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NATIONAL BUREAU OF STANDARDS REPORT

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LITERATURE AND INFORMATION SURVEY ON CHIMNEYS AND FIREPLACES

By

H. Shoub

NBS

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

THE NATIONAL BUREAU OF STANDARDS

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for
Federal Housing Administration

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ABSTRACT

To secure information relevant to questions that have been raised concerning the adequacy or correctness of the requirements for the construction of chimneys and fire places in the Federal Housing Administration Minimum Property Standards, a search was made of pertinent literature available at the National Bureau of Standards. In addition to a review of this material, a further bibliography of papers of interest was prepared. To the extent possible, answers with cited references were supplied for the points raised. It was suggested that while research data were not in every case available, practical experience could be a source of supplemental knowledge.

1. Introduction

The Federal Housing Administration Minimum Property Standards for One and Two Living Units (FHA No. 300) were considered to have inconsistencies and omissions in the requirements for fireplaces and chimneys, arising from a basic lack of knowledge of the factors affecting their fire safety.

FHA Proposal 1.26 (Appendix A) was formulated to identify some 18 areas in which more specific information on the design and construction of fireplaces and chimneys was needed. As a preliminary to possible further work or technical investigation, it was decided that a literature survey of published and unpublished data available at the National Bureau of Standards might prove fruitful in providing answers to at least some of the questions posed in the FHA proposal.

In addition to examining the material in the Bureau's Fire Research Section, a bibliographic study was undertaken. Reference was found to several very early works on fireplaces and chimneys. Three of these were of considerable significance, the earliest being that of M. Gauger, "La Mecanique du Feu," published in France in 1709 (an English translation was made by J. T. Desaguliers in 1715). Benjamin Franklin's contribution to the science of domestic heating appeared in 1745 with the publication of his "Papers on Philosophical Subjects." A remarkable work was Count Rumford's "Chimney Fireplaces" (1796). The result of scientific investigation, it contains rules for the construction of fireplaces that are valid and in use today. Indeed, it may be the basis of some of the "conclusions based on long experience" often found in papers relating to heating problems.

The bibliography of works on chimneys and fireplaces is presented in two sections, the first containing those papers available for review, for which a brief summary or indication of the contents is given, the other listing works which, while possibly having some information of interest, were not obtainable within the scope of the program outlined to FHA. Being closely associated, papers on both chimneys and fireplaces are presented together.

2. Bibliography of Papers Available for Review at NBS

1. Chimney Design and Theory, by Wm. Wallace Christie, Van Nostrand 1902: One chapter on residential chimneys; formulas for area of chimney flue as a function of size of grate in coal-burning stoves.

2. Thermal Insulation and Fire Protection of Small Chimneys, by Paul Becher, Ingeniøren (Copenhagen) Vol. 64, No. 42, 1955, pp. 827-31: Chimneys of various masonry constructions, times of curing, flue diameters, outer protections; fuels anthracite, coke, lignite, peat, wood, oil, city gas; examples of good and bad practice in chimney design, heat transmission data.

3. Tests on Types of Chimneys with Regard to Fire Resistance, by Gerhard Hansen, Ingeniøren (Copenhagen) Vol. 64, No. 42, 1955, pp. 832-33: Light-weight concretes (pumice, cinder, etc.) tested to 1000°C; small heating stove source; describes development of dangerous cracks; brick chimney reference.

4. The Construction of Central Heating Flues, by M. Bergström, Teknisk Tidskrift (Stockholm), 80 (13), 1950, pp. 288-94: Temperatures in soot fires to 1300°C; tests of chimneys having inner and outer shells of brickwork with intermediate layer of mineral wool; also outer layer of concrete approximately 4-in. thick; states that inner lining should be able to move freely when expanded by heat; minor cracking of inner shell not important if outer shell remains intact.

5. The Problem of the Flue from the Fireman's Point of View, by I. Strömdahl, Teknisk Tidskrift, 80 (13), 1950, pp. 283-6: Temperature rise in flue fires may be very rapid (in one test 900°C in 3 min, 1300°C in 15 min); wood supplanted coke as fuel.

6. Fires in Flues from the Point of View of Insurance Companies, by A. Sylven, Teknisk Tidskrift 80 (13), 1950, pp. 286-8: Quick fires of short duration seldom cause damage to a well-constructed brick chimney, even at very high temperatures; inner brickwork of double-shelled brick chimney with mineral wool between withstood 10 soot fires to as high as 1400°C before destruction.

7. Recommended Minimum Requirements for Small Dwelling Construction, Bureau of Standards Building and Housing Publication No. 18, 1932, pp. 19-22 and 79-89: Designs of chimneys and fireplaces, and methods of framing combustible members around them (mostly from NBFU); recommends round flues as providing better draft; ceramic flue lining, not parged brickwork; states that various studies indicate that the minimum height of chimneys for dwellings should be 30 to 35 ft; chimneys less than 30 ft are apt to be erratic in behavior; for fireplaces, good draft design requires an effective area of flue of 1/12 of the area of the fireplace opening.

8. The Problem of the Open Fire, by W. F. B. Shaw, J. Institute of Heating and Ventilating Engineers, Vol. 23, Sept. 1955, pp. 205-28: Review of open fire (coal or coke) heating; problem of excess air flow - recommends 4-in. wide chimney throat (based on work of Rumford, 1796).

9. Temperature of the Wall Behind a Back-Boiler Fire, by L. L. Fox and D. Whittaker, J. Institute of Heating and Ventilating Engineers, Vol. 26, 1958, pp. 80-5: Model byelaws state that thickness of the rear wall of the fireplace recess shall be not less than 4 in. for external walls or 8-1/2 in. for internal. On a bare 9-in. brick back wall, the highest temperature on outside surface was 130°F with coke fuel and 150°F with coal. Burning house coal at the greatest possible rate for 12 hours, a boiler fire produced a temperature of 175°F on a bare outside wall 9 inches thick, and 305°F on a 4-1/2 thick wall. With a 1-in. board cemented to the brick, temperatures of 265° and 570°F were attained on the brick for the two wall thicknesses.

10. Influence of Air Flow on Intermittent Heating with the Open Fire, by L. L. Fox and D. Whittaker, J. Institute of Heating and Ventilating Engineers, Vol. 26, 1958, pp. 221-31: Open fire performance related to chimney air flow and the heat capacity of a massive chimney-breast. Improvement of efficiency results from a reduction in chimney air flow.

11. Some Measurement of Temperatures of Metal Flues of Domestic Heating Appliances, by L. L. Fox and D. Whittaker, J. Institute of Heating and Ventilating Engineers, Vol. 23, 1955, pp. 183-92: Three types of small solid-fuel appliances in normal operation; gives temperatures of flue gas and surface of sheet metal flue pipe; coal and coke fuels-coal gave higher flue gas temperatures; states that in a closed fire with solid fuel, considerable and rapid changes in temperature are possible; some mention of fire hazard to adjacent timber (no data).

12. An Analysis of Survey Information on Chimney Fires, Joint Fire Research Organization (UK), May 1957: No evidence that use of fuels other than coal contributed substantially to the incidence of chimney fires (except for some coke, fuels other than coal are little used in Britain); suggests that frequent cleaning of lower part of the chimney may be an important factor in preventing fires.

13. Chimney Flues of Concrete Block, Centre Scientifique et Technique du Bâtiment (France), No. 44, Cahier 348, June 1960: Lightweight concrete chimney block units, some with coverings of 1 or 2 cm of plaster; temperatures on interior and exterior faces of flue for various flue gas temperatures; fuels were coal, wood, oil; effect of heat on various concretes.

14. Station for Tests of Chimney Flues, Centre Scientifique et Technique du Bâtiment (France), No. 47, Cahier 379, December 1960, p. 14: Tests for the effect of thermal shock (flue gases at 400° and 500°C) on concrete block chimney flues; gas permeability (before and after thermal shock) of the blocks.

15. Contribution to the Study of the Behavior Under Heat of Concretes for Chimney Flues, by M. L. Boy, Centre Scientifique et Technique du Bâtiment (France), No. 51, Cahier 408, August 1961: Description of concretes offering resistance to heat effects and thermal shocks, for use in chimney flues; concludes that concrete flue liners should not be subjected to thermal shock until several months after fabrication; currently used cements (in France) behave much the same under heat, but it is necessary to choose an aggregate with a low coefficient of expansion; temperature gradients in chimney walls are great enough to engender high thermal stresses.

16. Flues (Approval of New Materials and Non-traditional Methods of Construction), Cahiers du C.S.T.B. (France) No. 49, F. 4 1961, 392: Approval tests on various proprietary concrete chimney flue blocks, mainly with pozzualanic aggregate; description of cracking from thermal shock, and transmission of flue gases through block.

17. Testing of a Chimney, by Göte Larsson, Statens Provningsanstalt, Stockholm, Meddelande 125, 1959: Many fires originate in chimneys; tests with brick chimneys indicate that with a wall thickness of about 12 cm (4-3/4 in.), combustible materials will be ignited if maintained in long continued contact with the chimney having flue gas temperatures of 400°C; while ignition of combustibles near chimneys has been attributed to lack of tightness of the chimney walls, it appears that ignition occurs because of unsatisfactory insulation; if the expansion of a chimney is obstructed or restrained during a chimney fire, cracks can be formed through the entire brickwork of the chimney-thus, chimney brickwork should not support flooring unless the chimney has an internal, independent flue, not joined to the brickwork supporting the floor.

18. Residential Chimneys of Non-traditional Design, Institute TNO voor Bouwmaterialen en Bouwconstructies 1961-1: Optimal chimney cross-section for furnace output of 39,600 Btu/hr is round with diameter of 12 cm (4-3/4 in.); with this chimney in concrete of 6 cm. minimum thickness, the heat transmission coefficient of the concrete in room-dry condition not higher than 0.4 kcal/m.h. °C, and a constant flue gas temperature of 600 degrees C above the ambient, the temperature difference of the outer wall surface with the ambient depends on the wall thickness, and amounts to:

Wall thickness	6.0	6.5	7.0	7.5	8.0	cm
Temp. Difference on exterior	146	126	114	104	95	°C

Advantages of concrete chimney with ceramic flue liner over traditional brick chimney:

a. better draft and insulation

b. lower temperatures on outer covering

c. fewer cracks

d. no attack on mortar joints by flue gases or high temperatures.

Unlined concrete chimneys have lesser advantages over brick.

Disadvantages of concrete chimneys:

a. The resistance of concrete against attack by flue gas is significantly lower than that of brick.

b. The heat resistance of concrete is less than that of brick.

The report recommends:

a. Limiting cracks in an unlined chimney by use of horizontal reinforcing.

b. Providing a ceramic pipe flue lining to limit effects of gas attack and high temperatures, and to reduce temperature rise on the outer cover of the chimney.

c. Careful alignment of flue pipes, avoiding bulging mortar joints.

d. A nonquartz-bearing porous aggretate, low water-cement ratio in the concrete, density suitable for vibrating.

19. Flow of Heat in a Room with Fire and Chimney, by T. Ferguson, Engineering (London), Vol. 186, No. 4830, Oct. 3, 1958, pp. 454-6: Heat loss from fireplaces reduced by addition of an adjustable chimney throat restrictor; data for airflow resistance of chimney circuits.

20. ACI Standard Specification for the Design and Construction of Reinforced Concrete Chimneys (ACI 505-54), American Concrete Institute Journal 26 (1), 1954-55, pp. 1-48: Formulas for determing temperature gradients through concrete chimney shells.

21. Chimney Stacks Made of Precast Concrete Units, by G. Heinicke, Betonsteinzeitung (Wiesbaden), Vol. 22, No. 12, Dec. 1956, pp. 718-26: Describes requirements for chimney construction of concrete block, and the technical and economic advantages of the use of this material; illustrates methods of framing roof members around chimney.

22. Observed Performance of Some Experimental Chimneys, by R. S. Dill, P. R. Achenbach, J. T. Duck, Heating, Piping and Air Conditioning, Vol. 14, April 1942, pp. 252-6: Tests on two experimental, residential type chimneys operating at various stack heights, gas flows and inlet temperatures. Data for temperature gradients at different levels in chimneys; also draft data; brick masonry chimneys 38 ft high and 4 in. thick around a tile flue liner (inside dimensions 7-1/4 by 7-1/4 and 6-1/2 by 11 in.). Tests made at NBS.

23. Fire Hazard Tests with Masonry Chimneys, by Nolan D. Mitchell, NFPA Quarterly, Vol. 43, No. 2 Oct. 1949 (Reprint): Tests of 21 different masonry chimneys (brick, tile, concrete block and chimney units), unlined and with ceramic or vitreous enemeled steel liners; coal, wood, gas fuels; tests indicate that unlined masonry chimneys present greater fire hazards than do lined ones; liners should not be rigidly fixed to chimney wall; round liners appear to have some advantage over rectangular ones; concrete chimney

units having integrally cast liners developed cracks through both the liner and masonry wall; the required space between chimney wall and wood framing should be left unfilled except that noncombustible fire stopping may be used at the bottom (fills of mineral wool between joists and chimney resulted in some cases of ignition of the wood); wood plaster grounds should be removed; staying at floor or roof level should be limited to contact with floor or sheathing up to 1-1/2 in. from corners of chimney.

24. Fire Hazard of Domestic Heating Installations, by G. Q. Voigt, Bureau of Standards Research Paper RP 596, Sept. 1933: Tests with domestic stoves, furnaces and their pipes; temperature rise on partitions, ceilings and floors; effect of some protective materials; wood ignition from short-time exposure at temperatures of 250 to 300°C; long-term exposure may cause ignition at 150°C; temperatures frequently exceeding 125°C (257°F) should be avoided, but temperatures of 150°C (302°F may be occasionally tolerated; smoke pipes, uninsulated, passing through combustible partitions require 4-in. vented airspace, or may be insulated with 2-in. mineral wool; stoves having the fire box or ash pit directly on the floor can transmit temperatures capable of igniting wood through a 4-in. thick brick base; if a 5-in. air space is left between stove and floor, the floor should be further protected with 1/4-in. asbestos or similar material under sheet metal; the results indicate the possibility of igniting wood forms left under brick or concrete arches supporting fireplaces.

25. Residential Fireplace Design, Structural Clay Products Institute, Technical Notes on Brick and Tile Construction, Vol. 6, No. 10, Oct. 1955: Description of parts; National Building Codes recommendations; table of flue sizes for different sizes and types (single face, two face, etc.) of fireplaces.

26. Residential Chimney Design and Construction, Structural Clay Products Institute, Technical Notes on Brick and Tile Construction, Vol. 3, No. 1, Jan 1952: Brick chimneys 4-in. thick with standard 8- x 8-in. flue liners; one chimney, flue lining sections not cemented, space left between lining and brick; another, flue linings bonded and space between liner and brick filled solidly with cement mortar; in tests, airspace had no effect on the operation, and no appreciable insulating value; grouted liner considered preferable on the grounds of greater

strength and ability to stay in place when cracked; recommends standard construction and clearances from combustibles (NBFU Standard Ordinance for Chimney Construction).

27. Temperatures Developed in Chimneys for Low Cost Houses, NBS Technical News Bulletin No. 328, August 1944, p. 62: To establish performance requirements for tests of lightweight, prefabricated chimneys, tests were conducted with lined and unlined brick chimneys having 4-in. thick clay-brick walls; floor joists framed 2 in. away from chimney surface, but edges of floor boards and nailing strips for base trim in contact; after approximately 13 hr for the lined chimneys and slightly less time for the unlined, and with flue gas temperatures of 1100°F and 900°F, respectively, hazardous temperature conditions were created on surrounding wood.

28. The Heating of Panels by Flue Pipes, by D. I. Lawson, L. L. Fox, C. T. Webster, DSIR, Fire Offices Committee, Fire Research Special Report No. 1, London, HMSO, 1952: Temperature rise of a vertical panel near a cylindrical radiating surface may be computed; an asbestos shield is effective in reducing the temperature of the panel; advantageous to separate the shield and the panel, but little additional temperature reduction in separations greater than 1/2 in.; metal shield probably even more effective; theoretical and experimental derivation for flue pipes not covered or enclosed; tests with solid fuels.

29. Clearances and Insulation of Heating Appliances, by John A. Neele, Underwriters' Laboratories, Inc., Bulletin of Research No. 27, June 1945: Heating of adjacent woodwork by stoves and smokepipes; safe maximum temperature for long-continued exposure of wood taken as 90°F above room temperature;thoroughly dried and slightly scorched wood panels were found to develop higher temperatures on the surface than they did when first used; in order not to exceed the maximum 90°F rise, a clearance of 7 in. would have to be provided between a wood panel and a smokepipe at 450°F.

30. Performance of Type B Gas Vents for Gas-Fired Appliances, by L. M. Kline and H. Witte, Underwriters' Laboratories, Inc. Bulletin of Research No. 51, May 1959: Tests to determine the temperatures of flue gas through different vent systems; heat sources were a central furnace, a floor furnace, water heater, unit heater and room heater; four styles of vent pipes (double-wall with 1/2- and 1/4-in. airspace, single-wall and asbestos-cement), mostly 3-and 5-in. diameter; temperature rises of flue gases at inlet of draft hoods and of vents, of vent pipe walls, and on walls of vent pipe enclosures; least heat transmission with double-wall metal pipe with 1/2-in. airspace; also included in the report was a survey of the ignition of wood exposed at high temperatures for long periods of time, from which it was concluded that such exposure should be limited to 90°F above room temperature.

Underwriters' Laboratories, Inc. Standards for Safety, Gas Vents UL 441, Factory-Built Fireplaces UL 127 and Chimneys, Factory Built UL 103 have requirements for maximum temperatures on enclosures for the parts, or on the vents, fireplaces or chimneys at points of zero clearance from combustible members of a structure that generally reflect a 90°F rise limitation. Under certain circumstances of abnormal conditions of firing or operation wherein excessive temperatures, usually of short duration, may arise in a flue or fireplace, a greater temperature rise on surrounding structures is permitted. In no case, however, is the specified limiting rise greater than 175°F.

A study of NBS informal reports to several Government agencies, and the considerable body of correspondence on fireplaces and chimneys reveals some information, although in at least a few instances, it appears to be based on the results of other works, including those reviewed herein.

In tests of prefabricated enameled metal chimneys for solid or liquid fuel furnaces in war emergency housing, a limiting rise of 375 degrees F on the outer surface of the chimney covering was established for a flue gas temperature of 1000°F. This condition was considered to offer protection to the combustible framing and woodwork spaced a minimum of 2 in. from the chimney. It was concluded that satisfactory insulation could be achieved with asbestos paper plies totalling about 1-3/4 in. in thickness and having a low combustible content, 5 per cent or preferably less. Some asbestos-cement pipe coverings were also found to be capable of reducing heat transmission to the required extent.

The following points are made in letter correspondence of the Bureau:

In venting an oil burning floor furnace below combustible floor construction, the possible existence of a flue gas temperature of 1000°F must be considered. If this temperature prevails on the outer surface of the flue, unprotected combustible floors must be spaced 12 in. from the chimney, and columns or walls 9 in. away. Spacings can be reduced by one half if protection such as 1/8-in. asbestos millboard is placed in the air space between the flue and the wood.

Bonnet temperature above a coal-fired forced warm air furnace was 481°F when the flue temperature was 1360°F. At a point in a branch duct 4-1/2 ft from the top of the combustion chamber, the temperature was 400°F.

Solid foundations were not recommended for use under domestic heating plants where the foundation is in contact with combustibles; preferably there should be an open air space between combustion chamber and cement floor. States that a solid foundation has transmitted enough heat from the firebox to ignite combustible material beneath it.

Cement-asbestos flue pipe suitable for gas-fired stoves only.

No record of fires traceable to heat conduction through a properly built brick chimney.

Blanket-type insulation of mineral wool bound to flue with asbestos paper and woven wire fabric was satisfactory, but not premolded insulations of mineral wool or fiber glass (combustible binder).

3. Recent Works Not Included in Review

31. Chimney Fires, Fire, 1958, 51 (639) 197, 200.

32. Chimneys and Fire Protection (Swed.), A. H. Bergquist, Byggmastaren 1958, 134, 77-80.

33. Modern Flue and Chimney Construction, Bldg. Mat. 1958, 18(2), 69-70.

34. Structural Fire Protection, Fortschritte u. Forschungen im Bauwesen, Reihe D, Heft 27, Franckh'sche Verlagshandlung, Stuttgart 1957 (Fire resistance of flues of standard masonry and of lightweight concrete castings).

35. Experimental Observations Concerning Cracks in Flues, Claudon and Tirel, Ann. Inst. Bâtim. 1958, 11(121), 40-52.

36. Thermal Stresses in Flues, J. Tirel, Ann. Inst. Bâtim. 1958, 11 (121), 28-39.

37. Domestic Flues, P. Becher, Industries Thermiques, 1957, (11), 655-65.

38. Theory of the Construction of Chimney Flues, R. Cadiergues, Industries Thermiques, 1957, (11), 689-701.

39. Gas Flues, Archit. (Build.) J. 1958, 127 (3295), 624-34.

40. The Cracking of Flues, CSTB (France), Cahier 238, 1957.

41. Materials for Flues, A. Claudon, Industries Thermiques, 1957, (11), 666-88.

42. The Design of Domestic Open Fires, D. K. Darby, Plumber, 1958, 80 (1949) 45-50; (950) 43-4.

43. Space Heating and Associated Fire Hazards, Booklet No. 33, Fire Protection Assn., London, 1957.

44. Lighweight Concrete Shaped Blocks of up to 700 cm^2 Section, Standard DIN 18150, Deutscher Normenausschuss, Berlin, 1956.

45. Oil Fired Domestic Boilers and Air Heaters for Hot Water Supply and Space Heating: Safety Recommendations, Booklet No. 31, Fire Protection Association, London, 1957.

46. Fire Hazards of Chimneys and Flues, Technical Information Sheet 1001, Fire Protection Association, London.

47. Maximum Temperatures Attained in Chimney Flues, A. Claudon, Industries Thermiques, 1957, 3 (1), 21-40.

48. Fire Tests on Domestic Chimneys, by H. Seekamp and K. Mohler, Verl. von Wilm. Ernst u. Sohn, Berlin, 1956.

49. Aluminium-Sheet Chimneys, Light Metals Bul., 1956, 18 (8), 316.

50. Flue Pipes and Combustible Materials, Fire Prot. Assn. Journal, 1956 (33), 207.

51. Flue Piping Causes Fire, Fire Protection (Rev.),1956, 19 (185), 178.

52. Temperatures on a Wood Ceiling about a Furnace Plenum, R. Ditsworth, Heat. Air Condit. Contract.,1955, 27 (2) (Issue 715), 31-7.

53. Chimney Fires, Prot. Civile (France), 1956, (23), 46-7.

54. The Fireproof Chimney, Bayerischen Versicherungskammer, 1959.

55. The Protection of Floors under Fireplaces, F. Mayer, Osterr. Feuerwehr, 1955, 9 (1), 8-9.

56. Tentative Code of Minimum Obligatory Conditions for the Fixing of Fire-Grates and Associated Conduits, Ann. Inst. Bâtiment, 1955, 8 (94), Supp.

57. Design of Heating and Ventilating Systems, F. W. Hutchinson, N. Y., The Industrial Press, 1955.

58. A Guide to Current Practice, Inst. of Heat. Vent. Engrs, London 1955.

59. Asbestos-Cement Flue Pipes and Fittings, Light Quality, BS 567: 1954, British Standards Institution, London.

60. Domestic Fireplaces and Chimneys, Commonwealth Experimental Bldg. Sta. Dept. of Works and Housing, Australia, Notes on the Science of Building, No. SB31, Chatswood, N.S.W., Sept. 1954.

61. Prefabrication in Traditional House Building I, N. S. Pippard and W. G. Buckle, Prefabrication, 1954, 1 (7), 15-8 (Brit. prefab. brick chimney stack).

62. Fire Incidents with Fireplaces, Flue Pipes and Chimneys, R. Quester, Osterr. Feuerwehr, 1953, 7 (3) 47-7, 49.

63. The Hazard of Domestic Fire, J. F. Fry, J. Roy. Inst. Brit. Archit., 1953, 61 (1), 18-20

64. Fire Tests on Chimneys, S. Ausobsky, Osterr. Feuerwehr, 1952, 6 (12), 234-6.

65. Structural Timber under the Hearth, Fire Prot. Assn. J., 1952 (19), 307-8.

66. Flue Pipes and Hearths, Norsk Brannvern Forening, Oslo, Sept. 1952.

67. New Documents on Flue Construction, Ribaud, Puteaux, Fournol and Gouffé, CSTB (France), Cahier 111, 1951.

68. Regulations and Instructions on the Venting of Domestic Gas Heating Appliances, O. Rösler, Gas, Wasser, Wärme, 1951, 5 (1), 6-16.

69. Domestic Chimneys, P. Becher, Statens Byggeforskningsinstitut, Studie No. 6, Copenhagen, 1951.

70. Fire Resistance Tests on Chimney Blocks and Glass Panels, K. Walz and J. Strey, T.I.Z., 1951, 75 (13/14), 203-8.

71. Flues for Domestic Appliances Burning Solid Fuel, Brit. Stds. Instn., Council of Codes of Practice for Bldgs., CP 131.101 (1951), London.

72. Domestic Hearths. Fires Due to Defects, Fire Prot. Assn. J., 1951 (12), Jan. 9-11.

73. Three Hazards that Need Watching, Doors, Flues, Water Heaters, Fire Protection, 1951, 14 (130), 317-8.

74. Smoky Chimneys, Bldg. Research Sta., B.R.S. Digest No. 18, May 1950. (Principles of correct design of fireplaces and flues).

75. Chimney Constructions and Dimensions of Bricks, Virtala and Koskela, Valton Teknillinen Tutkimuslaitos, Tiedoitus 40 and 43, Helsinki, 1947.

76. Drawings of the Principles of Construction of the Swedish Fire Prevention Assn., Svenska Brandskyddsföreningen, Stockholm 1946 (construction of fireplaces and flues).

77. Precast Concrete Flues, Concrete Building, 1946, 21 (8), 103-7.

4. Available Information for FHA Proposal 1.26

It appears that some of the material covered in the Bibliography of Papers Available for Review at NBS (Section 2) gives, or, at least, suggests answers to some of the questions in Proposal 1.26 (see Appendix A). Each of the 18 questions will be considered briefly, and where possible, reference will be made, by number, to the papers reviewed in the bibliography.

1. Reference 7 recommends an effective flue area 1/12 area of fireplace opening. References 8, 10, 19 stress importance of restricting chimney air flow to increase efficiency of open fire. Reference 25 has a table of flue sizes for different sizes and types of fireplaces (no indication of source data).

2. No precise data seems available. Reports stress importance of preventing downdrafts and other erratic behavior caused by wind. Minimum would require consideration of many atmospheric conditions. Reference 7 states 30 to 35 ft minimum chimney height required to secure good draft and avoid misfunction.

3. References 4 and 6 describe tests of chimneys with brick liners (separated from outer brickwork by mineral wool layer). Lightweight concrete block chimney units are described in 13-16, 21. The advantage of concrete chimneys, especially with ceramic liners is shown in reference 18, which also gives a table of temperature differences from the ambient as a function of wall thickness of concrete chimneys (fixed flue gas temperature and concrete heat transmission coefficient). In reference 23 it states that unlined masonry chimneys present greater fire hazard; concrete chimney units with integrally cast liners developed cracks through both liner and masonry wall.

4. Air space or soft mortar fill required to allow movement of inner liner and minimize cracking (references 4, 17, 23). However, reference 26 states that grouted liner is preferable in that it has greater strength and ability to stay in place when cracked.

5. References 9, 17, 27 describe the development of hazardous conditions on the surface of masonry chimneys. Filling the 2-in. space between joist and chimney resulted in some cases of ignition of the wood (reference 23). Tests show that ignition temperatures of wood are significantly lower after long continued or even intermittent exposure at elevated temperatures (references 24, 29).

6. No precise data, but reference 23 indicates that flooring or roof sheathing may be in contact with a masonry chimney up to 1-1/2 in. in from corners of chimney. In tests described in reference 27, in which edges of floor boards and nailing strips for base trim were in contact with brick chimneys, hazardous temperature conditions were developed on the wood.

7. Reference 23 states that this practice is satisfactory on masonry chimneys.

8. There do not appear to be any data. Regulations stating that there must be a 2-in clearance of combustibles, or combustibles may be 6 in. from flue liner seem to equate 2 in. of masonry with a 2-in. airspace. (see reference 23 for effect of mineral wool between chimney and joist).

9. No references on chimney caps. It would appear that this part, which is subjected to severe conditions (thermal stress, attack by flue gas, effect of freezing and thawing, action of movement of chimney liner), should not be changed if the MPS design has proved satisfactory.

10. Reference 24 states that temperatures capable of igniting wood occurred through a 4-in. thick brick base from a stove having its fire box directly on the floor. For such stoves (and by analogy, fireplaces) recommends a 5-in. airspace between stove and floor and further protection of floor with 1/4-in. asbestos under sheet metal.

11. No data found. A little information available on brick fireplaces, but not on concrete masonry. Comparison of concrete masonry fireplace construction with concrete chimneys does not appear valid, as the chimney, except at the rare and relatively brief occurrence of a soot burnout, is not subjected to flame as is the fireplace structure.

12. Reference 9 gives temperatures on outer surface of a 9-in. brick wall (265°F under a 1-in. board after 12 hr maximum firing). It would appear that the provisions of Underwriters' Laboratories, Inc. Standard for Factory-Built Fireplaces, UL 127, would apply to steel fireplace liners.

13. Do not appear to be actual test data, but data from other tests indicating the temperature rise to be expected on combustibles at a distance from a heated surface may be applicable if temperatures on fireplace walls are obtainable (references 28,29).

14. Reference 9 states that the 4-in. wall behind a fireplace is allowed as an external wall only, in Britain. Figures in this reference indicate that a 9-in. brick wall would not limit the temperature rise on combustibles in contact as required by UL Standards (References 29,30).

15. No information on material of hearth.

16. No actual data on hearth extension. UL quotes National Code for outer hearth dimensions in UL 127, Factory-Built Fireplaces.

17. No references except UL 127 on placing combustible material near edges of fireplace opening. It would appear that effectiveness of fire screen may be a factor. Also, too close positioning of combustibles on face of fireplace to opening could possibly negate the intent of requirements specifying a minimum thickness of masonry.

18. It appears that this is covered by UL 127 on Factory-Built Fireplaces which states (para. 42) that insulating materials required to protect combustible parts of the building shall be supplied as an integral part of the fireplace assembly.

5. Conclusions

A study of the available material on chimneys and fireplaces has indicated answers to some of the questions proposed by FHA. Information pertinent to the specific points of inquiry have been presented herein, together with collateral material that may also have a bearing on the requirements of the Minimum Property Standards.

The amount of research being conducted at present on the fire hazards of chimneys and fireplaces is apparently very small. An examination of the Directory of Fire Research in the U. S. (Publication 904, NAS-NRC, 1961) indicates that no effort whatever is being expended in this direction. European work also is, at best, extremely limited. The results, too, are often not fully applicable to conditions here, as considerable differences may exist in materials, fuels and thermal output of heating units. For this reason, and also because it appears many workers are mining the same field, it is considered that a review of the papers in Section 3 would not yield data of any great significance, and quite possibly not compensatory of the effort required to secure them.

It would seem that the material presented here already answers some of the more important questions raised in Proposal 1.26. Where specific information is lacking, standards for fire safety, which must cover not only ordinary but the worst possible conditions, should err on the side of overprotection.

Further information is, of course, obtainable through research in any areas of interest the Federal Housing Administration may have. Specific recommendations cannot be made, however, without an indication of these particular interests. Such tests would be extensive and costly as the factors involved in any study would be numerous and complex. In lieu of this, it is suggested that use be made of all available data, supplemented where needed by the store of knowledge of good construction gained through practical experience. That reliance on the data and experience is a suitable course is evidenced by the fact that observation, as well as the meager available statistics on the causes of fire has indicated that fireplaces and chimneys are only a minor factor in fires occurring in residential properties.

APPENDIX "A"

PROPOSAL FOR STUDY OF

CONSTRUCTION AND DESIGN OF CHIMNEYS AND FIREPLACES

1.0 STATEMENT OF THE PROBLEM

A. Minimum fire protection construction and clearances between chimneys and fireplaces and adjoining combustible materials need to be determined.

B. Fundamental dimensions and design arrangements required to assure satisfactory performance of fireplaces and chimneys are needed for the Minimum Property Standards.

2.0 BACKGROUND

The Minimum Property Standards spell out minimum clearances for fire protection of combustible materials. They also provide dimensional limits for the design and arrangement of chimneys and fireplaces.

Tests have been conducted by Underwriters' Laboratories, the National Bureau of Standards, and private schools and laboratories to establish safe relationships between potentially hot surfaces and adjoining combustible materials. In addition, the National Fire Prevention Association and the National Board of Fire Underwriters have developed codes which specify many of the nominal clearances that must be maintained in building construction.

Despite the extensive research that has gone on, there are still many fire clearances in modern building structures that have not been definitely determined by actual experimentation or tests. Moreover, there are inconsistencies in design and arrangement of present day fireplaces and chimneys that have never been resolved.

At the present time, the MPS's are based on information obtained primarily from building codes or from judgments of the FHA staff. Although codes are a satisfactory source of such information to FHA, requirements contained in the various codes differ widely when compared one with another. Moreover, it appears that some of these requirements are based on compromise opinions rather than tested facts. FHA believes these differences and opinions need now to be resolved by actual tests.

This proposal outlines the major areas in which MPS requirements for fire protection of combustible materials and for design and arrangement of chimneys and fireplaces are believed to be inadequate. It is suggested that a program of tests be inaugurated to provide factual answers.

3.0 QUESTIONS

Answers are needed to unresolved questions arising from the MPS such as the following. Others should be added as the study progresses and their needs are recognized.

Chimneys

1) What should be the relationship between chimney flue area and fireplace opening area for various chimney heights and fireplace arrangements?

2) What should be the minimum height of chimney extension beyond the highest point of the adjoining roof?

3) If fire clay liners are omitted from masonry chimneys, what kind of brick or block at what minimum thickness should be allowed?

4) Most codes require 1/2" air space between the flue liner and the surrounding masonry of chimneys, yet the West Coast allows this space to be filled with mortar. Is this air space really necessary?

5) Most codes agree that a 2" air space should be required between wood framing members and the masonry chimney wall. Is this realistic in light of actual experiences and tests?

6) What air space should be required, based on actual tests, between masonry chimney walls and subflooring, flooring and roof sheathing, respectively?

7) According to most codes, furring strips not wider than $1\frac{1}{2}$" may be installed with zero clearances at corners of chimneys. Is this realistic in light of actual tests?

8) The MPS states that piers built integrally with the chimney for support of wood beams or girders may be used provided the wood is separated from chimney masonry with at least 2" air space. If more masonry is used, by how much may this 2" space be reduced?

9) The MPS requires a chimney cap of concrete or other waterproof noncombustible material with a minimum thickness of 2" at the outside edge. What limitations on design, materials, dimensions and reinforcement should be imposed on this chimney cap?

Fireplaces

10) The MPS requires that fireplaces be supported on concrete or masonry, yet San Francisco permits fireplaces to be supported on frame structures provided certain fire-preventing measures are met. What limitations should the MPS impose on fireplaces supported by frame structures?

11) The MPS requires that concrete masonry fireplaces shall be made of solid units, yet chimney liners may be constructed with air spaces. What kind of construction should be required for concrete masonry fireplaces both with and without fire brick liners?

12) Where a fire brick liner is not provided for a fireplace firebox wall, the MPS requires a masonry wall thickness not less than 12", but does not state the type of masonry to be used. What kind of brick or block of what total thickness may be substituted for the lining? If a steel fireplace liner is used, what wall thickness and air space should be required?

13) The MPS requires certain minimum air space separations between various combustion materials and the fireplace walls. According to actual tests how much should these air spaces be?

14) The MPS and most codes state that fire clay parging may be omitted if the fireplace wall thickness is at least 8", yet the same codes require as little as a 4" wall thickness behind the smoke chamber. What minimum thickness of masonry should be used according to tests as a substitute for refractory linings in the principal high temperature zones?

15) Codes permit hearths to be constructed of brick, concrete, stone, and tile, yet these materials spall when heated excessively. Of what materials according to tests should the hearths be constructed?

16) The MPS gives hearth dimensions in relation to fireplace openings. According to actual tests, how far should the outer hearth extend? May it be omitted completely? What limitations should be placed upon a raised hearth?

17) Codes require that combustible materials should not be placed within 6" of the edges of a fireplace opening. The MPS restricts this to $3\frac{1}{2}$". What dimensional restriction should be placed upon location of combustible materials near fireplace openings?

18) The MPS requires the outer hearth for factory-built fireplaces to be made of noncombustible materials not less than

3/8" thick which may be placed upon subfloor or finish floor. What restrictions should be made in adapting factory-built fireplaces to combustible materials in the structure?

4.0 PRIORITY

Although the MPS is being completed now for publication, the information is still needed to answer questions from FHA field offices and to prepare technical bulletins for distribution in conjunction with the MPS. The information obtained will be useful not only to FHA but to code-writing organizations, insurance companies and the building industry as a whole.

5.0 RECOMMENDATIONS

None.

U. S. DEPARTMENT OF COMMERCE
Luther H. Hodges, *Secretary*

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

THE NATIONAL BUREAU OF STANDARDS

The scope of activities of the National Bureau of Standards at its major laboratories in Washington, D.C., and Boulder, Colorado, is suggested in the following listing of the divisions and sections engaged in technical work. In general, each section carries out specialized research, development, and engineering in the field indicated by its title. A brief description of the activities, and of the resultant publications, appears on the inside of the front cover.

WASHINGTON, D. C.

Electricity. Resistance and Reactance. Electrochemistry. Electrical Instruments. Magnetic Measurements. Dielectrics. High Voltage.

Metrology. Photometry and Colorimetry. Refractometry. Photographic Research. Length. Engineering Metrology. Mass and Scale. Volumetry and Densimetry.

Heat. Temperature Physics. Heat Measurements. Cryogenic Physics. Equation of State. Statistical Physics.

Radiation Physics. X-ray. Radioactivity. Radiation Theory. High Energy Radiation. Radiological Equipment. Nucleonic Instrumentation. Neutron Physics.

Analytical and Inorganic Chemistry. Pure Substances. Spectrochemistry. Solution Chemistry. Standard Reference Materials. Applied Analytical Research. Crystal Chemistry.

Mechanics. Sound. Pressure and Vacuum. Fluid Mechanics. Engineering Mechanics. Rheology. Combustion Controls.

Polymers. Macromolecules: Synthesis and Structure. Polymer Chemistry. Polymer Physics. Polymer Characterization. Polymer Evaluation and Testing. Applied Polymer Standards and Research. Dental Research.

Metallurgy. Engineering Metallurgy. Microscopy and Diffraction. Metal Reactions. Metal Physics. Electrolysis and Metal Deposition.

Inorganic Solids. Engineering Ceramics. Glass. Solid State Chemistry. Crystal Growth. Physical Properties. Crystallography.

Building Research. Structural Engineering. Fire Research. Mechanical Systems. Organic Building Materials. Codes and Safety Standards. Heat Transfer. Inorganic Building Materials. Metallic Building Materials.

Applied Mathematics. Numerical Analysis. Computation. Statistical Engineering. Mathematical Physics. Operations Research.

Data Processing Systems. Components and Techniques. Computer Technology. Measurements Automation. Engineering Applications. Systems Analysis.

Atomic Physics. Spectroscopy. Infrared Spectroscopy. Solid State Physics. Electron Physics. Atomic Physics.

Instrumentation. Engineering Electronics. Electron Devices. Electronic Instrumentation. Mechanical Instruments. Basic Instrumentation.

Physical Chemistry. Thermochemistry. Surface Chemistry. Organic Chemistry. Molecular Spectroscopy. Molecular Kinetics. Mass Spectrometry.

Office of Weights and Measures.

BOULDER, COLO.

Cryogenic Engineering Laboratory. Cryogenic Equipment. Cryogenic Processes. Properties of Materials. Cryogenic Technical Services.

CENTRAL RADIO PROPAGATION LABORATORY

Ionosphere Research and Propagation. Low Frequency and Very Low Frequency Research. Ionosphere Research. Prediction Services. Sun-Earth Relationships. Field Engineering. Radio Warning Services. Vertical Soundings Research.

Radio Propagation Engineering. Data Reduction Instrumentation. Radio Noise. Tropospheric Measurements. Tropospheric Analysis. Propagation-Terrain Effects. Radio-Meteorology. Lower Atmosphere Physics.

Radio Systems. Applied Electromagnetic Theory. High Frequency and Very High Frequency Research. Modulation Research. Antenna Research. Navigation Systems.

Upper Atmosphere and Space Physics. Upper Atmosphere and Plasma Physics. Ionosphere and Exosphere Scatter. Airglow and Aurora. Ionospheric Radio Astronomy.

RADIO STANDARDS LABORATORY

Radio Physics. Radio Broadcast Service. Radio and Microwave Materials. Atomic Frequency and Time-Interval Standards. Millimeter-Wave Research.

Circuit Standards. High Frequency Electrical Standards. Microwave Circuit Standards. Electronic Calibration Center.

NBS