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NATIONAL BUREAU OF STANDARDS REPORT

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PERFORMANCE TESTS OF A TRION AUTOMATIC TRAVELING
CURTAIN SELF-CLEANING AIR FILTER

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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G-19294

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT
1000-30-4830

February 6, 1956

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PERFORMANCE TESTS OF A TRION AUTOMATIC TRAVELING CURTAIN SELF-CLEANING AIR FILTER (SPECIAL SIZE MODEL T 2-2)

by

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Building Technology Division

To

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U. S. DEPARTMENT OF COMMERCE
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PERFORMANCE TESTS OF A TRION MODEL T 2-2 AUTOMATIC SELF-CLEANING AIR FILTER

by

Henry E. Robinson and Thomas W. Watson

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 Trion, Inc., McKees Rocks, Pennsylvania, and was stated by the factory representative to be a special-sized model of 1750 cfm air capacity designed to fit the laboratory test equipment. Except for size, the unit, designated as Model T 2-2, was stated to be representative of the standard models produced by the company.

The test unit had a housing with actual outside dimensions of 32 inches in width, 52 inches in height and 12 inches in length. The exposed face of the curtain media on the upstream side was 24 inches square (4.0 sq. ft. gross face area). The unit was rated at 1750 cfm at a face velocity of 520 fpm based on the net air-passing exposed area of the upstream curtain (3.37 sq. ft.). Special upstream and downstream transitions, 14 inches in length with flanges 26 inches square were used to connect the unit to the test ducts. The openings formed by these transitions at the duct flanges were 24 inches square upstream and downstream. The downstream curtain face had an exposed gross area 24 inches square (4.0 sq. ft.)

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

The filter consisted of Trion MAF panel sections 25 1/4 inches in width, 8 inches in height and 2 inches thick, consisting of thin perforated and formed metal strips installed in vertical planes parallel to the direction of air flow, and stacked side by side to form 6 layers per inch of horizontal width, between which the air flows in sinuous or irregular paths.

Each panel had a 5/8-inch surrounding edge frame which reduced the net face area of the upstream curtain to 84% of the gross area. The panels were hung and pivoted at the ends on two heavy roller conveyor chains approximately 80 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 presenting the same face to incoming air at all times. The panel in passing around the lower sprocket dipped into and passed through a reservoir of oil for cleaning and re-oiling the media.

The endless curtain was 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 approximately 23 seconds every 12 minutes, resulting in an average curtain movement of about 6 7/8 inches per hour. For the tests herein the timer was re-adjusted so that it actuated the drive motor for 37.6 seconds every 12 minutes, yielding a curtain movement of 2 1/4 inches per shift, or 11 1/4 inches per hour. The drive motor current characteristics were stated as follows; 1/6 HP; 1 PH; 60 CY: 115 volts; 3.4 Amps; 1725 RPM.

The manufacturer furnished an adhesive designated as "Flowrex 100". Approximately 18 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 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 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

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

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/hr; 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 about 12 inches/hr. 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/sq. ft., and that for the unit as tested the height H of the exposed face = 2.0 ft.; width = 2.0 ft.; curtain shifting speed = 12 inches/hr; and the face velocity V = 520 x 0.84 fpm (based on gross face area), so that

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

or $$C = \frac{23.4 \times 12}{0.72 \times 2.0 \times 520 \times 0.84} = 0.447 \text{ gram per 1000 cf.}$$

Since the air flow capacity of the unit was 2.0 x 2.0 x 520 x 0.84 = 1750 cfm, appropriate average rate of dirt feed to the unit was therefore estimated to be 0.783 gram per minute consisting of 96% of Cottrell precipitate and 4% of cotton lint by weight. During the test, however, the actual average rate of curtain travel proved to be 11 1/4 inches per hour, and as a result the burden to which the unit was subjected in these tests was actually about 25 grams/sq. ft. instead of the intended value of 23.4 grams/sq. ft.

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 11 1/4 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 2.4 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, two 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, two 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 1.75 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 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 4-millimeter screen; the lint was dispersed into the air stream every 12 minutes (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 (0.75 gram of dust per minute) by operating the unit without dust feed for about 13 minutes following each 10-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 left running intermittently through the oil for a period of 60 hours (eight 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 net face velocities, of the pressure drops through the filter when it was initially clean, and when it had been allowed to clean itself after completion of the dirt-loading test. The pressure drop value 0.558 inch W.G. obtained at 520 fpm net face velocity after self-cleaning is higher than the initial clean value (0.537). It should be noted, however, that the pressure drop of the unit varied markedly, as shown in Table 2, not in response to the dirt load upon its media, apparently, so much as to the portion of the curtain receiving the air stream, i. e., the various filter cells making up the curtain apparently differed measurably in air flow resistance. It is believed that the greater pressure drop after self-cleaning is a result of the variability of cell resistance, rather than an indication of failure to clean the media thoroughly.

The operating performance of the unit at 520 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 to a "dirt burden" of 25.7 grams/sq. ft. of a deposit of approximately 4% lint and 96% Cottrell precipitate by weight. The plotted data on pressure drop exhibit variability, as mentioned above, but in general the pressure drop did not tend to increase measurably as dirt was accumulated on the media in the amount corresponding to the above dirt burden. The efficiency of the unit in arresting Cottrell precipitate appeared to be substantially constant throughout the test, irrespective of the dirt burden deposited on the media.

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 dirt on its media at the end of the dirt-loading test.

5. SUMMARY

A. Performance

The operating performance of the unit appeared to be practically unaffected by the dirt upon its media, up to the amount attained after several hours of steady operation at a dirt burden of 25.7 grams/sq.ft. Neither efficiency nor pressure drop showed any steady change as this burden was imposed, the average values over the duration of the dirt-loading test being approximately 64% and 0.51 inch W.G., respectively, at 520 fpm net face velocity. Variations in pressure drop from 0.473 to 0.585 inch W.G. were observed as the test progressed, but these are believed to have been due to differences in the air flow resistances of the several cells composing the filter curtain, rather than to the effect of dirt deposits on the media.

The efficiency of the clean unit in arresting the dust in the atmospheric air at the test laboratory averaged about 14%, individual values ranging from 11 to 17%. Its atmospheric air efficiency with the curtain loaded with dust was measured as 10%.

At the conclusion of the tests, examination of the test duct downstream of the unit showed evidence of slight oil carry-over. It is believed that oil carry-over would be negligible for a unit operated at curtain shift speeds not greater than 11 inches per hour.

B. Self-Cleaning

Automatic self-cleaning of the curtain by its passage through the oil reservoir appeared to be effective. No dust or lint was visible on either face of the media, or in the media so far as could be seen without disassembling the filter cells, upon inspection after the curtain had been allowed to rotate eight times through the oil bath at the rate of 11 1/4 inches per hour, with no air flow through the filter.

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 could be 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 150 microns, were found on the tapes. No lint fibres were observed; a few small droplets of what appeared to be oil were found on a tape, but it is believed this was of little importance since little was observed in the downstream duct at the end of the tests.

(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, with most under 5 microns; a few up to 30 microns were observed.

(3) Examination of the downstream duct of the test apparatus after the tests indicated a slight 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 smoky flame.

No difficulty was experienced in setting the adjustment of the curtain-shifting timer. 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.
594	2000	0.700	0.722
520	1750	.537	.558
446	1500	.393	.410
297	1000	.181	.190

*Initial pressure drop of the clean filter.

**Pressure drop of the unit after the dirt-loading test and 60 hours of intermittent self-cleaning action (approximately eight turns) without air flow.

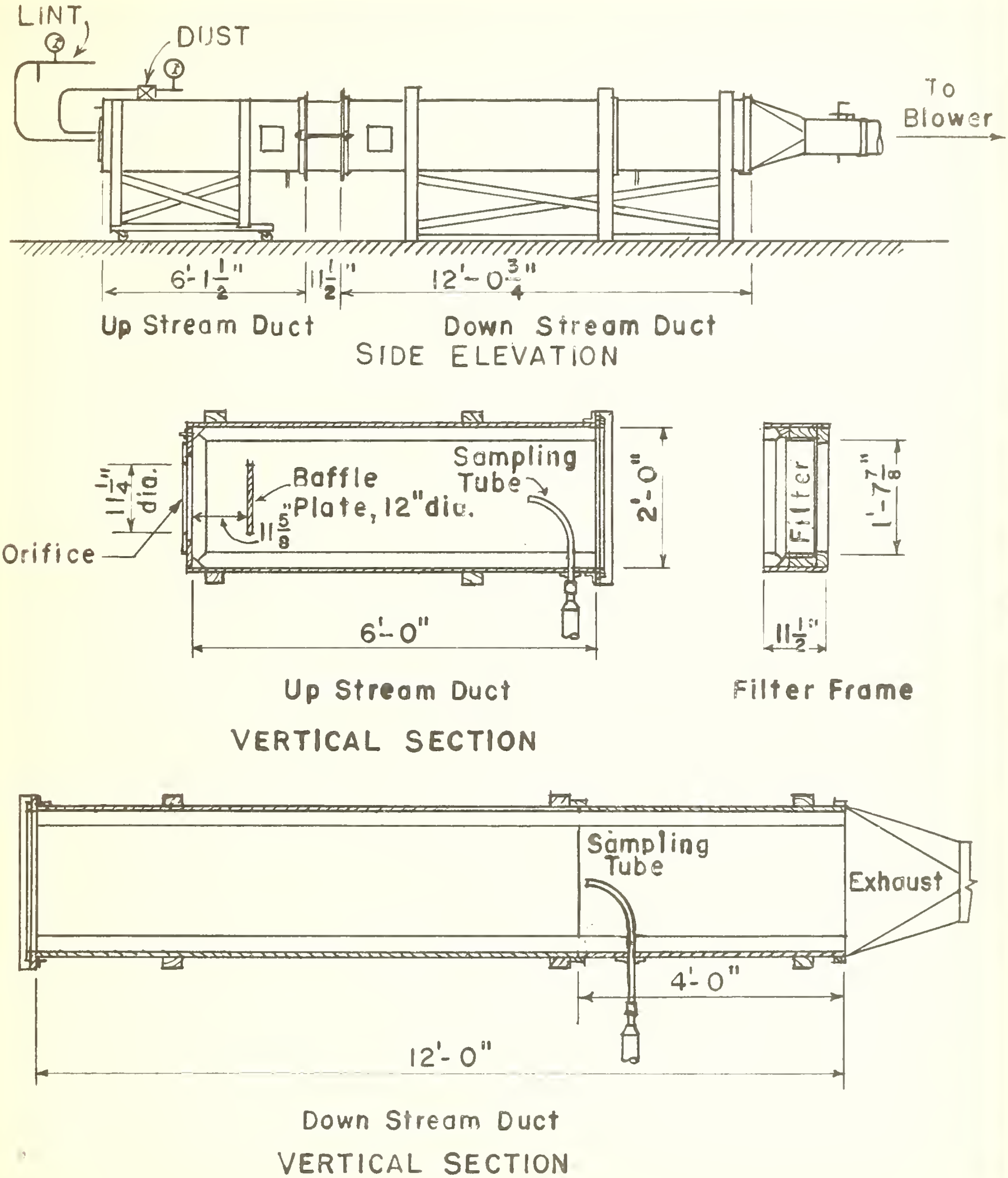
TABLE 2

Face Velocity fpm	Inlet Aero-sol*	Total Time minutes	Curtain Movement revolutions	Total Dirt Fed** grams	Average Pressure Drop inch W.G.	Effic-iency percent
520	A	-	-	0	0.516	11
		-	-	0	.510	17
520	C	11	0.03	18	.506	62
		33	.08	35	.479	64
		154	.36	113	.485	64
		400	.94	322	.493	65
		578	1.36	466	.507	64
		696	1.63	561	.543	65
		886	2.08	714	.503	64
520	A	-	-	714	.533	10

* A = Particulate matter in atmospheric air at NBS.

C = Cottrell precipitate in atmospheric air.

** Average proportions: 4 percent lint, 96 percent Cottrell precipitate by weight. (The dirt fed corresponds to a "dirt burden" on the curtain of 25.7 grams per square ft on leaving the air stream).



Air Filter Test Apparatus

Figure 1

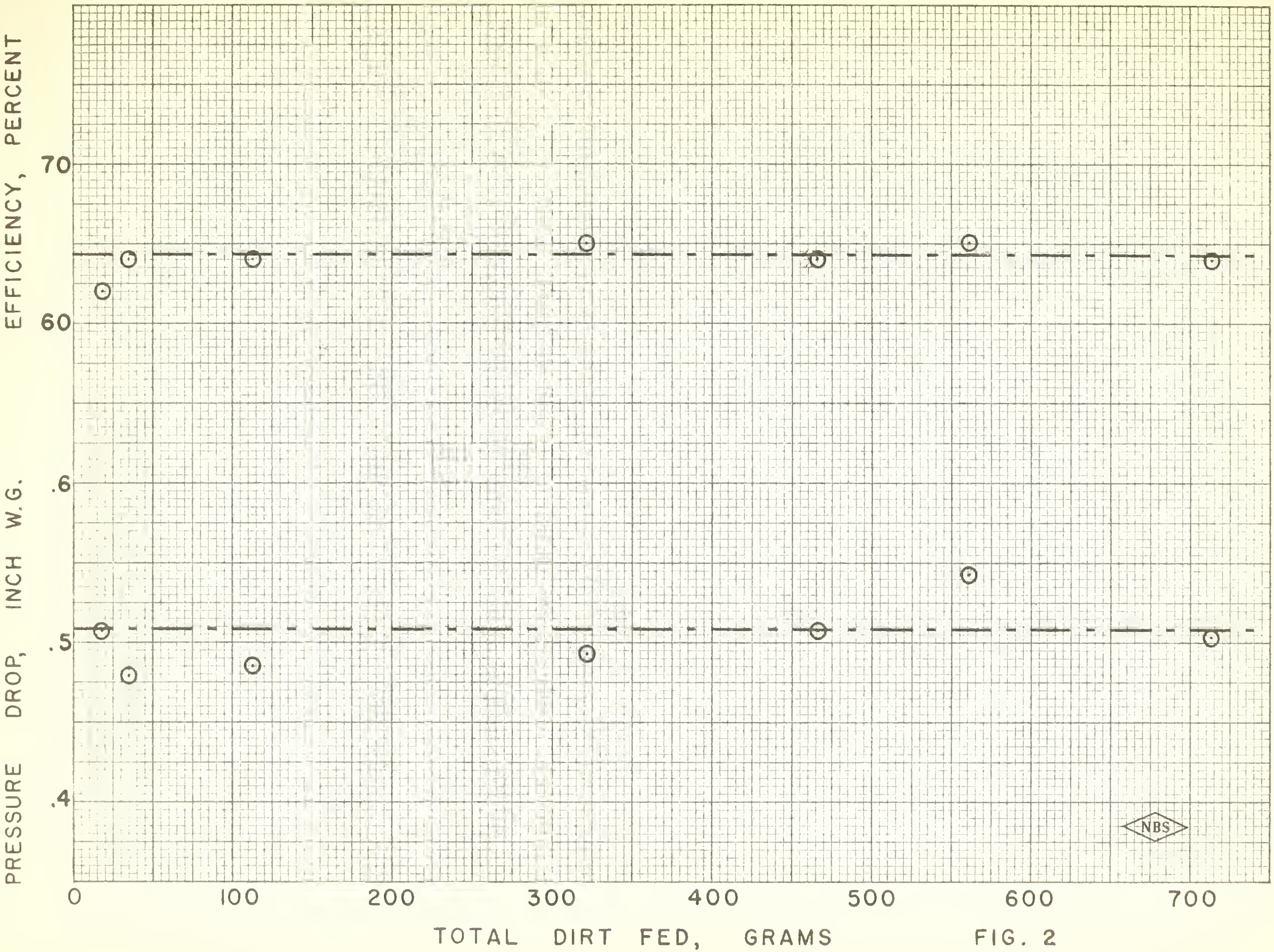

EFFICIENCY, PERCENT
70
60
PRESSURE DROP, INCH W.G.
.6
.5
.4
NBS
0
100
200
300
400
500
600
700
TOTAL DIRT FED, GRAMS

FIG. 2

THE NATIONAL BUREAU OF STANDARDS

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