4620

NATIONAL BUREAU OF STANDARDS REPORT

4620

PERFORMANCE OF A DONALDSON OIL BATH
AIR CLEANER MODEL A 10574

by

Carl W. Coblentz

Report to
Office of Chief of Transportation
Air Transportation Service
Department of the Army
Washington 25, D.C.

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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NBS PROJECT		NBS REPORT
1003-20-4838	April 6, 1956	4620

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Heating and Air Conditioning Section
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Abstract

The specimen filter was charged with 1380g of dust and the pressure loss, due to this dust load, increased from 7.9 inches W.G. to 9.5 inches W.G. at an air flow rate of 315 cfm, and the filtering efficiency decreased only slightly at the end of the test, averaging 94% for A.C. Spark Plug "fine" dust and 99% for A.C. Spark Plug "coarse" dust. Tilting of the filter up to 30 degrees had no effect on the filtering efficiency and did not produce a noticeable carry-over of the oil. The dust holding capacity of this filter corresponds to the dust load produced during 7.3 hours of operation at the design air flow rate with a dust concentration of 10 mg/cu ft.

1. INTRODUCTION

As a part of the research project, "Air Filter Systems for Army Aircraft", the performance characteristics of an oil-bath air cleaner manufactured by the Donaldson Company of St. Paul, Minnesota, were determined with a view to comparing this type of filter with others as an induction air cleaner for helicopter or other small aircraft engines.

2. SPECIMEN AND TEST APPARATUS

The test specimen was a Donaldson model A 10574 air filter designed for an air flow rate of 315 cfm for use on tractors and built of substantial sheet steel. The device weighed 27 pounds, including 3-1/2 quarts of oil. The outside shell was a cylinder 16-3/4 inches high and 10-3/16

inches in diameter, with a short inlet pipe protruding from the top and an outlet near the top on one side. The lower part, the oil pan, was detachable.

An inverted truncated cone was welded to the bottom of the oil pan and, for use, the cup so formed was filled with oil until the oil surface was flush with the upper rim of the cup. When assembled, the inlet air duct leading down the center of the shell reached about 1/2 inch below the oil level. According to the manufacturer's description, the dusty air mixes with the oil and then passes through a series of wire mesh screens where the oil and dust are captured and allowed to drain back into the outer part of the oil pan. Here, the dust settles to the bottom and the clean oil flows over into the inner cup to be entrained again by the air stream. By this process the air cleaning medium, the wire mesh, is continuously scrubbed as it cleans the air. The screen elements serve as a trap for the air-entrained oil, rather than as a simple filter for the dust.

The air cleaner was connected to a 5-inch test duct through which air was drawn by means of an exhaust blower. The air flow rate through the air cleaner could be adjusted in a wide range by a valve installed in the test duct between blower and air cleaner. The air flow rate was measured with an orifice flow meter designed in accordance with A.S.M.E. Research Publication, "Fluid Meters, Their theory and Application." The orifice flow meter was equipped with a water-filled U-tube manometer and an inclined gage connected in parallel. The latter was used to obtain more precise measurements at low air flow rates and was closed off at higher air flow rates when readings were taken on the U-tube manometer.

For each test run, a measured amount of dust was placed in a small hopper which fed the groove of a turntable to a predetermined level. This turntable was mounted on a variable speed Graham transmission and the test dust was drawn from the groove by a high pressure aspirator which broke up most of the agglomerations and supplied the dust to the open inlet of the test duct. By changing the speed of the turntable, the dust feed rate could be varied in the range from zero to 30 grams per minute to provide the desired dust concentration in the test duct.

The dust used was classified air cleaner test dust produced by the A.C. Spark Plug Division of General Motors Corporation. Both the "fine" and the "coarse" types of dust

were used and a few test runs were made with a mixture of 50% of each of the two kinds.

The efficiency of the test specimen was determined by drawing equal volumes of air out of the test duct upstream and downstream of the test specimen. By using identical sampling nozzles installed at the center of the duct and adjusting each sampling air flow rate to produce "iso-kinetic" flow in the duct and nozzle, it was assured that the dust concentration in the samples was representative of that in the main dust. "Isokinetic" sampling is obtained when the air flow rate, in feet per minute, in the entrance to the nozzle is equal to that in the main test duct at the entrance to the nozzle.

The sampling air flow rates were measured with two identical orifice flow meters which had been previously calibrated with a gas meter. The manometers of these flow meters were mounted on either side of a graduated scale to facilitate the adjustments for maintaining a constant sampling air flow rate during each test.

The sampling air was drawn through an absolute filter of glass fiber paper whose smallest fibers were about 0.3 micron thick. Tests of the air cleaning efficiency of similar paper by the Atomic Energy Commission indicated that such paper retained more than 99.99 per cent of all particles of 0.3 micron size and larger. These glass fiber papers were, therefore, selected as absolute filters for the air sampler, and the dust collected on these filters was determined by weighing the papers before and after each test to the nearest 0.1 milligram.

The efficiency of the air cleaner was calculated from the formula $E = \frac{U - D}{U} \times 100$

where: E = filtering efficiency, per cent,
U = weight increase of upstream sampler,
D = weight increase of downstream sampler.

The validity of this test method was ascertained by operating the test duct without an air cleaner and determining that the amount of dust collected by both samplers was equal. Further, in every test run, it was checked that the weight increase of the upstream sampler was close to the amount of the total dust introduced into the test duct multiplied by the ratio of the sampling air flow to the total air flow.

3. TEST PROCEDURES AND OBSERVATIONS

The first series of tests was made to determine the dust holding capacity, the pressure loss, and the efficiency of the test specimen at its design air flow rate of 315 cfm by using both types of the classified test dust and also a mixture of 50% of each. Approximately 50 grams of dust were introduced into the test duct during each of 28 individual test runs. Table 1 shows the results of these tests arranged in groups of two to six runs of the same type of dust. It will be noted that the pressure loss does not increase consistently, in one case even showing a decrease although 100 grams of dust were introduced into the test specimen. This fluctuation was of a magnitude of up to ±0.1 inch W.G. and was probably caused by the change of viscosity of the oil and air due to the change of temperature in the laboratory. Figure 1 shows the curves of least mean distances of the points of observation. The pressure loss increased from 7.87 inch W.G. to 9.45 inch W.G., as the filter was loaded with a total of 1379.8 grams of dust. The filtering efficiency averaged 99 per cent for coarse dust and dropped little due to the increasing filter load. The efficiency observed for fine dust was 95 per cent at the beginning of the test and dropped to 88.3 per cent when the filter was fully loaded. The efficiency for the mixture of 50% fine and coarse dust appears well in between those of the two test dusts used alone.

TABLE 1

Pressure Loss and Efficiency at Increasing Dust Load

No. of Tests	Dust Type	Dust Cum. Load g	Air Flow Rate CFM	Pressure Loss in. W.G. Start	Pressure Loss in. W.G. End	Efficiency %
6	50/50	276.8	315	7.87	8.07	97.5
2	Fine	377.1	315	8.15	8.07	95.0
2	Coarse	477.4	315	8.11	8.35	99.4
2	Fine	577.6	315	7.95	8.43	94.6
2	Coarse	677.9	315	8.35	8.82	99.1
2	Coarse	778.2	158	2.91	3.07	--
3	Coarse	928.6	315	8.11	9.37	99.0
3	Fine	1079.0	315	8.43	8.98	94.2
3	Coarse	1229.4	315	8.90	9.29	98.8
3	Fine	1379.8	315	8.98	9.45	88.3

PRESSURE LOSS AND EFFICIENCY v/s DUST LOAD

AT 315 CFM AIRFLOW RATE

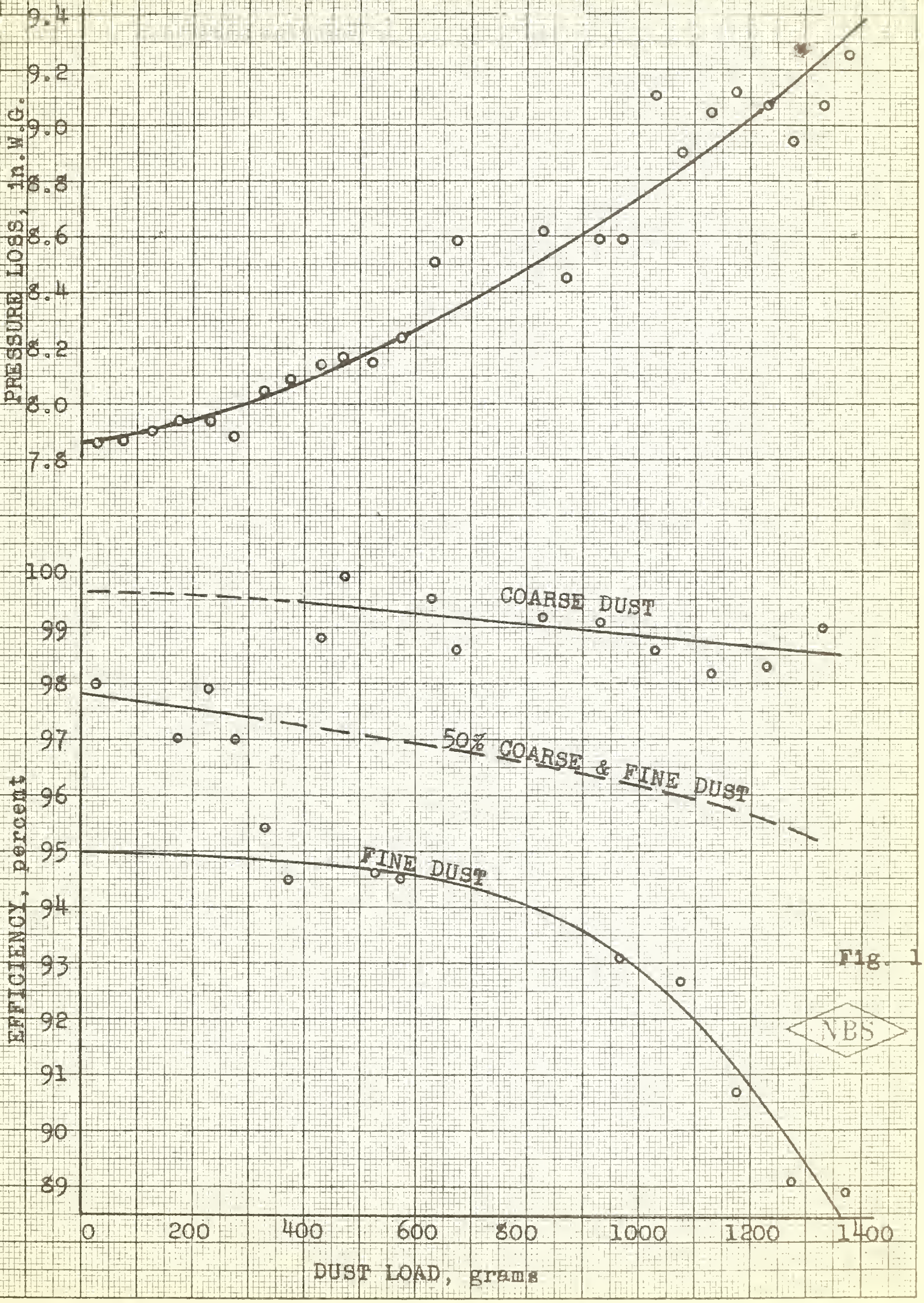

Fig. 1

The pressure loss of the test specimen at various air flow rates from 100 cfm to 370 cfm was determined. These measurements were made at about room temperature with a clean filter and motor oil SAE 30 and are summarized in Table 2 below:

TABLE 2

Pressure Loss at Air Flow Rates from
100 cfm to 370 cfm

Air Flow Rate, cfm	Pressure Loss in. W.G.
100	1.89
130	2.13
200	3.54
222	4.33
278	5.63
293	6.81
315	7.87
370	10.24

The upper curve of Figure 2 shows the curve of the least mean distances plotted from these points of observation. The lower series of curves of Figure 2 represent the efficiency of the test specimen at different air flow rates according to the data shown in Table 3. The values for the 315 cfm air flow rates are taken from Table 1. The efficiency of 97.2% of the mixture of 50% fine and coarse dust was taken from the extrapolated value of Figure 1 at a dust load of 400g. The points of observation shown in Figure 2 represent average values of the test results shown in Table 3. It will be noted that the change of the efficiency at the dust loads used in this series of tests was insignificant as indicated by the small slope during the first part of the load capacity test.

To determine the effect of tilting, a series of tests was made in which the test specimen was tilted alternately 15, 30 and 45 degrees. Table 4 shows the results obtained when the air cleaner was tilted 15 degrees and 30 degrees from the vertical. By comparing these values with Table 1, it will be noted that the pressure loss at 15 degrees tilting is about 1 inch W.G. higher than in the vertical position and at 30 degrees tilting the difference is about 2 inch W.G. at corresponding dust loads. The efficiency observed at these angles was practically the same as observed when the test specimen was in a vertical position. At a tilting angle up to 30 degrees, no carry-over of oil

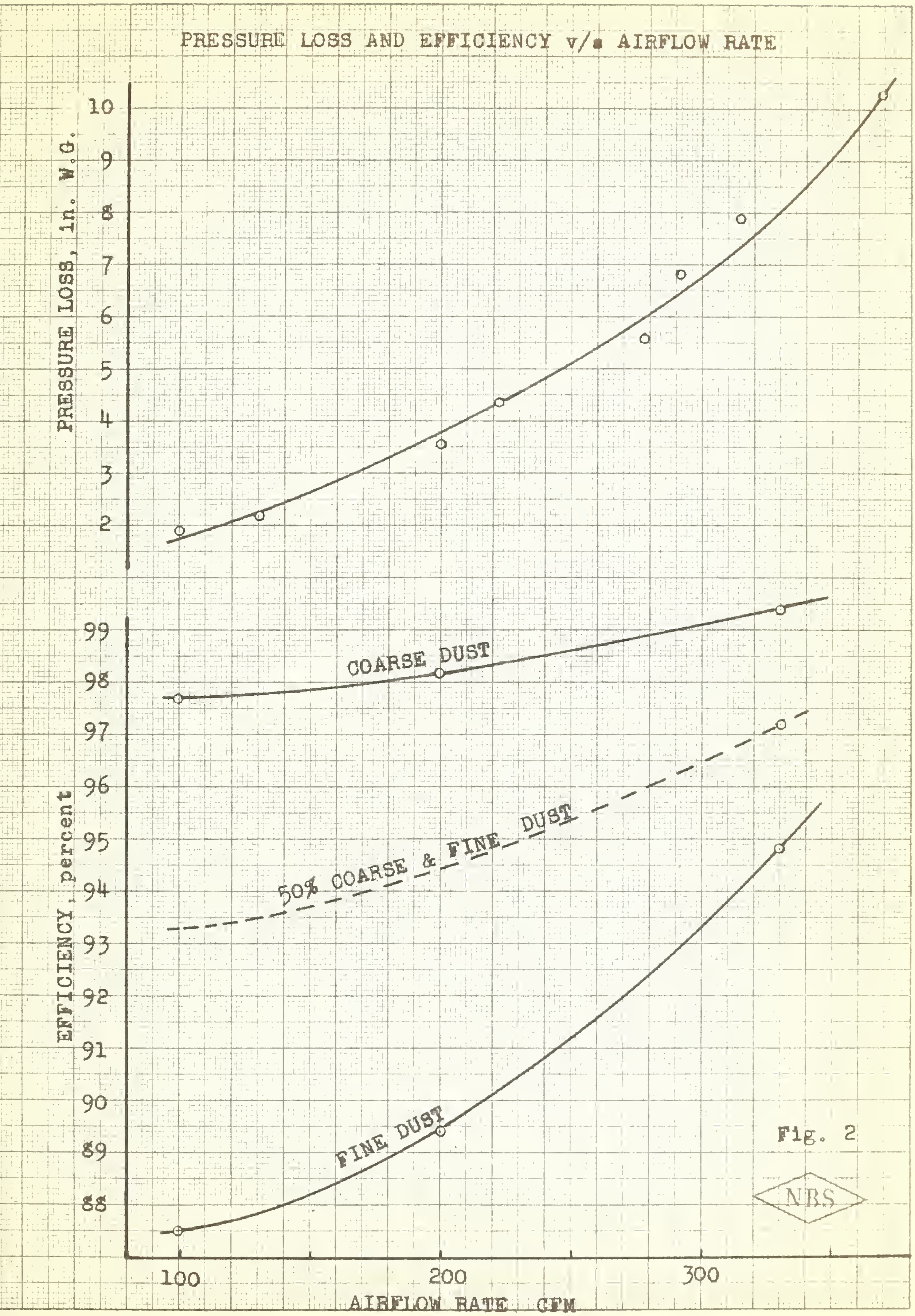
PRESSURE LOSS AND EFFICIENCY v/s AIRFLOW RATE
PRESSURE LOSS, in. W.G.
10
9
8
7
6
5
4
3
2
EFFICIENCY, percent
99
98
97
96
95
94
93
92
91
90
89
88
COARSE DUST
50% COARSE & FINE DUST
FINE DUST
100
200
300
AIRFLOW RATE, CFM
NBS

Fig. 2

was noticed. However, when the test specimen was moved to 45 degree position, it was noticed that oil was carried over and no test of the efficiency was conducted in this position.

TABLE 3

Pressure Loss and Efficiency at Different Air Flow Rates

Air Flow Rate CFM	Pressure Loss in. W.G. Start	End	Efficiency %	Dust Type	Cum. Load g
100	1.89	1.97	98.1	Coarse	50.1
100	1.89	1.97	88.3	Fine	127.4
100	1.97	1.97	97.6	Coarse	276.3
100	1.97	1.97	86.7	Fine	301.4
100	1.89	1.97	97.8	Coarse	326.6
200	4.02	4.17	98.6	Coarse	152.5
200	4.10	4.10	89.3	Fine	202.8
200	4.02	4.13	97.8	Coarse	227.9
200	4.02	4.10	89.4	Fine	253.0
315	8.15	8.07	95.0	Fine	377.1
315	8.11	8.35	99.4	Coarse	477.4
315	7.95	8.43	94.6	Fine	577.6
315	--	--	97.2	50/50	400.0

TABLE 4

Tilting of Filter at 315 cfm Air Flow Rate

Degrees Tilting	Pressure Loss in. W.G. Start	End	Efficiency %	Dust Type	Cum. Load g
15	8.86	9.06	99.4	Coarse	377.6
15	8.90	8.98	94.4	Fine	426.7
30	9.45	10.31	98.3	Coarse	476.8
30	9.37	9.65	94.1	Fine	427.0

4. DISCUSSION AND CONCLUSIONS

The tests conducted with the Donaldson oil bath air cleaner showed average efficiency values of 99 per cent on A.C. Spark Plug Division air cleaner test dust "coarse" and 94 per cent on "fine" dust. The efficiency decreased with the dust load while the pressure loss increased from 7.87

in. W.G. when the filter was clean to 9.45 in. W.G. when the filter was loaded with 1379.8 grams (3.04 lbs.) of dust. This dust load was considered as the dust holding capacity because of the noticeable loss of efficiency and the sharp increase of pressure drop at this point. Tilting the air cleaner up to 30 degrees did not appreciably affect its performance.

The dust load so established corresponds to a service period of 7.3 hours of continuous operation in a dust concentration of 10 mg/cu ft at the design air flow rate of 315 cfm.

The performance characteristics of this air cleaner are among the best so far observed in this laboratory. The dust holding capacity in particular is superior and may, in service, suffice for a 1000 hour operation under normal conditions.

The test specimen was built of steel for rough use on tractors and weighed 27 pounds. This weight could probably be cut in half by constructing the air cleaner entirely of light weight metal. The use of this type air cleaner for helicopters, then, appears feasible since the desired maximum three per cent power loss will not be much exceeded as indicated by the following computation: The 315 cfm design air flow rate is appropriate for a 240 H.P. engine which would have a total lift of approximately 2400 pounds, so that 13-1/2 pounds weight of the air cleaner would require 0.56 per cent of the total power. Since a power loss of approximately three per cent of the maximum engine output is expected for each 10 in. W.G. pressure loss in the air cleaner, the average 8.5 in. W.G. pressure loss observed on the test specimen would produce 2.5 per cent power loss; this adds up to a total loss of 3.06 per cent.

THE NATIONAL BUREAU OF STANDARDS

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