NATIONAL BUREAU OF STANDARDS REPORT

6387

A STUDY OF
STANDARD TEST PROCEDURES FOR SOILING ACOUSTIC TILE

by

Selden D. Cole
and
Paul R. Achenbach

Report to
Engineering Division
General Services Administration
Washington, D. C.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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to

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NBS

U. S. DEPARTMENT OF COMMERCE

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1. Introduction

After several discussions between members of the Design and Construction Division, Public Buildings Service, and members of the staff of the National Bureau of Standards, the study of the mechanisms by which acoustic tile become soiled with air-borne particulates was reactivated for the purpose of developing a standard test procedure for comparison of the susceptibility of various commercial products to soiling.

The following tasks were envisioned as necessary steps in developing such a standard test procedure:

1. Modify the existing soiling enclosure to provide an octagon shape of the interior space and insulate the walls of the test structure.

2. Rebuild the dust injector and blower system to permit standardization of air flow rate and dust loading of the air.

3. Select or develop a standard air contaminant.

4. Select or determine standard air delivery rates and velocities, and length of exposure.

5. Determine reproducibility of the results during repetitive tests, and the resolution of the methods used.

6. Evaluate the usefulness of the methods proposed by measuring the soiling characteristics of white plaster and six categories of commercial acoustic tile when exposed to the mechanisms of impingement, filtration, and thermal precipitation.

A study of the effect of repetitive painting of acoustic tile on its sound absorption coefficient was included in the program even though this effect is only indirectly related to the remainder of the project.

Earlier work on the apparatus required to produce controlled soiling of such surfaces indicated that difficulties might be encountered in obtaining satisfactory dispersal of the test dust in air and in producing uniform soiling for the eight mounting stations during any given test and reproducible results during successive tests under identical test procedures.

2. Apparatus Development

The development of a standard test procedure for measuring the susceptibility of acoustic tile to dust soiling involved modification of existing test equipment, and the design and construction of some new components for the apparatus. Modification and development of apparatus was carried out primarily on the test enclosure, tile mounting, dust dispersal mechanism, the equipment for discoloration measurement, and the components for aerosol impingement on the test specimens.

2.1 Test Enclosure

The test apparatus that had been used for previous studies of soiling of acoustic tile was modified in two respects. Whereas the plywood enclosure for soiling tile specimens had been square in plan view, it was changed to an octagon shape so the geometrical relationship between each of the eight tile specimens and the adjacent vertical walls would be identical. The walls of the enclosure were insulated with two inches of glass fiber blanket to provide an approach to isothermal conditions inside and to minimize convection currents at the surrounding walls. The enclosure was carefully sealed against air leakage to eliminate stray air currents during the soiling procedures.

The enclosure, Fig. 1, was 5' x 5' x 6' in size with the top one foot sealed off as a plenum chamber from the bottom five feet. The top deck of the plenum served as a base for a centrifugal exhaust blower used to create a negative pressure within the plenum relative to the space in the lower part of the box and/or the outside atmosphere. An inclined manometer indicated the differential pressure through pressure taps. An access door, as seen in Fig. 1, in one side of the box

ACOUSTIC TILE TEST [illegible]

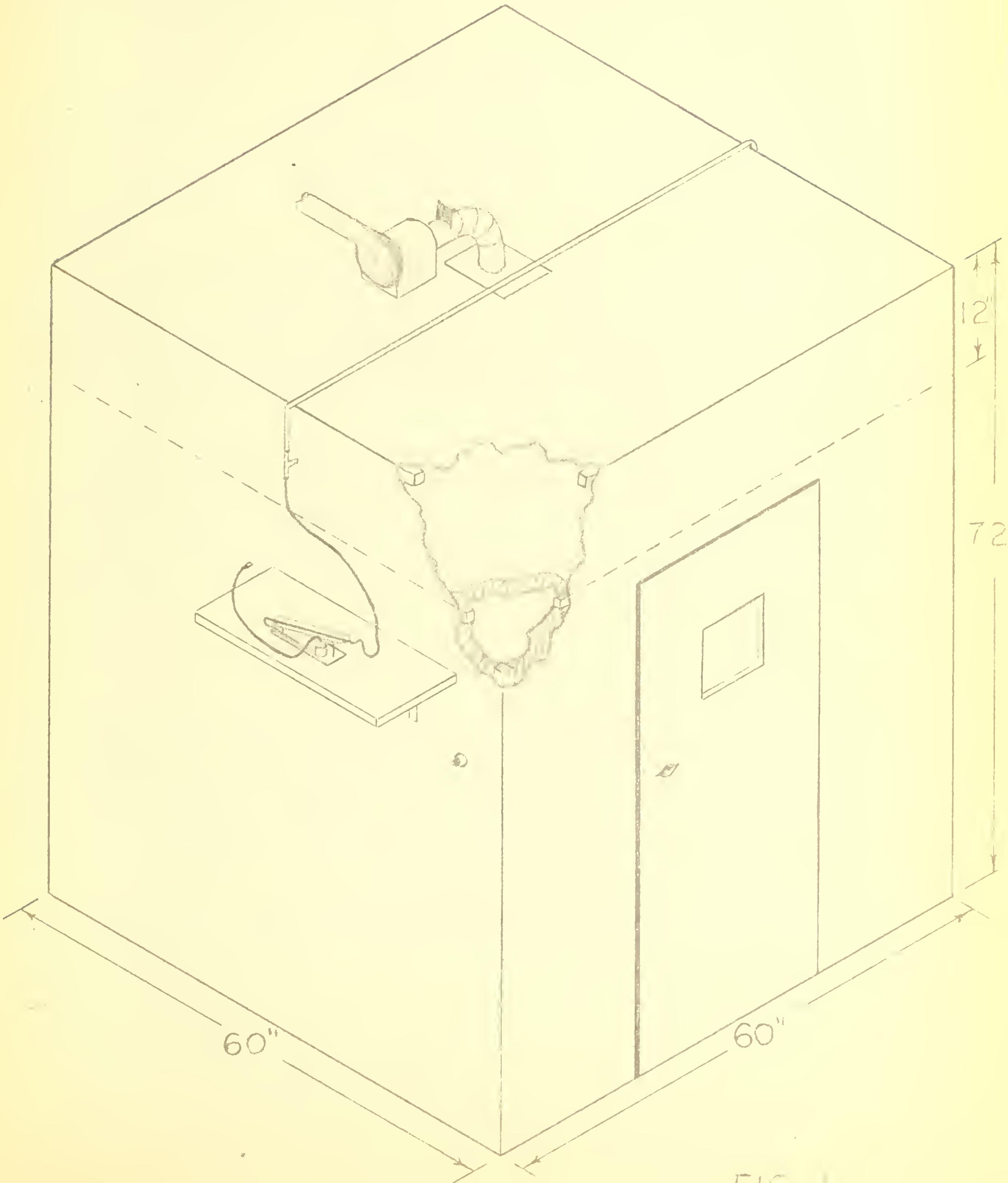

FIG. 1

opened into the airtight chamber. The ceiling of the chamber contained eight openings, each eleven inches square, over which the acoustic tile specimens were placed for test. A small round opening at the center of the ceiling served as a pressure relief or air exhaust opening.

2.2 Tile Mounting

Initially, the tile specimens were arranged in the pattern shown in Fig. 2. The eight specimens were placed in a symmetrical pattern with the outer edge of the tile located about 1 1/2 inches from the adjacent inner wall surface of the enclosure.

It was impossible to obtain a uniform discoloration of the specimens in a radial direction with this tile arrangement. The discoloration pattern was the same on each tile but the discoloration increased with distance from the wall of the enclosure. It was thought that the close proximity of the specimens to the enclosure walls interfered with the pattern of air motion and affected the dust deposit at the outer edge of the tile.

Subsequently, the entire ceiling of the enclosure was fitted with acoustic tile to determine the area in which the discoloration would be uniform. A number of such tests indicated that eight specimens arranged in the pattern shown in Fig. 3 would be uniformly soiled, so the original ceiling of the enclosure was replaced with another incorporating this pattern of openings.

2.3 Dust Dispersal

The test dust was introduced into the enclosure through a tube penetrating the sidewall about 20 inches above the floor. The dust was picked up from a circular groove in a turntable by means of an aspirator using compressed air. The amount of dust deposited in the groove could be varied and the turntable was rotated by a variable speed drive. The air pressure applied to the aspirator was regulated with a valve.

A non-oily carbon black made from acetylene was used as the test dust. Some experiments were conducted with bone char as the test dust, but it did not adhere well to the tile surfaces.

CEILING AT PLENUM

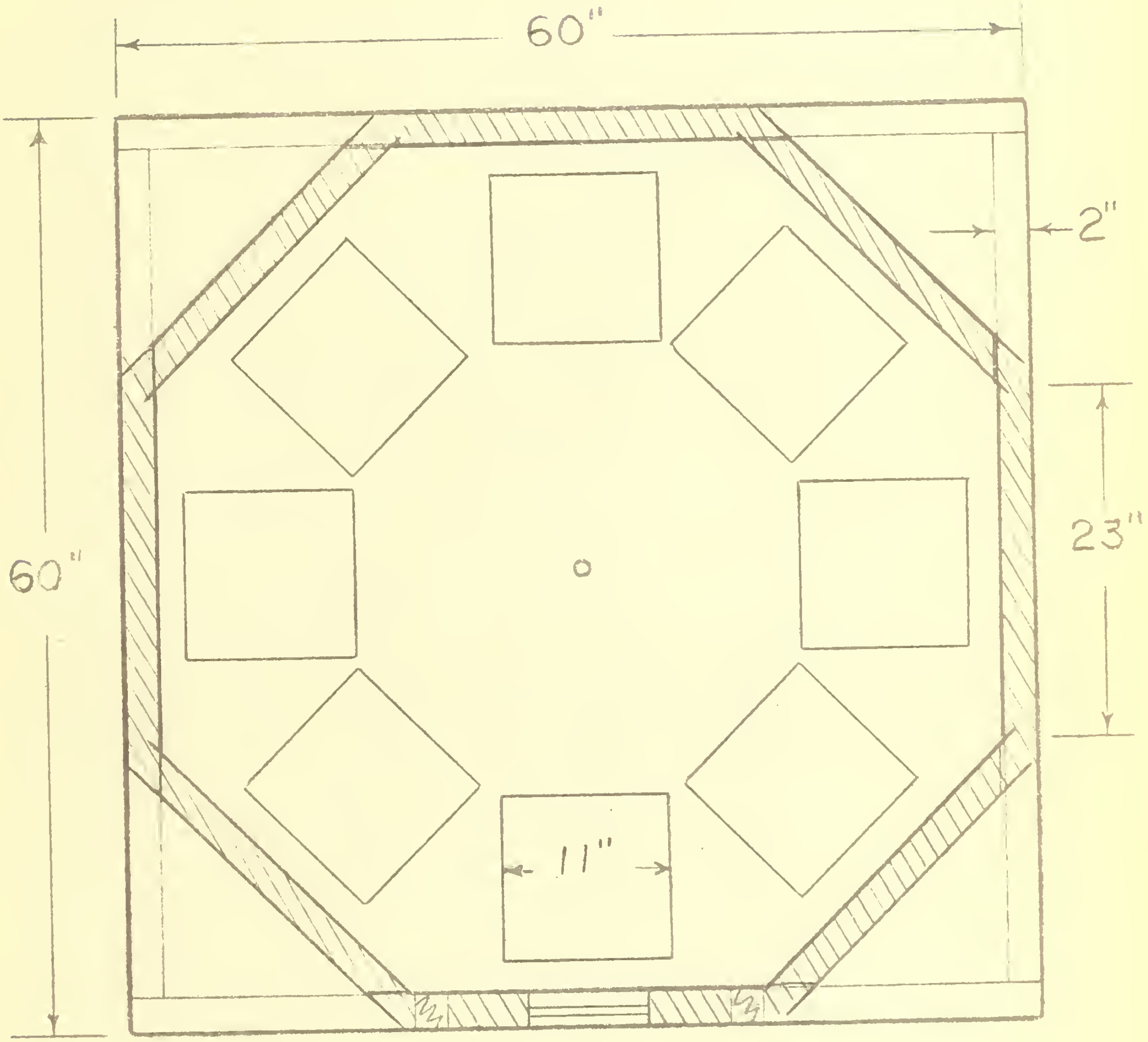

FIG. 2.

CEILING AT PLENUM

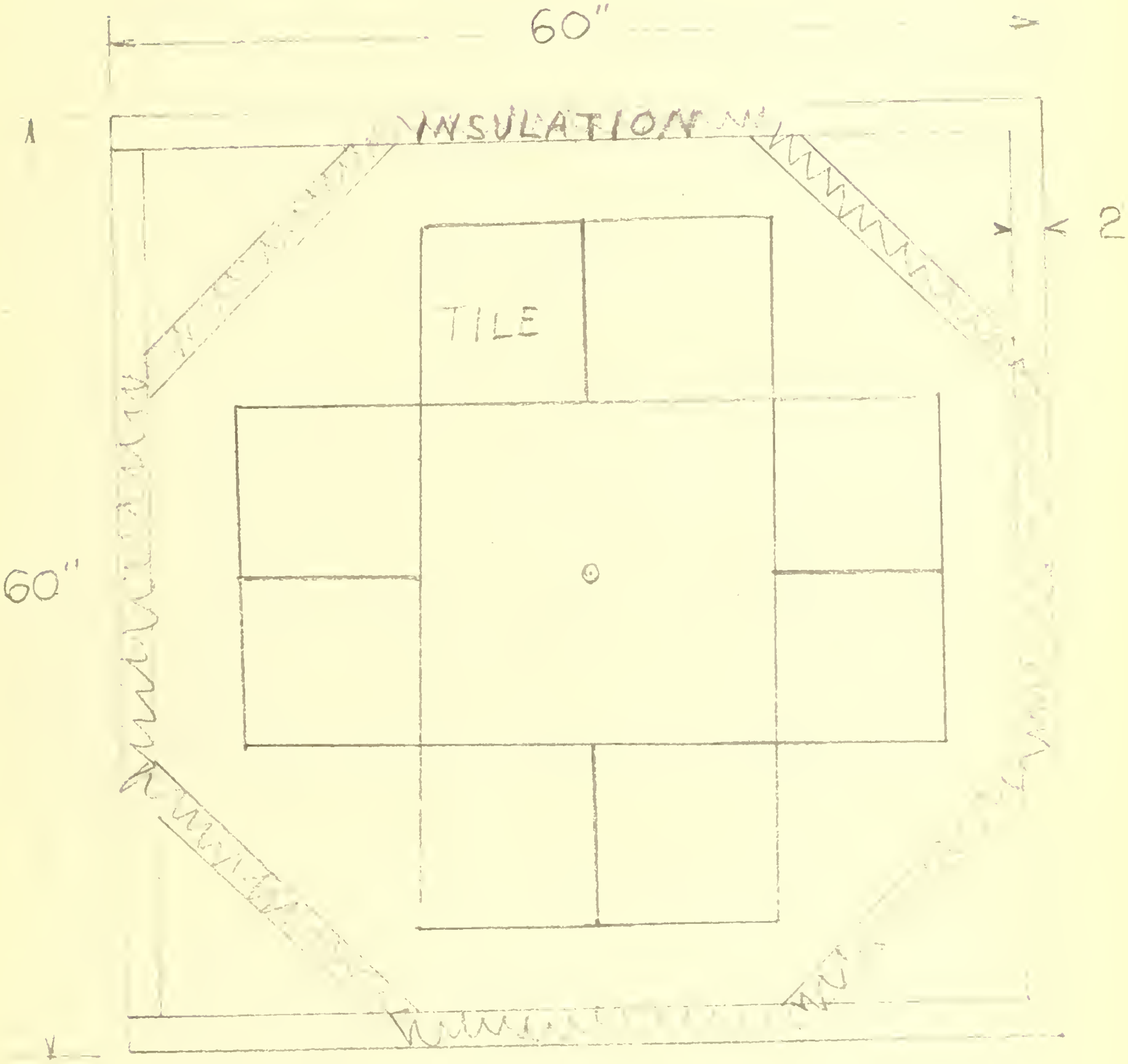

FIG. 3.

Consequently, an undesirably long operating time was required to obtain an appreciable discoloration with bone char.

2.4 Discoloration Measurement

The degree of discoloration of the acoustic tiles was measured with a photoelectric reflectance meter commercially known as "Photovolt." The meter had a two-inch scanning spot diameter and was used with a green tristimulus filter. Measurements with the green tristimulus filter served for determining "luminous apparent reflectance" or "whiteness." The reflectance of a surface as measured by this meter is its reflectance expressed in percent of the reflectance of magnesium oxide. The instrument is adjusted so that the 100 mark on the scale corresponds to the reflectance of magnesium oxide. Therefore, all readings obtained with the reflection meter are a percent reading of the reflectance of magnesium oxide.

A jig was constructed for holding the tile specimens while measurements were made of discoloration with the photovoltmeter. The jig located the tile specimen precisely with respect to a plastic cover plate containing three holes through which the viewing aperture of the photovoltmeter was inserted for reflectance measurements. The three holes were located along a diagonal through the center line of the specimen at an angle of about 30 degrees with the base. One hole was at the center of the tile and the other two were on opposite sides of the center hole along the diagonal line. The holes were non-overlapping and the field of reflectance measurement in the three positions did not overlap. Fig. 4 shows the jig and photovoltmeter with the viewing element located in one of the three holes in the cover of the jig.

2.5 Dust Impingement Apparatus

Fig. 5 and 6 show the rotating mechanism and distribution box designed for the impingement method of soiling the acoustic tiles. Fig. 5 shows the motor, the reduction gear box, and belt drive of the rotating arm apparatus. The upright member of the rotating arm was fitted with a pair of slip rings to conduct the electric current to the blower motor in the distribution box. This rotating arm was mounted at the center of the test enclosure.

Fig. 4

ROTATING APPARATUS FOR IMPINGEMENT

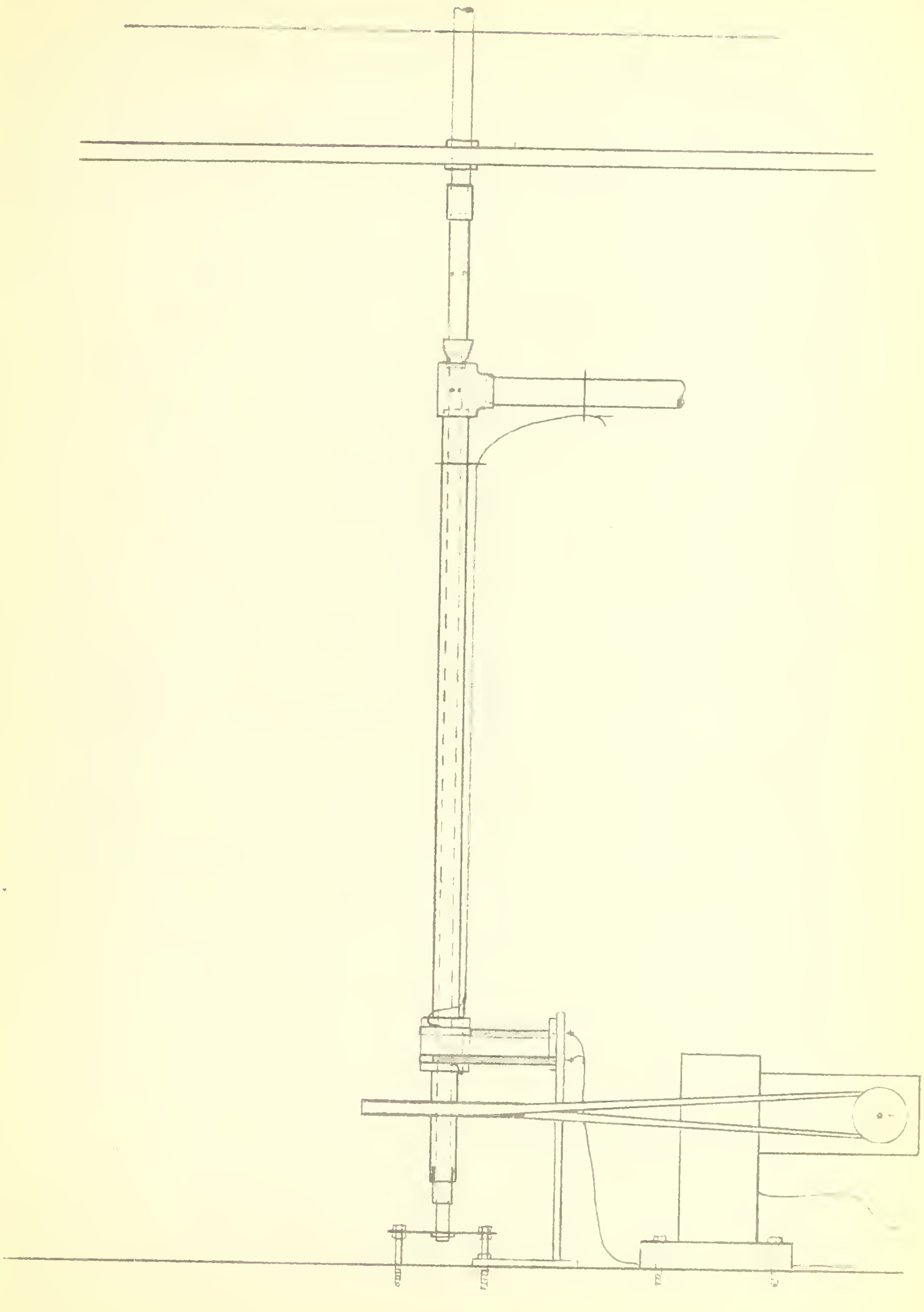

FIG. 5.

IMPINGEMENT DISTRIBUTION BOX

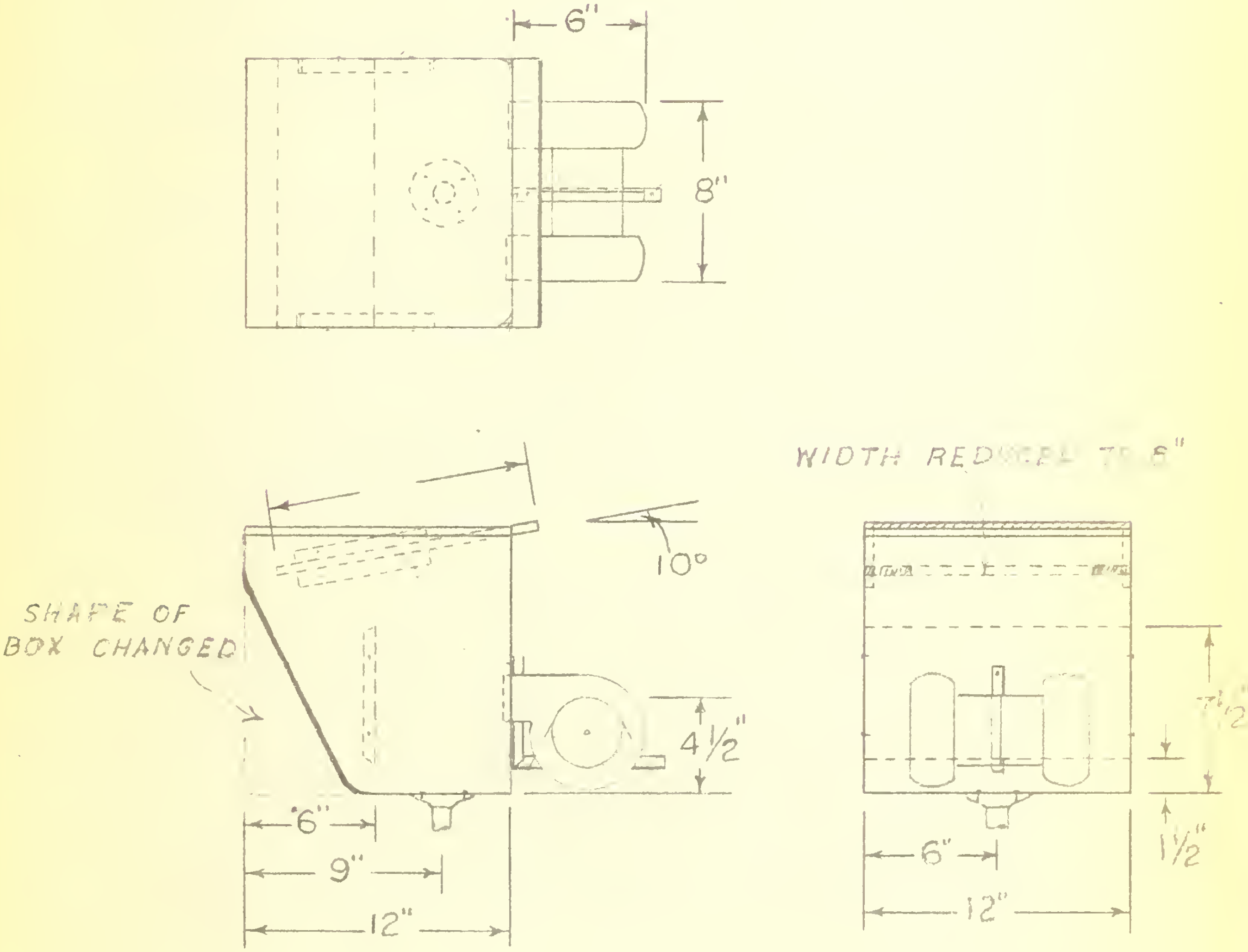

FIG 6.

Fig. 6 is a dust distribution box designed to deliver a controlled jet of dusty air toward the test specimens. It was built to deliver a stream of well-mixed air and carbon black through a short duct of high width to depth ratio such that the dimensions, direction, and velocity of the stream could be controlled. The aerosol could be picked up directly from the test enclosure through the side inlet openings of the blower, or the test dust could be injected directly into the distribution box through the rotating arm. The distribution box could be supported on the rotating arm at any height, the angle of impingement of the aerosol stream was adjustable, and the width of the impingement duct or slot could be changed to form any desired width of dust pattern on the specimens.

The distribution box shown in Fig. 6 was originally built in a cubical shape. However, it was found that carbon black was deposited in the lower corner of the box opposite the blower discharge. This deposition was greater during the first test made after cleaning the box than during successive tests under the same conditions. Thus, when one test was made after another under the same conditions, the discoloration produced on the tile became progressively greater when clean tiles were used for **each** test. It was necessary, therefore, to provide a curved side for the distribution box opposite the discharge of the blows to prevent this dust deposit. The revised shape of the distribution box is shown in Fig. 6.

3. Study of Test Procedures

The nature of this problem indicated trial and error experiment and the use of judgment in developing test procedures that might serve as a standard for soiling tests of acoustic tile. This process led to a reasonably good procedure for attaining repetitive results under impingement conditions, but a much lower degree of success for the filtration process. The project had to be terminated for lack of funds before much experimentation could be carried out on the thermal precipitation process. The studies made of test procedures are described in the following sections of the report.

3.1 Dust Impingement

Under impingement conditions the principal problem was to obtain repetitive results of equal and uniform discoloration of the test specimens. The following elements of the test procedure were studied to arrive at a satisfactory method for measuring comparative discoloration by impingement: (1) the amount of carbon black needed to produce enough discoloration to minimize the percentage error in successive tests, (2) the best positioning of the tile specimens on the ceiling of the enclosure, (3) the optimum distance between the outlet of the rotating impingement box and the tile, (4) the angle and velocity of impingement of the aerosol, (5) the place of injection of the carbon black into the enclosure and the duration of the injection period, and (6) the design of the impingement distribution box that would inhibit deposition of carbon black inside the box.

These problems were resolved by experiment to attain the desired control of one variable at a time. Different weights of carbon black were used to determine the amount necessary to give a reduction in reflectance of 10 to 25 percent. The ceiling of the enclosure was completely covered with tile to determine the best location of the test specimens. The termination of the aerosol injection tube within the enclosure was varied until the greatest uniformity of discoloration was attained. Several angles and velocities of impingement of the aerosol on the specimens were used. The shape of the distribution box was redesigned one or more times to eliminate deposition of carbon black inside the box during the test. The modifications to the apparatus are described in the preceding sections of this report.

A procedure of introducing 40 grams of carbon black in two batches of 20 grams each, using 1 1/2 hours injection time for each batch and a one-hour interval between injection periods, provided a satisfactory soiling rate. The nozzle of the rotating box was positioned about 17 in. from the tile surface, the impingement angle was almost 90 degrees, and the aerosol velocity at the nozzle outlet was about 1000 ft/min. The eight tile specimens were arranged as shown in Fig. 3. When all of these detailed procedures were followed the dust distribution on each tile was essentially the same and the reduction of reflectance of eight specimens of the same tile was equal within

about one percent reflectance. In successive tests using the same procedure the reflectance was reduced more in a given test than in the preceding one by about 1.7 percent reflectance in a total of about 15 percent change.

3.2 Dust Filtration

Many methods were explored for providing a dusty atmosphere in the enclosure without significant air currents at the ceiling level where the tile specimens were located so deposition could occur under the sole influence of a slight pressure difference across the tile. In all of these tests the carbon black was injected into the enclosure with an air jet. Small propeller fans of two different diameters were used near the floor of the enclosure forcing the air upward and downward in different tests to attain a uniformly dusty atmosphere in the enclosure with low air motion at the ceiling level. Several designs of housing were placed around the fans in an effort to attain a uniform deposit on all eight specimens. During these exploratory tests it was not difficult to attain substantially equal discoloration on eight identical specimens, but the discoloration was shaded from lighter to darker toward the inner edge of the tile. Screens and sheet metal baffles were used in attempts to attain uniform radial distribution of the carbon black deposit.

The test procedure most often used for these exploratory tests consisted of introducing 20 grams of soiling material into the chamber over a period of one hour followed by a one-hour settling period before the door of the enclosure was opened for removing the tile. This amount of carbon black produced a reduction in reflectance ranging from about five percent under one set of conditions to about 55 percent under different conditions.

During all of these tests the discoloration of the specimens was greater toward the inner edge of the tile. It was concluded that the specimens were mounted too near the vertical sidewalls of the enclosure, the distance from the outer edge of the tile to the wall being only 1 1/2 inches for the mounting pattern shown in Fig. 2. The project was terminated before tests could be made under filtration conditions with the revised mounting pattern illustrated in Fig. 3.

3.3 Thermal Precipitation

Four test runs were made during which the air in the test enclosure was heated and the impingement apparatus was not operated. Low-wattage, lead-sheathed heating cable was distributed on the floor of the enclosure to provide a reasonably uniform heating of the air from a low level. A different amount of heat was used for each test. However, the entire space and the insulated wall and ceiling surface were at nearly the same temperature so little discoloration was observed. Based on previous studies, it is believed that a temperature difference between the air and tile surface would have to exist before significant thermal precipitation would be observed.

3.4 Effect of Painting on Sound Absorption

The horn coupler, under development by the Sound Section of the National Bureau of Standards for measurement of the sound absorption of acoustic tile and for studying the effect of repeated painting on absorptivity, did not produce the flat wave front required for such tests and was abandoned. The alternative method was the use of a 10 ft by 10 ft panel in the sound chamber. However, this method appeared to be too expensive for this study, so a new approach to this objective is needed.

4. Soiling Tests of Commercial Tile

A series of tests were made with the impingement apparatus developed during this study to determine the comparative soiling characteristics of 19 different types of acoustic tile and a specimen of white plaster prepared at this Bureau. The 19 types of acoustic tile were stock materials supplied by 7 manufacturers.

The test specimens were classified in six broad categories by representatives of the Acoustic Materials Association, as follows:

Type I, Regular Perforated Cellulose Fiber Tile. Specimens 1-4 inc.
Type II, Textured or Fissured Cellulose Tile or Board. Specimens 5 & 6.
Type III, Perforated Mineral Tile. Specimens 7-9 inc.
Type IV, Fissured Mineral Fiber Tile. Specimens 10-12 inc.
Type V, Textured or Smooth Mineral Fiber Tile or Board. Specimens 13-16 inc.
Type VI, Perforated Metal Pans with Mineral Fiber Pads. Specimens 17-19 inc.

A twentieth specimen consisted of white plaster over brown scratch coat on metal lath, 3/4 in. thick.

Eight specimens were attached to the ceiling of the test enclosure at one time and subjected to the test procedure described earlier in this report for the impingement conditions. One of the eight specimens in each case was a control, taken from a group of identical specimens specially selected for uniformity. The control specimens were used in each group as a basis for establishing whether or not substantially equal soiling conditions had existed in successive tests so all the test results could be compared.

The reflectance of three areas on each specimen, as determined by the construction of the measuring jig, was measured with the photovoltmeter initially and at the end of the soiling test to determine the decrease in reflectance.

4.1 Test Results

Table 1 summarizes the initial and final reflectance values at the center of each specimen, and the average of the initial and final values at the three stations of observation along a diagonal line on each tile. The table also shows the change in reflectance during the tests expressed as a difference between initial and final values and as a ratio of final to initial reflectances.

It will be noted in Table 1 that the initial reflectance of the 19 specimens ranged from 66.5 to 79.5 with only two having higher reflectance values than the white plaster specimen. Initially, the average of the reflectance at the three stations of measurement differed from that at the center by a few tenths of a percent in all cases except for specimens 11 and 15. The random fissures in some of the specimens might have caused a variation in the observed reflectance in different areas depending on the number and depth of the fissures covered by the viewing head.

At the conclusion of the impingement tests, the average of the reflectances at the three stations of measurement differed from that at the center by less than one percent in all cases except for specimens 12, 13 and 18.

Table 1

Reflectance of Acoustic Tile Before and After Impingement Soiling

Type No.	Specimen No.	Center Station Initial	Center Station Final	Average of 3 Stations Initial	Average of 3 Stations Final	Diff. Between Initial & Final Center	Diff. Between Initial & Final 3 Stations	Ratio of Final to Initial Center	Ratio of Final to Initial 3 Stations
I	1	71.5	46.5	71.6	46.3	25.0	25.3	65.0	64.7
I	2	68.5	49.0	68.8	49.1	19.5	19.7	71.5	71.4
I	3	68.5	43.5	68.5	43.6	25.0	24.9	63.6	63.7
I	4	67.0	48.5	67.3	48.3	18.5	19.0	72.4	71.8
II	5	74.0	52.5	74.3	53.5	21.5	20.8	71.0	72.0
II	6	68.0	42.5	67.6	42.5	25.5	25.1	62.5	62.9
III	7	71.0	51.0	71.1	51.3	20.0	19.8	71.8	72.2
III	8	73.5	47.5	73.6	47.5	26.0	26.1	64.7	64.6
III	9	77.0	64.5	76.8	63.5	12.5	13.3	83.8	82.7
IV	10	72.5	46.5	73.0	46.8	26.0	26.2	64.1	64.1
IV	11	71.5	46.0	73.6	48.5	25.5	25.1	64.4	65.9
IV	12	76.5	47.0	77.0	46.0	29.5	31.0	61.5	59.8
V	13	66.5	46.0	65.8	43.8	20.5	22.0	69.2	66.6
V	14	79.5	69.5	79.5	68.6	10.0	10.9	87.4	86.3
V	15	76.5	63.0	75.5	61.3	13.5	14.2	82.4	81.2
V	16	66.5	51.5	65.8	50.0	15.0	15.8	77.5	76.0
VI	17	72.0	59.0	72.0	58.6	13.0	13.4	82.0	81.4
VI	18	69.5	57.5	68.8	58.8	12.0	10.0	82.7	85.5
VI	19	72.0	59.0	72.0	59.5	13.0	12.5	82.0	82.7
Plaster	20	76.5	58.0	76.5	58.0	18.5	18.5	75.8	75.8
Control I		78.5	68.0	79.1	67.6	10.5	11.5	86.7	85.5
Control II		80.5	69.0	80.0	68.5	11.5	11.5	87.3	85.7
Control III		79.5	69.0	79.6	68.8	10.5	10.8	86.7	86.5

The change in reflectance of the three specimens used for controls in the three successive tests differed by a maximum of one percent in a total change of about 11 percent. This agreement indicates that all of the observed changes in reflectance on the 19 commercial tiles and the plaster specimen are comparative within a tolerance of about one percent. This agreement in the results on the three control specimens also indicates the ability of the test method to produce identical results during repetitive impingement tests.

Table 1 shows that tile specimen 14 had the lowest change in reflectance of all the specimens and also the highest ratio of final to initial values. Seven of the specimens exhibited a change in reflectance ranging from 2 1/2 to 3 times that of specimen 14. The three specimens of Type VI had the lowest average decrease in reflectance of any of the types taken as a group. However, the decreases in reflectance of specimens 9, 14, and 15 were of the same order of magnitude as those for Type VI tile. In all types of tile other than Type VI there were rather large variations in discoloration of the several kinds of tile within the group.

The final values of reflectance of six of the specimens were higher than the final value for white plaster.

5. Conclusions

The apparatus and procedure described in this report appear to provide a satisfactory method for comparing the rate of discoloration of acoustic tile by the impingement of an aerosol containing carbon black. Further experimentation would be required to develop equally good procedures for comparing the effects of filtration and thermal precipitation on the soiling of acoustic tile. Enough study was made of the processes of impingement, filtration, and thermal precipitation during this and previous work to establish that all three processes are important in some applications. Further study would also be required to evaluate the effect of different aerosols on the comparative rates of discoloration of different tile specimens.

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THE NATIONAL BUREAU OF STANDARDS

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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.

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