# NATIONAL BUREAU OF STANDARDS REPORT

5827

PERFORMANCE TESTS OF A FARR CO. "ROLL-KLEEN" AUTOMATIC RENEWABLE MEDIA AIR FILTER

by

Thomas W. Watson and 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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Heat Transfer Section
Building Technology Division

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NBS

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## 1. INTRODUCTION*

At the request of the Public Buildings Service, General Services Administration, the performance characteristics of automatic renewable media 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 renewable media 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, performance characteristics, and movement of the media.

## 2. DESCRIPTION OF THE FILTER SPECIMEN

The filter was manufactured by the Farr Company of Los Angeles, California, and was of the automatic renewable media type. It was identified by the manufacturer's representative as a Farr "Roll-Kleen" Air Filter, Special Model 3-70 (3 ft. wide by 7 ft. high) capacity 2080 cfm at 520 fpm inlet face velocity.

The test unit had a housing with actual outside dimensions of 36 inches in width, 84 inches in height, and 26 3/8 inches in length. Special upstream and downstream transitions, with flanges 30 inches square, matching those of the duct of the test apparatus, were used to adapt the unit for test. The air inlet and outlet openings formed by these transitions were 24 inches square (4.0 sq. ft.).

The "Roll-Kleen" filter is designed to move a long blanket or strip of filtering media across the air flow opening in the housing, in a manner similar to that in which strip film is moved in a box camera. A roll of

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

clean blanket media is held at the top of the housing, from which the media is unrolled as needed by a wind-up roller or spool at the bottom of the housing, driven by a gear motor drive directly connected by means of a standard roller chain. In passing from the top to the bottom roller, the media slides over a stationary back-up grid of 3 by 6 inch mesh wire. The drive motor characteristics are given as 40 watts, 110 volts, 60 cycles, 1 phase.

The filtering media, designated as Farr "Modiglas E3D," consists of a long strip or blanket (34 inches wide and about 2 inches thick when uncompressed) of interlaced matted and bonded fine glass fibers. The blanket is bonded on the downstream side to a flame-proof four-mesh fabric sheet. The fibers are uniformly coated with a tricresyl-phosphate adhesive. As furnished on a spool, the blanket is tightly rolled and compressed in thickness, but expands upon being unrolled for use.

The unit is designed so that the shift drive mechanism is intermittently energized by means of an adjustable differential pressure switch actuated by the pressure drop through the filtering media. A differential pressure switch (Dwyer No. 1626.1; Range 0.15 to 1.00 inch W.G.; 15 amps; 125, 260, 460 v a-c) was used for the tests reported here. The pressure control was adjusted to energize the drive motor when the pressure drop reached a value of about 0.50 inch W.G., and to open the drive motor circuit when the movement of clean media into the air stream lowered the pressure drop to about 0.43 inch W.G. Motion of the media during periods of shift occurred at the rate of about 55 ft. per hour.

## 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 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 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.

An air filter of this kind equipped with a differential pressure switch to actuate the media shift mechanism operates at a sort of "steady-state" condition, in which the pressure drop slowly increases to an upper limit as dust is received, and is then rapidly reduced to a somewhat lower limit as clean media is moved into the air stream due to action of the pressure switch. An average pressure drop is thus maintained by intermittent shifting of the media as the pressure drop through the filter changes within these limits. It is evident that the dirtiness of the filter media as it is moved out of the air stream is dependent on the magnitude of the average pressure drop at which the unit is adjusted to operate, and that the rate of usage of media therefore depends on it. Further, since dust-arresting efficiency of this type of media increases slightly as the media becomes choked with dirt, the efficiency of the unit may be affected by the operating pressure drop. In order that the tests represent conditions reasonably appropriate for service applications, the differential pressure control was adjusted to yield an average pressure drop of the magnitude commonly experienced with automatic self-cleaning air filters (about 0.46 inch W.G.).

The following procedure was used in these tests. The clean unit was installed in tandem between the upstream and downstream sections of the test duct, and all discoverable air leaks were sealed. The differential pressure control was adjusted to actuate the media shift drive-motor when the pressure drop across the media increased to 0.50 inch W.G; its operating differential was such that the control opened the drive-motor circuit when the pressure drop decreased to 0.43 inch W.G.

With the filtering media in the air stream all clean, the pressure drop was measured at several face velocities, and the efficiency of the filter on atmospheric air was determined at rated face velocity. Next, the efficiency was determined with 100 percent Cottrell precipitate. The process of dirt-loading the filter at rated face velocity was then begun, using a mixture of 96 percent Cottrell precipitate and 4 percent cotton lint by weight, separately dispersed into the air stream at a concentration of 1.0 gram of mixture per 1000 cf of air. The lint used for this purpose was No. 7 cotton linters previously ground in a Wiley mill with a 4-millimeter screen; the required weight of lint was dispersed into the air stream every 10-12 minutes through an aspirator operating at approximately 35 psi gage inlet air pressure.

When the pressure drop of the filter reached the upper limit of the differential pressure switch, and thereafter fluctuated about the average value established by the control setting, the filter operation became substantially "steady-state." Readings of pressure drop just before and after the shifts of the media, and of the media travel as indicated by a mark on the curtain, were recorded from this point on; occasional measurements of dust-arresting efficiency were also made as this condition was continued. Some of these determinations were made so that a shift of the media occurred during the air-sampling period, and some were made without such a shift.

As shown in Figure 2, after the filter had been operated at a dirt concentration of 1.0 gram per 1000 cf, for a period in which approximately 240 grams of dirt per foot width of filter were fed, the dirt concentration was reduced to 0.5 gram per 1000 cf, with occasional efficiency measurements being made. This was continued until the amount of dirt fed increased from 240 to 364 grams per foot width of filter. At this stage, the efficiency of the filter with atmospheric air as the aerosol was again measured.

During the tests, at appropriate times, strips of 3/4 inch cellophane adhesive tape were stretched across the test duct with the adhesive side facing upstream to catch samples of dust particles approaching in the air stream.

The tapes were placed in the duct at a position 15 inches downstream of the downstream flange of the test unit, or about 20 inches downstream of the filtering media of the unit.

## 4. TEST RESULTS AND DISCUSSION

Tabulated in Table 1 are measurements, at four face velocities, of the pressure drop through the filter when the media was clean, and average values of the efficiency of the unit on atmospheric air and on Cottrell precipitate for the filter when clean and when dirt-loaded to the "steady-state" condition corresponding to an average pressure drop of about 0.47 inch W.G. at rated face velocity.

The operating performance of the unit at 520 fpm face velocity is summarized in Table 2 and in Figure 2. Referring to Figure 2, it is seen that the pressure drop increased gradually from its initial value, as dirt was fed to the filter, to a value of about 0.50 inch W.G. At this point the differential pressure control caused about six inches of new clean media to be shifted into the air stream, which lowered the pressure drop to about 0.43 inch W.G. Thereafter, the unit operated automatically in a "steady-state" condition with the pressure drop varying between maximum and minimum values of 0.50 and 0.43 inch W.G., respectively. The travel of the media as this process continued is also shown; it is seen that the plotted points describe a substantially straight line having constant slope, i.e., that the use of media per gram of dust received per foot of filter width was substantially constant. The efficiency of the filter on Cottrell precipitate in atmospheric air is shown at the top of Figure 2. It increased from an initial value of 75 percent to an approximately steady value of 84 percent for the "steady-state" operating condition.

The results above were obtained with the filter being loaded with a dirt mixture at a concentration of 1.0 gram per 1000 cf of air. When the test was continued with the dirt concentration reduced to 0.5 gram per 1000 cf, substantially the same results were obtained, as shown on the right-hand portion of Figure 2, although the time required to feed a given quantity of dirt was doubled because of the halved concentration.

For a filter of this type, with a filter curtain H feet from top to bottom of the air-passing area, receiving at a face velocity of V fpm an aerosol having a dust concentration

of C grams per 1000 cf, the rate of dirt-loading, S, is given by

$$S = \frac{60VHC}{1000} = 0.06 \text{ VHC grams/hr per ft of media width} \quad \text{(a)}$$

If T is the average rate of travel of media in feet per hour, the "burden", B, or weight of dust received by a square foot of the media by the time it leaves the air stream, is given by

$$B = \frac{60HVC}{1000T} = 0.06 \frac{VHC}{T} = \frac{S}{T} \quad \text{(b)}$$

For the "steady-state" operating condition shown in Figure 2, S/T is given in effect by the inverse slope of the line showing media travel versus total dust received per foot of media width, in appropriate units. Table 2 gives the values of S, T, and B derived from the data plotted in Figure 2 and from the elapsed-time records of the tests, for the "steady-state" operating condition for both aerosol dirt concentrations. It is seen that the value of the burden B is very nearly the same for the tests at the two concentrations.

It would be expected on general grounds that for the same filtering media, face velocity, and aerosol, the burden B would be affected chiefly by the pressure drop at which the unit was operated. The fact that almost identical burdens resulted for two dirt concentrations for the same average pressure drop gives support for the use of a relation like equation (b) for making estimates of media usage for various possible values of the dirt concentration C or for units of various heights of exposed filtering blanket. It should be recognized, however, that B (here about 50 grams/sq. ft.) may have a quite different value for some other operating pressure drop or face velocity, or for some other aerosol or filtering media.

The results show plainly that for a unit equipped with a differential pressure switch controlling the media shifting mechanism, the use of media is proportional to the concentration or amount of dirt being received. For a unit equipped with a timer-clock, the rate of use of media would be constant and unresponsive to dirt loading rates, and the pressure drop would rise and fall in magnitude with increase or decrease in dirt concentration.

The efficiency of the unit appeared to be unaffected by movement of the media during an efficiency measurement. After the unit had been removed from the test duct, the section of the duct five feet long downstream of the flanges, and upstream of a 3/4 inch thick wood strip fastened flat across the bottom of the test duct, was carefully swept out with a fine brush. The amount of material obtained from the duct by this sweeping was 18.0 grams, or 2.5 percent of the dirt load reaching the filter, constituting the fall-out in the first five feet of the duct from the air passed through the filter. This material consisted for the most part of large dust particles with some few glass fibers.

Cellophane tapes, stretched across the test duct with the adhesive side facing upstream, indicated upon visual and microscopic examination after exposure to the air stream that some particles of sizes up to approximately 125 microns had passed through the filter during the dirt-loading tests. Particles smaller than five microns were observed in quantity by microscopic examination of the downstream filter papers obtained in tests with both aerosols. No lint was observed on the tapes during these tests.

The intermittent shifting action of the media occurred without significant noise.

TABLE 1

Initial and Final Performance of Air Filter

| Face Velocity fpm | Air Flow cfm | Pressure Drop (1) inch W.G. | Average Efficiency | |
|---|---|---|---|---|
| | | | Atmospheric Air percent | Cottrell Precipitate percent |
| 250 | 1000 | 0.076 | | |
| 375 | 1500 | .141 | | |
| 520 | 2080 | .234 | 10 | 75 |
| 625 | 2500 | .318 | | |
| 520 | 2080 | .47 ± .04[2)] | 23[2)] | 84[2)] |

1) Pressure drop of the clean filter.
2) Values for the filter at "steady-state" condition when dirt-loaded with a mixture of 96 percent Cottrell precipitate and 4 percent lint by weight.

TABLE 2

Summary of Performance with Cottrell Precipitate at 520 cfm

| Condition | Initial | "Steady-State" | "Steady-State" |
|---|---|---|---|
| Duration, hours | 0.85 | 3.1 | 4.2 |
| Aerosol conc., (C), gram/1000 cf | 1.0 | 1.0 | 0.5 |
| Avg. efficiency, percent | 75.6 | 83.8 | 84.6 |
| Avg. pressure drop, inch W.G. | 0.240 | 0.465 | 0.466 |
| Pressure drop, inch W.G., avg. max./avg. min. | - | 0.503/.427 | 0.505/.427 |
| Rate of dirt ldg.*, (S), grams/hr. per ft. of media width | - | 62.4 | 31.2 |
| Rate of travel of media, (T), ft./hr. | - | 1.25 | 0.61 |
| "Steady-state" burden* on media, (B), grams/ft.$^2$ | - | 50.0 | 51.0 |

*Dirt load: 4 percent lint, 96 percent Cottrell precititate by weight.

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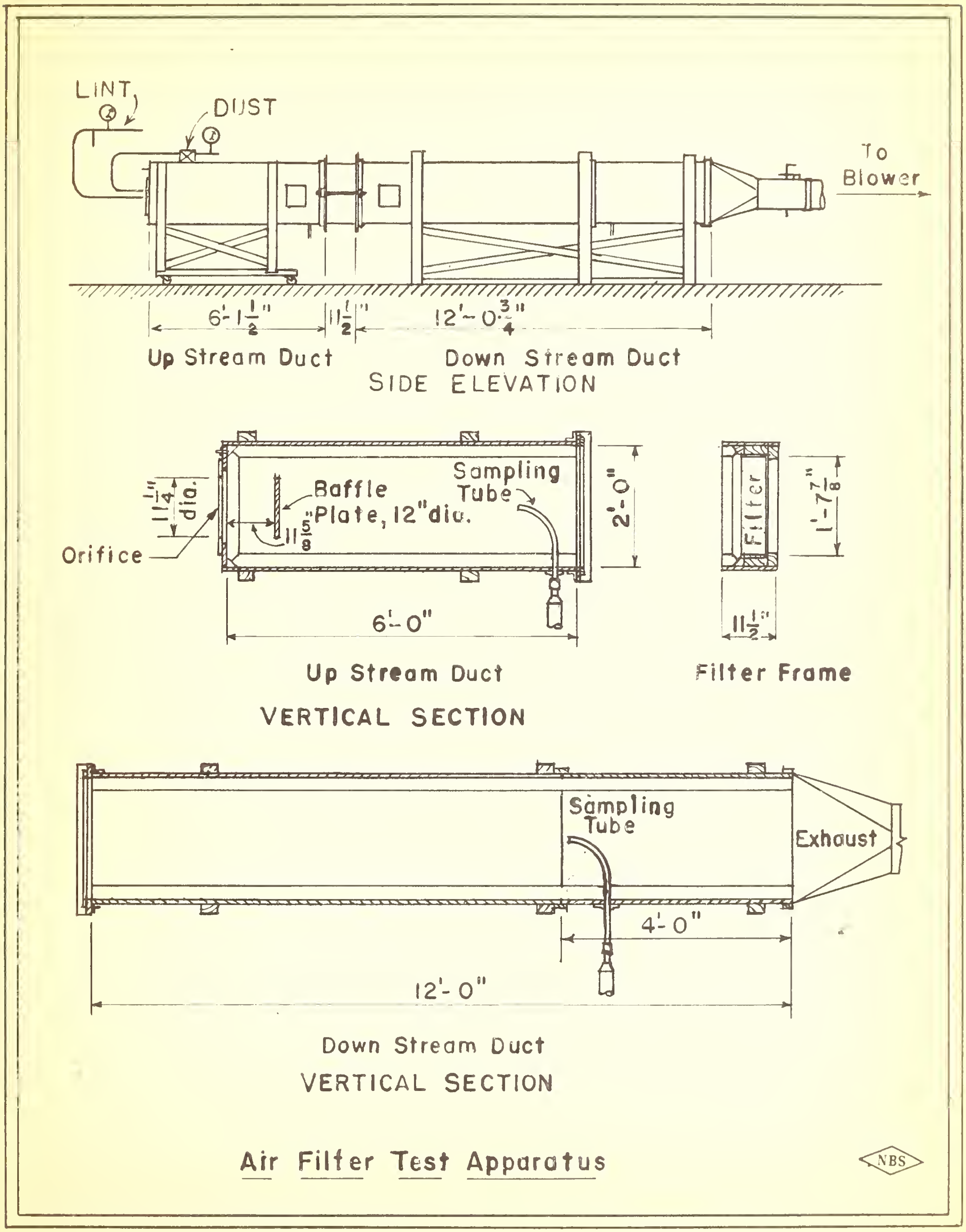
LINT
DUST
To Blower
6'-1 1/2"
11 1/2"
12'-0 3/4"
Up Stream Duct
Down Stream Duct
SIDE ELEVATION
11 1/4" dia.
Orifice
Baffle Plate, 12" dia.
11 5/8"
Sampling Tube
2'-0"
6'-0"
Filter
1'-7 7/8"
11 1/2"
Up Stream Duct
Filter Frame
VERTICAL SECTION
Sampling Tube
Exhaust
4'-0"
12'-0"
Down Stream Duct
VERTICAL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

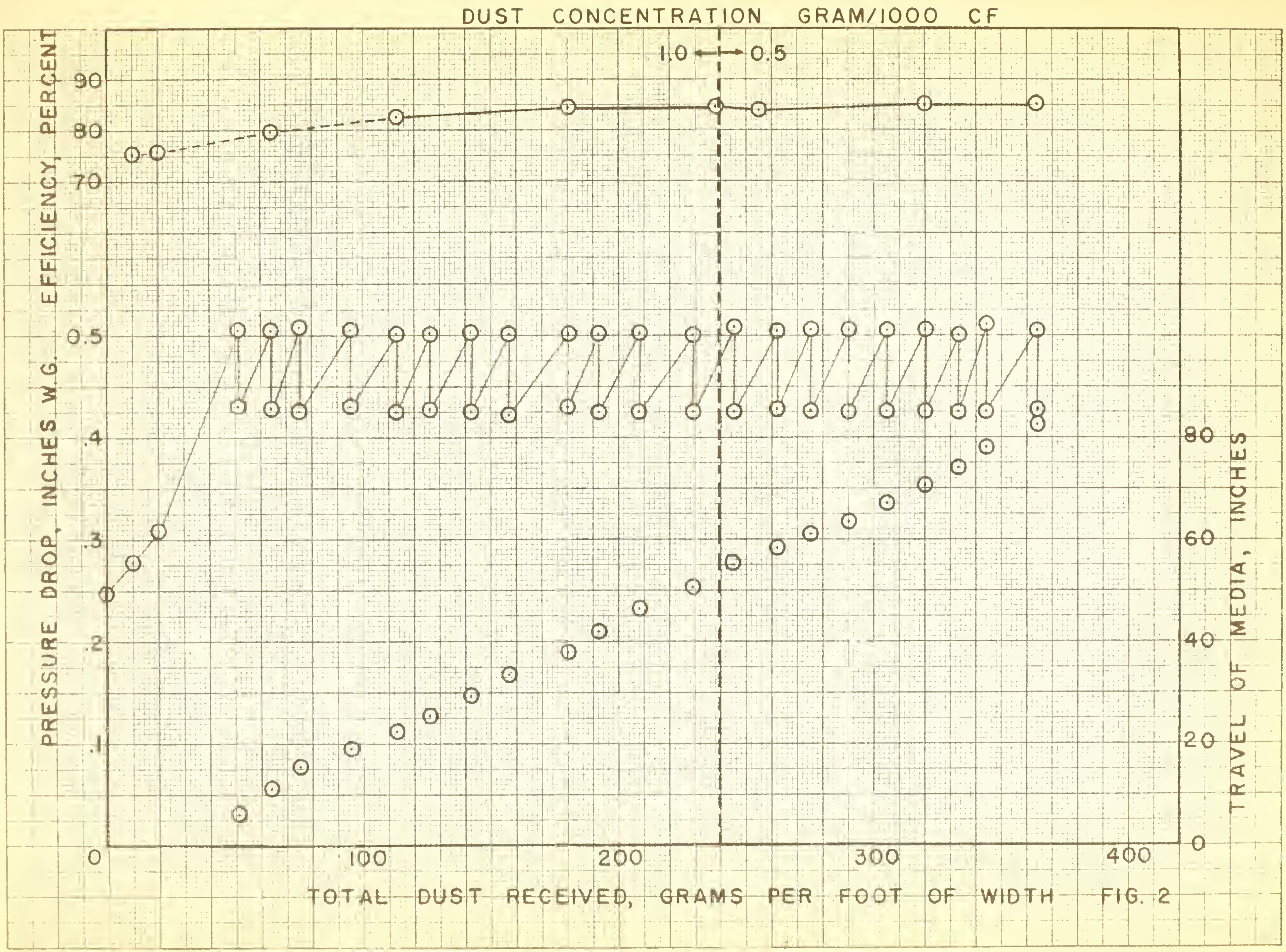
DUST CONCENTRATION GRAM/1000 CF
1.0 ← → 0.5
PRESSURE DROP, INCHES W.G. EFFICIENCY, PERCENT
90
80
70
0.5
.4
.3
.2
.1
0
100
200
300
400
TRAVEL OF MEDIA, INCHES
80
60
40
20
0
TOTAL DUST RECEIVED, GRAMS PER FOOT OF WIDTH

FIG. 2

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Sinclair Weeks, *Secretary*

NATIONAL BUREAU OF STANDARDS
A. V. Astin, *Director*

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**Optics and Metrology.** Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.
**Heat.** Temperature Physics. Thermodynamics. Cryogenic Physics. Rheology. Engine Fuels. Free Radicals Research.
**Atomic and Radiation Physics.** Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Physics. Nuclear Physics. Radioactivity. X-rays. Betatron. Nucleonic Instrumentation. Radiological Equipment.
**Chemistry.** Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Molecular Structure and Properties of Gases. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.
**Mechanics.** Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Controls.
**Organic and Fibrous Materials.** Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Plastics. Dental Research.
**Metallurgy.** Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion. Metal Physics.
**Mineral Products.** Engineering Ceramics. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.
**Building Technology.** Structural Engineering. Fire Protection. Air Conditioning, Heating, and Refrigeration. Floor, Roof, and Wall Coverings. Codes and Safety Standards. Heat Transfer.
**Applied Mathematics.** Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics.
**Data Processing Systems.** SEAC Engineering Group. Components and Techniques. Digital Circuitry. Digital Systems. Analog Systems. Application Engineering.
• Office of Basic Instrumentation. • Office of Weights and Measures.

## BOULDER, COLORADO

**Cryogenic Engineering.** Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Gas Liquefaction.
**Radio Propagation Physics.** Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Sun-Earth Relationships. VHF Research.
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