinations made by H. W. Allinger, College of Agriculture.

and the oil, dirt, and filter cloths were incinerated in electric muffles at 1100° F. The total ash from each filter and the equivalent ash per 1000 miles are significant indications of the wear that occurred in the engines during the service of the particular filter. As would be expected the wear and consequently the ash per thousand miles is highest when the machine is new and the rubbing surfaces are not yet fully smoothed. The ash is made up principally of iron (ferric oxide) with smaller amounts of silica and silicates and oxides of copper, lead, tin, antimony, chromium, manganese, zinc, magnesium, and other metals. A small portion of the iron and most of the silica comes from the dust that enters with the air through the carbureter. A small amount of silica comes from the cast iron worn from cylinder walls and piston rings. The chemical work was done by H. W. Allinger of the Division of Chemistry, University Farm.

Of the cars listed all but No. 3 were used in the same region and kind of service. No. 3 had a transcontinental trip in June and July of 10,025 out of a total of 12,728 miles. Probably three-fourths of its total mileage was on earth roads and under summer conditions. It will be noted that "eastern" oils were used in all of the machines and that frequent draining was not practiced in any of them. All the oils except one were of medium viscosity. Although car No. 1 had the advantage of heavy oil, its record of ash per thousand miles, which may be regarded as indicative of relative wear, is more than twice the average of the other three machines. As the drivers are known to be skilled and careful, there is no reason to doubt that the difference in wear as indicated by the ash resulted primarily from difference in efficiencies of the two types of air cleaners used.

As the coarse material stirred up by a passing machine usually settles back to earth in one or two seconds, while the fine dust hangs in the air for minutes and in some cases for hours, it is evidently of relatively great importance that an air cleaner should be able to handle the very fine dust. If it can do this, it can, as a rule, unquestionably take care of the coarse also. Possible exceptions to this rule are some of the simple oily surface-type cleaners, not self-washing, which may, after catching a coarse particle in an oil film, allow it to be rolled along by the friction of the air stream and finally permit it to be drawn away and pass on into the carbureter, while the finer dust may be held securely. Even if a dry centrifugal or inertia-type cleaner shows high efficiency when tested with coarse material, there is no assurance whatever that it will not in regular service permit more than half the dust it encounters to pass on into the engine.

SIZE OF DUST PARTICLES IN THE AIR

Use of a micrometer microscope magnifying 450 diameters shows that many of the particles in the dust that floats for a minute or more above our roads are too small to be measurable except by special means and that some are almost, if not quite, invisible and probably less than one micron in diameter. On the other hand, occasional bits of organic matter are found almost of sufficient size for the unaided eye to distinguish them as separate particles. Summers states[3] that "Particles still in the air 2 minutes after a vehicle has passed are approximately 0.00025 in. (6.35 microns) in diameter." The value given is no doubt approximately correct for the maximum size particles of silica still floating after two minutes in calm air. It should, however, be remembered that two minutes is much too low a time limit in view of the fact that much dust will often float for upwards of an hour.

STOKES' LAW NOT RIGIDLY APPLICABLE

As Stokes' law for the rate of fall of small particles in viscous fluid media assumes still media and spherical particles, the law does not rigidly apply to the settling of dust particles in the pipe line used in the tests before described. Hence calculations using the law to find the maximum size of particles floating through the pipe line would yield only a rough approximation. Assuming spherical particles of silica (density 2.5) falling three inches in the 23.4 seconds required to traverse the pipe, the calculations would indicate the diameters of the particles to be 6.5 microns and under; while those assumed as falling the full six inches diameter of the pipe in traversing its length would be 9.3 microns and under. As the dust particles in question are not spheres but very irregular in shape, and as the air is not still but definitely in motion, though at a low velocity, it is safe to assume values somewhat larger for the actual sizes of the largest particles that floated through the pipe line.

[3] Summers, C. E. The physical characteristics of road and of field dust. Jour. Soc. Aut. Engr. 16:243–247, figs. 1–8. 1925.

SPECIFICATION BY AIR VELOCITY

To specify particle sizes, either maximum allowable, or average, in dust to be used for air cleaner testing, would be of little practical value or service, because the dust that an air cleaner must handle in practice is heterogeneous, the particles differing widely in chemical composition and in density. To specify the air speed to be maintained in a machine of given type and dimensions in which dust from field soils is being produced is a much more reliable method of securing a test dust having satisfactory characteristics.

Air flotation apparatus made in accordance with the sketch of figure 9 will produce such dust provided the speed of the air passing

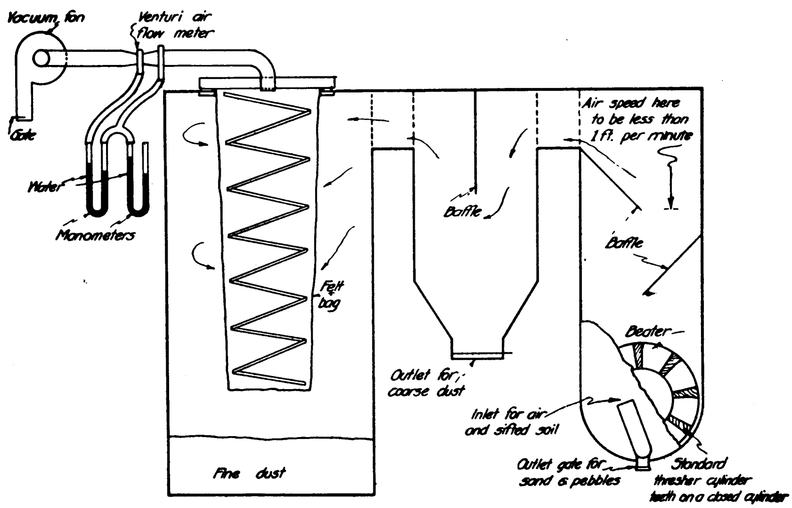


Fig. 9. Sketch of apparatus for making fine dust. The fineness is regulable by controlling the rate of air flowing through the system. The air meter permits duplication of the degree of fineness. The manometer at the right indicates when the felt bag needs shaking down.

from the beater chamber to the settling tanks does not exceed one foot per minute. A venturi air meter having a throat diameter of ¼ inch is probably the most satisfactory type and size to use for this purpose, being easily made and not too bulky. It must, however, be calibrated. This can be done readily by making comparison with a small Durley[4] circular-orifice-in-thin-plate-type meter.

[4] Durley, R. J. Air flowing into atmosphere through circular orifices in thin plates. Trans. Am. Soc. Mech. Engrs. **27**:193–231, figs. 1–17. 1906.

A MACHINE FOR PRODUCING FINE DUST

In the dust machine as used by the author at Davis the beater has a tooth-tip circle 13½ inches in diameter and a length of 3¼ inches parallel to the shaft. The 24 thresher cylinder teeth 2¼ inches long in the clear are placed staggered in eight oblique rows so that every part of the bottom space of the housing is swept. The clearance

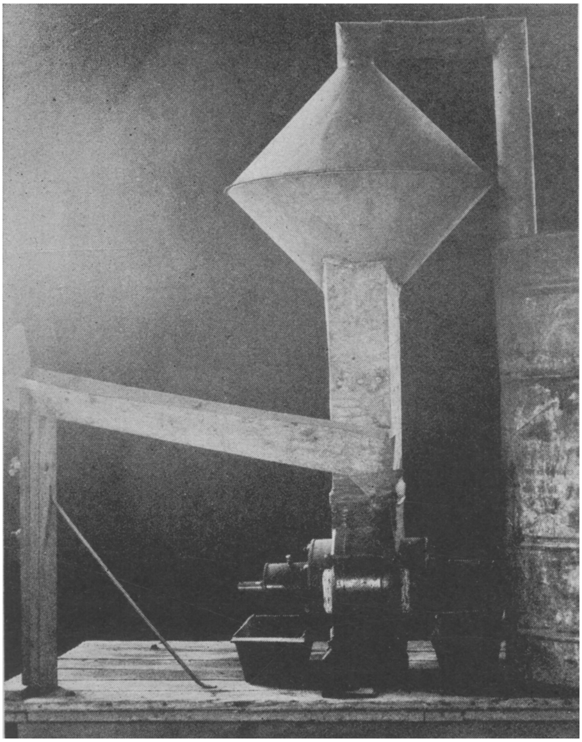


Fig. 10. Modified form of apparatus for making dust. Placing the settling chamber for coarse dust directly above the beater allows the material to drop back repeatedly until it is sufficiently fine. (Motor is not shown).

between tooth tips and housing at the bottom is $\frac{1}{16}$ inch. The anti-friction bearings are mounted wholly outside of the housing with open air spaces between, so that any dust escaping past the felt washers that surround the shaft where it goes through the walls of the housing may not penetrate the bearings. An earlier machine somewhat differently designed in this respect gave trouble repeatedly from bearings cutting out. The beater shaft is flexibly connected with a 2-horsepower, 1160 r.p.m. motor. The settling tank for the fine dust is a cylinder 30 inches in diameter by 36 inches high. The other parts are in approximately the proportions of the sketch.

The soils used as raw material are dried and broken up to pass a ¼-inch mesh screen. The screened material is fed in slowly by way of the air inlet tube which enters the housing at one end near the bottom. Pebbles and coarse sand collect in the recess at the bottom of the housing and are removed at intervals. The coarser dust may be removed as may be necessary, or the construction may be modified by placing the coarse dust chamber directly above the beater chamber as in figure 10, in which case the coarse material may fall back for further beating.

Since the whole inside of the system is at a pressure slightly under atmospheric, there is no leakage of dust to the air of the room except an imperceptible one through the walls of the felt bag.

If the same raw materials are used and the same rate of air flow through the system is maintained, the characteristics of the dusts produced will be uniform insofar as they relate to the testing of air cleaners. To keep the air flow rate constant the outlet gate of the vacuum fan must be adjusted frequently and the felt bag shaken down occasionally. The manometers, left and right respectively, indicate when such care is needed.

SUMMARY

This study was undertaken because wide differences had been noted between results of tests of efficiency reported by different persons for the same air cleaners. Differences in the character of the dusts used in the tests were presumed to be the chief cause of the variation in the results. Hence this study was confined to the characteristics of dust. Samples of twenty-one dusts representative of the range of those used for air cleaner testing were obtained. When screen methods failed to give a satisfactory basis for comparisons, a method by air-flotation and settling was devised and used. The method involves the sending of weighed samples of the several dusts into a pipe-line system through which a constant rate of air-flow is maintained. The dust that settles in each part of the system is weighed separately, and that which floats through is calculated. The results for dusts actually

used for air cleaner testing show a range of 96 per cent to 39 per cent settling, or 4 per cent and 61 per cent, respectively, floating through. A dust still finer shows 28 per cent settling and 72 per cent floating through. The per cent of floatability is taken as measuring the difficulty a dry centrifugal type air cleaner would encounter in handling a given dust. Examples are cited showing that this type of cleaner fails to protect satisfactorily against excessive wear under severe dust conditions. Suggestions are made for making dust of proper characteristics for the testing of air cleaners, and a machine for dust production is described.

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The titles of the Technical Papers of the California Agricultural Experiment Station, Nos. 1 to 20, which HILGARDIA replaces, and copies of which may be had on application to the Publication Secretary, Agricultural Experiment Station, Berkeley, are as follows:

1. The Removal of Sodium Carbonate from Soils, by Walter P. Kelley and Edward E. Thomas. January, 1923.
4. Effect of Sodium Chlorid and Calcium Chlorid upon the Growth and Composition of Young Orange Trees, by H. S. Reed and A. R. C. Haas. April, 1923.
5. Citrus Blast and Black Pit, by H. S. Fawcett, W. T. Horne, and A. F. Camp. May, 1923.
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11. Studies on the Effects of Sodium, Potassium, and Calcium on Young Orange Trees, by H. S. Reed and A. R. C. Haas. October, 1923.
12. The Effect of the Plant on the Reaction of the Culture Solution, by D. R. Hoagland. November, 1923.
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