NATIONAL BUREAU OF STANDARDS REPORT

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CRITERIA FOR SUBSTITUTE DUCT MATERIALS

(Project No. 1-T-102)

by

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U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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- Office of Basic Instrumentation
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to

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

CRITERIA FOR SUBSTITUTE DUCT MATERIALS

Abstract

A study was made by the National Bureau of Standards to establish a set of performance criteria by which substitute materials for metal ducts could be judged for use in warm air heating systems. This investigation was performed under an agreement with the Office of the Administrator, Housing and Home Finance Agency, authorized under Title III of the Housing Act of 194[illegible], as amended, and was identified as Project No. 1-T-102 "Criteria for Substitute Duct Materials".

The study led to the conclusions that a substitute duct material should be tested after the material was formed into ducts and that these ducts should be evaluated for their acceptability by means of tests for Flame Spread, Deformation at Elevated Temperature, Penetration of Flame, Rigidity, Deterioration, Odor, and Practicability of Joints and Fittings. The application of the fire resistance tests are to be governed by the type of furnace and air distribution system involved and the type of building in which the ducts are to be installed. The proposed criteria were developed primarily for application to residential duct systems.

I. INTRODUCTION

At the request of the Housing and Home Finance Agency a study was made to determine what criteria should be recommended as a basis for evaluating materials offered to the Federal housing agencies as substitutes for metal ducts in warm air heating systems. This study was to be principally concerned with residential applications although it was recognized that the requirements for other applications would be similar, but not necessarily identical to those in dwellings.

After several conferences between representatives of the Housing and Home Finance Agency and members of the staff of the National Bureau of Standards the following characteristics were listed as worthy of consideration and investigation in establishing a set of criteria for substitute duct materials.

1. Rate of flame spread inside the duct.

2. Deformation of ducts with interior and exterior exposure to elevated temperature.

3. Flame penetration of duct wall by an outside source of heat.

4. Weight gain when soaked in water (new material).

5. Weight gain when soaked in water after duct has been heated to 200°F for a period of time.

6. Weight gain after extended exposure to high humidity at room temperature.

7. Dimensional changes at elevated temperatures.

8. Dimensional changes caused by high humidity.

9. Mold growth at high humidity and at room temperatures.

10. Odor emission at operating temperatures.

11. Rigidity when heated to operating temperatures.

12. Rigidity after exposure to high humidity.

13. Rigidity when surrounded by damp sand or wet concrete.

14. Susceptibility to damage by dropping.

15. Deterioration resulting from alternately heating and cooling the duct.

16. Ease of painting.

17. Practicability of joints and fittings for fabrication.

Laboratory tests were made of a few commercial materials proposed for substitute ducts to study flame spread, ease of ignition, moisture absorption, dimensional changes when heated, mold growth, odor emission, rigidity, damage from dropping, and deterioration due to alternately heating and cooling. Other tests were made to determine what temperatures were produced in a warm air heating system employing a hand-fired coal furnace and forced circulation of the air through the system during normal operation and during a simulated electrical failure of the blower motor when all dampers on the furnace remained open. The test procedures used and the results of these tests are presented in separate NBS reports numbered 1947 and 2541.

PROPOSED CRITERIA FOR SUBSTITUTE DUCT MATERIALS

The criteria considered essential for selecting satisfactory substitute materials for metals in warm air heating systems are:

I. Fire Resistance

II. Rigidity.

III. Deterioration.

IV. Odor

V. Practicability of Joints and Fittings.

A description of the test procedures to be used, the limits to be applied in determining acceptance or rejection, and the recommended application of the tests to different types of warm air systems for the above criteria follows.

I. Fire Resistance

It is proposed that one or more of the following tests be made of substitute duct materials depending on the type of furnace and air distribution system used and the type of building involved as shown in Part D below.

Part A. Type of Test

1. Flame Spread Test on inside of the duct.

2. Deformation Test with interior and exterior exposure to elevated temperatures.

3. Penetration Test with exterior exposure to hot gases.

Part B. Test Procedures

1. Flame Spread Test (as described in report 1947)

A 3-foot section of duct of the test material shall be mounted in an inclined position with a 20 degree angle between its longitudinal axis and the horizontal. A Tirrell burner (3/8-inch tip), for which the height of the flame with the burner vertical has been adjusted to 5 inches with an inner cone 2 inches high, shall be mounted on a stand at a 45-degree angle with respect to the horizontal. The stand shall be placed so that the flame impinges at a 45-degree angle to the side of the interior surface of the duct at a point 4 inches from the lower end. This flame shall be applied continuously to the inside surface of the duct until the flame emerges from the upper end or until it penetrates the wall surface, or until it becomes evident that neither will happen.

The appearance of the test specimen, the extent of burning of the material, and the flame travel shall be recorded at regular intervals during the test.

2. Deformation Test

A piece of duct of such length that it includes any supports furnished as attached supports, but not less than 12 inches long, shall be simply supported at each end in an oven and exposed to a controlled temperature of 400°F for high-temperature systems or 350°F for low-temperature systems for a period of 24 hours and the deformation recorded at least twice during the test and at the end of the test. Ducts intended for vertical placement shall be mounted vertically in the furnace and restrained at top and bottom while being exposed to the same temperature as for the horizontal specimens. Lateral deflection of the specimen shall be observed. Other evidences of structural failure or deterioration shall be noted during these tests.

3. Penetration Test

A six-foot length of the specimen duct, which has been conditioned to constant weight at 90 percent relative humidity, at 75°F, shall be placed horizontally in a test furnace having a combustion space about two feet square with the two open ends of the duct protruding equal distances from the furnace wall into the ambient air. Four thermocouples shall be placed 12 in. below the test specimen and about 8 in. from the walls of the furnace to average the furnace temperature. The thermocouples shall be constructed in accordance with the requirements outlined in Standard Methods of Fire Tests of Building Construction and Materials (ASTM Designation E119-50). Hot gases shall be passed upward around the test specimen with the gas temperature controlled in accordance with the Standard Time-Temperature Curve, Fig. 1, shown in this same ASTM Standard. The test shall be continued until flame first penetrates the duct wall or until the duct wall is ruptured by physical failure and the time required for either type failure to occur shall be noted. The exterior of the furnace shall be insulated to reduce heat transmission to the ambient air. The ambient temperature as measured by a shielded instrument along the axis of the duct and at a distance of 2 ft from the open ends of the duct shall not exceed 100°F during the test.

(Note: It is considered doubtful that aluminum duct would withstand the Penetration Test described above and it is uncertain whether or not cement-asbestos or fiber glass ducts would withstand these test conditions either. However, the Penetration Test is recommended only for those buildings for which a fire rating is required - see Part D - and therefore, would not be applicable to one- and two-family dwellings in many cities.)

Part C. Types of Furnaces and Air Distribution Systems Considered.

1. Up-draft through furnace casing (either basement or 1st floor mounting).

   a. Overhead supply and underfloor return ducts.

   b. Overhead supply and no return ducts.

   c. Overhead warm air panel and no return ducts.

   d. Overhead warm air panel and connected return ducts.

   e. Floor furnace with supply plenum and connected return ducts.

2. Down-draft through furnace casing (1st floor mounting).

   a. Underfloor supply ducts and overhead returns.

   b. Underfloor supply ducts and underfloor returns.

   c. Supplies in concrete and overhead returns.

   d. Supplies in concrete and no returns.

   e. Crawl space plenum and floor or baseboard supply registers with no return ducts.

   f. Crawl space plenum and floor or baseboard supply registers with overhead returns.

3. Horizontal furnace position (1st floor ceiling or attic mounting).

   a. Attic supplies and attic returns.

   b. Overhead supplies and overhead returns near 1st floor ceiling.

   c. Ceiling panel, closed circuit.

Part D. Recommended Application of Fire Resistance Tests.

1. All substitute duct materials must pass the Flame Spread test for all applications.

2. Substitute duct materials must pass the Deformation test for all applications in both the supply and return duct systems of furnaces mounted horizontally, or those mounted vertically with down-draft in the furnace casing, and for all applications in the supply duct system of vertically-mounted furnaces with up-draft in the casing.

3. Substitute duct materials for use in structures requiring a fire rating must pass the Penetration test for all applications in both the supply and return duct system except when a duct is embedded in concrete or when a duct is used in a crawl space plenum but does not connect to a wall stack, floor register, or grille.

Part E. Recommended Limits for Acceptance of Substitute Duct Materials for above Applications.

1. In the Flame Spread test the flame shall not issue from the end of the 3-foot test section in less than 40 minutes. A hole burned through the wall of the test specimen during the test shall cause rejection of the material unless it is being proposed only for use embedded in concrete.

2. In the Deformation test the specimen tested horizontally shall not deflect more than 3/16-inch in any direction in 24 hours and the specimen tested in a vertical position with end restraint shall not deflect laterally more than 1/2 inch in the same length of time.

3. In the Penetration test the time required for flame or hot gases to pass through the duct wall or for physical failure to occur shall be equal to or greater than the required fire resistance of the floor, wall, or ceiling through which the duct system passes in any given installation.

Part F. Required Installation Procedures.

1. Coverings or exterior insulations that are combustible shall not be applied to any type of warm air duct (metal or non-metal) during installation. Clearance shall be provided between duct walls and any combustible material, in accordance with Pamphlet No. 90 of the National Board of Fire Underwriters, entitled "Standards for Air Conditioning, Warm Air Heat, Air Cooling and Ventilating Systems".

2. Combustible materials shall not be used for ducts within 6 feet of a furnace in either the supply or return duct system.

Note: It has not been established that such a severe restriction on material adjacent to a furnace is necessary for the supply system of vertical furnaces with downward flow of air in the casing or for the return system of vertical furnaces with upward flow in the casing when the Flame Spread and Deformation tests described above have been met. However, ducts in these two locations would be heated by conduction from the furnace casing and, in some cases, by radiation from heating surfaces. Additional laboratory tests would be required to determine what temperatures would be attained on these ducts at the junction with the furnace casing.

II. Rigidity

Before and during 2 weeks (14 days) exposure in a room maintained at a temperature of 75°F and a relative humidity of 90 percent the specimen ducts shall not sag visibly in a longitudinal direction and the cross sectional dimensions shall not change by more than 5 percent as a result of carrying their own weight on supports placed 4 ft apart.

III. Deterioration

The specimen ducts shall not delaminate, crack, collapse, spall, peel, blister, or wrinkle during 2 weeks (14 days) exposure in a room maintained at a temperature of 75°F and a relative humidity of 90 percent or when alternately heated and cooled for 15 cycles between the temperatures of 250°F and 75°F.

IV. Odor

The specimen ducts shall not emit a noticeable odor at a temperature of 250°F after the first 4 hours exposure.

V. Practicability of Joints and Fittings.

Materials used as joints and fittings for connecting separate pieces of substitute duct materials shall be subject to the same criteria as the duct material.

When the joints and fittings for making up a duct system are supplied by a manufacturer of a substitute duct, it shall be possible to readily assemble separate lengths of the duct using these joints and fittings after a weeks exposure of all parts to either high humidity (90 percent) or low humidity (20 percent) by using simple hand tools without trimming, dressing, stretching, or lubricating the separate pieces. Joints shall be substantially air tight and, if slip joints are used, they shall have a lap of least one inch.

DISCUSSION OF OTHER REQUIREMENTS

A. Moisture Absorption

The weight increase of a substitute duct when immersed in water might be indicative of the amount of damage it would suffer if such material were exposed to rain at a building site before installation or if a below-grade system were flooded with water after installation. However, duct materials do not consistently receive such exposure to water so it was our opinion that a material, otherwise suitable for warm air ducts, should not be rejected because it would absorb water.

The weight of moisture absorbed underhigh humidity conditions is only important insofar as it affects rigidity, deterioration, or mold formation. The two of these effects are evaluated under the proposed criteria.

B. Dimensional Changes

In our opinion, the dimensional changes due to temperature will be reflected qualitatively by the Deformation Test recommended as one of the criteria and the dimensional changes caused by high humidity will be revealed adequately by the Rigidity Test proposed as one of the criteria.

C. Damage from Dropping

Consideration of the types of materials likely to be offered as substitute materials for ducts in warm air heating systems indicated that most of the materials, if damaged, could either be restored to a usable condition by bending them back in shape or the damaged portion could be cut out leaving a large portion of the original piece undamaged. Very few materials would be shattered throughout by dropping from a height of 4 feet as from a truck bed. Consequently, a criteria that would attempt to describe the amount of damage permissible in a drop test was considered unnecessary.

D. Painting

Painting of warm air heating ducts will be desired in some installations, but ducts would not ordinarily be painted in a crawl space; they would not be painted if surrounded by concrete, and they would frequently be enclosed in furring spaces in recreation rooms. Therefore, ease of painting was not considered to be sufficiently important to warrant making it a requirement for acceptance.

E. Mold

The tests made of some commercial materials proposed for warm air heating ducts showed that they would support mold growth at a temperature of 85°F accompanied by a relative humidity of 90 percent and indicated that they might mold at the conditions likely to be present at times around the heating ducts during the summer-season in crawl spaces, in basements, and in concrete floors. However, extensive research would be required to correlate the quantitative results of mold tests in a laboratory with the seasonal and variable conditions that would exist in actual use of substitute duct materials in crawl spaces and basements. Such a correlation has not been worked out. Therefore, it appears impractical to include a criteria for molding of substitute duct materials at the present time. The lower margin of temperature and humidity that will promote mold growth is about 75°F dry bulb and 75 percent relative humidity. It is probable that these conditions would be exceeded around warm air heating ducts at times during the summer season.

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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