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NATIONAL BUREAU OF STANDARDS REPORT

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PERFORMANCE TESTS OF AN AIR-MAZE "AUTOMAZE" AUTOMATIC AIR FILTER

by

Thomas W. Watson
Henry E. Robinson

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

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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PERFORMANCE TESTS OF AN AIR-MAZE "AUTOMAZE" AUTOMATIC AIR FILTER MODEL NO. 3 - 9

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to
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NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

PERFORMANCE TESTS OF A MODEL NO. 3 - 9 AUTOMAZE AUTOMATIC AIR FILTER

by

Thomas W. Watson and Henry E. Robinson

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 Air-Maze Corporation, Cleveland, Ohio, and was identified by the factory representative as a Model 3 - 9 Automaze "Pulse-Action" Automatic Self-Cleaning Air Filter, having a rated capacity of 3100 cubic feet per minute.

The test unit had a housing with actual outside dimensions of 34 1/4 inches in width, 60 inches in height and 12 3/8 inches in length. The exposed face of the curtain media was blanked off on the upstream and downstream sides to yield a square 24 inches on a side (4.0 square feet gross face area). The unit was tested at 2020 cubic feet per minute air delivery, corresponding to a face velocity of 505 feet per minute based on the exposed area of the upstream curtain. Special upstream and downstream transitions, 12 inches in length with flanges three inches wide matching those of the duct of the test apparatus, were used to adapt the unit for test.

*This report is submitted for information only, and is not released for use in connection with advertising or sales promotion.

The filtering curtain consisted of Air-Maze "Kleenflo AA 35" panel sections 36 1/4 inches in width, ten inches in height and two inches thick, each consisting of seven layers of v-crimped wire screen of various meshes arranged to form a progressively denser media from the upstream to the downstream face.

The panels were hung and pivoted at the ends on two heavy roller conveyor chains approximately 90 inches in length, thus forming an endless curtain that rotated over sprockets on horizontal shafts located in the top and reservoir assemblies. The curtain rotated upward on the upstream face and downward on the downstream face, with the panels riding in Ferris-wheel fashion and presenting the same face to incoming air at all times. The panel sections in passing around the lower sprocket dipped into and passed through a reservoir of oil for cleaning and re-oiling the media.

The filter curtain was shifted periodically and with a sudden rapid motion by a single-action air cylinder drive mechanism mounted to act upon a lever and clutch on the lower sprocket shaft of the unit. An electric timing clock periodically opened a solenoid valve that admitted air (at from 70 to 150 pounds per square inch) to the cylinder, and caused the curtain to shift a pre-set distance. Upon closure of the solenoid valve, the piston returned by spring action to its original position in the cylinder in readiness for the next shift.

The electric timer was set by the factory to actuate the shift mechanism once every five minutes, resulting in an average curtain movement of about 7.5 inches per hour. For the tests herein, the timer and shift mechanism were readjusted so that the curtain was shifted about 0.65 inch every 2.5 minutes, or at an average rate of approximately 15.5 inches per hour.

The air compressor unit furnished to supply compressed air for the air drive mechanism was as follows: 1/2 horsepower, 1725 rpm, 115/125 volts, 1 phase, 60 cycles, amps 7.8/3.9. The unit was equipped with an air tank, automatic pressure control switches and a safety valve.

The manufacturer furnished an adhesive designated as "Filter Kote AB Oil." Approximately 33 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 three-inch wide slats at right angles to each other was located in the duct about 3 1/2 feet 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 inleakage 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 a filter paper sampling area 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 feet, and receiving air containing a dust concentration of C grams per 1000 cubic feet, 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

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

The average pressure drop of a unit, and to some extent its efficiency, regardless of its size provided the face velocity is the same, depends 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 feet; S = 7 inches per hour; C = 0.065 gram per 1000 cubic feet (1 grain per 1000 cubic feet); V = 500 feet per minute. Using these values, a representative service burden was computed to be

$$B = \frac{0.72 \times 7 \times 500 \times 0.065}{7} = 23.4 \text{ grams per square foot.}$$

In selecting conditions for the test it was desirable to increase the curtain shifting speed S to about 15.5 inches per hour to shorten the time required for several revolutions

of the curtain. It was assumed that the test should be conducted with a burden B = 23.4 grams per square foot, and that for the unit as tested the height H of the exposed face = 2.0 feet; width = 2.0 feet; curtain shifting speed = 15.5 inches per hour; and the face velocity V = 505 feet per minute (based on gross face area), so that

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

or $$C = \frac{23.4 \times 15.5}{0.72 \times 2.0 \times 505} = 0.499 \text{ gram per 1000 cubic feet.}$$

Since the air flow capacity of the unit was 2.0 x 2.0 x 505 = 2020 cubic feet per minute, the appropriate average rate of dirt feed to the unit was therefore estimated to be 1.01 grams per minute consisting of 96 percent of Cottrell precipitate and four percent of cotton lint by weight. During the test, however, the actual average rate of curtain travel proved to be 15.6 inches per hour, and as a result the burden to which the unit was subjected in these tests was actually about 23.3 grams per square foot.

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 so that it shifted the curtain at an average rate of 15.5 inches per hour. During a period of 17 hours immediately prior to the tests the curtain was allowed to shift automatically for a total of approximately 2.9 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 1.0 gram per thousand cubic feet of air, i.e., a net dust feed rate of 2.02 grams per minute. The sampling times for the efficiency tests with Cottrell precipitate as the aerosol were ten minutes each and the curtain made four shifts during each test. When these had been obtained, the process was begun of loading the unit with a mixture of four 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 four-millimeter screen; the lint was dispersed into the air stream every 20 minutes (following a curtain movement) through an aspirator operating at approximately 35 pounds per square inch 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 de-energized 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 (1.01 grams of dust per minute) by operating the unit without dust feed for about ten minutes following each ten-minute efficiency determination.

The dirt-loading process was continued until the curtain had made two or more revolutions under the imposed dust burden conditions.

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 allowed to shift intermittently through the oil for a period of 22 hours (3.8 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 initially clean, and when it was allowed to clean itself after completion of the dirt-loading test. The pressure drop value 0.196 inch W. G. obtained at 505 feet per minute face velocity after self-cleaning was lower than the initial clean value (0.211). Some variation of pressure drop with curtain position is to be expected, due to variability of panel sections and the changing percentage of free area for air flow at different curtain positions.

The operating performance of the unit at 505 feet per minute 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 to a "dirt burden" of 23.3 grams per square foot of a deposit of approximately four percent lint and 96 percent Cottrell precipitate by weight. The data plotted in figure 2 show that the pressure drop and efficiency of the unit increased at first, but leveled off at substantially constant values of 0.25 inch W. G. and 73 percent, respectively, when a steady-state condition was reached at a "burden" of 23.3 grams per square foot. This occurred after about one complete curtain revolution, or at a value of about 300 grams of total dirt fed.

The efficiency of the unit in filtering atmospheric air is also given in table 2, both for the unit when clean, and for the unit with a dirt burden of 23.3 grams per square foot on its media at the end of the dirt-loading test.

5. SUMMARY

A. Performance

Due to the self-cleaning feature 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 505 feet per minute face

velocity, the efficiency of the unit in arresting Cottrell precipitate was about 73 percent for equilibrium operation at a dirt burden of 23.3 grams per square foot. The corresponding pressure drop averaged 0.25 inch W. G., with little variation.

The efficiency of the clean unit in arresting the dust in the atmospheric air at the test laboratory averaged about eight percent, individual values ranging from seven to 12 percent. Its atmospheric air efficiency with the curtain loaded with dust was measured as ten percent.

At the conclusion of the tests, examination of the test duct downstream of the unit showed evidence of slight oil carry-over. Oil carry-over would be less, and probably would be negligible, for a unit operated with this oil at curtain shift speeds not greater than eight inches per hour.

B. Self-Cleaning

Automatic self-cleaning of the curtain by its passage 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 15.6 inches per hour for 22 hours with no air flow, for a total of 3.8 revolutions. A panel section of the media was then removed from the curtain and examined under a bright light. No dust or lint was visible on either face of the media or in it.

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 using a suitable scraper.

C. General

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

(1) Cellophane tapes stretched across the duct 15 inches 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 25 to 5 microns in size, and smaller, were caught. Relatively few larger particles, ranging from 25 to 150 microns were found on the tapes. No lint fibers were observed; a few small droplets of oil were found on the tape, but it is believed this would be negligible for curtain shift speeds not greater than about eight inches per hour.

(2) 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 in size, with most under 5 microns; a few up to 25 microns were observed.

A cloth was wetted with 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 smoky flame.

No difficulty was experienced in setting the adjustment of the air-cylinder drive mechanism and timer. The intermittent shifting action of the curtain by the air-cylinder mechanism occurred rapidly but without objectionable noise.

Table 1

Face Velocity fpm	Air Flow cfm	Pressure Drop* inch W.G.	Pressure Drop** inch W.G.
625	2500	0.305	0.282
505	2020	.211	.196
375	1500	.123	.116
250	1000	.063	.060

*Initial pressure drop of the clean filter

**Pressure drop of the unit after the dirt-loading test and 22 hours of intermittent self-cleaning action (approximately four turns) without air flow.

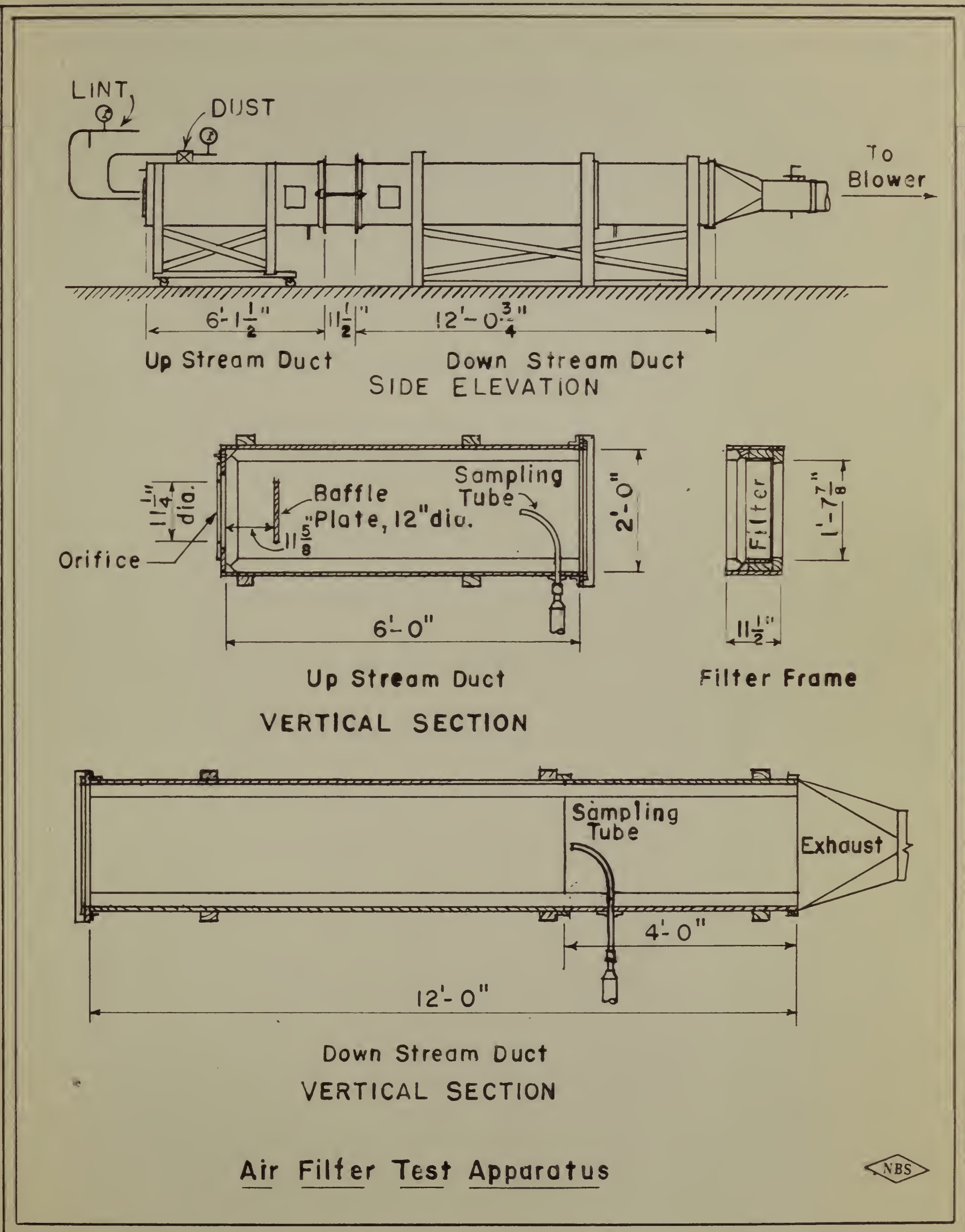
Table 2

Face Velocity fpm	Inlet Aerosol*	Total Time minutes	Total Curtain Movements revolutions	Total Dirt Fed** grams	Average Pressure Drop inch W.G.	Efficiency percent
505	A	25	0.07	0	0.204	7
		50	.14	0	.213	6
		75	.22	0	.218	12
					0.212 avg.	8 avg.
505	C	0	0.0	0	--	--
		10	.03	20	.230	70
		39	.11	40	.224	71
		49	.14	60	.238	67
		210	.60	221	.259	75
		310	.89	323	.255	73
		410	1.18	424	.256	73
		530	1.52	545	.253	72
		590	1.70	606	.254	74
		610	1.75	626	.237	74
		720	2.07	727	.247	74
505	A	745	2.07	727	.248	10

*A = Particulate matter in atmospheric air at NBS.

C = Cottrell precipitate in atmospheric air.

**Average proportions: Four percent lint, 96 percent Cottrell precipitate by weight. (The dirt fed corresponds to a "dirt burden" on the curtain of 23.3 grams per square foot on leaving the air stream.)



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"
Up Stream Duct
Filter
1'-7 7/8"
11 1/2"
Filter Frame
VERTICAL SECTION
Sampling Tube
Exhaust
4'-0"
12'-0"
Down Stream Duct
VERTICAL SECTION
Air Filter Test Apparatus
NBS

Figure 1

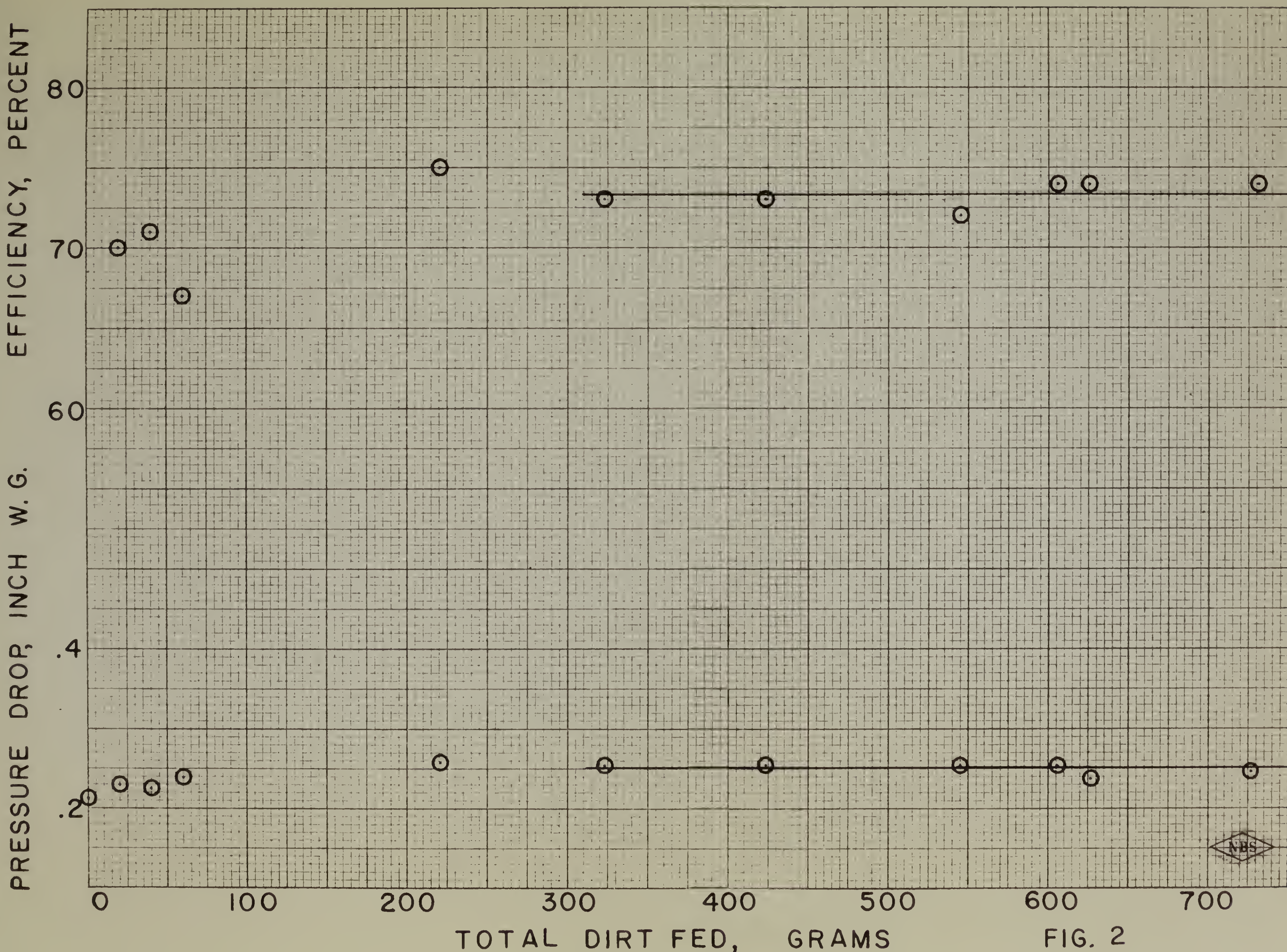

EFFICIENCY, PERCENT
80
70
60
PRESSURE DROP, INCH W. G.
.4
.2
0
100
200
300
400
500
600
700
TOTAL DIRT FED, GRAMS

FIG. 2

THE NATIONAL BUREAU OF STANDARDS

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