NATIONAL BUREAU OF STANDARDS REPORT

4569

AIR-MAZE AIRCRAFT FILTERS

by

Carl W. Coblentz
William F. Goddard, Jr.

Report to
Engineering and Development Branch
Office of the Chief of Transportation
Department of the Army
Washington, D. C.

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Heating and Air Conditioning Section
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AIR-MAZE AIRCRAFT FILTERS

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Abstract

The characteristics of a group of twelve Air-Maze aircraft engine filters were determined with different aerosols and air flow rates. Tests were made with the filters oiled, dry and as received. The group consisted of new filters of two different designs and of filters which had been worn to various degrees in service. The filtering efficiency with A.C. Spark Plug Division "coarse" dust reached 98.7%. This type filter is small and light and its pressure loss moderate when the filters are clean; but the pressure loss increases sharply when the filters become loaded with dust. The advantages of the two different designs are described and the effect of the length of service and the value of proper maintenance are explained. The attainment of adequate maintenance appears to be extremely difficult in military use.

1. INTRODUCTION

The performance characteristics and service requirements of the Air-Maze aircraft engine air filters were determined as a part of the research project "Air Filter Systems for Army Aircraft". This type filter is being used in the L-19 Army aircraft. It is an oiled-impingement type filter consisting of pleated flock covered wire screens. This filter is mounted on the air-intake of the carburetor and may be removed for cleaning or replacement.

2. FINDINGS

The filtering efficiency, using A.C. Spark Plug Division "coarse" dust reached 98.7%. Efficiency is about equal with A.C. "fine" dust and with Cottrell precipitate.

The efficiency determined with "coarse" dust was considerably higher than that obtained with "fine" dust; the filtering efficiency of the 50% mixture of fine and coarse dusts was well in between the efficiencies of these dusts alone, as could be expected. The following table shows the gravimetric efficiencies determined for the first two test runs with 15.1g dust each, after the filters had been cleaned and oiled.

TABLE 1

FILTER EFFICIENCY WITH DIFFERENT DUSTS

Tests No.	Filter No.	Dust	Efficiency 1.Run	Efficiency 2.Run	Average
2181-2	6	A.C. Fine	96.5	97.5	97.0
2149-10	7	"	96.7	97.4	97.0
4044-5	7	50% Fine + Coarse	97.8	98.1	98.0
4051-2	6	A.C. Coarse	98.6	98.7	98.7
1187-8	6	Cottrell Precipitate	95.6	98.2	96.9

Tests made with the filters "as received" show values of efficiency lying between those determined for the cleaned filters when tested oiled and those when tested dry. It can be assumed that part of the oil had been lost in storage due to absorption by the wrapping paper, or had been run out of the flocking, indicating the importance of careful oiling for obtaining the highest possible efficiency of this type filter. If the filters are not properly oiled after being cleaned, the filtering efficiency drops to about one-half and the dust holding capacity is reduced.

The importance of the oiling of the filters is expressed in the following table which compares the efficiencies of two filters oiled and not oiled for three consecutive dust charges of 15.1g A.C. "fine" dust.

During the third test run, the oiled new filters passed 2.1% of the dust introduced into the system, whereas, under the same conditions, the filter when dry passed 60.6% or about 30 times as much dust as when it was oiled. Fig. 1 presents the values of the following table as a graph.

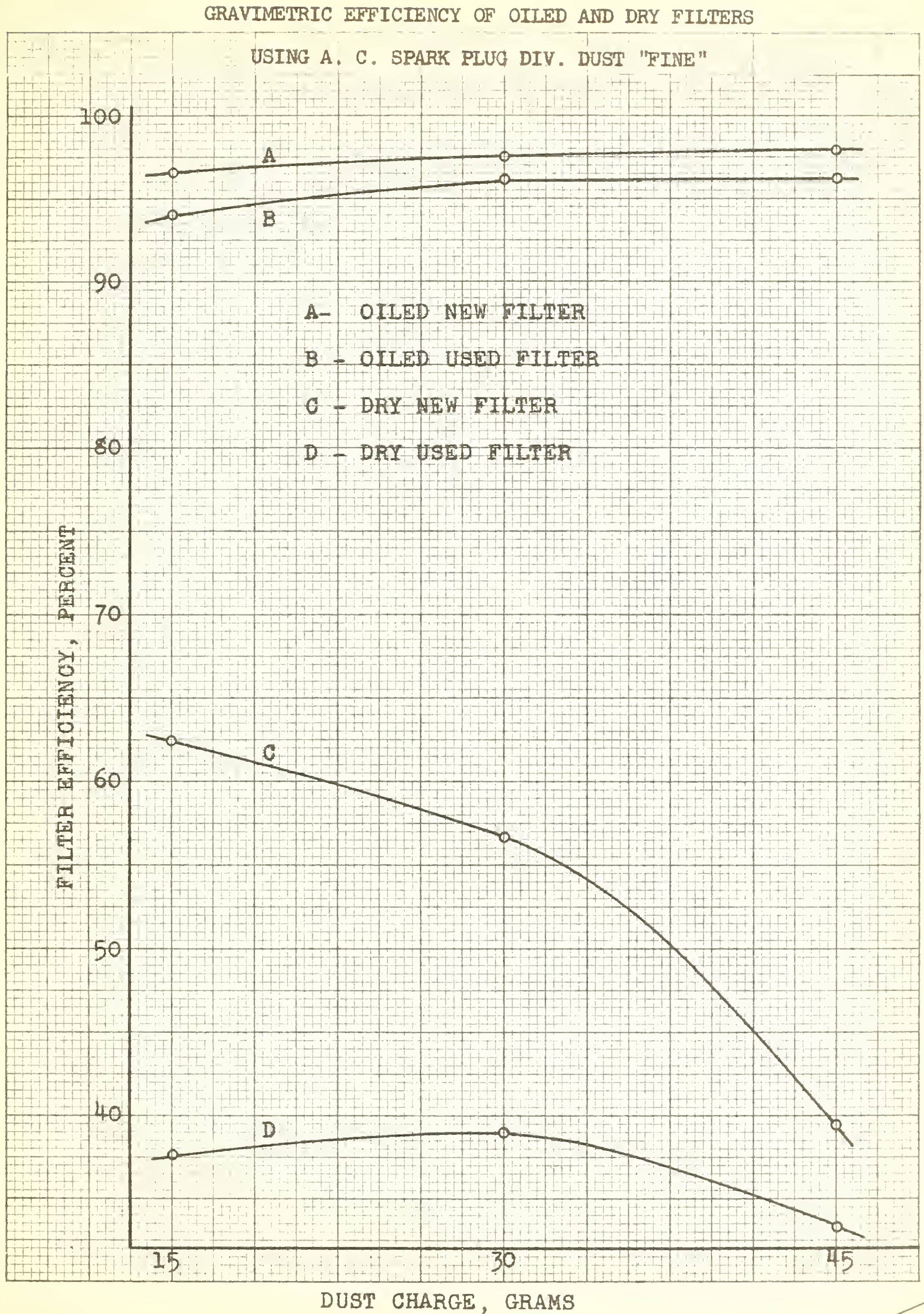
GRAVIMETRIC EFFICIENCY OF OILED AND DRY FILTERS
USING A. C. SPARK PLUG DIV. DUST "FINE"
100
90
80
70
60
50
40
A
B
C
D
A- OILED NEW FILTER
B - OILED USED FILTER
C - DRY NEW FILTER
D - DRY USED FILTER
FILTER EFFICIENCY, PERCENT
15
30
45
DUST CHARGE, GRAMS

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TABLE 2

GRAVIMETRIC EFFICIENCY OF OILED AND DRY FILTERS

Tests No.	Condition of Filter	Efficiency 1. Charge	2. Charge	3. Charge
2181-3	New, oiled	96.5	97.5	97.9
1288, 1311-2	New, dry	62.4	56.6	39.4
2151-3	Used, oiled	94.0	96.1	96.2
1181-3	Used, dry	37.6	39.0	33.2

The effect of filter wear was determined by comparing three filters of the same design with different lengths of service. Table 3, below, shows the number of the filters and their length of previous service and the values calculated for the efficiency with A.C. "fine" dust and Cottrell precipitate using the gravimetric as well as the dust spot methods. The effectiveness of the filter decreases sharply when the flock wears off as a result of repeated cleanings and due to the air stream in operation.

TABLE 3

EFFECT OF FILTER WEAR ON EFFICIENCY

Filter No.	Hrs. of Service	A.C. Fine Gravimetric	A.C. Fine Dust Spot	Cottrell Precipitate Gravimetric	Cottrell Precipitate Dust Spot
6	New	97.0	97.8	96.9	96.5
3	331	88.0	81.7	95.2	92.9
5	1226	84.5	79.7	90.2	91.2

These values, which are plotted on a graph in Fig. 2, indicate the loss of efficiency not only to be a function of the wear, but also, to be different when different aerosols are used. When Cottrell precipitate was used, the efficiency decreased almost linearly with the hours of service, whereas, with A.C. "fine" dust, the decrease of the efficiency was more than twice as much during the first 300 hours of service as it was during the succeeding 900 hours.

EFFECT OF FILTER WEAR ON THE EFFICIENCY.

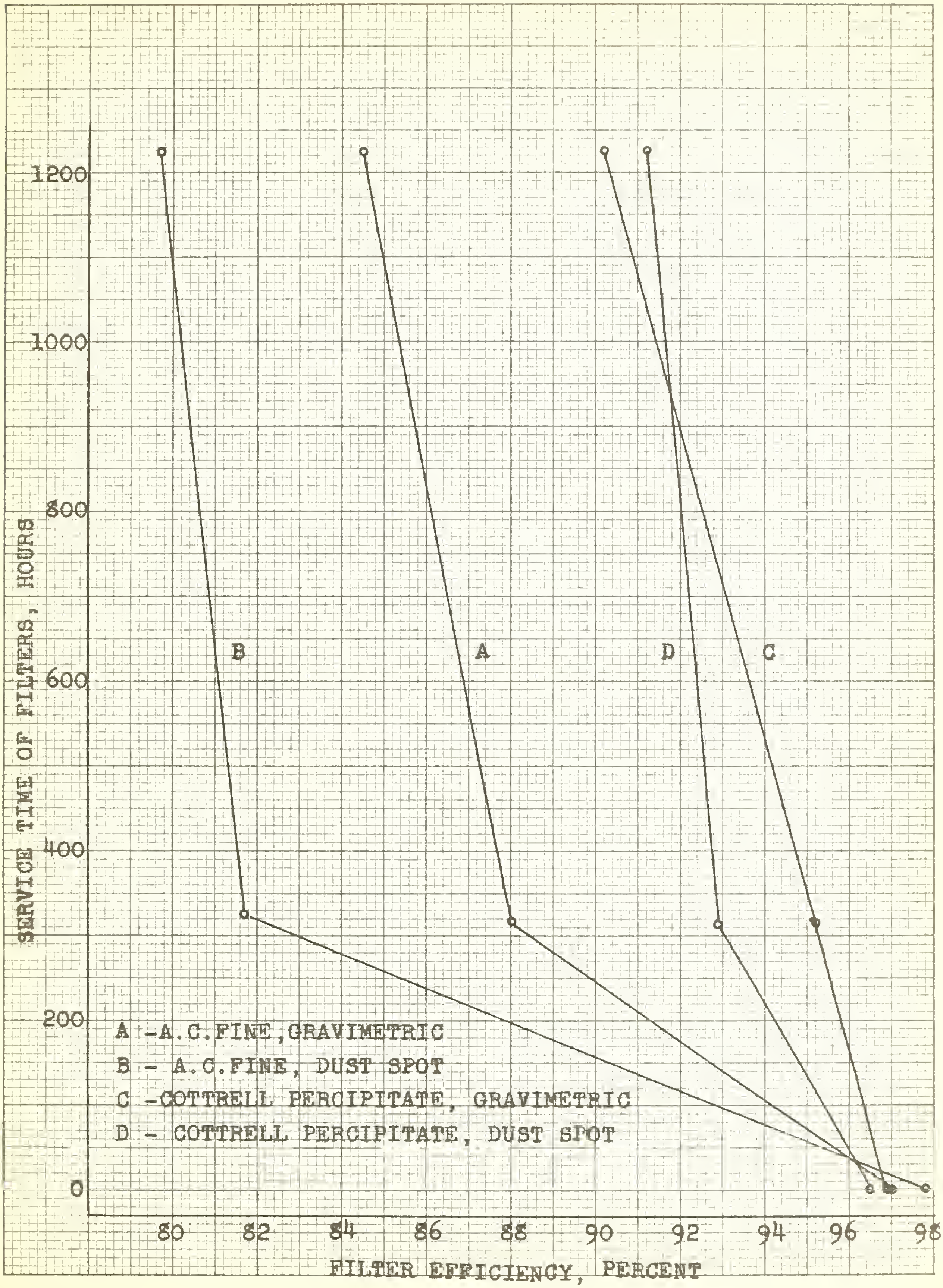

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Table 4 presents a summary of the efficiency and pressure loss for both the old and the new design filters at air flow rates of 200 CFM, 305 CFM, and 360 CFM, using A.C. "fine" dust as an aerosol. As it had been noticed that the specimen filters of each type did not produce identical test results, all tests of this series were conducted with at least two specimens of each type. The average values from the duplicated tests are more representative than the individual tests would be, as they alleviate the deviation of test observations resulting from certain construction differences in the filters, as well as from slightly varying conditions that may affect these observations.

These average values are shown as a graph in Fig. 3, indicating that the pressure loss and the efficiency are higher on the old design filters for any comparable air flow rate and dust charge.

The filtering efficiency of the older design with two flocked screens was found to be better than that of the new design which has only one flocked screen. The efficiency of the old design at 305 CFM exceeded 98% and decreased for both higher and lower flow rates.

The pressure loss of the Air-Maze filters stays rather low as long as the filters are not overloaded, but increases fast once a certain load has been reached.

It was noted that neither the weight nor the pressure loss presented a positive criterion of the condition of the used filters. It was noted, however, that a pressure loss of less than 1 inch W.G. at the design air flow rate occurred only when the flock had worn off to such a degree that the filtering efficiency had dropped considerably and the filter should have been replaced.

3. SPECIMEN AND TEST APPARATUS

The test specimens were products of the Air-Maze Corporation of Cleveland, Ohio. The Office of the Chief of Transportation furnished 12 filters for testing, all having the same outside dimensions of $7\frac{1}{2}$ x 7 x 1 inch with a free filtering area of 6-3/4 x 6-1/4 inches or 0.293 square feet. According to the manufacturer's catalog, these filters are designed for a face velocity of 1050 ft/min. corresponding to about 305 CFM air flow rate.

TABLE 4

GRAVIMETRIC EFFICIENCY AND PRESSURE LOSS OF NEW AND OLD DESIGN FILTERS AT DIFFERENT AIR FLOW RATES WITH A.C. SPARK PLUG DIV., DUST "FINE"

Air Flow Rate, CFM		Filter No.	Clean Press. Loss in. WG	15g Dust Charge Eff. %	15g Dust Charge Press. Loss in. WG	30g Dust Charge Eff. %	30g Dust Charge Press. Loss in. WG	45g Dust Charge Eff. %	45g Dust Charge Press. Loss in. WG	60g Dust Charge Eff. %	60g Dust Charge Press. Loss in. WG
200		6	1.57	89.1	2.40	94.1	4.17	94.8	9.89	--	--
200		7	3.11	93.4	3.81	94.3	5.70	96.2	10.46	--	--
	Average	6+7	2.34	91.3	3.11	94.2	4.94	95.5	10.18	--	--
200		11	0.87	89.1	1.34	85.1	1.81	91.2	2.40	93.2	3.38
200		12	0.91	84.6	1.38	91.9	1.73	87.4	2.44	--	--
	Average	11+12	0.89	86.9	1.36	88.5	1.77	89.3	2.42	93.2	3.38
305		6	2.44	96.5	3.42	97.5	4.88	97.9	9.68	--	--
305		7	2.67	96.7	4.10	98.6	6.38	98.0	15.29	--	--
	Average	6+7	2.56	96.6	3.76	98.1	5.63	98.0	12.49	--	--
305		11	1.58	91.0	2.09	93.4	2.87	92.4	4.22	94.1	6.93
305		12	1.58	89.3	2.01	94.3	2.68	95.4	4.06	96.6	7.76
	Average	11+12	1.58	90.2	2.05	93.8	2.76	93.9	4.14	95.4	7.35
360		6	4.33	94.4	6.14	97.2	10.17	--	--	--	--
360		7	4.40	97.2	6.18	96.2	10.00	--	--	--	--
	Average	6+7	4.37	95.8	6.16	96.7	10.09	--	--	--	--
360		11	2.36	90.1	3.34	93.7	4.25	93.6	5.82	96.3	9.14
360		12	2.44	93.3	3.26	94.5	4.13	97.2	5.27	97.3	9.94
	Average	11+12	2.40	91.7	3.30	94.1	4.19	95.4	5.55	96.8	9.54

EFFICIENCY AND PRESSURE LOSS OF OLD AND NEW DESIGN FILTERS

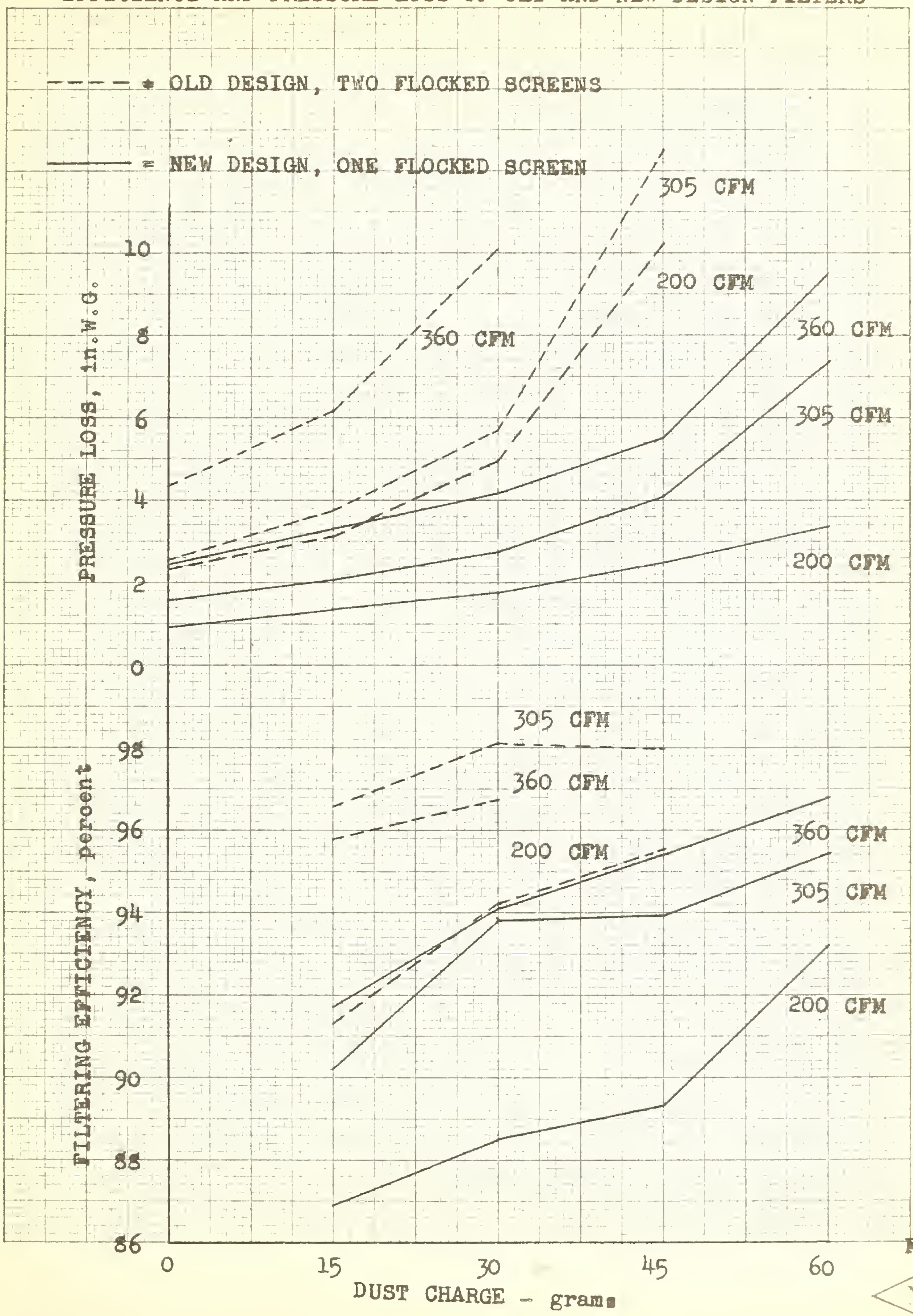

Fig.

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Some of the test specimens were new and others had different lengths of service. The used filters had two pleated flock covered wire screens as the filter media. There were two new filters of this same construction and two new filters of a new design - one flocked screen, the other screen being bare. The cotton flock had worn off considerably on some of the used filters leaving a practically bare wire mesh.

Table 5 shows a listing of the test specimens giving the consecutive numbers, time of service as reported by the Transportation Corps, their weight as received after removing the holding clips and gaskets, and their pressure loss at 305 CFM air flow.

Fig. 4 is a photograph of the test apparatus, showing the 20 ft. long duct made of 5 inch brass pipe in the middle of which is an adapter to hold the rectangular test specimen. The two halves of the adapter are equipped with foam rubber strips so that any outside air leakage is prevented when the two halves are pulled against the specimen with 4 steel bolts. Vertical and horizontal stops are provided to assure proper alignment of the test specimen in the adapter. The air is drawn into the duct by a blower installed in a room behind the test panel and the air flow rates are measured with orifice flow meters designed in accordance with the A.S.M.E. Research Publication "Fluid Meters, Their Theory and Application."

For each test run, a measured amount of dust is placed in a small hopper which feeds into the groove of a turntable to a constant level. The turntable is mounted on a variable speed Graham transmission and the dust is picked up from the groove by a high pressure aspirator which breaks up any agglomerations and supplies the dust to the open inlet of the test duct, at the desired feed rate. By changing the speed of the turntable, infinite variations of dust concentrations can be obtained for any air flow rate and can be maintained constant during each test run.

The test dust used is classified air cleaner test dust produced by the A.C. Spark Plug Division of General Motors Corporation. Most tests were made with "fine" dust; for comparative purposes, a few tests were made with "coarse" dust and also with a mixture of 50% each fine and coarse dust and also with Cottrell precipitate.

TABLE 5

No.	Length of Service Hrs.	Weight g	Pressure Loss at 305 CFM, in. WG
1	Used	234.9	1.38
2	986	239.7	1.14
3	330	248.4	1.12
4	Used	222.9	0.75
5	1225	237.6	0.83
6	New	218.4	1.97
7	New	220.6	1.93
8	200-300	288.2	2.36
9	434	221.7	1.22
10	200-300	227.6	1.07
11	New	249.0	1.26
12	New	236.4	1.26

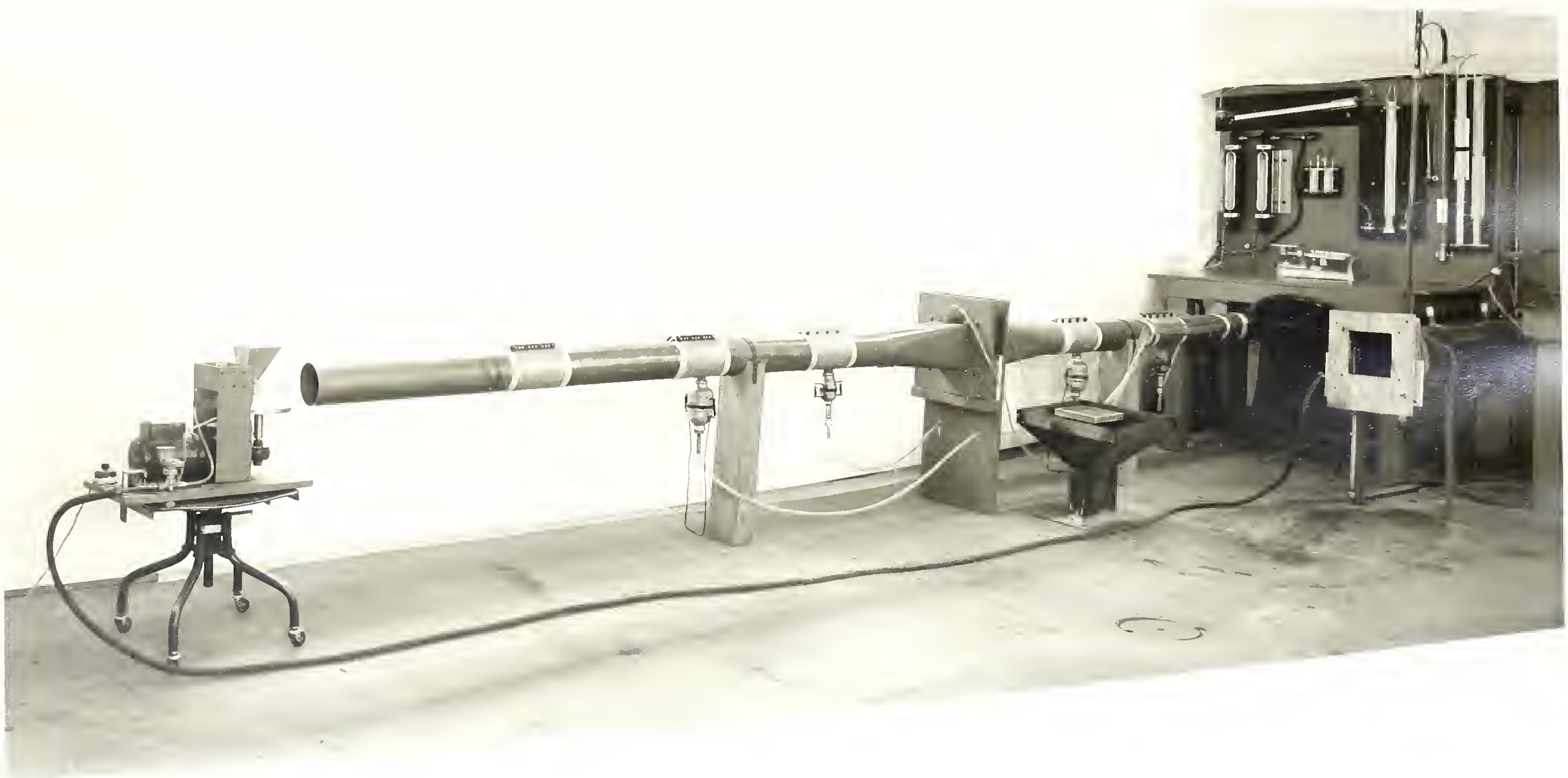

Fig. 4

The efficiency of the test specimen is determined by sampling the air upstream and downstream of the air cleaner with identical sampling nozzles installed in the center of the duct. A representative sampling is assured by maintaining isokinetic flow between nozzle inlet and duct. The dust drawn through the sampling nozzle is collected on glass fiber paper whose smallest fibers are about 0.3 micron in diameter. Tests of the air cleaning efficiency of similar paper by the Atomic Energy Commission indicate that such paper retains more than 99.99 per cent of all particles 0.3 micron and larger and it can, therefore, be considered an absolute filter for these tests.

Fig. 5 is a photograph of this sampling device. It shows one nozzle installed in a 3 inch duct, chosen for ease of photography, and three others with different openings to compensate for a wide range of air velocities in the test duct. One sampling paper holder is shown with the nozzles and another one is installed between the two bell caps. These holders consist of aluminum rings between which the glass fiber paper is clamped tight.

The air flow rate through the upstream and downstream samples is measured with two identical orifice flow meters which were calibrated with a gas meter. The manometers connected to these flow meters are mounted on either side of a graduated rule to facilitate the adjustments for maintaining equal flow through the two samplers during each test. The filter efficiency was calculated from the formula

$$E_G = \left(1 - \frac{D}{U}\right) \times 100\%$$

where E_G = gravimetric efficiency, per cent,
D = weight gain of downstream sampler,
U = weight gain of upstream sampler.

In order to ascertain that the observed sampler gains are representative for the prevailing dust concentrations in the duct, the test apparatus is operated without filter, at frequent intervals, in which case the upstream and downstream filter gains must be equal.

The efficiency of the filter was also determined by another method based on the discoloration caused by the dust. This method is known as the "National Bureau of

Fig. 5

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Standards Dust Spot Method" and is described in the paper "A Test Method for Air Filters" by R. S. Dill, ASHVE Transactions, Vol. 44, p 339, 1938. In this method, equal air samples from upstream and downstream of the filter are passed through known areas of Whatman #41 filter paper. The areas of the upstream and downstream filter papers are selected by repeated trials to obtain an approximately equal change of light transmission through these papers for a given test condition.

4. TEST PROCEDURE AND OBSERVATIONS

All filters were tested at the design air flow rate of 305 CFM and Table 6 shows a summary of the more indicative test results. In order to determine the characteristics of this type filter, tests were made under nine different conditions:

A/ Filters oiled; tested with A.C. "fine" dust.
B/ Filters as received; tested with A.C. "fine" dust.
C/ Filters dry (cleaned and not oiled); tested with A.C. "fine" dust.
D/ Filters as received; tested with A.C. "coarse" dust.
E/ Filters oiled; tested with A.C. "coarse" dust.
F/ Filters oiled; tested with 50% each A.C. "fine" and "coarse" dust.
G/ Filters oiled; tested with Cottrell precipitate.
H/ Filters oiled; tested with A.C. "fine" dust and 200 CFM air flow.
I/ Filters oiled; tested with A.C. "fine" dust and 360 CFM air flow.

Between two and four individual test runs were made with each filter for every condition tested to observe the change of its characteristics with the increase of the dust load. 15g to 20g of dust were used for each run and the filter weight was determined before and after each test run so that an approximation of the filtering efficiency was obtained as the ratio of the weight increase of the filter to the weight of the dust introduced into the duct. This efficiency, E_F, was mostly lower than the efficiency E_G computed from the weight increase of the samplers because dust dropped off the filter when it was removed from the test duct to be weighed.

The pressure drop across the filter was observed and the duration of the tests was noted. From the latter, the dust concentration upstream of the filter was calculated. This concentration was maintained at about 10 mg/cu ft, equivalent to a heavy dust cloud.

A comparison of the efficiency of the filter resulting from the use of dust of different mean particle size was made. Sufficient tests with the four different dusts used were conducted on the two new filters, numbers 6 and 7, to obtain average value for each dust.

The new design filters were loaded with 60g of dust for all three air flow rates showing a minimum efficiency of 86.9% and a maximum pressure loss of 9.54 in. W.G. The old design filters were charged with 45g of dust for the 200 CFM and 305 CFM tests at which dust loads, the desired maximum pressure loss of 10 in. W.G. was exceeded.

At the design air flow rate and using A.C. "fine" dust, the efficiency of the new type filter was 90.2% for the first 15g of dust introduced after cleaning and oiling the filter, and 96.6% under the same condition of the old type filter. This means that almost three times as much dust passes through the new filter than the old one.

Under conditions as indicated above, the pressure loss of the new design filters was 1.58 in. W.G. against 2.56 in. W.G. for the old design. This margin in favor of the new design increased significantly as the dust load increased. Whereas, the pressure loss of the old design at a load of 45g increased to 12.45 in. W.G., the pressure loss of the new design reached only 7.35 in. W.G. with a dust load of 60g.

The weight of these filters appeared to vary less with the condition of the screen flock than the amount of residual dust which had not been removed from the filter in recent cleaning operations. The pressure loss of any one filter at a constant air flow rate depends on the condition of the screen flock and its oiling, and the amount of dust load accumulated on the filter.

The light weight and small space requirements, however, make the use of this kind of filter attractive as an induction air cleaner for small aircraft.

TABLE 6

SUMMARY OF TEST RESULTS
A/ FILTERS OILED, A.C. "FINE", 305 CFM

Filter Number		1			2			5		6			7		
Test Number		2151	2152	2153	1121	1122	1123	1127	1128	2181	2182	2183	2149	21410	21411
OBSERVED VALUES															
Filter Weight Start	g	299.6	314.1	328.2	272.2	---	---	269.1	---	267.7	291.4	306.2	296.3	311.1	325.5
Filter Gain	g	14.5	14.1	14.0	Total 40.5			Total 26.1		14.7	14.8	14.8	14.8	14.4	14.8
Dust Introduced	g	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
Duration of Test	Min.	4.22	4.89	4.45	5.57	4.89	4.98	5.05	4.86	4.30	4.07	4.80	4.55	4.18	4.37
Pressure Loss Start	In. WG	1.54	2.05	2.87	0.96	1.97	2.87	0.95	1.14	2.44	3.39	4.88	2.68	3.98	6.38
Pressure Loss Finish	In. WG	1.97	2.91	4.85	1.97	2.83	5.75	1.14	1.30	3.42	4.88	9.68	4.10	6.38	15.29
Sampler Gain Upstream	mg	70.4	67.2	52.8	68.9	67.8	73.4	73.4	71.0	57.2	59.0	62.9	55.2	58.0	58.6
Sampler Gain Downstream	mg	4.2	2.6	2.0	9.2	6.1	4.0	11.1	11.6	2.0	1.5	1.3	1.8	1.5	1.0
COMPUTED VALUES															
Dust Concentration	mg/Cu. ft.	11.7	10.1	11.1	8.9	10.1	9.9	9.8	10.2	11.5	12.2	10.3	10.9	11.0	11.3
Efficiency - E_G Gravimetric	%	94.0	96.1	96.2	86.7	91.0	94.6	84.9	83.7	96.5	97.5	97.9	96.7	97.4	98.2
Efficiency - E_F Filter Gain	%	96.1	93.5	92.9	Average 89.6			Average 86.4		97.5	98.1	98.1	98.1	95.5	98.1
Efficiency - E_D Discoloration	%	---	---	---	---	79.6	83.3	77.9	76.6	---	---	---	91.6	93.9	96.5

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SUMMARY (

A/ FILTERS OILEI

Filter Number						12		
Test Number		2151	3	2144	2145	2146	2147	2148
Filter Weight Start	g	299.6	1	331.2	274.4	288.3	302.7	316.8
Filter Gain	g	14.5	1	13.7	13.9	14.4	14.1	14.2
Dust Introduced	g	15.1	1	15.1	15.1	15.1	15.1	15.1
Duration of Test	Min.	4.22	3	4.62	4.35	4.42	4.12	4.63
Pressure Loss Start	In. WG	1.54	3	4.17	1.57	1.93	2.64	4.06
Pressure Loss Finish	In. WG	1.97	2	6.93	2.01	2.68	4.06	7.76
Sampler Gain Upstream	mg	70.4	2	47.9	52.4	55.8	68.4	59.8
Sampler Gain Downstream	mg	4.2	9	2.8	5.6	3.2	2.8	2.0
Dust Concentration	mg/ Cu. ft.	11.7	0	10.7	11.4	11.3	12.2	10.7
Efficiency - E_G Gravimetric	%	94.0	4	94.1	89.3	94.3	95.4	96.6
Efficiency - E_F Filter Gain	%	96.1	5	90.9	92.2	95.5	93.4	94.2
Efficiency - E_D Discoloration	%	---	1	91.7	88.9	90.0	91.8	94.0

TABLE 6

SUMMARY OF TEST RESULTS
A/ FILTERS OILED, A.C. "FINE", 305 CFM

Filter Number		1			2			5		6			7			11				12			
Test Number		2151	2152	2153	1121	1122	1123	1127	1128	2181	2182	2183	2149	21410	21411	2141	2142	2143	2144	2145	2146	2147	2148
OBSERVED VALUES																							
Filter Weight Start	g	299.6	314.1	328.2	272.2	---	---	269.1	---	267.7	291.4	306.2	296.3	311.1	325.5	289.0	303.1	317.1	331.2	274.4	288.3	302.7	316.8
Filter Gain	g	14.5	14.1	14.0		Total 40.5		Total 26.1		14.7	14.8	14.8	14.8	14.4	14.8	14.1	14.0	14.1	13.7	13.9	14.4	14.1	14.2
Dust Introduced	g	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
Duration of Test	Min.	4.22	4.89	4.45	5.57	4.89	4.98	5.05	4.86	4.30	4.07	4.80	4.55	4.18	4.37	4.57	4.67	4.93	4.62	4.35	4.42	4.12	4.63
Pressure Loss Start	In. WG	1.54	2.05	2.87	0.96	1.97	2.87	0.95	1.14	2.44	3.39	4.88	2.68	3.98	6.38	1.57	2.09	2.83	4.17	1.57	1.93	2.64	4.06
Pressure Loss Finish	In. WG	1.97	2.91	4.85	1.97	2.83	5.75	1.14	1.30	3.42	4.88	9.68	4.10	6.38	15.29	2.09	2.87	4.22	6.93	2.01	2.68	4.06	7.76
Sampler Gain Upstream	mg	70.4	67.2	52.8	68.9	67.8	73.4	73.4	71.0	57.2	59.0	62.9	55.2	58.0	58.6	60.0	51.7	38.2	47.9	52.4	55.8	68.4	59.8
Sampler Gain Downstream	mg	4.2	2.6	2.0	9.2	6.1	4.0	11.1	11.6	2.0	1.5	1.3	1.8	1.5	1.0	5.4	3.4	2.9	2.8	5.6	3.2	2.8	2.0
COMPUTED VALUES																							
Dust Concentration	mg/Cu. ft.	11.7	10.1	11.1	8.9	10.1	9.9	9.8	10.2	11.5	12.2	10.3	10.9	11.0	11.3	10.8	10.6	10.0	10.7	11.4	11.3	12.2	10.7
Efficiency - E_G Gravimetric	%	94.0	96.1	96.2	86.7	91.0	94.6	84.9	83.7	96.5	97.5	97.9	96.7	97.4	98.2	91.0	93.4	92.4	94.1	89.3	94.3	95.4	96.6
Efficiency - E_F Filter Gain	%	96.1	93.5	92.9		Average 89.6		Average 86.4		97.5	98.1	98.1	98.1	95.5	98.1	93.6	92.8	93.5	90.9	92.2	95.5	93.4	94.2
Efficiency - E_D Discoloration	%	---	---	---	---	79.6	83.3	77.9	76.6	---	---	---	91.6	93.9	96.5	87.7	86.8	89.1	91.7	88.9	90.0	91.8	94.0

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B/ FILTERS AS RECEIVED, A.C. "FINE", 305 CFM (Continuation of TABLE 6)

Filter Number		2			3		5		9			11			12		
Test Number		1251	1252	1253	12154	12155	12161	12162	1281	1282	1283	1264	1265	1266	1267	1268	1269
								OBSERVED VALUES									
Filter Weight Start	g	239.7	---	---	248.4	---	237.6	254.5	221.7	232.8	246.6	249.0	259.8	271.8	236.4	245.9	255.4
Filter Gain	g		Total 53.0		Total 34.4		16.9	16.5	11.1	13.8	11.3	10.8	12.0	11.0	9.5	9.5	7.7
Dust Introduced	g	20.1	20.1	20.1	20.1	20.2	20.1	20.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
Duration of Test	Min.	7.54	10.25	6.22	5.45	6.36	5.84	6.80	4.73	4.55	4.68	4.92	5.08	5.18	4.85	5.08	5.18
Pressure Loss Start	In. WG	1.14	1.69	2.52	1.18	1.57	0.79	1.02	1.22	1.57	2.05	1.26	1.89	3.50	1.26	1.73	3.19
Pressure Loss Finish	In. WG	1.77	2.71	6.42	1.69	2.36	1.02	1.30	1.57	2.16	2.91	2.09	3.86	10.70	1.81	3.31	5.99
Sampler Gain Upstream	mg	88.8	90.0	93.0	97.4	93.2	54.4	48.2	82.4	67.4	60.6	69.6	69.8	71.7	72.2	71.4	74.0
Sampler Gain Downstream	mg	19.8	14.4	12.8	25.0	19.2	11.8	14.6	16.0	16.4	18.0	21.0	15.2	16.0	27.3	26.6	32.6
								COMPUTED VALUES									
Dust Concentration	mg/ Cu. ft.	9.1	6.7	10.6	12.1	10.4	11.3	9.7	10.5	10.9	10.6	10.0	9.7	9.6	10.2	9.7	9.5
Efficiency - E_G Gravimetric	%	77.6	83.8	86.2	74.3	79.4	78.3	69.3	81.6	75.6	70.3	69.8	78.2	77.7	62.2	61.3	56.0
Efficiency - E_F Filter Gain	%		Average 87.8		Average 85.0		83.9	82.1	73.5	---	75.0	71.6	79.6	72.9	63.0	63.0	51.0
Efficiency - E_D Discoloration	%	69.8	76.8	83.5	76.1	77.5	64.3	68.1	---	---	---	84.5	84.4	88.3	83.6	83.1	80.8

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C/ FILTERS DRY (NOT OILED), A.C. "FINE", 305 CFM

D/ FILTERS AS RECEIVED, A.C. "COARSE", 305 CFM

E/ FILTERS OILED, A.C. "COARSE", 305 CFM

(Continuation of TABLE 6)

		C/ FILTERS DRY (NOT OILED), A.C. "FINE", 305 CFM							D/ FILTERS AS RECEIVED, A.C. "COARSE", 305 CFM			E/ FILTERS OILED, A.C. "COARSE", 305 CFM	
Filter Number		1			6				10			6	
Test Number		1181	1182	1183	1288	1311	1312	1313	1284	1285	1286	4051	4052
OBSERVED VALUES													
Filter Weight Start	g	243.6	---	---	211.1	---	---	---	227.6	238.4	247.2	266.0	281.1
Filter Gain	g	Total 17.2			9.2	---	---	---	10.8	8.8	8.3	15.1	15.1
Dust Introduced	g	15.0	15.1	15.1	15.1	15.1	15.1	15.2	16.5	15.1	15.1	15.1	15.2
Duration of Test	Min.	5.10	5.21	5.10	5.83	4.65	4.44	1.44	3.45	2.95	2.97	2.40	2.53
Pressure Loss Start	In. WG	1.50	1.61	1.73	2.08	2.25	2.28	---	1.14	1.26	1.42	2.40	3.27
Pressure Loss Finish	In. WG	1.61	1.77	1.81	2.75	2.91	2.83	---	1.30	1.50	1.54	3.23	4.10
Sampler Gain Upstream	mg	69.5	73.4	71.6	72.8	78.8	68.6	31.5	72.2	77.2	84.4	73.4	63.0
Sampler Gain Downstream	mg	43.4	44.8	47.8	27.4	34.2	41.7	22.8	19.3	28.4	27.2	1.0	0.8
COMPUTED VALUES													
Dust Concentration	mg/Cu. ft.	9.6	9.5	9.7	8.5	10.6	11.1	11.5	14.6	15.6	15.5	20.7	19.6
Efficiency - E_G Gravimetric	%	37.6	39.0	33.2	62.4	56.6	39.4	27.6	73.2	63.2	67.8	98.6	98.7
Efficiency - E_F Filter Gain	%	Average 38.1			61.0	---	---	---	65.2	58.4	55.	100	99.3
Efficiency - E_D Discoloration	%	50.6	55.0	53.2	---	---	---	---	---	---	---	---	---

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F/ FILTERS OILED,
50% "FINE-COARSE", 305 CFM

G/ FILTERS OILED,
COTTRELL PRECIPITATE, 305 CFM

(Continuation of TABLE 6)

Filter Number		6		7			5			6		3		1	
Test Number		4053	4043	4044	4045	4046	1184	1185	1186	1187	1188	1189	11810	1174	1175
								OBSERVED VALUES							
Filter Weight Start	g	296.2	292.8	267.9	282.7	297.0	284.5	---	---	330.6	---	318.7	---	237.0	---
Filter Gain	g	14.8	15.1	14.8	14.3	15.1		Total 40.2		Total 27.6		Total 28.4		Total 9.7	
Dust Introduced	g	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1	15.1
Duration of Test	Min.	3.42	3.07	2.28	3.42	3.50	6.78	5.44	5.62	5.20	5.38	5.62	5.32	5.34	5.62
Pressure Loss Start	In. WG	4.10	4.84	3.30	3.46	5.00	0.98	1.10	1.34	3.90	5.31	1.57	2.04	1.38	1.54
Pressure Loss Finish	In. WG	6.34	8.78	3.30	5.00	9.60	1.14	1.38	1.96	5.42	7.98	2.08	5.79	1.61	1.65
Sampler Gain Upstream	mg	59.8	78.4	86.2	86.2	81.8	79.5	77.4	70.8	76.7	66.6	65.1	57.8	68.2	69.2
Sampler Gain Downstream	mg	1.2	1.0	1.9	1.6	1.0	8.0	7.4	9.4	3.4	1.2	3.2	2.8	49.6	50.6
								COMPUTED VALUES							
Dust Concentration	mg/ Cu. ft.	14.5	16.2	14.5	14.5	14.2	7.3	9.1	8.8	9.5	9.2	8.8	9.3	9.3	8.8
Efficiency - E_G Gravimetric	%	98.0	98.7	97.8	98.1	98.8	90.0	90.4	86.7	95.6	98.2	95.1	95.2	27.3	26.9
Efficiency - E_F Filter Gain	%	97.7	100	97.7	94.4	100		Average 88.8		Average 91.4		Average 94.0		Average 31.2	
Efficiency - E_D Discoloration	%	---	---	---	---	---	90.0	92.4	91.5	95.9	97.1	92.1	93.6	54.1	61.6

H/ FILTERS OILED, A.C. "FINE", 200 CFM (Continuation of TABLE 6)

Filter Number		6			7			11					12		
Test Number		5271	5272	5273	5261	5262	5263	5274	5275	5276	5277	5278	5312	5313	5314
OBSERVED VALUES															
Filter Weight Start	g	303.7	---	---	352.6	---	---	295.0	---	---	---	---	287.6	---	---
Filter Gain	g	Total 40.7			Total 21.5			Total 40.3			---	---	Total 36.2		
Dust Introduced	g	15.0	15.1	15.1	15.1	15.0	15.1	15.1	15.1	15.0	15.1	15.1	15.1	15.1	15.0
Duration of Test	Min.	7.13	6.87	7.22	6.92	6.92	7.42	7.13	7.60	7.63	7.10	6.90	7.50	7.53	7.75
Pressure Loss Start	In. WG	1.57	2.36	4.17	3.11	3.62	5.52	0.87	1.30	1.77	2.28	3.34	0.91	1.30	1.65
Pressure Loss Finish	In. WG	2.40	4.17	9.88	4.02	5.87	10.46	1.38	1.85	2.52	3.38	5.11	1.42	1.78	2.44
Sampler Gain Upstream	mg	50.5	57.4	52.2	48.2	57.9	52.6	56.0	49.6	56.8	53.3	49.1	51.2	60.5	50.9
Sampler Gain Downstream	mg	5.5	3.4	2.7	3.2	3.3	2.0	6.1	7.4	5.0	3.7	4.2	7.9	4.9	6.4
COMPUTED VALUES															
Dust Concentration	mg/Cu. ft.	10.5	11.1	10.4	10.8	10.8	10.0	10.5	9.9	9.9	10.6	10.9	10.1	10.0	9.7
Efficiency - E_G Gravimeter	%	89.1	94.1	94.8	93.4	94.3	96.2	89.1	85.1	91.2	93.2	91.5	84.6	91.9	87.4
Efficiency - E_F Filter Gain	%	Average 92.5			Average 73.0			Average 89.2			---	---	Average 80.1		
Efficiency - E_D Discoloration	%	---	---	---	---	---	---	---	---	---	---	---	---	---	---

I/ FILTERS OILED, A.C. "FINE", 360 CFM (Continuation of TABLE 6)

Filter Number		6		7		11				12			
Test Number		6023	6024	6021	6022	6013	6014	6015	6016	6025	6026	6031	6032
						OBSERVED VALUES							
Filter Weight Start	g	303.8	---	314.3	---	299.5	---	---	---	312.8	---	---	---
Filter Gain	g	Total 25.8		Total 24.6			Total 53.0				Total 50.0		
Dust Introduced	g	15.1	15.1	15.1	15.1	15.0	15.1	15.1	15.1	15.1	15.0	15.1	15.1
Duration of Test	Min.	3.50	3.67	3.85	3.52	3.58	3.58	4.03	3.52	3.73	3.72	3.33	3.86
Pressure Loss Start	In. WG	4.32	6.05	4.40	6.08	2.36	3.26	4.17	5.73	2.44	3.18	3.69	5.34
Pressure Loss Finish	In. WG	6.16	10.14	6.24	10.00	3.42	4.32	5.89	9.12	3.30	4.24	5.19	9.90
Sampler Gain Upstream	mg	32.0	35.8	35.2	28.8	30.4	31.7	28.0	33.0	33.0	34.8	35.6	29.7
Sampler Gain Downstream	mg	1.8	1.0	1.0	1.1	3.0	2.0	1.8	1.2	2.2	1.9	1.0	0.8
						COMPUTED VALUES							
Dust Concentration	mg/Cu. ft.	11.9	11.2	10.9	11.9	11.7	11.7	10.4	11.7	11.2	11.2	12.6	10.8
Efficiency - E_G Gravimetric	%	94.4	97.0	97.2	96.2	90.1	93.7	93.6	96.3	93.3	94.5	97.2	97.3
Efficiency - E_F Filter Gain	%	Average 86.0		Average 82.0			Average 87.9				Average 82.9		
Efficiency - E_D Discoloration	%	---	---	---	---	---	---	---	---	---	---	---	---

THE NATIONAL BUREAU OF STANDARDS

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