NATIONAL BUREAU OF STANDARDS REPORT

4110

PERFORMANCE TESTS OF A DOLLINGER STAYNEW AUTOMATIC AIR FILTER MODEL A-4 (TYPE HD PANELS)

by

Henry E. Robinson
Thomas W. Watson

Report to

General Services Administration
Public Buildings Service
Washington 25, D. C.

NBS

U. S. DEPARTMENT OF COMMERCE
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PERFORMANCE TESTS OF A DOLLINGER MODEL A-4 STAYNEW AUTOMATIC FILTER

1. INTRODUCTION

At the request of the Public Buildings Service, General Services Administration, the performance characteristics of self-cleaning automatic oil-type air filters were determined to provide information to assist in the preparation of new air filter specifications.

The test results presented herein were obtained on a specimen automatic oil-type air filter submitted by its manufacturer at the request of the Public Buildings Service and included determinations of dust arresting efficiency with two aerosols (atmospheric air and Cottrell precipitate), pressure drop, dirt load and cleanability of the specimen.

2. DESCRIPTION OF THE FILTER SPECIMEN

The filter was manufactured by the Dollinger Corporation, Rochester 3, New York, and was identified by the factory representative as a Dollinger Staynew Automatic self-cleaning air filter Model A-4, capacity 1715 cfm. The drive motor current characteristics were stated as follows: 1/6 HP; 1 PH; 60 CY; 115 volts; 3.0 Amps; 1725 RPM.

The test unit had a housing with actual outside dimensions of 27 3/4 inches in width, 52 inches in height and 19 5/8 inches in length. The exposed face of the curtain media on the upstream side was 21 3/4 inches wide by 23 1/2 inches high (3.55 sq.ft. gross face area). The unit was rated at 1715 cfm air delivery at a face velocity of 550 fpm based on the net air-passing exposed area of the upstream curtain (3.12 sq. ft.). Special upstream and downstream transitions, 12 inches in length with flanges 30 inches square matching those of the duct of the test apparatus, were used to adapt the unit for test. The openings formed by these transitions at the duct flanges were 24 inches square upstream and downstream. The downstream curtain face had an exposed area 21 3/4 inches wide and 23 1/2 inches high (3.55 sq. ft.).

The filter consisted of Type HD panel sections 23 inches in width and about 10 1/4 inches in height, consisting of a layer of 12-mesh bronze screen to which were attached several layers of woven copper mesh. The panels were joined together by 1 1/4x23-inch metal strips (which reduced the net face

area of the curtain to 87.8% of the gross area) and attached to two endless chains forming an endless curtain that rotated over sprockets on horizontal shafts located in the top and reservoir assemblies. There were two endless curtains, one upstream approximately 102 1/2 inches in length and one downstream about 80 inches in length. Both curtains rotated downward on their upstream face and upward on their downstream face. The lower end of the upstream curtain in passing around its lower sprocket dipped into a reservoir of oil for cleaning and re-oiling the media. The downstream curtain did not enter the oil bath, but was scrubbed at the lower sprocket by a rotating cylindrical nylon brush when the curtain moved.

The curtains were shifted intermittently by a timer-controlled motor and gear box. The synchronous electric timer was set by the factory to actuate the drive motor for a period of 20 seconds every 15 minutes, resulting in a curtain movement of approximately 2 1/2 inches per shift. For the dirt-loading tests the timer was re-adjusted for a curtain movement of 3 inches per shift, or 12 inches per hour.

The manufacturer furnished an adhesive designated as "Pingene 50". Approximately 25 gallons were required to fill the reservoir to the indicated level.

3. TEST METHOD AND PROCEDURE

Efficiency determinations were made by the NBS "Dust-Spot Method" using the following aerosols: (a) outdoor atmospheric air drawn through the laboratory without addition of other dust or contaminant; and (b) Cottrell precipitate, dispersed in the outdoor atmospheric air. The test method is described in the paper "A Test Method for Air Filters" by R. S. Dill (ASHVE Transactions, Vol. 44, P. 379, 1938). The test duct and arrangement are shown in Figure 1. A baffle made of two 3-inch wide slats at right angles to each other was located in the duct about 3-1/2 ft. downstream of the test assembly to intermix the air discharged from it.

For these tests, the unit was installed in the test duct and its exterior housing was carefully sealed to prevent in-leakage of air. The desired rate of air flow through the air cleaner was established and samples of air were drawn from the center of the test duct, at points one foot upstream and eight feet downstream of the air cleaner assembly, at equal rates for equal times, and passed through known areas of Whatman No.

41 filter paper. The filter papers used in the upstream and downstream positions were selected to have the same light transmission readings when clean, as determined by means of a photometer using transmitted light. Using filter paper sampling areas downstream equal to 30 percent of the filter paper area upstream, an efficiency of 70 percent would be indicated if the upstream and downstream dust-spots on the papers had the same opacity, as indicated by the change in the light transmissions of the dust-spot areas before and after the sample was drawn. If the opacities of the dust-spots differed, the efficiency was calculated by means of the formula

$$\text{Efficiency, percent} = 100 \left[1 - \frac{A_2}{A_1} \cdot \frac{O_2}{O_1} \right]$$

where A_1 and A_2 were the areas of the dust-spots upstream and downstream, respectively, and O_1 and O_2 were the opacities of the dust-spots upstream and downstream respectively.

In testing the unit, it was desirable to subject it to a dirt-loading condition that would simulate a service condition and that would allow the results to be applicable for a wide range of unit sizes.

In service, a unit having an upstream exposed curtain height of H ft, and receiving air containing a dust concentration of C grams per 1000 cf, at face velocity V, shifts its curtain periodically or uniformly at an average rate of S inches per hour. Under these conditions, the curtain, when it leaves the air stream entering the front face of the unit, will have received a "burden" of

$$\frac{12H \times 60V \times C}{S \times 1000} \text{ or } \frac{0.72\ HVC}{S} \quad \text{grams of dust per square foot.}$$

The average pressure drop of a unit, and to some extent its efficiency, regardless of its size provided the face velocity is the same, depend on the average dirtiness of its curtain, and therefore on the magnitude of the "burden" as defined above. On this basis, a test of a small-sized unit can be expected to be reasonably representative for a much larger unit, if the "burdens" are the same.

To evaluate a burden reasonably representative of what might be experienced in actual service, the following in-service

conditions were assumed: H = 7 ft; S = 7 inches/hour; C = 0.065 gram per 1000 cf (1 grain per 1000 cf); V = 500 fpm. Using these values, a representative service burden was computed to be

$$B = \frac{0.72 \times 7 \times 500 \times 0.065}{7} = 23.4 \text{ grams/sq.ft.}$$

In selecting conditions for the test it was desirable to increase the curtain shifting speed S to 12 inches/hr, to shorten the time required for several revolutions of the curtain. Assuming that the test should be conducted with a burden B = 23.4 grams/sq.ft., and that for the unit tested the height of exposed face = 1.96 ft.; width = 1.81 ft.; curtain shifting speed S = 12 inches/hr; and velocity V = 550 fpm; then

$$23.4 = \frac{0.72 \text{ HVC}}{S}$$

$$\text{or} \quad C = \frac{23.4 \times 12}{0.72 \times 1.96 \times 550 \times 0.878} = 0.413 \text{ gram per 1000 cf.}$$

The air flow capacity of the unit was 1.81 x 1.96 x 0.878 x 550 = 1715 cfm, and the appropriate average rate of dust feed to the unit was therefore 0.71 gram per minute. With 4% by weight of lint added, the average rate of dirt feed to the filter was 0.74 gram per minute.

The following procedure was employed in these tests. The clean unit was installed in the test duct, its oil reservoir was filled to the indicated level, and all discoverable air leaks into its housing were sealed. The timer control was adjusted to shift the curtain 12 inches per hour. During a period of 36 hours immediately prior to the tests the curtain was allowed to shift automatically for a total of approximately 4 revolutions through the oil reservoir, with no air flow, to saturate the curtain media. The initial resistance of the clean filter at various rates of air flow was then measured. Next, three determinations of the efficiency of the clean unit were made at rated velocity, using as the aerosol outdoor air drawn into the test duct through a nearby open window.

Following these, three efficiency determinations were made at rated velocity, using as the aerosol outdoor air in which was dispersed Cottrell precipitate at a concentration of approximately 0.99 gram per thousand cubic feet of air, i.e., a

net dust feed rate of 1.7 grams per minute. The sampling times for the efficiency tests with Cottrell precipitate as the aerosol were 10 minutes each and the curtain made one shift during each test. When these had been obtained, the process was begun of loading the unit with a mixture of 4 percent cotton lint, and 96 percent Cottrell precipitate, by weight, separately dispersed into the air stream. The lint used for this purpose was No. 7 cotton linters previously ground in a Wiley mill with a 4 - millimeter screen; the lint was dispersed into the air stream every 15 minutes (immediately after each curtain movement) through an aspirator operating at approximately 35 psi inlet air pressure. At suitable periods as loading progressed, the efficiency of the unit was determined using 100 percent Cottrell precipitate in outdoor air. The pressure drop was recorded at intervals during the tests.

In order that the dirt-loading process simulate continuous operation of the unit in service at the desired burden, the curtain-shifting timer mechanism was deenergized during all periods when the air flow through the unit was stopped -- e.g., overnight, or at lunch periods. Similarly, the increased rate of dust feed occurring during efficiency determinations was in effect reduced to the desired average net rate of feed (0.71 gram per minute) by operating the unit without dust feed for ten minutes following each 14-minute efficiency determination.

The dirt-loading process was continued until the curtain had made two or more revolutions under the imposed dust burden conditions. Although some variation of pressure drop occurred as a result of the periodic changes of curtain position, an equilibrium of efficiency and pressure drop appeared to have been substantially attained at this stage of the test.

At the conclusion of the dirt-loading tests the efficiency was determined again using laboratory air as the aerosol. In order to ascertain the self-cleaning performance of the unit, the curtain was left running intermittently for a period of 17 hours (two revolutions) with no air flow through the unit. The resistance of the cleaned filter at various air flows was then observed.

4. TEST RESULTS

Tabulated in Table 1 are measurements, at four different face velocities, of the pressure drops through the filter when it was clean, and when it had been allowed to clean itself

after the dirt-loading test. In each case, the observed values apply for a particular position of the curtain. As may be seen from the pressure drop data in Table 2 for the clean unit tested with atmospheric air (which could have caused no significant change in curtain resistance) the pressure drop of the clean unit was observed to vary from 0.278 to 0.303 inch W.G., depending upon curtain position.

The operating performance of the unit at 550 fpm net face velocity is summarized in Table 2. The table gives data on the efficiency of the unit in arresting Cottrell precipitate, and on its pressure drop, as the curtain was progressively loaded, from a clean condition to an operating equilibrium condition corresponding to a "dirt burden" of 24.3 grams per sq. ft., with a mixture of approximately 4 percent lint and 96 percent Cottrell precipitate by weight. It is believed that the unit was operating substantially at the equilibrium condition for this burden after the curtain had turned more than 1.5 revolutions. This is indicated by the trend of the efficiency and pressure drop curves plotted from the data of Table 2, as shown in Figure 2. Also, the efficiency of the unit in filtering atmospheric air is given for the clean unit, and for the unit when its media was loaded with a dirt deposit corresponding to a "dirt burden" of 24.3 grams per sq. ft.

5. SUMMARY

A. Performance

Due to the self-cleaning action of the unit, which occurs periodically during operation, the performance of the unit depends on, and must be related to, the dirt deposit on the curtain, expressed in this report by means of the "dirt burden" on the curtain as it leaves the airstream on the upstream side. On this basis, at 550 fpm net face velocity, the efficiency of the unit in arresting Cottrell precipitate was about 76 percent for equilibrium operation at a dirt burden of 24.3 grams per sq. ft. The corresponding pressure drop averaged 0.35 inch W.G., with a plus or minus variation of about 0.02 inch depending upon the curtain position.

The effect of the magnitude of the burden is shown by the corresponding figures obtained when the curtain was practically clean, even though the rate of dirt feed was the same, i.e., at the start of the dirt-loading test. The

efficiency and pressure drop of the unit at this stage were about 75 percent and 0.30 inch W.G., respectively. As the deposit on the curtain increased to the equilibrium condition, the efficiency and pressure drop rose to the values given in the preceding paragraph.

The efficiency of the clean unit in arresting the dust in the atmospheric air at the test laboratory was on the order of 9 percent, individual values ranging from 7 to 11 percent. Its efficiency appeared to be approximately the same with the curtain clean, and with a dirt burden of 24.3 grams per sq. ft.

At conclusion of the tests, examination of the test duct downstream of the unit showed no evidence of oil carry-over. Some oily patches were observed on the downstream face of the downstream curtain at the conclusion of the tests. It is concluded that oil carry-over would be negligible for a unit operated at curtain shift speeds not greater than 12 inches per hour.

B. Self-Cleaning

Automatic self-cleaning of the curtain by its intermittent motion through the oil reservoir appeared to be effective. At the conclusion of the dirt-loading test, the curtain was allowed to move intermittently through the oil at a rate of 12 inches per hour for 17 hours with no air flow for a total of two revolutions. The pressure drop of the unit, at 550 fpm face velocity, was reduced from its value when dirty (about 0.35) to a value of 0.306 inch W.G., as compared with the initial average value of 0.289 for the clean filter as indicated in Table 2. On inspection of the unit after the test and this self-cleaning operation, the upstream curtain appeared to be quite clean except at the edges of the 1 1/4-inch metal junction strips, some dirt deposits remained in a few places on the media. This type of deposit is considered to be of little practical importance. The downstream curtain had a slightly dusted appearance, and a few small oily areas, but no significant dust deposits.

The lint and dust removed from the filter curtain settled to the bottom of the oil reservoir as a heavy sludge, leaving the oil substantially clear. The sludge was readily removed from the reservoir by means of the catch pan provided.

C. General

The following observations were made concerning particulate matter downstream of the test unit.

(1) Cellophane tapes stretched across the duct 15" downstream of the unit with the adhesive side facing upstream, and exposed for several hours each during the dirt-loading test, showed on examination under the microscope that many particles from 15 to 5 microns, and smaller, in size were caught. Relatively few larger particles, ranging from 20 to 200 microns, were found on the tapes. No lint fibres were observed; late in the tests 4 or 5 small droplets of what appeared to be oil were found on a tape, but it is believed this was of little importance since none was observed in the downstream duct at the end of the tests.

(2) A cellophane tape exposed at the downstream dust sampling station 8 ft. from the test unit throughout the entire test showed many fine particles, and relatively few large particles of dust; no lint was observed.

(3) Examination by microscope of the downstream filter papers from efficiency determinations showed that almost all of the particles on the paper were under 20 microns, with most under 5 microns; a few up to 50 microns were observed.

(4) Examination of the downstream duct of the test apparatus after the tests indicated no observable oiliness of the duct. Upon careful sweeping of the downstream duct, no observable quantity of dust was obtained from it.

A cloth was wetted with the oil submitted with the unit, and taken outdoors and ignited with a wooden safety match. The cloth did not ignite readily, but once ignited it burned strongly with a smokey flame.

No difficulty was experienced in setting the adjustment of the curtain-shifting timer as desired. The intermittent shifting action of the curtain occurred smoothly and without objectionable noise.

TABLE 1

Net Face Velocity	Air Flow	Pressure Drop*	Pressure Drop**
fpm	cfm	inch W. G.	inch W.G.
321	1000	0.112	0.116
482	1500	.233	.239
550	1715	.296	.306
642	2000	.400	.407
802	2500	.580	.623

* Initial resistance of the clean filter.

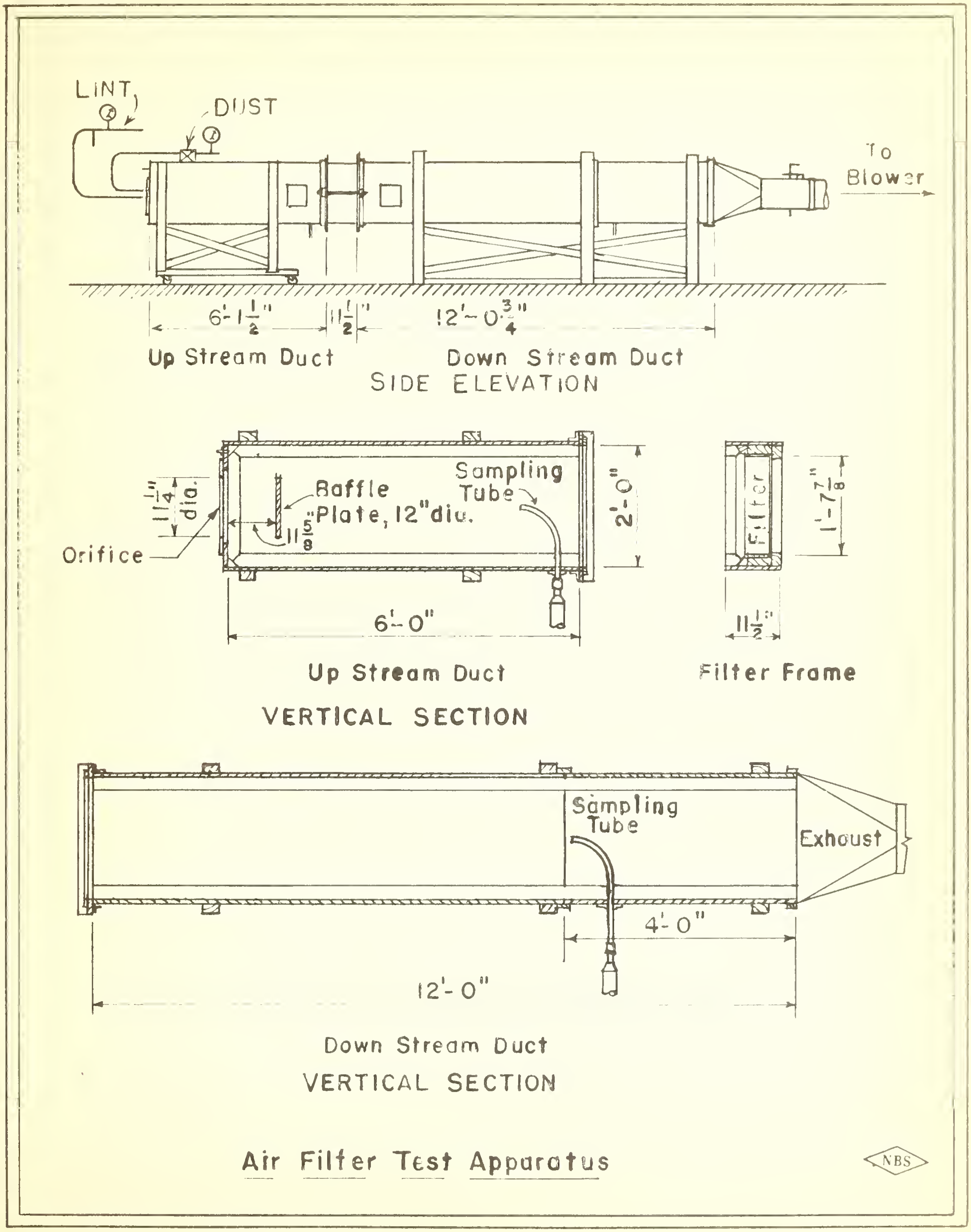
** Resistance of the unit after the dirt-loading test and 17 hours of intermittent self-cleaning action (approximately two turns) without air flow.

TABLE 2

Face Velocity	Inlet Aerosol*	Total Time	Curtain Movement	Total Dirt Fed**	Pressure Drop	Efficiency
fpm		minutes	revolutions	grams	inch W.G.	percent
550	A	-	-	0	0.278	8
		-	-	0	.285	11
		-	-	0	.303	7
					0.289 avg.	
550	C	10	0.02	17	.315	74.5
		34	.07	34	.308	75.7
		58	.11	51	.305	74.5 (PM)
		82	.16	70	.316	75.0 (AM)
		436	.85	313	.340	75.5 (PM)
		460	.90	330	.319	77.1 (AM)
		634	1.24	476	.325	74.7
		838	1.64	626	.347	76.3 (PM)
		864	1.69	644	.356	74.7 (AM)
		1050	2.05	773	.349	74.9
	A	-	-	773	.335	13.
		-	-	773	.326	7.

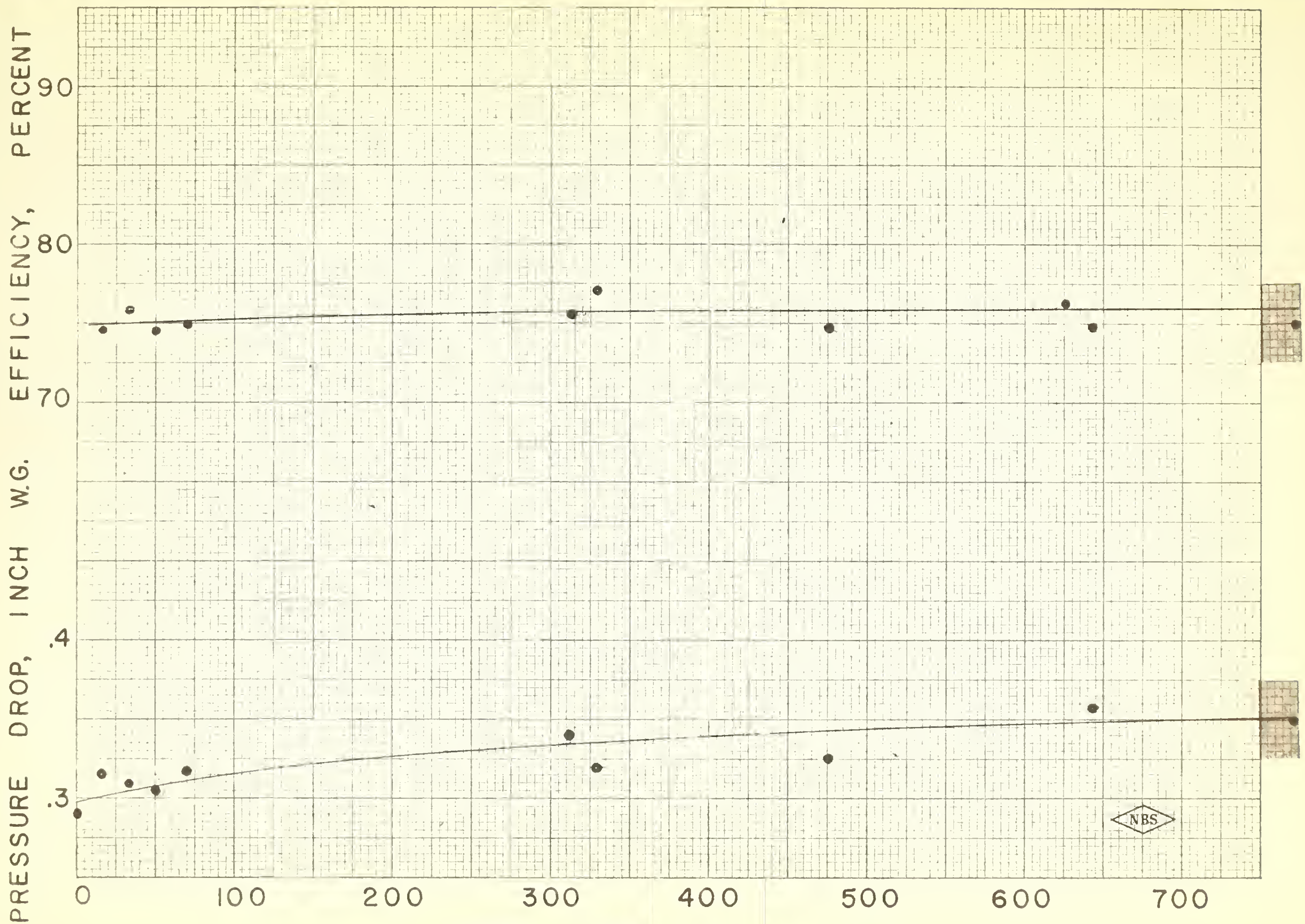
*A = Particulate matter in atmospheric air at NBS
C = Cottrell precipitate in atmospheric air

** Average mixture: 3.9 percent lint, 96.1 percent Cottrell precipitate by weight. (The dirt fed corresponds to a "dirt burden" on the curtain of 24.3 grams per sq. ft. on leaving the airstream)



LINT
DUST
To Blower
6'-1 1/2"
11 1/2"
12'-0 3/4"
Up Stream Duct
Down Stream Duct
SIDE ELEVATION
11 1/4" dia.
Orifice
Baffle Plate, 12" dia.
11 5/8
Sampling Tube
2'-0"
6'-0"
Filter
1'-7 7/8"
11 1/2"
Up Stream Duct
Filter Frame
VERTICAL SECTION
Sampling Tube
Exhaust
4'-0"
12'-0"
Down Stream Duct
VERTICAL SECTION
Air Filter Test Apparatus
NBS

Figure 1



PRESSURE DROP, INCH W.G. EFFICIENCY, PERCENT
90
80
70
.4
.3
0
100
200
300
400
500
600
700
TOTAL DIRT FED, GRAMS
NBS

Fig. 2

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