NATIONAL BUREAU OF STANDARDS REPORT

3336

PERFORMANCE TESTS OF A TRION ELECTRIC 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
NATIONAL BUREAU OF STANDARDS

U. S. DEPARTMENT OF COMMERCE
Sinclair Weeks, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section is engaged in specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant reports and publications, appears on the inside of the back cover of this report.

Electricity. Resistance and Reactance Measurements. Electrical Instruments. Magnetic Measurements. Electrochemistry.

Optics and Metrology. Photometry and Colorimetry. Optical Instruments. Photographic Technology. Length. Engineering Metrology.

Heat and Power. Temperature Measurements. Thermodynamics. Cryogenic Physics. Engines and Lubrication. Engine Fuels. Cryogenic Engineering.

Atomic and Radiation Physics. Spectroscopy. Radiometry. Mass Spectrometry. Solid State Physics. Electron Physics. Atomic Physics. Neutron Measurements. Infrared Spectroscopy. Nuclear Physics. Radioactivity. X-Ray. Betatron. Nucleonic Instrumentation. Radiological Equipment. Atomic Energy Commission Radiation Instruments Branch.

Chemistry. Organic Coatings. Surface Chemistry. Organic Chemistry. Analytical Chemistry. Inorganic Chemistry. Electrodeposition. Gas Chemistry. Physical Chemistry. Thermochemistry. Spectrochemistry. Pure Substances.

Mechanics. Sound. Mechanical Instruments. Fluid Mechanics. Engineering Mechanics. Mass and Scale. Capacity, Density, and Fluid Meters. Combustion Control.

Organic and Fibrous Materials. Rubber. Textiles. Paper. Leather. Testing and Specifications. Polymer Structure. Organic Plastics. Dental Research.

Metallurgy. Thermal Metallurgy. Chemical Metallurgy. Mechanical Metallurgy. Corrosion.

Mineral Products. Porcelain and Pottery. Glass. Refractories. Enameled Metals. Concreting Materials. Constitution and Microstructure.

Building Technology. Structural Engineering. Fire Protection. Heating and Air Conditioning. Floor, Roof, and Wall Coverings. Codes and Specifications.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering.

Electronics. Engineering Electronics. Electron Tubes. Electronic Computers. Electronic Instrumentation. Process Technology.

Radio Propagation. Upper Atmosphere Research. Ionospheric Research. Regular Propagation Services. Frequency Utilization Research. Tropospheric Propagation Research. High Frequency Standards. Microwave Standards.

●Office of Basic Instrumentation

●Office of Weights and Measures.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT		NBS REPORT
1000-30-4837	June 7, 1954	3336

PERFORMANCE TESTS OF A TRION ELECTRIC AIR FILTER

by
Henry E. Robinson
Thomas W. Watson
Heating and Air Conditioning Section
Building Technology Division

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

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

PERFORMANCE TESTS OF A TRION MODEL NO. 8-102-00 ELECTRIC AIR FILTER

1. INTRODUCTION

At the request of the Public Buildings Service, General Services Administration, the performance characteristics of electrostatic air cleaners 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 electrostatic filter unit submitted by its manufacturer at the request of the Public Buildings Service and included determinations of dust arresting efficiency with three aerosols (atmospheric air, kerosene lamp smoke, and Cottrell precipitate), pressure drop, specific dirt load and cleanability of the specimen.

2. DESCRIPTION OF THE FILTER SPECIMEN

The cleaner was manufactured by Trion, Inc., 1000 Island Avenue, McKees Rocks, Pennsylvania, and was of the electrostatic type. It was identified as a Trion Electric Air Filter, Model No. 8-102-00 with one cell, rated velocity 333 feet per minute (1332 CFM total capacity). The power pack nameplate data furnished by the manufacturer were as follows:

Type B   60 cycles   110 volts   5 amps
Ionizer volts 13.5 kv Plate 6.7 kv
Maximum output 9 ma

The test unit had a housing with actual outside dimensions of 25 1/4 x 27 1/2 inches and was 24 1/8 inches long. It was rated as having 4 sq. ft. of transverse area, i. e., 1332 CFM air delivery at 333 fpm velocity. The face openings were 22 1/8 x 24 inches upstream and 18 3/8 x 18 5/8 inches downstream. The downstream face was adapted to receive a nominal 20 x 20 x 1 inch after-filter, which for this unit was a 19 1/2 x 19 1/2 x 7/8 inch viscid impingement type air filter, manufactured by the Research Products Corporation of Madison, Wisconsin.

The unit had a filter cell 23 3/4 inches in height, 18 inches in length, and 22 1/8 inches in width, containing 51 aluminum plates spaced approximately 3/8-inch apart, presenting a total surface area of approximately 168 square feet.

The manufacturer furnished an adhesive (a water-emulsifying oil) designated as "Trion No. 368", and an applicator for oiling the collecting plates of the cell by spraying them from both the upstream

and downstream face. The after-filter was oiled in preparation for the test by immersing the filter in the oil and letting the excess drain off with the filter standing on edge for 18 hours prior to the test.

The power pack, connected to a 110-volt 60-cycle supply, was adjusted by the manufacturer's representative to a setting of 1.6 milliamperes on the power pack instrument; the ionizer and plate voltages that resulted were measured by means of a high-resistance voltmeter which was compared with an accurate electrostatic voltmeter.

3. TEST METHOD AND PROCEDURE

Efficiency determinations were made by the NBS "Dust-Spot Method" using the following aerosols: (a) outdoor air drawn through the laboratory without addition of other dust or contaminant; (b) kerosene lamp smoke; and (c) Cottrell precipitate. 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 was located in the duct about 3-1/2 ft downstream of the test unit to intermix the air discharged from it.

For these tests, the unit was installed in the test duct and 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 points of the test duct one foot upstream and eight feet downstream of the air cleaner at equal rates and passed through known areas of Whatman No. 41 filter paper. For the atmospheric air and oil lamp smoke tests, the samples were drawn at equal rates through equal areas of filter paper (3/4-inch diameter spots). The downstream sample was drawn continuously during the test; the upstream sample was drawn intermittently in a number of one-minute periods uniformly distributed over the duration of the test, aggregating one-tenth of the downstream sampling period. Under these conditions an efficiency of 90 percent would be indicated if the upstream and downstream dust-spots on the filter 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, which were determined by means of a photometer using transmitted light. The filter papers used in the upstream and downstream positions were selected to have the same light transmission readings when clean. If the opacities of the dust-spots differed, the efficiency was calculated by means of the formula

$$\text{Efficiency, percent} = 100\left(1 - \frac{t_1}{t_2} \cdot \frac{O_2}{O_1}\right) = 100 - 10\left(\frac{O_2}{O_1}\right)$$

where O_1 and O_2 were the opacities of the dust-spots upstream and downstream, respectively, and t_1 and t_2 were the aggregate times during which the upstream and downstream samples, respectively, were drawn.

For the efficiency tests with Cottrell precipitate as the aerosol, the samples upstream and downstream were drawn at equal rates and for equal times but unequal dust-spot areas were used to obtain opacities that were approximately equal. If the opacities of the dust-spots differed, the value of the efficiency was calculated by means of the formula above, with the radio $^{A_2}/_{A_1}$ substituted for the ratio $^{t_1}/t_2$, where A_2 and A_1 were the areas of the dust-spots downstream and upstream respectively.

The following procedure was employed in these tests. After the clean and oiled unit had been installed in the test duct, and all discoverable air leaks into its housing had been sealed, its input and output voltages were adjusted to recommended values by a representative of the manufacturer; (input 110 volts; ionizer 15.2 kv; plates 7.0 kv; output current 1.6 ma.). Three determinations of the efficiency of the clean unit were made at the rated velocity, using as the aerosol outdoor air drawn into the test duct through a nearby window. A determination of efficiency with the unit not energized was also made. Following these, single determinations were made, using outdoor air, at velocities 20 percent greater, and 20 percent less than the rated velocity.

Next, three efficiency determinations were made at rated velocity, using as the aerosol outdoor air with the addition of kerosene smoke generated by an open lamp flame near the inlet to the test duct.

Following these, three efficiency determinations were made at rated velocity, using as an aerosol outdoor air in which was dispersed Cottrell precipitate at a concentration of one gram per thousand cubic feet of air. 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 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. In these tests, and during the loading process, the rate of feed of the dispersant was one gram per thousand cubic feet of air. The pressure drop and the ionizer and plate voltages of the unit were recorded at intervals during the tests. The dirt-loading process was continued until about 900 grams of the lint and Cottrell precipitate mixture had been fed (i.e., 2/3 gram per CFM of unit rating).

At suitable periods as the dirt-loading process progressed, strips of transparent cellulose adhesive tape (3/4 in wide) were stretched vertically across the test duct near its axis, with the adhesive side facing upstream. Tapes were located at three positions (1) 12 inches upstream, (2) 15 inches downstream, and (3) 8 ft downstream, of the test unit; the tapes at stations (1) and (3) were in the same longitudinal positions in the test duct as the inlets to the upstream and downstream sampling tubes. The adhesive surface of such a tape captured a sample of the particulate matter in the air flowing past it, and after suitable times of exposure to the aerosol, scrutiny of the tapes by eye and with a microscope afforded considerable information as to the vertical distribution, the nature, number, and size of the particles caught at the various stations. Photographic enlargements (10X), by transmitted light were made of sections of the tapes corresponding to a position at mid-height in the test duct.

The filter cell was removed from the test unit after the tests and cleaned by means of a stream of cold water from a high pressure hose nozzle, directed at and into the cell plates from both ends of the unit. The cleanability of the after-filter was determined separately, by the same means.

4. TEST RESULTS

A summary of the test data, giving efficiencies in percent with the three aerosols, and the pressure drop of the complete unit including the after-filter, in inch W.G., at rates of air flow corresponding to various face velocities, is given in Table 1. Also, a summary of the test data obtained in the dirt-loading test conducted at the rated face velocity of 333 fpm is given in Table 2.

Photographs No. 1, 2 and 3 included in this report are 10X enlargement of the center 3/4 x 1-inch sections of cellophane tapes located at the three similarly numbered stations described under Test Method and Procedure. Tapes Nos. 2 and 3 were exposed at their respective stations simultaneously during the dirt-loading test for a period in which 124 grams of mixture were fed to the test unit. This exposure was during the interval in which the dirt-load increased from 41 to 165 grams, as shown in Table 2. Photograph No. 1 shows a tape exposed at station No. 1 for an equal length of time. After exposure the tapes were carefully removed from the test duct for photographing and microscopic study.

Throughout the tests with atmospheric air and oil lamp smoke there was no observed instance of electrical sparking or flashing in the unit audible to the ear. However, during the Cottrell and lint loading test electrical sparking or flashing occurred intermittently, the frequency increasing from about one to three times per hour at the start to about 6 or 10 times per hour at the end of the loading test.

5. SUMMARY

A. Performance

The efficiency of the air cleaner in arresting the particulate matter existent in atmospheric air drawn through the unit varied considerably with the face velocity at which it was operated, as shown in Table 1. At the rated velocity (333 fpm), the average efficiency on atmospheric air (90.2 percent), and that on oil lamp smoke (89.6 percent), were very nearly the same. The efficiencies are reported to three significant figures obtained from the test data. In reporting thus, however, it is considered desirable to point out that an uncertainty on the order of one or two percent is possible in determining efficiencies, although in these results the differences between comparable efficiency values were consistently of a lesser magnitude.

The efficiency of the unit in arresting Cottrell precipitate, initially at a high value of about 98 percent, as shown in Tables 1 and 2, decreased with dirt-loading to under 90 percent, later rising to just above 90 percent. The lower values of efficiency were obtained when the ionizer, and especially the plate, voltages had decreased considerably under their initial adjusted values. At the same time, the output current, as indicated by the power-pack milliammeter, was approximately triple the value observed when the unit was less loaded with dirt.

The pressure drop through the test unit decreased slightly during the tests reported in Table 1. It is believed that this was due to slight drainage of oil from the after-filter media to the lower retaining frame. The greater part of the pressure drop through the complete unit was due to the resistance of the after-filter. It is noted in Table 2 that in the dirt-loading test, the pressure drop of the complete unit increased by 0.140 inch W.G. for a total dirt-load of 915 grams. This rise was due chiefly to an increase in the pressure drop of the after-filter, as a result of an accumulation of cotton lint and of comparatively large particles of Cottrell precipitate on its media.

B. Cleanability

The filter was subjected to the cleaning process described under Test Method and Procedure. No difficulty was experienced in thoroughly cleaning the ionizer and collector sections of the unit, using moderate care. The after-filter was also satisfactorily cleaned using the same procedure.

C. General

On completion of the dirt-loading test, the unit was removed from the test duct and examined. The ionizer structure and bars, and the insulators, were generally coated with a moderate layer of dust and lint. The collector plates were well covered with an oily deposit of dust and lint, with a slightly thicker deposit on the plates for a distance of two or three inches from the leading edge. There was a slight amount of bridging of the plate spaces by lint fibers, such bridging being chiefly near the bottom and aft edges of the plates. Lint fibers extended downstream as much as 1/2 inch from the aft edges of the plates.

The upstream face of the after-filter showed considerable amounts of lint, deposited more heavily at the tops and bottoms of six vertical strips about 1 1/2 inches wide. The after-filter media was darkened on its upstream face by a moderate deposit of dust particles; it was evident that many of the particles were relatively large, but because fine particles are less readily observed, it cannot be stated that many fine particles were not also present. The downstream face of the after-filter was observed to be slightly darkened uniformly by dust.

The dirt (dust) deposits on the electrostatic unit, and on the after-filter, appeared to be well-saturated with oil. Microscopic examination of the cellophane tape exposed at station (2) showed a few droplets of what appeared to be oil, but the number and amount of such droplets were so small that oil entrainment in the effluent air is considered of no practical importance.

After the unit had been removed from the test duct, the downstream section of the latter was carefully swept out with a fine brush. The amount of material obtained from the duct by this sweeping was 8 grams, consisting almost wholly of fairly large dust particles, with little observable lint.

The cellophane tape samples shown in Photographs 1, 2 and 3, corresponding to stations (1), (2) and (3), respectively, indicate in a general way the performance of the complete unit at the rated ionizer and plate voltages (15.0 and 6.9 kv). The tape shown in Photograph 1 was obtained at a different time than those in Photographs 2 and 3, but was exposed for an equal length of time, and may be considered as representative for the upstream station. Photograph No. 1 shows many particles under 5 microns in actual size, and a distribution of larger particles up to a few as large as 400 microns, as well as many fibers of lint. (In these photographs, 1/16 inch corresponds to an actual dimension of about

160 microns.) Photograph No. 2, for the tape 15 inches downstream of the unit, shows many large particles up to about 300 microns in size, and a few lint fibers, but very few fine dust particles considering their number upstream of the unit. Photograph No. 3, for the tape 8 ft downstream of the unit, shows an absence of the larger particles of Photograph No. 2, which apparently settled out of the air stream, although a few fibers of lint remained.

Comparison of the numbers of particles on the upstream and downstream tapes indicates, in an obvious way, a high order of efficiency for the relatively clean unit in arresting Cottrell precipitate, as is also indicated by the earlier discoloration test results presented in Table 2. The latter results show that the relatively clean unit had a considerably higher efficiency when Cottrell precipitate was being received in the air stream than when the aerosol was outdoor air or kerosene lamp smoke. The overall efficiency of the relatively clean unit on particles of the sizes found in Cottrell precipitate appears therefore to have been better than on the finer particles in outdoor air or kerosene smoke. Nevertheless, the downstream tapes, and the deposits on the after-filter, show that many quite large particles of dust and lint escaped beyond the electrostatic unit. Whether the large particles were passed through the unit because they were not arrested at all, or were caught and later dislodged from the collector plates by electrical sparking, is not known from these tests.

As the photographs show, many large particles and some lint passed unarrested through the after-filter. Assuming that one of the functions of the after-filter is to arrest as much as possible of the material escaping the electrostatic unit, the arrestance characteristics of the after-filter are of major importance in determining the presence, in the air leaving the complete unit, of such particulate matter as is shown in the downstream tape photographs.

Table 1

Face Velocity fpm	Inlet Aerosol*	Ionizer Voltage kv	Plate Voltage kv	Output Current milliamps	Pressure Drop inch WG	Duration of Test minutes	Efficiency percent
333	A	0	0	0	0.140	20	4.6**
333	A	15.1	6.9	1.7	.140	180	90.9
333	A	15.1	7.0	1.7	.138	180	90.0
333	A	15.1	7.0	1.7	.138	180	89.8
266	A	15.2	7.0	1.6	.089	180	94.8
400	A	15.1	7.0	1.6	.189	180	84.4
333	S	15.1	7.0	1.6	.135	20	90.7
333	S	15.1	7.0	1.6	.135	20	89.6
333	S	15.1	7.0	1.6	.135	20	88.5
333	C	15.0	7.0	1.7	.135	10	97.6
333	C	15.0	7.0	1.7	.137	9	98.5
333	C	15.0	7.0	1.7	.138	10	98.5

*A = Particulate matter in atmospheric air at NBS.

S = Kerosene lamp smoke in atmospheric air.

C = Cottrell precipitate in atmospheric air (1 gram/1000 CF)

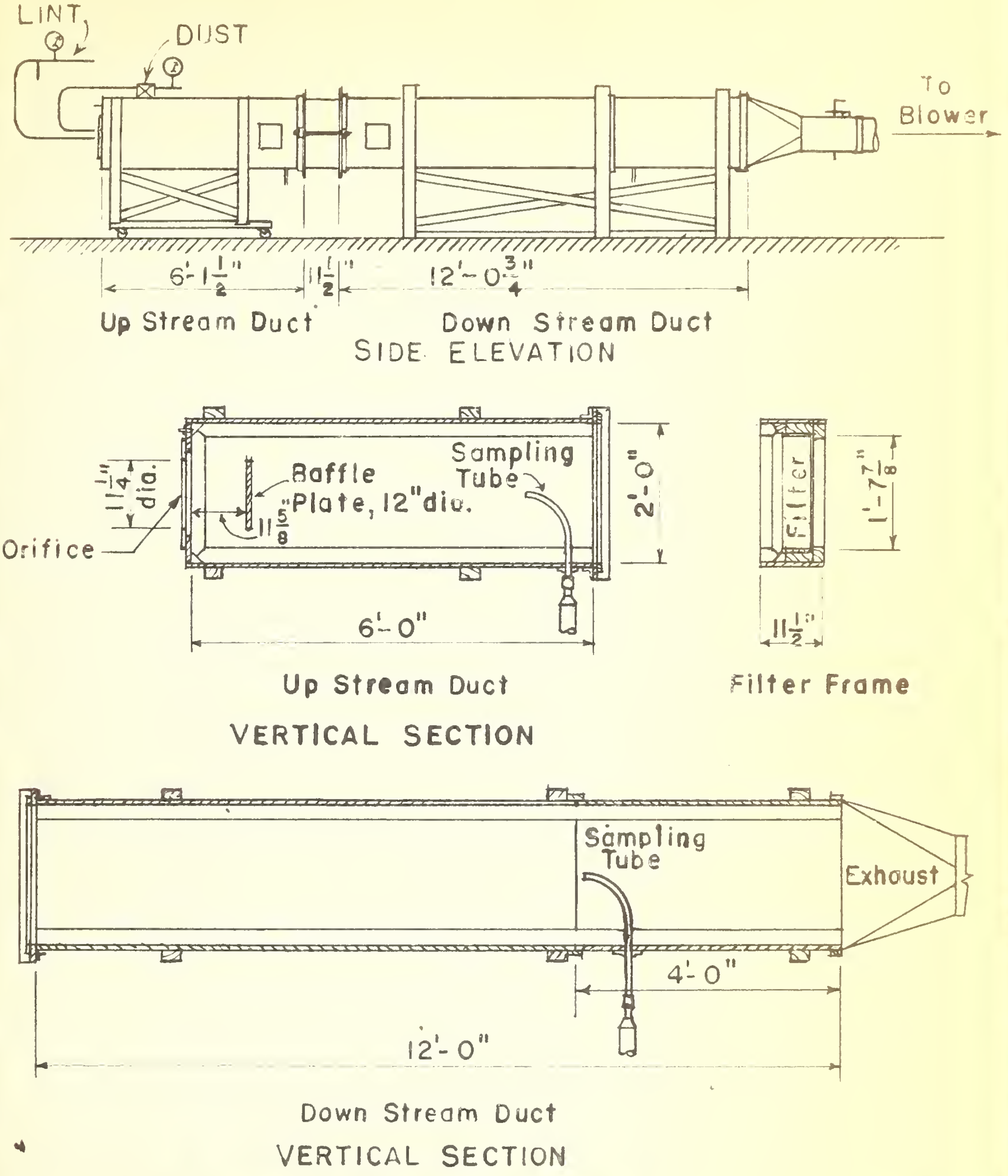
** Since unit was not energized, the efficiency was chiefly that of the after-filter.

Table 2

Face Velocity fpm	Dirt Load* grams	Ionizer Voltage kv	Plate Voltage kv	Output Current milliamps.	Pressure Drop inch WG	Efficiency** percent
333	41	15.0	7.0	1.7	0.138	98.2 (avg.)
	165	14.9	6.8	1.9	.141	94.4
	278	14.6	6.3	2.3	.142	91.9
	419	14.1	5.8	3.3	.153	90.0
	490	13.0	4.8	6.0	.170	-
	561	13.1	4.9	5.8	.183	87.3
	703	13.6	5.2	5.5	.212	87.4
	844	13.5	4.8	5.4	.257	90.1
	900	13.5	5.0	5.5	.273	90.8
	915	13.3	5.0	5.0	.278	90.4

*Average mixture: 3.9% lint, 96.1% Cottrell precipitate by weight.

**Efficiency determined with 100% Cottrell precipitate.



Air Filter Test Apparatus

Figure 1

Photograph No. 1

Photograph No. 2

Photograph No. 3

THE NATIONAL BUREAU OF STANDARDS

Functions and Activities

The functions of the National Bureau of Standards are set forth in the Act of Congress, March 3, 1901, as amended by Congress in Public Law 619, 1950. These include the development and maintenance of the national standards of measurement and the provision of means and methods for making measurements consistent with these standards; the determination of physical constants and properties of materials; the development of methods and instruments for testing materials, devices, and structures; advisory services to Government Agencies on scientific and technical problems; invention and development of devices to serve special needs of the Government; and the development of standard practices, codes, and specifications. The work includes basic and applied research, development, engineering, instrumentation, testing, evaluation, calibration services, and various consultation and information services. A major portion of the Bureau's work is performed for other Government Agencies, particularly the Department of Defense and the Atomic Energy Commission. The scope of activities is suggested by the listing of divisions and sections on the inside of the front cover.

Reports and Publications

The results of the Bureau's work take the form of either actual equipment and devices or published papers and reports. Reports are issued to the sponsoring agency of a particular project or program. Published papers appear either in the Bureau's own series of publications or in the journals of professional and scientific societies. The Bureau itself publishes three monthly periodicals, available from the Government Printing Office: The Journal of Research, which presents complete papers reporting technical investigations; the Technical News Bulletin, which presents summary and preliminary reports on work in progress; and Basic Radio Propagation Predictions, which provides data for determining the best frequencies to use for radio communications throughout the world. There are also five series of nonperiodical publications: The Applied Mathematics Series, Circulars, Handbooks, Building Materials and Structures Reports, and Miscellaneous Publications.

Information on the Bureau's publications can be found in NBS Circular 460, Publications of the National Bureau of Standards ($1.25) and its Supplement ($0.75), available from the Superintendent of Documents, Government Printing Office. Inquiries regarding the Bureau's reports and publications should be addressed to the Office of Scientific Publications, National Bureau of Standards, Washington 25, D. C.


NBS