NATIONAL BUREAU OF STANDARDS REPORT

2541

SIMULATED USE TESTS OF SUBSTITUTE DUCT MATERIALS

by

O. N. McDorman
P. R. Achenbach

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O. N. McDorman
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to

Office of the Housing Administrator
Housing and Home Finance Agency
Washington, D. C.

NBS

SIMULATED USE TESTS OF SUBSTITUTE DUCT MATERIALS

Abstract

Simulated use tests were made of substitute duct materials to determine mold growth, water absorption, delamination upon alternate heating and cooling, weight and dimensional changes during exposure to high humidity, deformation and deterioration at elevated temperatures, odor generation, and damage from dropping. Some deformation measurements were made on light gage metal ducts for comparison. The temperatures produced in a high-temperature forced warm air heating system during full-load and runaway operation of a coal furnace were also measured. These data and other data reported in NBS Report 1947 were used to develop criteria for substitute duct materials on flame spread, deformation at elevated temperatures, penetration of flame, rigidity, deterioration, odor, and practicability of joints and fittings.

I. INTRODUCTION

At the request of the Housing and Home Finance Agency a study was made to determine criteria for selecting suitable materials to be used as substitutes for metal ducts in warm air heating systems. To assist in setting proper limits on the physical characteristics for such materials similated use tests were made of some commercial materials, certain measurements were made on metal ducts now commonly used for warm air heating systems, and temperature studies were made in a typical high temperature forced warm air heating system to determine what temperatures would be reached in the ducts if the blower stopped running while the dampers were wide open on a coal furnace.

Tests to determine mold growth, water absorption, delamaination upon alternate heating and cooling, and weight and dimensional changes during exposure to high humidity were made on two commercial materials. In addition, a test to determine deformation and deterioration at elevated temperatures, an odor test, and a dropping test were made on one of these two materials.

The results of certain fire hazard tests on these same two commercial materials are described in a separate report (NBS Report 1947 entitled Fire Hazard Tests of Substitute Duct Materials). Measurements of the deflection of light gage galvanized iron and aluminum ducts comparable to the lightest that are now permitted by NBFU Pamphlet No. 90 for warm air heating systems in residences were made when four-foot sections were simply supported at each end.

The criteria recommended for evaluating substitute duct materials are listed and discussed in NBS Report #2540.

II. TEST MATERIALS

Substitute materials made available for test in connection with this investigation were:

(a) Several 18 foot lengths of Sonoair duct manufactured by the Sonoco Products Co., Hartsville, South Carolina. This material was a laminated fiber duct having an inside diameter of 8 inches and an outside diameter of 8-7/16 inches. The cellulose plies of this duct were spirally wound and cemented together with an organic binder. The inside and outside surfaces of the duct were coated with paraffin.

(b) Several sheets of Sal-Mo No. 77 Ductboard manufactured by the Sall Mountain Co., Hamilton, Ohio. This material was an admixture of asbestos and other materials. The sheets measured 33 inches by 48 inches and were 1/8-inch thick.

Galvanized iron ducts of U. S. Gage No. 30 and aluminum ducts of B&S Gage No. 26 were studied for deflection when supported at 4-foot intervals.

III. TESTS

A. Water Absorption

Specimens of the Sonoair duct and the Sal-Mo ductboard were tested for absorption of water during immersion.

(a) Sonoair duct.

All test pieces that were used in this phase of the study were circular cross sections of the duct, 3 inches high, 8-7/16 inches outer diameter and 8 inches inner diameter.

The edges of the test pieces were treated with wax in order to render them impermeable to water, which allowed the water to come in contact only with the inner and outer surfaces of the duct material. The following table is a summary of the results obtained when test pieces at room temperature were submerged in water of room temperature after having undergone a pre-conditioning period at 200°F. All the tests were run in duplicate, test piece numbers 1 and 2.

Table 1

PERCENT ABSORPTION OF WATER BY SONOAIR DUCT

Length of Pre-Conditioning Period at 200°F hours	Percent Gain in Weight Due to the Absorption of Water during Immersion Periods								
	4 hours			8 hours			24 hours		
	1	2	Avg	1	2	Avg	1	2	Avg
0	27.1	35.4	31.2	44.6	57.2	50.9	100.1	95.5	97.8
2	15.2	22.8	19.0	21.9	30.3	26.1	49.2	64.0	56.6
8	24.0	15.9	20.0	33.6	21.5	27.6	73.0	56.8	64.9
24	8.8	9.3	9.0	12.6	11.0	11.8	32.7	28.9	30.8

The results in Table 1 indicate that heating the specimens to 200°F before immersion decreased the water absorption. In most cases this effect was progressive for preheating periods up to 24 hours.

A test was conducted to determine whether the water was being absorbed through the inner or outer surface of the Sonoair duct. The lower end of the specimen was sealed with aluminum foil, which restricted water contact to the outer surface. The water level was maintained at a height of 2-3/4 inches. The test was made at room temperature with these observations;

Table 2

Hours of Immersion	Weight of Specimen
0	186.8 grams
4	187.7
7	188.2
24	189.5

The results indicate that only a small amount of water was absorbed by the outer surface and that most of the absorption indicated by the data in Table 1 occurred through the inside surfaces.

(b) Sal-Mo Ductboard.

Eight specimens measuring approximately 8-1/4 inches by 8-1/4 inches by 1/8 inch thick were used. The edges of the specimens were coated with wax so the water was in contact with only the two large surfaces. A summary of the results in Table 3 shows that preheating the specimens had practically no effect on the amount of water absorbed and that only a small amount of water was absorbed after the first 4 hours of immersion.

Table 3

PERCENT ABSORPTION OF WATER BY SAL MO DUCT

Length of Pre-Conditioning Period at 200°F	Percent Gain in Weight Due to the Absorption of Water during Immersion Periods								
	4 hours			8 hours			24 hours		
hours	1	2	Avg	1	2	Avg	1	2	Avg
0	58.6	59.4	59.0	61.2	62.2	61.7	68.0	68.3	68.2
2	58.3	59.8	59.0	61.8	62.2	62.0	67.6	68.8	68.2
8	62.5	64.0	63.2	64.3	66.3	65.3	67.3	70.5	68.9
24	61.6	59.4	60.5	63.6	61.5	62.5	67.3	64.7	66.0

B. Effect of High Humidity

(a) Sonoair Duct.

Two specimens of duct 3 inches long were subjected to a relative humidity of 100% at a temperature of 76°F for 21 days. Dimensions and weight were observed at intervals during the test periods. The results in Table 4 show small changes in length and thickness of the specimens during 21 days and an average gain in weight of 18 percent.

Table 4

Exposure Days	Height, inches Specimen 1	Height, inches Specimen 2	Thickness, inches Specimen 1	Thickness, inches Specimen 2	Weight, grams Specimen 1	Weight, grams Specimen 2
0	3	3	7/32	7/32	163.3	162.0
7	3-1/32	3-1/32	8/32	8/32	182.2	180.2
14	3-1/32	3-1/32	9/32	8/32	188.2	187.6
21	3-1/32	3-1/32	9/32	8/32	192.6	190.6

(b) Sal-Mo Ductboard.

Two specimens of this ductobard about 8 inches square were subjected to a relative humidity of 100% at a temperature of 76°F for 14 days. Dimensions and weight were observed at intervals during the test period. The results in Table 5 show that the width and length increased 1/16 inch during the test period whereas the average increase in weight was 11.5 percent.

Table 5

Exposure Days	Length, inches Spec. 1	Length, inches Spec. 2	Width, inches Spec. 1	Width, inches Spec. 2	Thickness, inches Spec. 1	Thickness, inches Spec. 2	Weights, grams Spec. 1	Weights, grams Spec. 2
0	8-1/4	8-3/16	8-1/4	8-3/16	1/8	1/8	128.3	123.5
7	8-5/16	8-1/4	8-5/16	8-1/4	1/8	1/8	140.1	134.7
14	8-5/16	8-1/4	8-5/16	8-1/4	1/8	1/8	142.5	138.2

C. Delamination during Alternate Heating and Cooling.

(a) Sonoair Duct.

Two test pieces of duct material were alternately heated for 2 hours at 200°F and then chilled for 2 hours at about 40°F in a refrigerator. There was no evidence of any change at the end of the first cycle. At the end of the second cycle a delamination of 1-1/2 inches in length was observed in the outer ply of the spirally-wounded paper. Five additional cycles resulted in no further structural change.

The test was repeated under the same conditions except that the specimen was cooled to room temperature. Similar results were observed.

(b) Sal-Mo Ductboard.

Two test pieces were alternately heated for 2 hours at 200°F and then chilled for 2 hours at about 40°F in a refrigerator. There was no evidence of any delamination or breakdown after seven cycles. The test was repeated under the same conditions except that the specimen was cooled to room temperature. Similar results were observed.

D. Mildew Resistance Tests.

Mildew resistance tests were made on five specimens of Sal-Mo ductboard, identified as samples A and B, and five specimens of Sonoair duct, identified as samples C and D, by the Organic and Fibrous Materials Division. The test procedure used, the test results observed, and the conclusions reached are contained in the following report. Fig. 1 is a photograph of one specimen of each sample of the duct materials and the cardboard sample used as a control taken at the conclusion of the 14 day test period. There was no apparent difference between the five specimens in any one of the four samples tested.

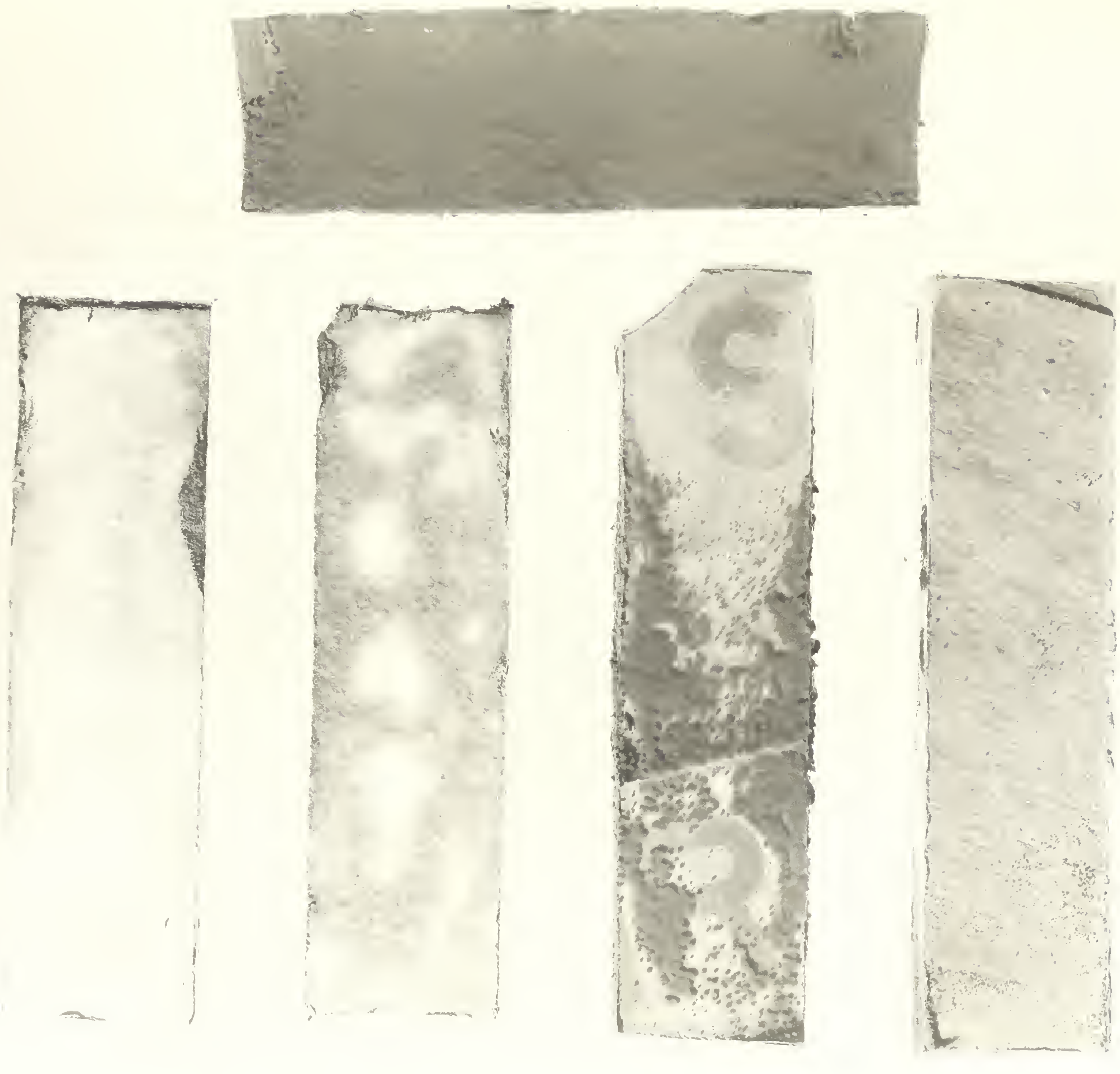

FIG. 1

Procedure

Specimen. Four samples, consisting of five specimens for each sample, were submitted for the microbiological test for mildew resistance. Samples "A" and "B" were asbestos and cotton measuring 2" x 6" with "A" heated at 100°C for 120 hours. Samples "C" and "D" were cellulosic ply duct dipped in paraffin measuring 2" x 6" with "C" heated at 100°C for 120 hours. One control of untreated cardboard was inoculated to test the viability of the organism.

Culture medium. The substrate was an agar medium containing all of the growth requirements for Chaetomium globosum except carbon which the organism got through the breakdown of the cellulose found in the fibers. The medium was as follows:

Agar	10.00 g
Sodium nitrate	3.00 g
Dipotassium phosphate	1.00 g
Magnesium sulfate	0.25 g
Potassium chloride	0.25 g
Distilled water - to make	1000.00 ml

Forty milliters of the above medium were dispensed into each of twenty-one 16 oz. French square bottles having screw caps with fiber glass filters in the tops. These bottles were then autoclaved for 20 minutes at 121°C, 15 lbs pressure and then each laid on its side until the agar had cooled and hardened.

Inoculum. 1. Organism - Chaetomium globosum, culture ATCC 1042.4.

2. Scrapings from a 10-cm Petri dish surface of a ripe fruiting culture of Chaetomium globosum was added to 100 ml of sterile distilled water. The transfer was made with a flamed platinum wire loop. The spore clusters were squeezed against the sides of the flask until the spores went into suspension.

Method. The specimens and control previously described were laid flat on the substrate in the bottles and each inoculated with 2 ml of the inoculum which was evenly distributed over the surface of the specimens. They were then incubated for a period of 14 days at 29°C (84.2°F) at approximately 90% relative humidity.

Observations:

Sample	Specimen	Treatment	Growth: Mycelial	Growth: Reproductive
A Asbestos	1	Heated 100°C for 120 hr.	Heavy (1)	Slight (3)
	2		Heavy (1)	Slight (3)
	3		Heavy (1)	Slight (3)
	4		Heavy (1)	Slight (3)
	5		Heavy (1)	Slight (3)
B Asbestos	1	Unheated	Heavy (1)	Slight (3)
	2		Heavy (1)	Slight (3)
	3		Heavy (1)	Slight (3)
	4		Heavy (1)	Slight (3)
	5		Heavy (1)	Slight (3)
C Ply Duct Paraffin Dipped	1	Heated 100°C for 120 hr.	Slight (5)	Moderate (3)(4)
	2		Slight (5)	Moderate (3)(4)
	3		Slight (5)	Moderate (3)(4)
	4		Slight (5)	Moderate (3)(4)
	5		Slight (5)	Moderate (3)(4)
D Ply Duct Paraffin Dipped	1	Unheated	None	Slight (2)(4)
	2		None	Slight (2)(4)
	3		None	Slight (2)(4)
	4		None	Slight (2)(4)
	5		None	Slight (2)(4)
Control Cardboard	1	Untreated	Moderate	Heavy

Note.
1. (1) designates heavy mycelial growth.
2. (2) designates good growth on edges.
3. (3) designates sparse growth on surface.
4. (4) designates reproductive growth on surface and sides.
5. (5) designates mycelial growth on sides.

Conclusion. The observed results indicate a general lack of resistance to mold by the organic substitute duct. This is especially true of the asbestos samples "A" and "B" where "B", the unheated sample, showed equally as much mycelial and reproductive growth as "A". Samples "C" and "D" differed to a slight degree in the amount of visible growth present, where "C", the heated sample, showed the greatest amount. It is reasonable to assume in the case of "C" and "D" that during the process of heating, the paraffin on "C" was broken-down or melted, leaving it susceptible to attack by the organism.

For the most part, growth on "C" and "D" was reproductive which occurred on the edges and between the layers of duct. This may indicate that the paraffin did not penetrate the sample completely.

Upon testing the residual strength by breaking the specimens in the hands, sample "D" was the only one which showed any remaining strength comparable to the untreated samples and that was extremely little.

E. Dropping Test.

(a) Sonoair Duct.

Tests were made to simulate rough treatment of ducts which might occur during shipment or delivery to a construction site prior to installation. Specimens were dropped from a height of 4 feet to simulate falling from the tailgate of a freight truck. Four-foot sections were dropped in such a manner that a concrete pavement was struck flat and at angles of 45° and 90°. Specimens were also dropped upon cinder block and wooden members. At the conclusion of these tests the ducts were considered to be in usable condition. The specimen dropped on the edge of a cement block was not punctured and collars of the same material still fitted properly.

F. Deformation at Elevated Temperatures.

(a) Sonoair Duct.

Test apparatus was constructed in which the specimen duct could be exposed to air temperatures simulating those expected during normal or abnormal operation of a forced warm air heating system.

A recirculating forced warm air heating system was used for the first part of the test. This system consisted of a blower of 400 cfm capacity, an electric heater mounted in a metal duct, a 4-foot specimen of the 8-inch Sonoair duct, and enough galvanized pipe and elbows to make a closed circuit. The temperature of the warm air at the center of the specimen duct was measured by means of a 4-junction averaging thermocouple. A temperature of 200°F was maintained at this point by thermostatic control. Several tests were conducted, the longest for a period of 7 hours. No sagging of the duct along its axis or change in shape of its cross section could be observed by means of a steel straight edge. The duct was removed from the apparatus and examined internally. No evidence of discoloration or delamination was apparent.

The second part of the test was conducted with still air. A 4-foot specimen of Sonoair duct was attached to the electric heater in a vertical position. Temperatures were observed by

two thermocouples. One was located in air at midheight in the duct. The second was sealed into the duct wall one inch from the edge adjacent to the heat source. The specimen was subjected to a temperature of approximately 400°F for one hour. Smoke appeared at a temperature of approximately 380°F. It persisted for about 5 minutes. During the remainder of the tests no additional smoke was observed. The test was repeated with a duct covered with a double thickness of rock wool batts. A temperature of 400°F was maintained for 3 hours. The results were similar. At the conclusion of the test the duct, in our opinion, would be considered serviceable although the duct was darkened considerably during the tests at 400°F.

G. Odor Test.

The Sonoair duct emitted no strong odor at a temperature of 250°F.

H. Deformation of Metal Ducts.

Two rectangular metal ducts were constructed for these tests. One was formed of galvanized iron No. 30 gauge U. S. and the second was made of 24 S aluminum alloy No. 26 gauge B & S.

The dimensions of the galvanized iron duct were about 11-1/2 inches by 13-1/2 inches whereas the aluminum duct was approximately 12 inches square. The aluminum specimen represented the largest duct that could be made of 26 gauge aluminum and still comply with the requirements of NBFU Pamphlet No. 90 for installation of warm air heating ducts. The galvanized iron duct should have been made of 28 gauge material to comply with NBFU Pamphlet No. 90.

The principal dimensions of the duct openings were measured with the specimens unsupported while standing vertically, one opening resting on the floor. The ducts were then supported in a horizontal position by two 2-inch boards spaced 48-inches apart. The dimensions of the openings were measured under all possible oritentations.

The maximum dimensional changes observed were galvanized iron, 3/16 inch or 1.6% and aluminum, 1/4 inch or 2.0%. There was no visible sagging of either duct at the middle of the 4-foot span.

Table 6

SECTIONAL DIMENSIONS OF METAL DUCTS, INCHES

Duct Material	Duct Position: Vertical on Floor	Horizontal Max.	Horizontal Min.	Deformation in Horizontal Position
galv. iron	13-1/2	13-9/16	13-7/16	± 1/16
galv. iron	11-3/8	11-3/8	11-3/16	+ 3/16, -0
aluminum	12-3/8	12-1/2	12-5/16	+1/8, -1/16
aluminum	12-1/4	12-9/32	12.0	+1/32, -1/4

1. Temperatures in Warm Air Heating Systems.

A replica of an actual warm air heating system used in some FHA-insured houses in Newport News, Virginia, was built to determine the temperatures attained in ductwork and on surrounding wood members under normal full-load operation and under abnormal operating conditions. The system consisted of a coal-burning furnace with 18-inch combustion chamber, a circulating blower, a warm air plenum on top of the furnace, an elbow to connect the plenum to the supply duct, and 6 feet of horizontal metal supply duct. The furnace and supply duct are shown in Fig. 2 and the blower and return duct connection to the furnace are shown in Fig. 3. The horizontal duct was framed with nominal 2-by 2-inch wood members spaced a minimum of 1-inch from the metal duct preparatory to furring the duct into the ceiling. The wood framing and the ceiling joists can be seen in Fig. 2, 4, 5, and 6 from several sides of the furnace. Fig. 7 is a photograph of the furnace and duct system after application of plasterboard to the wood frame and ceiling joists. Only six feet of metal duct was used because a substitute duct material was to be used beyond this point, and because information on the temperatures attained in the first six feet of duct were of special importance in this investigation.

Thermocouples were used to measure air temperatures in the supply and return system, metal temperatures of the supply duct, temperatures of wood framing around the supply duct and the temperatures of the flue gases, furnace dome, and furnace jacket near the top. Temperatures were observed at the several stations during four-hour test periods at each of six test conditions. The furnace was operated with the flue gas temperature maintained at about 900°F by damper control and with the dampers wide open for each of three conditions of air circulation; namely, a blower air delivery of 350 cfm, gravity circulation of air through the system with the blower stopped, and with the warm air outlet covered and the blower stopped.

A high volatile bituminous coal was used for these tests to obtain high combustion rates and long flames in the combustion chamber. The furnace was equipped with about 15 feet of vertical chimney without a stack damper. At the beginning of each test with a runaway fire the furnace was refilled with fuel and the dampers were left wide open while burning the entire charge.

A summary of the principal temperatures observed during these tests is contained in Table 7. The temperatures summarized are the maximum temperatures that occurred during each test condition. The furnace burned from 10 to 12 lb. of coal per hour during Tests 1-3, inclusive and from 20 to 25 lb. of coal per hour during Tests 4-6, inclusive. The following significant results are shown in Table 7:

FIG. [illegible]

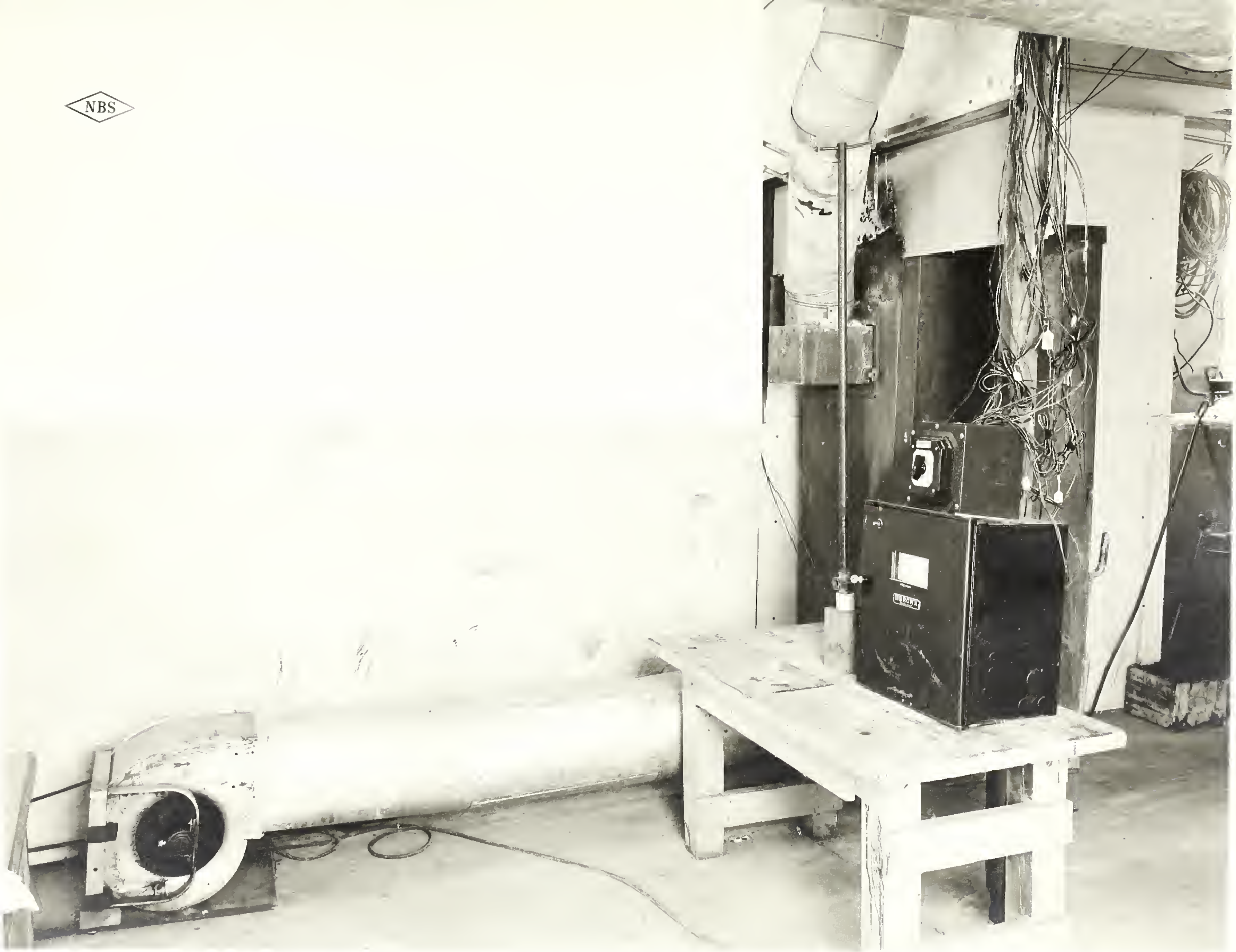

FIG. 3

FIG. 4

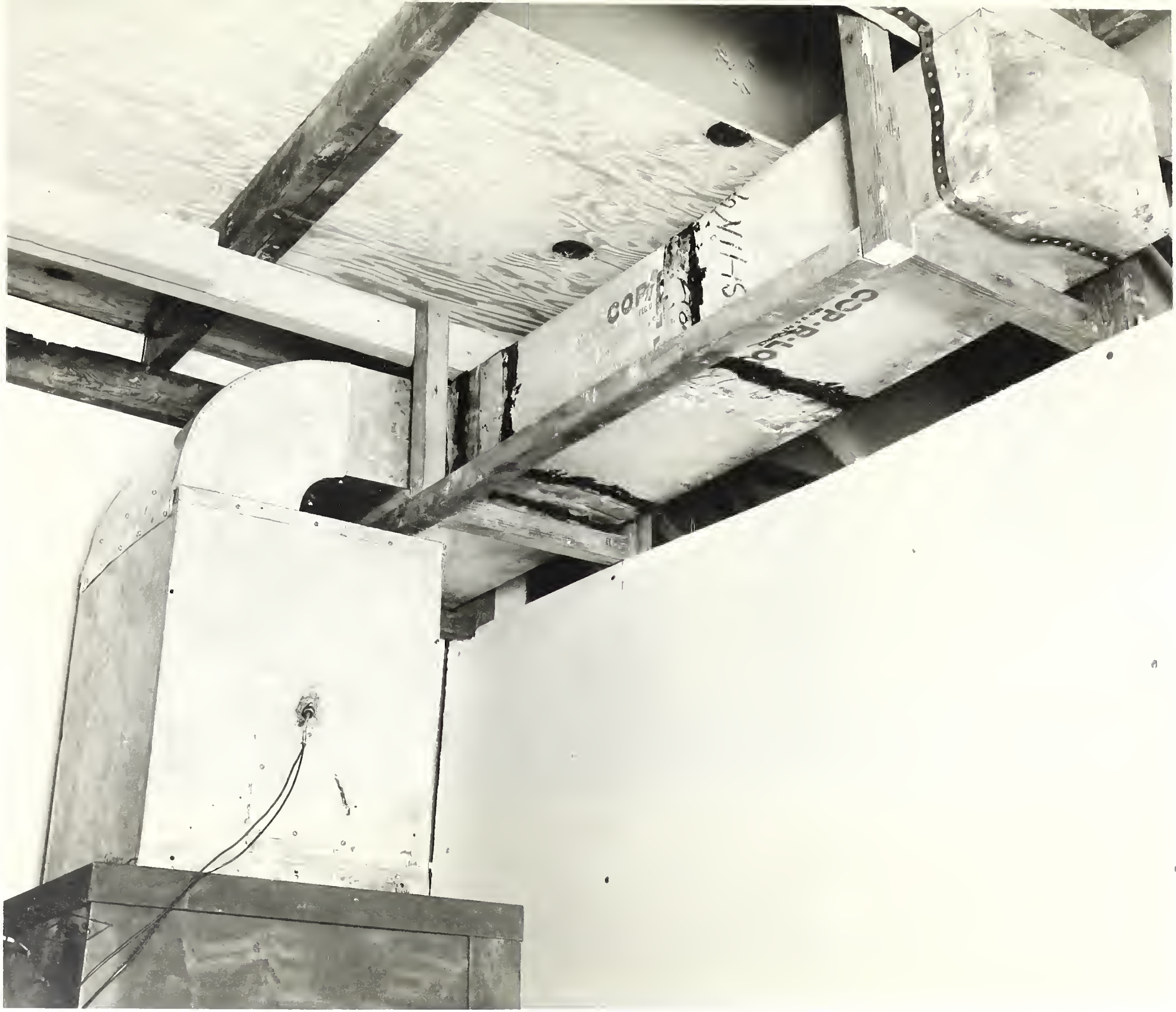

FIG. 5

FIG. 6

FIG. 7

Table 7

SUMMARY OF RESULTS
TEMPERATURES IN A REPLICA FURNACE AND DUCT SYSTEM
DURING FULL LOAD AND RUNAWAY CONDITIONS

Test No.	1	2	3	4	5	6
Nominal Stack Temp.,°F	900	900	900	Max.	Max.	Max.
Blower Operation	On	Off	Off	On	Off	Off
Warm Air Supply Outlet	Open	Open	Closed	Open	Open	Closed
Flue Gas Temp.[a] °F	931	910	918	1470	1525	1175
Jacket Temp. 12" from Top, °F	333	407	370	368	568	652
Furnace Dome Temp. °F	904	885	805	1032	1156	1160
Air Temperatures						
Furnace Plenum °F	296	480	530	325	643	783
Horizontal Supply Duct						
Entrance °F	277	440	481	305	592	716
Midpoint °F	270	408	365	297	533	601
Outlet °F	269	414	368	295	538	582
Cold Air Return °F	86	87	85	83	90	90
Metal Temp.						
Top of Plenum °F	380	452	442	444	636	687
Duct Entrance, Top °F	251	314	332	280	412	448
Duct Midpoint, Top °F	242	305	303	264	348[b]	420
Duct Outlet, Top °F	231	270	272	252	362	368
Wood Framing Temp.						
Bottom of Ceiling Joist near Duct Entrance, °F	192	230	256	220	317	325
Bottom of Ceiling Joist at Duct Outlet, °F	183	219	230	209	296	289
Top of 2"x2" near Duct entrance, °F	180	192	214	194	242	279[c]
Top of 2"x2" at blank end of Duct, °F	200	243	260	208	344	335
Adjacent Face of 2"x4" at blank end of Duct, °F	185	221	248	220	295	319

[a]18 inches from smoke cellar.

[b]Thermocouple loose during this test.

[c]Fire started near this thermocouple station on 2x2-inch member between plenum and duct 20 min. after refiring.

(a) With the blower running the maximum air temperature in the horizontal duct was 305°F, the maximum metal temperature in the horizontal duct was 280°F, and the highest temperature observed on the wood framing was 220°F in Test 4 with a runaway fire. At the outlet end of the 6-ft. metal duct the air temperature was 295°F and the metal duct temperature was 252°F on the top side.

(b) With gravity circulation of air through the system ignition of the wood was imminent after one firing cycle with a runaway fire, as shown in Test 5. Under these conditions the maximum air temperature observed in the 6-ft horizontal duct was 592°F, the maximum metal temperature observed on this duct was 412°F, and the highest temperature observed on the wood framing was 344°F. At the outlet end of the 6-ft metal duct the air temperature was 538°F and the metal duct temperature was 362°F on the top side.

(c) When the warm air supply outlet was closed (actually covered with a tight sheet metal cover) as in Test 6, ignition of the wood occurred within 20 minutes after refiring the furnace. Test 6 followed immediately after Test 5 without cooling of the system. The test data indicate that ignition would probably have occurred almost as soon if the conditions of Test 5 had been continued for another firing cycle. Ignition originated on the 2x2-inch framing member located between the top of the plenum and the bottom of the elbow connecting the plenum and overhead duct. Presumably, this member was at a higher temperature than those stations at which thermocouples were located. The fire in the wood members was extinguished as quickly as possible and the test was terminated. Fig. 8 is a photograph of the charred ceiling joists as viewed from above. In this view the plywood sheets that covered the ceiling joists on the upper side are propped up to reveal the burned joists. The stick at the right holding up the plywood is resting on the metal duct.

The air temperatures and metal temperatures in the plenum and duct were appreciably higher during the brief duration of Test 6 than during Test 5, but the temperatures on the wood framing were higher at some stations in Test 6 and lower at others than for Test 5.

V. DISCUSSION AND CONCLUSIONS

The above tests provide information on the characteristics of substitute duct materials which should be considered in developing criteria on water absorption, effect of high humidity, delamination on alternate heating and cooling, mildew resistance,

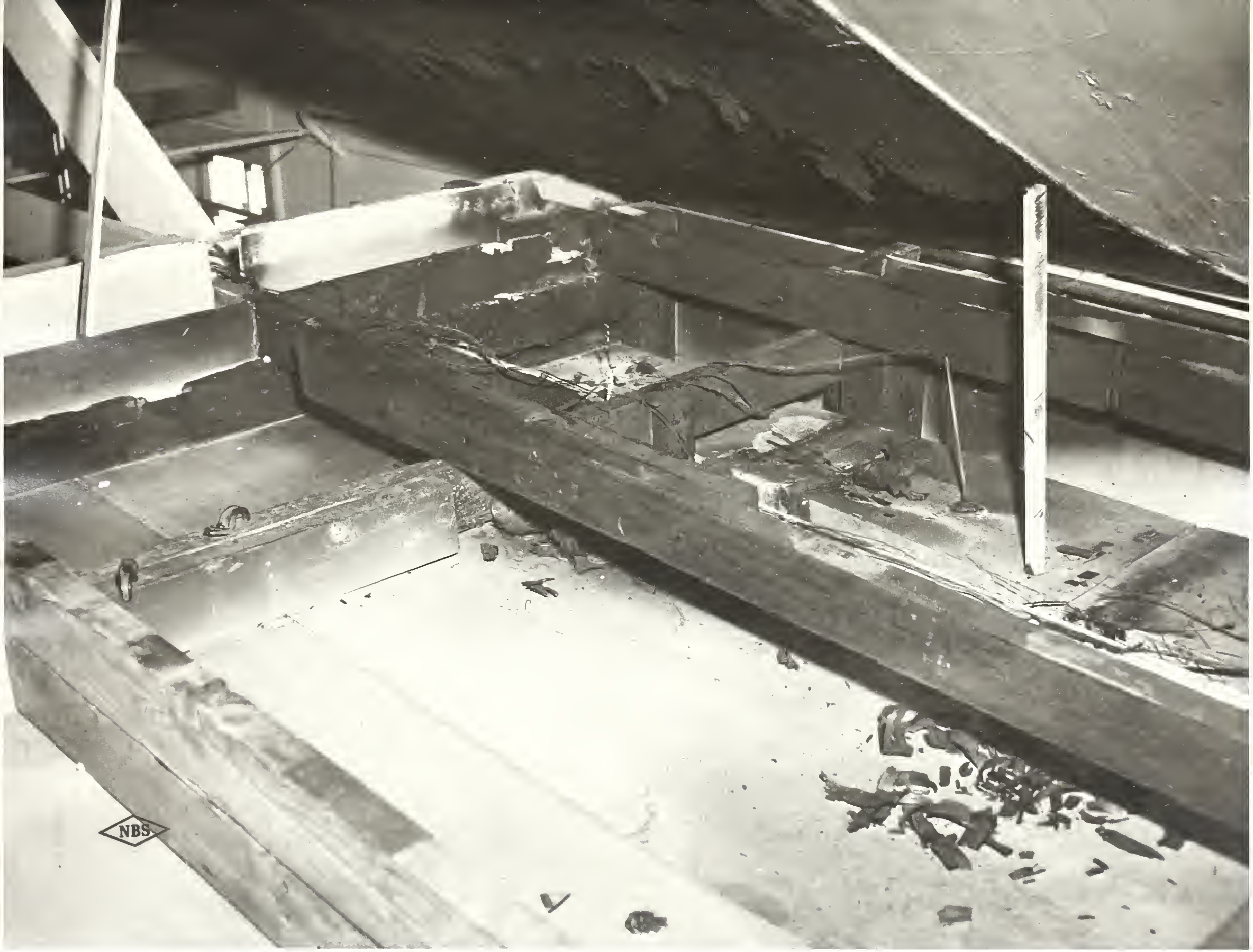

FIG. 8

resistance to damage from handling, deformation at elevated temperature, and odor. Criteria were not developed for all of these characteristics because some were considered unnecessary and others could not be made sufficiently definitive with present testing procedures.

The tests made with a forced warm air heating system employing a coal-fired furnace and a supply duct system furred into the ceiling construction showed that a 1-inch spacing of wood members from the heating duct was not enough to prevent ignition when the furnace was operated with the dampers wide open and the circulation of air was restricted by blower failure or damper closure. These tests also provide information on the temperatures that can occur in the duct system and on the metal and wood surfaces near the furnace during such abnormal conditions.

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 ($1.00). Information on calibration services and fees can be found in NBS Circular 483, Testing by the National Bureau of Standards (25 cents). Both are available from the 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.

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