NATIONAL BUREAU OF STANDARDS REPORT

3259

PERFORMANCE TESTS OF A WESTINGHOUSE
PRECIPITRON ELECTRONIC AIR CLEANER

by

Henry E. Robinson
Thomas W. Watson

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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NBS PROJECT **NBS REPORT**

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PERFORMANCE TESTS OF A WESTINGHOUSE
PRECIPITRON ELECTRONIC AIR CLEANER
TYPE FA-22

by
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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 WESTINGHOUSE TYPE FA-22 PRECIPITRON ELECTRONIC AIR CLEANER

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 the Westinghouse Electric Corporation, Sturtevant Division, Hyde Park, Boston 36, Massachusetts, and was of the electrostatic type. It was identified as a Westinghouse Precipitron Type FA-22 with two type CA-12 cells, Style 1559587, rated velocity 333 feet per minute (1332 CFM total). The power pack had the following nameplate data:

Precipitron Power Pack

Type M	Style No. 1560601	
Volts 115	Amps 0.8	Watts 90
Cycles 60-50	Phase 1	
Ionizer volts 12,800	Plate 5,500	

The test unit had a housing with actual outside dimensions of 24x24-1/4 inches and was 26-1/2 inches long, and was rated as having 4 sq. ft. of transverse area, i.e., 1332 CFM air delivery at 333 fpm velocity. The upstream and downstream faces had flanges 30 inches square matching those of the duct of the test apparatus. The face openings were 20x22-1/2 inches upstream and 20x20-1/2 inches downstream. The downstream face was adapted to receive a nominal 24x24x1 inch after-filter, which for this unit was a 24x23-1/16x1 inch

"A-Lum-O-Aire" aluminum wool (dry type) air filter manufactured by the Carey Electronics Engineering Co. of Springfield, Ohio.

There were two similar filter cells in the housing, each having actual outside dimensions of 11-7/8 inches in height, 15 inches in length, and 22 inches in width, and each containing 61 aluminum plates spaced approximately 5/16-inch apart, presenting a total surface area of approximately 120 square feet for each cell. The manufacturer supplied a piece of 0.025 inch aluminum angle 1-1/2x1/2x22 inches in size, which was inserted beneath and around the downstream bottom edge of the top cell, with the 1-1/4 inch dimension parallel to the direction of air flow, for the purpose of preventing oil blow-off from the upper plates.

The manufacturer furnished an adhesive (a water-emulsifying oil) designated as "Precipitron Adhesive T-675", and an applicator for oiling the collecting plates of the cells by spraying them from the upstream face. In accordance with the request of the manufacturer's representative, the "A-Lum-O-Aire" after-filter was oiled in preparation for the test by immersing the filter in an oil and letting excess oil drain off with the filter standing on edge for 18 hours prior to the test. The adhesive supplied by Westinghouse for spraying the collecting plates was not sufficient in quantity for immersing the after-filter, so a suitable water-emulsifying oil was selected for this purpose from a group of oils that had been submitted by manufacturers for oiling viscid impingement air filters.

The power pack, connected to a 115-volt 60-cycle supply, was adjusted by the manufacturer's representative to recommended settings prior to the tests; 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

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

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 ratio 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 115 volts; ionizer 13.2 kv; plates 6.1 kv). 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 open 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 inch 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.

One of the filter cells was removed from the test unit 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 enlargements of the center 3/4x1-inch section of each of the cellophane tapes located at the three similarly-numbered stations described under Test Method and Procedure. The tapes 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. 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 only one 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 8 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 (92.2 percent), and that on oil lamp smoke (91.8 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 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 dense aluminum wool 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 0.057 inch W.G. for a total dirt-load of 887 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 cells were 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

Upon completion of the dirt-loading test, the unit was removed from the test duct and examined. Dirt deposits were heaviest on the ionizer bars, and on the upstream edges and first 3 or 4 inches of the collector plates, the thickness of the deposits being up to about 1/32 inch. A continuous, but thinner, layer of dirt was deposited over the remaining area of the collector plates, extending to the after edge. Considerable bridging of lint fibers from one collector plate to another, spanning the gap between them, was observed; such bridging appeared to be most extensive in alternate plate spacings. Some lint fibers were observed to extend downstream for as much as 1/2 inch from the aft edges of the plates. The dirt (dust) deposits on the plates appeared to be well saturated with oil; there was little or no perceptible difference in amount of deposit on the various collector plates, except for the difference mentioned in regard to lint bridging.

The upstream face of the after-filter showed considerable amounts of lint, deposited more heavily over certain areas or patches of the face. The after-filter media was darkened by a light deposit of dust; it was evident that many of the dust 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 cellophane tape samples obtained at stations (1), (2) and (3), as shown in Photographs No. 1, 2 and 3, respectively, indicate in a general way the performance of the complete unit. 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 several large particles up to about 150 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 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 unit in arresting Cottrell precipitate, as is also indicated by the discoloration test results presented in Table 2. The latter results show a considerably higher efficiency for the unit 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 unit on particles of the sizes found in Cottrell precipitate appears therefore to be 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.

No evidence of oil droplet entrainment in the effluent air was observed, either by microscopic examination of the downstream cellophane tapes, or by examination of the test duct downstream of the unit after the tests.

Table 1

Face Velocity fpm	Inlet Aerosol*	Ionizer Voltage kv	Plate Voltage kv	Pressure Drop inch WG	Duration of Test Minutes	Efficiency percent
333	A	0	0	0.145	15	6.3**
333	A	13.2	6.1	.145	120	92.3
333	A	13.2	6.2	.142	180	92.1
333	A	13.3	6.2	.142	180	92.3
266	A	13.2	6.1	.093	180	95.5
400	A	13.3	6.2	.190	180	88.0
333	S	13.3	6.2	.138	30	91.9
333	S	13.3	6.2	.138	20	91.9
333	S	13.3	6.2	.138	20	91.6
333	C	13.3	6.2	.139	8	98.3
333	C	13.3	6.2	.139	10	98.5
333	C	13.3	6.2	.139	10	98.6

* 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)

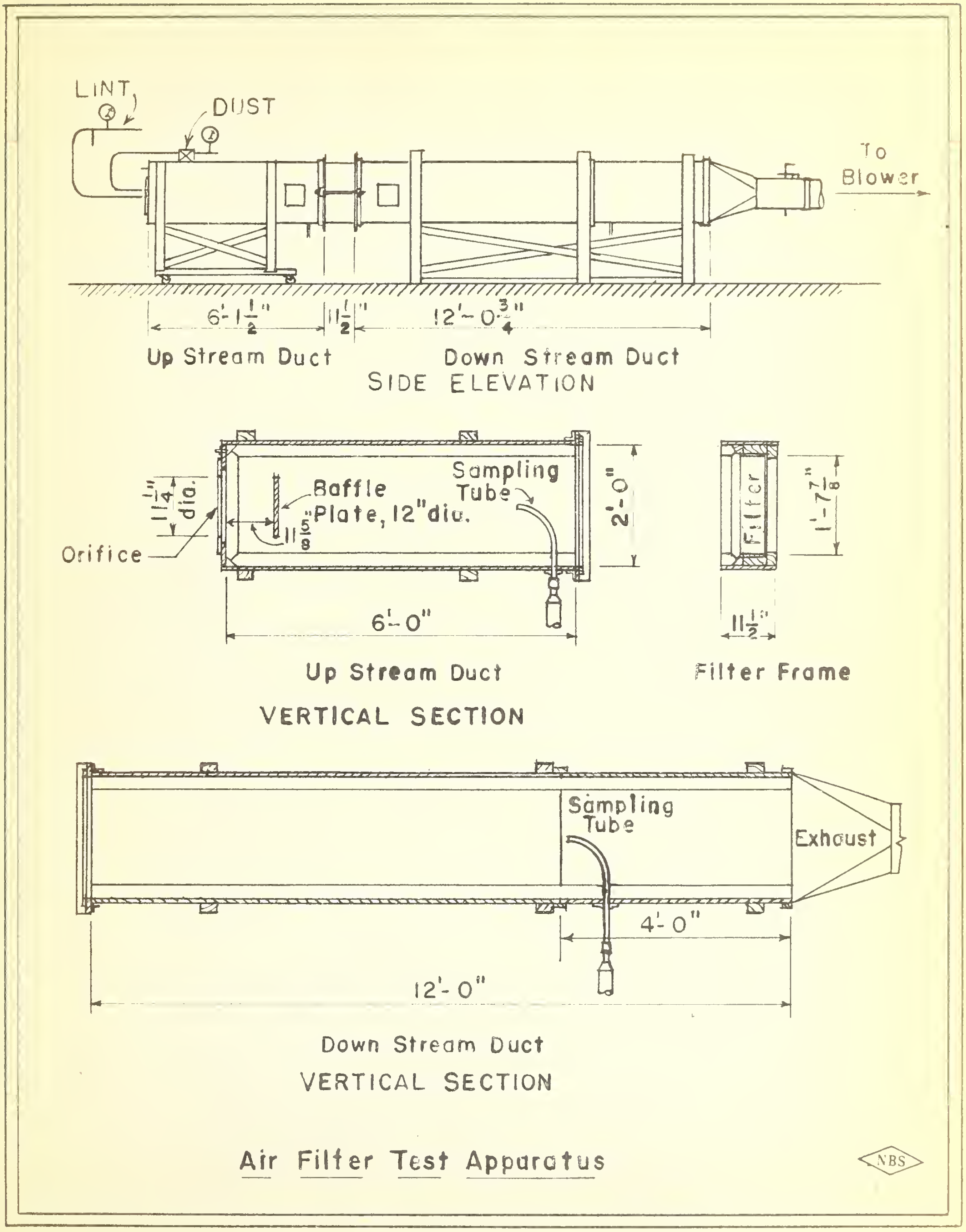
** Since unit was not energized, the efficiency was chiefly that of the after-filter.

Table 2

Face Velocity fpm	Dirt Load* grams	Ionizer Voltage kv	Plate Voltage kv	Pressure Drop inch W.G.	Efficiency** percent
333	41	13.5	6.2	0.139	98.5 (avg.)
	165	13.5	6.3	.150	97.3
	321	-	-	.153	98.5
	448	13.4	6.2	.158	98.8
	561	-	-	.166	98.0
	731	-	-	.181	97.9
	872	13.0	6.0	.196	97.2
	887	13.3	6.2	.196	97.9

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

** Efficiency determined with 100% Cottrell precipitate.



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

Photograph No. 1

Photograph No. 2

Photograph No. 3

THE NATIONAL BUREAU OF STANDARDS

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