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Engineering Standards as Collaborative Projects: Asbestos in the Table of Clearances

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The Table of Clearances to Combustible Construction, an American national engineering standard for the insulation of boilers and other heating devices, was established in 1943 as a collaborative project of the insurance industry, fire protection organizations, and the federal government. This standard, published as NFPA 89M, was to have exceptionally enduring economic, legal, and medical implications. NPFA 89M, incorporated into hundreds of building codes at all levels of government between 1943 and 1991, approved as code compliant only nine insulation assemblies, of which eight contained asbestos. The ninth could be used on boilers and furnaces but not on hot pipes. Thus, all insulations for hot pipes were, in almost every jurisdiction in the United States before 1991, required by law to contain asbestos. Despite the ubiquity of asbestos in building codes before 1991, all U.S. manufacturers of heating equipment, and most contractors and suppliers in the marketplace during the NFPA 89M period, are now being sued for billions of dollars because of their use and/or sale of asbestos in insulation, gaskets, and seals. This essay addresses the collaborative process by which the Table of Clearances to Combustible Construction became a national standard and its current relevance to asbestos litigation.

The Table of Clearances to Combustible Construction, an American national engineering standard for the insulation of boilers, hot pipes, furnaces, and other heating devices, was established in 1943 as a collaborative project of the insurance industry (Underwriters' Laboratories and the National Board of Fire Underwriters), the fire safety engineering community (National Fire Protection Association, NFPA), and three federal agencies: the National Bureau of Standards (NBS) of the Department of Commerce, the Federal Housing Administration (FHA), and the War Department, represented principally by the U.S. Navy. The boiler

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manufacturing and heating-contracting industries also played minor roles in this development process.[1]

This standard, eventually published as NFPA 89M, was to have economic, legal, and medical implications far beyond the wildest dreams of the project committee formed in the late 1930s to determine by testing what insulation assemblies could be trusted to keep combustible surfaces near heating appliances below 160°F when the latter were in normal operating mode.[2] NPFA 89M, incorporated into hundreds of building codes at all levels of government, heating-equipment manuals, and other engineering standards between 1943 and 1991, approved as code compliant only nine insulation assemblies, of which eight contained asbestos. The ninth, sheet metal spaced out from the heated surface by one inch, could be used on boilers and furnaces but not pipes, as no means of safely jacketing hot pipes with metal existed before the 1990s.[3] Thus all insulations for hot pipes were, in almost every jurisdiction in the United States before 1991, required by law to contain asbestos.[4]

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[1] Manufacturing industry representation on technical (codemaking) committees is, and has been since the early twentieth century, limited by rule to a 30% minority. See, for example, American National Standards Institute (ANSI), *ANSI Essential Requirements: Due Process Requirements for American National Standards* (2003), at www.ansi.org, accessed 4 June 2009; National Fire Protection Association (NFPA), "Regulations Governing Technical Committees," in *Yearbook and Committee List* (Boston, 1964), 79-86; and Building Officials and Code Administrators International (BOCA), "Democratic National Code Revision," *The BOCA National Mechanical Code*, 7th ed. (Country Club Hills, Ill., 1990), inside front cover.

[2] John A. Neale, *Clearances and Insulation of Heating Appliances*, Underwriters' Laboratories, Bulletin of Research no. 27 (1943; Chicago, 1972), reported to the heating industry generally in W. G. Labes, "Safe Mounting, Clearances for Heating Equipment," *Heating, Piping and Air Conditioning* 20, no. 2 (1948): 80. The 1971 edition of the NFPA standard was National Fire Protection Association, "Manual on Clearances for Heat Producing Appliances, NFPA No. 89M, 1971 Edition of No. 89M," in *National Fire Codes:* v.4: *Building Construction and Facilities* (Boston, 1971-1972). Individual standards are individually paginated.

[3] The insulation assemblies in the Table of Clearances were, of course, minimal standards required by the authorities having jurisdiction (AHJ's). "Deluxe" jacketed heating equipment included jacket linings of fiberglass or aircell asbestos to keep the exterior of the jacket cool to the touch and to provide better fuel efficiency. These were conveniences for consumers, however, not code issues. See American Society of Heating, Refrigerating and Air-Conditioning Engineers, *ASHRAE Guide and Data Book* (New York, 1964), 367-68 and catalog data section: 86.

[4] Bends, joints and valves, as well as electrical polarity issues, made metal jacketing infeasible on pipes until the pipes themselves were re-engineered in the 1990s. E. J. Wesemann, "Thermal Insulation," in Reno C. King, J. H. Walker, and Sabin Crocker, *Piping Handbook*, 5th ed. (New York, 1967), 6-1 to 6-21; and William C. Turner and John F. Malloy, *Handbook of Thermal Insulation Design Economics for Pipes and Equipment* (New York, 1980), 195. On the electrical

Despite this nearly universal endorsement of asbestos by local, state, and federal building and machinery codes before 1990, all manufacturers of heating equipment, and most still-solvent heating contractors and supply firms that were in the marketplace during the NFPA 89M period, are now being sued for billions of dollars because of their use and/or sale of asbestos in insulation, gaskets, and seals.[5] The collaborative process by which the Table of Clearances to Combustible Construction became a national standard, and its current relevance to asbestos litigation, are the subjects of this essay.

The Asbestos Litigation Master Narrative

Sheila Jasanoff tells us that "A master narrative is a compelling and frequently repeated story about the way the world works that takes hold of our imaginations and shapes the ways in which we perceive reality, as well as our possibilities for collective action."[6] The asbestos litigation master narrative, with which most of us are familiar, was itself the product of a project group, that of Ron Motley's South Carolina law firm and its expert witness Barry I. Castleman, whose 1985 doctoral dissertation at Johns Hopkins the firm supported.[7] Journalist Paul Brodeur also played an

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polarity problem, see J. B. Marks, "Protection of Thermal and Cryogenic Insulating Materials by the Use of Metal Jacketing and Mastic Coatings," in *Thermal Insulation, Materials, and Systems for Energy Conservation in the '80s: A Conference*, ed. F. A. Govan, D. M. Greason, and J. D. McAllister, for ASTM Committee C-16 on Thermal Insulation, U.S. Dept. of Energy and Oak Ridge National Laboratory (Philadelphia, Pa., 1983), 753.

[5] The Table of Clearances appeared in nearly all model codes between 1950 and 1988. These were in their turn affirmatively adopted by federal, state, and local governments as building law. Examples include National Board of Fire Underwriters, *National Building Code: A Code Prescribing Regulations Governing the Construction, Alteration, Equipment, Use and Occupancy, Location and Maintenance, Moving and Demolition of Buildings and Structures*, golden anniversary ed. (New York, 1955), 222; International Conference of Building Officials, *Uniform Building Code* (Pasadena, Calif., 1958), 346; American Insurance Association, Engineering and Safety Dept., *The National Building Code* (New York, 1976), 560; International Conference of Building Officials, Southern Building Code Congress, and American Insurance Association, *One and Two Family Dwelling Code under the Nationally Recognized Model Codes* (Pasadena, Calif., 1971), 126; International Conference of Building Officials, and International Association of Plumbing and Mechanical Officials, *Uniform Mechanical Code* (Whittier, Calif., 1982), 47.

[6] Sheila Jasanoff, Messenger Lecture, Cornell University, "The Facts of the Matter: How Science Speaks Truth to Power," Sept. 2008.

[7] Barry I. Castleman, "Asbestos: An Historical Case Study of Corporate Response to an Industrial Health Hazard" (Sc. D. diss., Public Health Policy, Johns Hopkins University, 1985). On the Motley firm's role, see Paul Brodeur, *Outrageous Misconduct: The Asbestos Industry on Trial* (New York, 1985), 139, 142, 149, and 216.

important role in popularizing the narrative in his 1985 *Outrageous Misconduct: The Asbestos Industry on Trial.*[8] The representative excerpts below from this apparently very persuasive and popular mythology are from the website of the University of Sheffield's Department of Estates:[9]

> Asbestos has been used for more than 2,000 years. It was named by the Ancient Greeks. . . . The Greeks also noted its harmful biological effects. Even though the Greek geographer Strabo and (it is reputed) the Roman naturalist Pliny the Elder, both observed the "sickness of the lungs" in the slaves that wove asbestos into cloth, they were in such awe of asbestos' seemingly magical properties that they ignored the symptoms. . . . Asbestos use was brought back in the 1700s, but did not become popular until the Industrial Revolution during the late 1800s. It then began to be used as insulation for steam pipes, turbines, boilers, kilns, ovens, and other high-temperature products. Ancient observations of the health risks of asbestos were either forgotten or ignored.
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> At the turn of the twentieth century, researchers began to notice a large number of deaths and lung problems in asbestos mining towns. In 1917 and 1918, it was observed by several studies in the United States that asbestos workers were dying unnaturally young. . . .
>
> In the 1930s major medical journals began to publish articles that linked asbestos to cancer. . . . This served as a warning to the asbestos companies, and afterwards they tried to cover up the health effects of asbestos. Asbestos companies continued to use asbestos in manufacturing and construction.
>
> Despite that many materials [sic], such as fibreglass insulation, were created to replace asbestos, companies that used asbestos ignored the safer alternatives. They ignored the danger for the sake of profits, much like the tobacco industry. The conduct of the asbestos companies is especially egregious, however, because the victims were largely exploited workers who were unaware of the serious health risks they were exposed to on a daily basis. [10]

Like most, if not all, master narratives, this narrative tells us more about the biases of the narrators than about anything that may have occurred in the historical past. First, it is demonstrably inaccurate in almost every particular: no ancient author warned of the dangerous of asbestos; information about asbestos' inhalation hazards was readily

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[8] Brodeur, *Outrageous Misconduct*.

[9] I am by no means the only person to characterize Paul Brodeur's works as "mythology." See Richard E. Berg, professor of physics at the University of Maryland, "Electromagnetic Radiation and the Health Effects of Ionizing Radiation," http://www.physics.umd.edu/lecdem/honr228q/specialtopics/health.htm, accessed 1 March 2011.

[10] University of Sheffield (UK), Estates & Facilities Management Department, "History of Asbestos," http://www.shef.ac.uk/efm/buildingoperations/asbestosmanagement/history, accessed 11 Feb. 2011.

available throughout the twentieth century; and alternative materials were not developed for asbestos' principal uses until the last quarter of the century.[11] Second, the role of building codes and engineering standards is entirely missing from this account. Asbestos is frequently characterized in the master narrative as "untested," although, as we shall see in the case of boiler and pipe insulation, the testing history of the mineral, which dates from the nineteenth century, was both voluminous and intellectually rigorous.

This master narrative, codified into five successive editions of Barry Castleman's *Asbestos: Medical and Legal Aspects*, has provided the framework for hundreds of thousands of asbestos torts in the United States, producing billions in revenue for plaintiff law firms.[12] In complaints, the arguments based on it take the form of a series of claims of negligence, breach of warranty, and conspiracy to suppress information about the health effects of asbestos. It is not unusual for Castleman's book to be incorporated by reference into the complaint. Dozens of defendants, often including small family-owned hardware stores and heating contractors, are named in these complaints.[13]

The legal rhetoric is illuminating. A 2010 complaint against a manufacturer of boilers, for example, alleges that "Defendant," during the

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[11] The "studies" mentioned by Sheffield University probably include Frederick Ludwig Hoffman, "Mortality from Respiratory Diseases in Dusty Trades (Inorganic Dusts)," U.S. Dept. of Labor, *Labor Statistics Bulletin* 231 (1918): 172-80; and Henry K. Pancoast, T. G. Miller, and H. R. M. Landis, "A Roentgenologic Study of the Effects of Dust Inhalation upon the Lungs," *Transactions of the Association of American Physicians* 32 (1917): 97-108. Although Pancoast was a physician, Hoffman had no scientific credentials of any kind. His highest level of academic achievement was a high school diploma; notoriously, he was the author of the classic work of scientific racism, published as *The Race Traits and Tendencies of the American Negro*, Publications of the American Economic Association 11, nos. 1-3 (New York, 1896): 1-329.

On alternatives, see "Fibrous Concrete (Proceedings of the Symposium on Fibrous Concrete), 1980," *Advances in Bioengineering* (1980); Richard W. Arnold, Jr., "Selecting Alternatives to Asbestos," *Materials Engineering* 105, no. 9 (1988): 59-62, 64-65; ASME Expert Panel on Alternatives to Asbestos in Brakes, and U.S. Environmental Protection Agency, *Analysis of the Feasibility of Replacing Asbestos in Automobile and Truck Brakes* (New York, 1988); A. A. Hodgson, A. M. Pye, P. C. Elmes, and Society of Chemical Industry (Great Britain), *Alternatives to Asbestos: The Pros and Cons*, Critical Reports on Applied Chemistry 26 (New York, 1989).

[12] The most recent edition is Barry I. Castleman and Stephen L. Berger, *Asbestos: Medical and Legal Aspects*, 5th ed. (New York, 2005).

[13] Kyla Asbury, "Hurricane Couple Names 89 Defendants in Asbestos Case," *West Virginia Record* (10 Oct. 2010), available at http://www.wvrecord.com/news/230458-hurricane-couple-names-89-defendants-in-asbestos-case, accessed 24 Feb 2011. On the hardware stores, see Patrick Leahy, "Misleading Advertisement for the Fairness in Asbestos Compensation Act," *Congressional Record* 145, no. 19 (1 Nov. 1999): 27655-56.

period at issue, "was engaged in the business of designing, processing, manufacturing, selling and distributing asbestos-insulated boilers." Then follows a brief statement justifying the venue, typically one known to be plaintiff-friendly, then a list of the employers at whose jobsites plaintiff claims exposure to the defendant's "asbestos-insulated boilers."[14] Next, we are told that "Defendant . . . owed Plaintiff the duty of ordinary care in its marketing, designing, selling, labeling, manufacturing and/or distributing of asbestos-containing products," proceeding to the inevitable claim that defendant

> . . . breached its duty of ordinary care and was negligent in that it knew and/or should have known that its asbestos containing products were likely to injure and cause respiratory disease in persons who were exposed to its products without warnings or with [sic] adequate warnings that exposure to [defendant's] asbestos containing products was likely to cause injury and respiratory disease and failed to place warnings or adequate warnings on its products, although it knew or in the exercise of ordinary care, should have known, that such warnings were necessary to avoid injury to individuals, including the Plaintiff.

Further negligence is then asserted in that defendant "Marketed a product containing asbestos fibers," adding that defendant should have warned plaintiff of the dangers of asbestos-containing materials, and should also have advised plaintiff what measures might have been taken to minimize those risks. Several further accusations are typically made: including that defendant "Failed to develop alternative, non-asbestos containing products in a timely manner when adequate substitutes were available," and "Negligently designed the asbestos containing products."[15]

Complaints then conclude with a list of the harms plaintiff has suffered and will suffer in future as a result of the defendant's alleged "negligence" in complying with national building codes and engineering standards that had taken, as we shall see, half a century to establish. Oddly, these codes and standards have only recently been introduced as elements of asbestos litigation defense.

The accounts of tortious behavior in these complaints, clearly based on the asbestos litigation master narrative, have been persuasive to juries in cases involving millions, and sometimes tens or even hundreds of millions of dollars, despite their failure to account for, or even so much as mention, the ubiquity of asbestos in building codes that required and/or specified the mineral in thousands of assemblies including heating, construction,

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[14] On venue shopping, see, for example, Peter Geier, "Lawyers Seek New Strategies for 'Sea Change' in Asbestos Torts," *National Law Journal* (11 Nov 2005), available at http://www.law.com/jsp/nlj/PubArticleNLJ.jsp?id=900005440944&slreturn=1&hbxlogin=1, accessed 26 Feb 2011.

[15] This complaint summary is drawn from Darrough vs. Union Carbide Corporation et al., No. 0122-CC01923, in the Circuit Court of the City of St. Louis, State of Missouri, 2010.

electrical installations, plumbing, theater safety curtains, and underground pipe.[16]

According to the narrative, asbestos defendants incorporated the mineral into their products because it was profitable to do so, ignoring safer alternatives. The engineering and testing histories of asbestos-containing materials show, however, that asbestos was used in thousands of approved assemblies because it was the material that passed standard engineering performance tests developed by the National Bureau of Standards (NBS), the National Fire Protection Association (NFPA), the American Society for Testing Materials (ASTM), the National Board of Fire Underwriters (NBFU), the American Society of Mechanical Engineers (ASME), the U.S. Public Health Service (USPHS), and other organizations concerned with public safety and health. In these respects, the case of boiler and pipe insulation is representative of asbestos in construction codes and engineering standards generally.[17]

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[16] For trenchant criticism of asbestos litigation from the legal standpoint, see Lester Brickman, "Asbestos Litigation: Malignancy in the Courts?" in *Civil Justice Forum* 40 (Aug. 2002); the same author's "Ethical Issues in Asbestos Litigation," *Hofstra Law Review* 33 (2005): 833-912; his "On the Applicability of the Silica MDL Proceeding to Asbestos Litigation," *Connecticut Insurance Law Journal* 12 (2005/2006): 289-314; and "The Use of Litigation Screenings in Mass Torts: A Formula for Fraud?" *SMU Law Review* 61 (2008): 1221-354. See also Stephen J. Carroll et al. and Institute for Civil Justice (U.S.), *Asbestos Litigation Costs and Compensation: An Interim Report* (Santa Monica, Calif., 2002); and Stephen J. Carroll et al., *Asbestos Litigation* (Santa Monica, Calif., 2005).

For examples of large jury awards, see Kate Moser, "Jury Awards $200 Million in Punitive Damages in Asbestos Case," *Law.com* (3 May 2010). This case was remanded for retrial later in the year. See also http://www.law.com/jsp/article.jsp?id=1202457545735&slreturn=1&hbxlogin=1, accessed 11 Feb 2011; Andy Largomarsino, "N.J. Court Upholds Family's $30 Million Asbestos Award, Largest in State History," *NewJerseyNewsroom.com* (14 April 2010), http://www. newjerseynewsroom.com/economy/nj-court-upholds-familys-30-million-asbestos-award-largest-in-state-history, accessed 18 Feb 2011; Simmons Browder Gianaris Angelides & Barnerd, LLC, "Verdicts & Settlements" [webpage], Chicago, Ill., Simmons Browder, 2001, http://www.simmonsfirm.com/verdicts. html, accessed 18 Feb 2011; Waters & Kraus, LLP, "Jury Awards $35.1 Million to Retired U.S. Navy Boiler Tender Exposed to Asbestos; Verdict Is One of LA County's Largest Ever in an Asbestos Case," Dallas Texas, Waters & Kraus, 17 Oct. 2007, http://www.waterskraus.com/index.aspx?id=news_davis35mil, accessed 18 Feb 2011; and Chris Frank, "$12.8 Million Awarded in Asbestos Suit (reprinted from *The Advocate*, 9 October 1996)," Baton Rouge, La., available at http://www. mckernanlawfirm.com/CM/Verdicts/128-Million-Dollar-Settlement.asp; accessed 18 Feb 2011.

[17] This subject is treated in greater depth in Rachel Maines, *Asbestos and Fire: Technological Trade-offs and the Body at Risk* (New Brunswick, N.J., 2005).

Boiler and Pipe Insulation Standards

The introduction of steam technology, especially explosion-prone nineteenth-century marine power boilers, presented significant safety challenges, which eventually required legislation and regulation at the federal, state, and local levels. While heating boilers did not represent the kind of hazards posed by steamboats operating on the muddy Lower Mississippi, they shared with all steam technology the necessity to address the issues of hot metal exposed to combustible materials. Boilers and their pipes could heat wood and other organic materials to ignition, resulting in fires.[18] They could also burn persons who came in contact with them, and add heat to environments where it was not needed or wanted, such as ships' boiler rooms, and metal foundries, where pipes and their insulation needed protection from external as well as internal heat.[19] Finally, the loss of heat from boilers and pipes wasted fuel, which was expensive and contributed to environmental pollution.[20] In wartime, fuel conservation has been of critical importance to defense efforts.[21]

All of these considerations, but particularly the first two, which were life safety issues, motivated two communities of safety professionals to begin systematic scientific testing of insulation materials in the late nineteenth century. The Engineering Department of the U.S. Navy, which had tested all the then-available insulation materials in 1887, determined that carbonate of magnesia with an admixture of 15 percent asbestos was the most effective and efficient insulation material for naval purposes.[22] As additional materials became available, the Navy tested each of them in turn, maintaining an active insulation research program as well as revised instructions to ships' maintenance crews through the peacetime years of the 1930s.[23] Even crumpled aluminum foil was tested as a possible pipe

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[18] See, for example, Elmer C. Jensen, "The Pipe Shaft Fire in the New York Life Building, Chicago," *Fireproof Magazine* 10, no. 1 (1907): 26-27.

[19] On burns, see D. L. Cox, "Heat Insulation," *The Society of Naval Architects and Marine Engineers Transactions* 44 (1937): 482. On the special problems of insulating pipes in foundries, see William J. Deckman, "Asbestos Cloth Protects Insulation on Piping Near Boilers," *Heating-Piping* 4 (1932): 201.

[20] "Value of Sheet Asbestos on Hot Pipes," *Mechanical Engineering* 42 (Jan. 1920): 69, and (March 1920): 188-89.

[21] Alfred Cecil Hardy, *Shipbuilding: Background to a Great Industry*, ed. E. Tyrrell (London, 1964), 66-72; and P. S. Thorsen & Company, Inc., "Insulation Plays an Important Part in the Economy of Ship Operation," paper read at International Meeting of Naval Architects and Marine Engineers, 14-19 Sept. 1936, New York City.

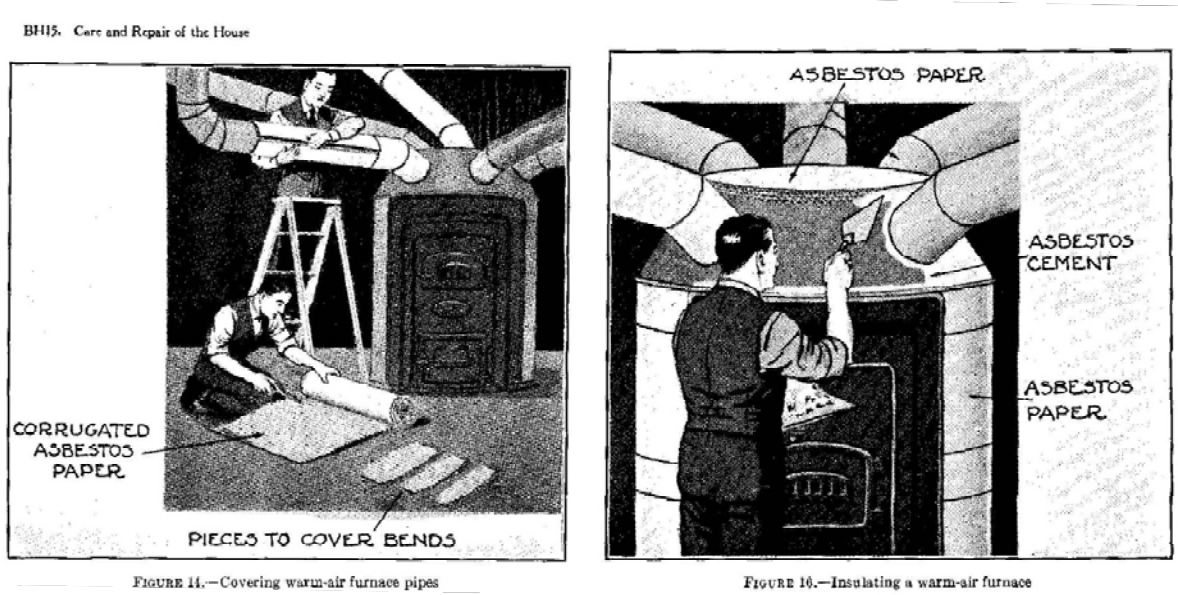
[22] "Keeping the Heat In: Magnesia, Mixed with Asbestos Fibers," *Scientific American* 174 (1946): 122 and 124.

[23] Ralph R. Gurley, "Proposed Method of Computing Weight Factors of Heat Insulating Materials for Pipe Coverings," *Journal of the American Society of Naval Engineers* 46 (Nov. 1934): 451-63; and Gurley and W. P. Sinclair, "Pipe

insulation.[24] In Britain, the National Physical Laboratory also tested boiler and pipe insulations, with similar results.[25]

In the first quarter of the twentieth century, the National Bureau of Standards and the U.S. Public Health Service began working toward national standards for building construction, plumbing, heating, and electrical installations downstream of the meter assembly, publishing their results as standards for state and local government adoption by 1912 (see Fig. 1).[26]

Figure 1
National Bureau of Standards Instructions to Homeowners for Insulating Warm Air Furnaces



Source: National Bureau of Standards, *Care and Repair of the House,* BH15 (Washington, D.C., 1931).

In the 1930s, these two Federal agencies were joined by a third, the Federal Housing Administration (FHA), which began insuring home mortgages in 1936. This agency needed standards of fire safety and rules for inspection for the same reasons that banks did: buildings must be

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Covering Materials for High Temperatures," *Journal of the American Society of Naval Engineers* 47 (May 1935): 247-56.

[24] Cox, "Heat Insulation," 470-85.

[25] "Efficiency of Steam-Pipe Coverings at High Temperatures," *Engineering* 224 (Aug. 1922): 155.

[26] See, for example, Rudolph James Wig and Phaon Hilborn Bates, *Tests of the Absorptive and Permeable Properties of Portland Cement, Mortars and Concretes, together with Test of Dampproofing and Waterproofing Compounds and Materials* (Washington, D.C., 1912).

compliant with fire code to be eligible for mortgage loans.[27] The government, especially the military side of it, also needed best-practice standards for the thousands of structures built for the war effort in the 1940s.[28] This combination of interests resulted in a collaboration among the three federal agencies with the National Board of Fire Underwriters, Underwriters' Laboratories, and the National Fire Protection Association, all of which had been testing insulations for heating equipment since the late nineteenth century.[29]

Four years before the Navy selected 85 percent magnesia as its insulation of choice, in 1883, the Boston Manufacturers Mutual Fire Insurance Company issued its Special Report No. 14, *Report upon Coverings for Steam Pipes*, prepared by chemistry professor John Morse Ordway (1823-1909) at the Massachusetts Institute of Technology (MIT). At the time that Ordway began his tests of insulation materials, many steam users were insulating boilers with hair felt, and pipes with blocks of wood, wool fabric, or cork. All of these were, of course, combustible, and both the hair felt and the wool fabric charred and smelled bad when heated, and harbored vermin when cool.[30] Plaster of Paris, though incombustible and not odiferous, corroded the metal surfaces to which it was applied.

Ordway tested the extent to which pipes covered with the various materials heated the air around them, and noted the volume and weight of tested insulating materials, which included ordinary air space, asbestos paper, charcoal, "fossil meal" (diatomaceous earth), wood, wire mesh, burlap, flour, cotton canvas, hair felt, various pastes (including mica), pasteboard, rice chaff, slag wool, sphagnum moss, oiled paper, straw, and several patent pipe coverings. In all, Ordway tested fifty-one insulation assemblies. He was satisfied with none of them, and argued for additional research, which was undertaken immediately after publication of his report.[31]

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[27] U.S. Bureau of Community Environmental Management, *Basic Housing Inspection*, Public Health Service publication no. 2123 (Washington, D.C., 1970).

[28] U. S. Department of Commerce, *Recommended Building Code Requirements for New Dwelling Construction with Special Reference to War Housing: Report of Subcommittee on Building Codes Central Housing Committee on Research, Design, and Construction*, Building materials and structures report BMS 88 (Washington, D.C., 1942).

[29] Scott Knowles, *Experts in Disaster: A History of Risk and Authority in the Modern United States* (Philadelphia, 2011).

[30] R. T. Strohm, "Pipe Coverings," *American Electrician* 15, no. 5 (1903): 221-22.

[31] John M. Ordway, *Report upon Coverings for Steam Pipes*, Boston Manufacturers Mutual Fire Insurance Co. special report no. 14 (Boston, 1883), reprinted as "Experiments upon Non-Conducting Coverings for Steam Pipes," *Journal of the Franklin Institute* 116 (1883): 411-34, from a paper read before the American Society of Mechanical Engineers in November 1883.

The Boston Manufacturers' Mutual, then under the leadership of fire safety pioneer Edward Atkinson, returned to MIT in the 1890s with a proposal to develop a fire safety laboratory and a commission for physicist Charles Ladd Norton (1870-1939) to continue the research on insulation begun by John Ordway, who was by then in his seventies.[32] Norton tested thirty-two assemblies in 1895, including wool, goose feathers, hair felt, lamp-black, cork charcoal, anthracite coal powder, several magnesia compounds, fossil meal, chalk, plaster of Paris, asbestos, sand, wire lath, slag wool, paper, cork strips, straw rope, rice chaff, bituminous and anthracite coal ashes, and pastes of clay, fossil meal, and hair. In an important advance from Ordway's work, Norton distinguished between combustible and incombustible coverings, and designated the former as unsuitable for hot surfaces.[33]

The factory mutual insurance companies that sponsored Ordway and Norton's research at MIT had been established in the nineteenth century to reduce fire losses and fire insurance premiums by establishing and enforcing fire safety practices among members.[34] Conventional ("stock") fire insurance companies of the period did not offer significant discounts for safe practices and charged very high rates for certain types of risks, such as factories, hotels, and theaters, all of which were, in the nineteenth century, highly fire-prone occupancies on both sides of the Atlantic.[35] The

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[32] "Charles L. Norton," MIT webpage, http://web.mit.edu/hmtl/www/norton.html, accessed 7 Oct. 2007.

[33] Charles Ladd Norton, *Tests of Steam Pipe and Boiler Coverings*, Mutual Boiler Insurance Company circular no. 6 (Boston, 1898); his "Tests of Fire Retardent [sic] Materials," *Technology Quarterly* 13, no. 2 (1900): 128-38; and *Heat Lecture Notes* (Cambridge, Mass., 1920).

[34] Mutual Assurance Society against Fire on Buildings of the State of Virginia, *Constitution, Rules and Regulations of the Mutual Assurance Society against Fire on Buildings in the State of Virginia, as amended and revised July 11th, 1898; Incorporated 1794* (Richmond, Va., 1898); C. J. H. Woodbury, *The Fire Protection of Mills* (New York, 1882); Manufacturers Mutual Fire Insurance Company, *The Factory Mutuals, 1835-1935; Being Primarily a History of the Manufacturers Mutual Fire Insurance Company* (Providence, R.I., 1935); Federation of Mutual Fire Insurance Companies, *Judging the Fire Risk: An Explanation of the Factors Which Affect the Physical Desirability of Mutual Fire Insurance Risks* (Chicago, 1950); Richard Hooker, *A Century of Service: The Massachusetts Mutual Story* (Springfield, Mass., 1951); Associated Factory Mutual Fire Insurance Companies, Factory Mutual Engineering Division, *Handbook of Industrial Loss Prevention: Recommended Practices for the Protection of Property and Processes against Damage by Fire, Explosion, Lightning, Wind, Earthquake* (New York, 1959); and their *Handbook of Industrial Loss Prevention,* 2d ed. (New York, 1967).

[35] Sara E. Wermiel, *The Fireproof Building: Technology and Public Safety in the Nineteenth-Century American City* (Baltimore, Md., 2000), 105-93. On theaters, see "Protection Against Fire in Theatres," *Scientific American* 90 (1904): 160; William Paul Gerhard, *The Safety of Theatre Audiences and the Stage Personnel against Danger from Fire and Panic: A Paper,* Publications of the British Fire

factory mutuals were originally organized as not-for-profit communities of shared risk; firms that did not meet fire safety standards were denied membership. This motivation to improve fire safety led to the establishment of the fire research laboratory at MIT.

Ordway and Norton's results were quickly taken up by another group of specialized insurers, the boiler and machinery insurance companies, many of which were also organized on the mutual plan. The Vulcan Boiler and General Insurance Company of Manchester, England, for example, originally a mutual insurance organization for steam users, published Norton's results as state-of-the-art for 1900, noting that "Magnesia, with sufficient asbestos to hold it together, is a good composition. Pure asbestos is one of the best insulators available, but its cost is high when of high quality."[36] The Hartford Steam Boiler Inspection and Insurance Company in the United States, established in 1866 and by the turn of the nineteenth century well on its way to becoming a significant influence on boiler safety in the United States, also accepted the MIT studies as the best data available at the time.[37] William Booth's 1905 textbook, *Steam Pipes*, endorsed the MIT results as well.[38]

Also established in 1866 was the National Board of Fire Underwriters (NBFU, later the American Insurance Association), an organization of fire insurance underwriters, which drew up one of the nation's first uniform recommended municipal building codes in 1905.[39] By 1911, the NBFU had begun to establish industry-wide standards for assessing fire insurance

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Prevention Committee no. 41 (London, 1899); Citizens' Association of Chicago, Committee on Theatres and Public Halls, *Report of the Committee on Theatres and Public Halls to the Executive Committee of the Citizens' Association of Chicago* (Chicago, 1887); John Ripley Freeman, *On the Safeguarding of Life in Theaters, Being a Study from the Standpoint of an Engineer* (New York, 1906); David R. Plunket, *Report from the Select Committee on Theatres and Places of Entertainment: Together with the Proceedings of the Committee, Minutes of Evidence, Appendix, and Index, Ordered, by the House of Commons, to be printed, 2 June 1892* (London, 1892); Edwin O. Sachs, *Modern Opera Houses and Theatres*, vol. 3 (London, 1897); Joseph Meredith Toner, *Notes on the Burning of Theatres and Public Halls* (Washington, D.C., 1876).

[36] Vulcan Boiler and General Insurance Co., *Steam Pipes: Their Construction and Arrangement* (New York [n.d., c.1900]), 90-105; quotations are from p. 105.

[37] Glenn Weaver, *The Hartford Steam Boiler Inspection and Insurance Company, 1866-1966* (Hartford, Conn., 1966); and Wilson Wilde, *". . . In the Pursuit of Greater Safety, Reliability, and Efficiency": The Story of the Hartford Steam Boiler Inspection and Insurance Company* (New York, 1978).

[38] Wm H. Booth, *Steam Pipes: Their Design and Construction; A Treatise of the Principles of Steam Conveyance and Means and Materials Employed in Practice, to Secure Economy, Efficiency, and Safety* (New York, 1905), 152-72.

[39] National Board of Fire Underwriters. *Pioneers of Progress: National Board of Fire Underwriters, 1866-1941* (New York, 1941), 125 and 149.

risks.[40] Between 1899 and the mid-1960s, the NBFU performed laboratory tests on materials and assemblies under fire conditions, the results of which were incorporated into both their recommended building codes and into insurability standards.[41] Much of this work was carried on in conjunction with the National Fire Protection Association, which was established in 1896, and the American Standards Association, later the American Society for Testing Materials (ASTM), organized in 1898.[42]

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[40] National Board of Fire Underwriters, *Proposed Building Law for Medium Sized Cities, as Drafted by a Commission Appointed Pursuant to Chapter 579, Laws of 1892 of New York State . . . Issued June, 1893, by the Committee on Construction of Buildings of the National Board of Fire Underwriters* . . . (New York, 1893); and their *Uniform Requirements Recommended by the National Board of Fire Underwriters for Use of Boards, Bureaus and Inspectors Relating to Standard Mill Construction, "Inferior" Construction, General Hazards, Oil Rooms, General Protection, Stairway and Elevator Closures, Watchmen, Thermostats and Miscellaneous Matters* (Boston, 1911).

[41] National Board of Fire Underwriters, *Dwelling houses; code of suggestions for construction and fire protection recommended by the National Board of Fire Underwriters, New York, to safeguard homes and lives against the ravages of fire.* (New York, 1916); its *Regulations of the National Board of Fire Underwriters governing the production, storage, and handling of nitro-cellulose motion picture films*. New York: 1919; *Specifications... for the manufacture and installation of steam fire pumps* (New York, 1911); *Shingle roofs as conflagration spreaders; an appeal to the civil authorities and civil and commercial bodies.* New York: 1916; National Board of Fire Underwriters. Electrical Bureau. *Index to laboratory reports 1 to 1000*. New York and Chicago: 1899.

[42] See, for examples, National Board of Fire Underwriters, *Rules and Requirements of the National Board of Fire Underwriters for the Construction and Installation of Fire Doors and Shutters as Recommended by the National Fire Protection Association* (New York, 1906); *Electrical Ordinances and Rules* (Atlanta, 1933); National Board of Fire Underwriters and National Fire Protection Association, Committee on Gases, *Recommended Good Practice Requirements of the National Board of Fire Underwriters for the Installation and Use of Internal Combustion Engines: Also Coal Gas Producers; As Recommended by the National Fire Protection Association NBFU Pamphlet No. 37* (New York, 1934); *An Ordinance Providing for Fire Limits and the Construction and Equipment of Buildings in Small Towns and Villages* (New York, 1914); *Regulations of the National Board of Fire Underwriters for the Installation, Maintenance and Use of Gasoline Vapor Gas Machines, Lamps and Systems as Recommended by the National Fire Protection Association* (New York, 1926); *Regulations of the National Board of Fire Underwriters for the Installation of Pulverized Fuel Systems as Recommended by the National Fire Protection Association* (New York, 1935); National Board of Fire Underwriters and National Fire Protection Association, *Recommended Good Practice Requirements of the National Board of Fire Underwriters for the Installation, Maintenance and Use of Piping and Fittings for City Gas* (New York, 1932); *Regulations of the National Board of Fire Underwriters for the Installation and Operation of Gas Systems for Welding and Cutting as Recommended by the*

Electricity, a new technology at the turn of the century, was the focus of an entire NBFU scientific campus, the Underwriters Laboratories.[43]

The Table of Clearances

The NBFU standards and minimum requirements for insurability, updated at regular intervals, allowed fire insurance companies to make informed decisions about the fire safety of insured structures and occupancies. Continuing the research begun by Ordway and Norton, and drawing also on academic and National Research Council investigations performed in the same period, the NBFU compiled a definitive list of boiler and pipe insulation assemblies that tests had shown would protect nearby combustible surfaces from ignition.[44] The NBFU's "Table of Clearances from Combustible Construction with Specified Forms of Protection" became the national standard for fire underwriting in 1943, with the fifth edition of the NBFU *Building Code*.[45] Of nine approved insulation assemblies, eight contained asbestos, including "rock wool bats," which included asbestos as a binder.[46]

Because, as noted earlier, fire insurance was and is required by mortgage and other lenders, the NBFU standards proved a highly effective method of enforcing compliance with state-of-the-art knowledge of fire risks and safety measures. Many municipalities enacted the NBFU's model

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National Fire Protection Association (New York, 1936); and *Regulations of the National Board of Fire Underwriters for the Installation of Blower and Exhaust Systems for Dust, Stock and Vapor Removal as Recommended by the National Fire Protection Association* (New York, 1937).

[43] Harry Chase Brearley, *A Symbol of Safety: An Interpretative Study of a Notable Institution Organized for Service—Not Profit* (Garden City, N. Y., 1923).

[44] Examples of academic research on insulation at this period include Frederick James Emeny and John Hanes Godfrey, "The Insulating Properties of Different Steam Pipe Coverings" (Master of Engineering thesis, Cornell, 1895); A. Cammack and Forrest E. Woodman, *Efficiency of Steam Pipe Coverings* (Ames, Iowa, 1906); and L. B. McMillan, "The Heat Insulating Properties of Commercial Steam Pipe Coverings," *American Society of Mechanical Engineers Transactions* 37 (Dec. 1915): 921-74. For the National Research Council program, see R. H. Heilman, "Heat Losses through Insulating Materials," *Mechanical Engineering* 46 (Oct. 1924): 593-606; and his "Determination of the Thermal Conductivities of Insulation for Temperatures up to 1000 Deg. Fahr. on Other Than Flat Surfaces," *Mechanical Engineering* 48 (1926): 1297-1306.

[45] National Board of Fire Underwriters, *Building Code Recommended by the National Board of Fire Underwriters, New York*, 5th ed. (New York, 1943), 206.

[46] Cox, "Heat Insulation," 476. See also "Rock Wool Manufacture Possibilities in South Africa," *South African Mining and Engineering Journal* 59, no. 2890 (1948): 521-22; "New J-M Rock Wool Plant Will Help Meet Canadian Demand for Insulation Materials," *Engineering and Contract Record* 61, no. 7 (1948): 7476; A. Winer, "Mineral Wool Insulation from Asbestos Tailings," *Canadian Mining & Metallurgical Bulletin* 67 (1974): 97-104; and "Manufacture of Rock-Wool Insulation," *Power and Works Engineering* 52, no. 611 (1957): 183-87.

code in its entirety, making its provisions enforceable as local law.[47] Other building safety organizations, such as the Building Officials Conference of America (BOCA, later Building Officials and Code Administrators), devised similar codes incorporating the already proven and tested Table of Clearances. A number of state governments, including California, Indiana, Connecticut, and Rhode Island, enacted the BOCA code, called the *Uniform Building Code*, as state law; hundreds of municipalities incorporated it into local ordinances.[48] As the *International Fire Code*, the *Uniform Code* was incorporated into New York state building and fire law in 1984.[49]

Through the connection between fire insurance and mortgage lending, the NBFU's standards for boiler and pipe installation, including the "Table of Clearances," became the federal standard for government-funded or loan-guaranteed housing in 1937.[50] Mortgages could be guaranteed by the

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[47] For example, *Building Code Recommended by the National Board of Fire Underwriters, New York, Adopted, as Modified by the City of Bessemer, Alabama (*Bessemer Ala., 1942).

[48] This organization began publishing as the Pacific Coast Building Officials Conference, *Uniform Building Code* (Los Angeles, 1937). Later publications include Building Officials' Conference of America, *Basic Building Code of the Building Officials Conference of America* (New York, 1950-1955); International Conference of Building Officials, *Uniform Building Code* (Pasadena, Calif., 1958); International Conference of Building Officials, *Uniform Building Code* (Whittier, Calif., 1988). Examples include Tri-County Regional Planning Commission, Denver, Colo., and Colorado State Planning Commission, *Uniform Building Code of Colorado, including Electrical and Plumbing Requirements; Available for Adoption by Any Zoned, Unincorporated Area or Municipality in Colorado (*Denver, 1945); Connecticut. Dept. of Public Safety, *Basic Building Code*, rev. ed. (Hartford, Conn.: 1978); Detroit (Mich.) Dept. of Buildings and Safety Engineering, *Official Building Code of the City of Detroit, Michigan* (Detroit, Mich., 1956); Rhode Island State Building Code Standards Committee, *Rhode Island State Building Code: Mechanical Code* (Providence, R.I., 1978); and *1985 Triennial Edition of the State Building Code: Title 24, Part 2, California Administrative Code: Based Upon the 1979 and 1982 Editions of the Uniform Building Code as Published by the International Conference of Building Officials* (Sacramento, Calif., 1985).

[49] New York State Fire Prevention and Building Code Council, *New York State Uniform Fire Prevention and Building Code* (New York, 1984), 487 and 502-4, "Generally Accepted Standards." For earlier efforts along these lines, also specifying asbestos, see New York State Building Code Commission, *Code Manual for the State Building Construction Code* (New York, 1951); New York State Building Code Commission, *Code Manual for the State Building Construction Code* (New York, 1954); and New York State Building Code Commission, *Code Manual for the State Building Construction Code* (New York, 1959).

[50] Standards were written individually for each underwriting registry area. Examples include (all U.S. Federal Housing Administration: *Minimum Construction Requirements for New Dwellings Located in the State of*

federal government only if heating appliance installation in the mortgaged structure complied with the provisions of the applicable NBFU code.[51] Hundreds of thousands of homes sold to returning World War II veterans

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Massachusetts, rev. ed. (Washington, D.C., 1939); (all FHA, Washington, D.C., 1938): *Property Standards, Part VI, Minimum Requirements for Connecticut, Hartford, Conn., FHA form no. 2226*; *Minimum Construction Requirements for New Dwellings Located in the State of Maine*; *Minimum Construction Requirements for New Dwellings Located in the State of New Hampshire*; *Minimum Construction Requirements for New Dwellings Located in the State of Vermont; Minimum Construction Requirements for New Dwellings Located in the District Covered by the Reno Underwriting Office; Minimum Construction Requirements for New Dwellings Located in the State of Arizona*; *Minimum Construction Requirements for New Dwellings Located in the State of Delaware*; *Minimum Construction Requirements for New Dwellings Located in the State of Idaho*; *Minimum Construction Requirements for New Dwellings Located in the State of Montana*; *Minimum Construction Requirements for New Dwellings Located in the State of Nebraska*; *Minimum Construction Requirements for New Dwellings Located in the State of New Mexico*; *Minimum Construction Requirements for New Dwellings Located in the State of North Dakota*; *Minimum Construction Requirements for New Dwellings Located in the State of Minnesota: effective August 15, 1937, FHA form no. 2330; Minimum Construction Requirements for New Dwellings Located in the Counties of Queens, Nassau, and Suffolk*, rev. ed.; *Minimum Construction Requirements for New Dwellings Located in the State of Kansas*, rev. ed.; *Minimum Construction Requirements for New Dwellings Located in the State of North Carolina*, rev. ed.; *Minimum Construction Requirements for New Dwellings Located in the State of Oklahoma*, rev. ed.; *Minimum Construction Requirements for New Dwellings Located in the State of Oregon*; *Minimum Construction Requirements for New Dwellings Located in the State of Rhode Island*; *Minimum Construction Requirements for New Dwellings Located in the State of South Dakota*; *Minimum Construction Requirements for New Dwellings Located in the State of Utah*, rev. ed.; *Minimum Construction Requirements for New Dwellings Located in the State of Washington*; *Minimum Construction Requirements for New Dwellings Located in the State of Wyoming*; *Minimum Construction Requirements for New Dwellings Located in the Territory Covered by the District of Columbia Insuring Office*. Also (all FHA), *Minimum Construction Requirements for New Dwellings Located in the Southern District of Florida, Effective June 1, 1937* (Washington, D.C., 1937); *Minimum Construction Requirements for New Dwellings Located in the State of Louisiana*, rev. ed. (New Orleans, 1938); *Minimum Construction Requirements for New Dwellings Located in the Eastern Missouri District*, rev. ed. (Washington, D.C., 1939); *Minimum Construction Requirements for New Dwellings Located in the State of New Jersey*, rev. ed. (Washington, D.C., 1940); *Minimum Construction Requirements for New Dwellings Located in the State of West Virginia*, rev. 15 Aug. 1940 (Charleston, W.Va., 1940); and *Minimum Construction Requirements for New Dwellings Located in the State of Iowa*, rev. ed. (Washington, D.C., 1939).

[51] Frederick Taft Moses, *Firemen of Industry, 1854-1954: The Hundredth Anniversary of Firemen's Mutual Insurance Company* (Providence, R.I., 1954), 74-76.

under the GI Bill with Veterans Administration loan guarantees were inspected under this standard after 1945. Federal housing regulations were enforced first by the Federal Housing Authority and later by the Department of Housing and Urban Development, with the NBFU provision remaining in the federal code until 1985.[52] Hill-Burton Act hospitals and group medical practice facilities after 1946 were also subject to this code, with new provisions added to it in 1965, 1968, and 1976 after a series of fatal fires in hospitals and nursing homes. NFPA 89M appeared in this code in the specifications for heating safety.[53]

The U.S. military, as noted above, had also continued its insulation research. By 1937, the Navy had determined that "The present day high-pressure steam plants, with temperatures in excess of 500 degrees F., have created a new problem in heat insulation. The old standby for many years, 85 per cent hydrated magnesia carbonate insulation, is not suitable as it calcines and decomposes at temperatures in excess of 500 degrees F."[54] Rock wool, even with its admixture of asbestos, "fuses at about 1200 degrees F.," making it, too, unsuitable for use at higher temperatures. Diatomaceous earth, reinforced with asbestos fibers, performed well in

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[52] U.S. Federal Housing Administration, *Minimum Property Standards for Urban Renewal Rehabilitation, One Through Eleven Living Units*, FHA no. 950 (Washington, D.C. [undated, c1963?]), clause 1556, "Heating" [unpaged]; U.S. Dept. of Housing and Urban Development, *Design and Construction Standards: Housing. Review Draft, July 1969* (Washington, D.C., 1969), 50.

[53] U.S. Federal Housing Administration, *Flame Spread Limitations of Interior Finish Materials in Multifamily Housing, Nursing Homes and Housing for the Elderly*, MPS Interpretation Bulletin no. 23 (Washington, D.C., 1965); U.S. Federal Housing Administration, *Minimum Property Standards for Nursing Homes*, U.S. Dept. of Housing and Urban Development, HUD handbook (Washington, D.C., 1968), 47; and U.S. Public Health Service, *Minimum Requirements of Construction & Equipment for Hospital & Medical Facilities*, DHEW publication no. HRA 76-4000 (Bethesda, Md., 1976). The Hill-Burton Act, officially the Hospital Survey and Construction Act, was passed in 1946.

On hospital fires, see "Davenport, Iowa, Hospital Fire," *NFPA Quarterly* 43, no. 3 (1950): 144-47; American Hospital Association, Council on Hospital Planning and Plant Operation, *Draft of a Suggested Hospital Fire Safety Code Suitable for Adoption on a State-Wide Basis (*Chicago, 1948); Illinois Division of Fire Prevention, *Report of the Illinois State Fire Marshal on the St. Anthony's Hospital Fire at Effingham, Illinois, April 4, 1949* (Springfield, Ill., 1949); Ernest Juillerat, Jr., "The Hartford Hospital Fire," *NFPA Quarterly* 55, no. 3 (1962): 295-303; James K. McElroy, "The Tragedy of St. Anthony Hospital," *NFPA Quarterly* 43, no. 1 (1949): 12-33; "10 Killed in New Jersey; Fire Guts Nursing Home," *Waterloo* [Ohio] *Daily Courier*, 29 Jan. 1973; "Nursing Home Fire Was Set; Woman Said She Did It for Excitement," *Daily Intelligencer* [Doylestown, Pa.], 23 June 1956; "Twenty Patients Dead in Nursing Home Fire," *NFPA Quarterly* 46, no. 3 (1953): 172-75; C. Cihlar, "Ohio Nursing Home Fire: An Analysis," *Hospitals* 44 (1970): 28; Albert B. Sears, Jr., "Nursing Home Fire, Marietta, Ohio." *Fire Journal* 64, no. 3 (1970): 5-9.

[54] Cox, "Heat Insulation," 470.

place, but was difficult to apply and would not adhere to hot surfaces. It was also unacceptably heavy for most marine installations. Glass and other mineral wools had been tested, and were "not considered satisfactory," in part because the supporting medium at that time was combustible.[55] A 1940 *Boiler Operator's Guide*, written by an inspector licensed by the National Board of Boiler and Pressure Vessel Inspectors, did not recognize as acceptable any insulating materials other than asbestos or 85 percent magnesia (15 percent asbestos).[56]

By 1945, mineral wool with "asbestos, clay and chemical binders," and sometimes also including diatomaceous earth, was considered acceptable for "temperatures up to 1600 or 1800 F."[57] Even with the asbestos binder, however, rock wool not only fused but lacked sufficient K value—that is, it allowed an unacceptable amount of heat to pass through it.[58] High-temperature insulation was developed during World War II that "used pre-calcined diatomaceous earth in combination with asbestos fibers," which could withstand "temperatures up to almost 2000 degrees, Fahrenheit." It was, however, expensive.[59]

By 1958, diatomaceous silica with asbestos fibers was ranked highest in K value of all reviewed materials in *Materials in Design Engineering's* thermal insulation guide. By 1962, although efforts had been made to improve the durability and heat resistance of glass fiber, it was still useful only at temperatures below 600°F, and cellular glass up to about 800°F.[60] In the second edition of the *Modern Marine Engineer's Manual*, pub-

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[55] Cox, "Heat Insulation," 485; see also British views in "Glass Silk as a Heat Insulator," *Engineer* 152 (7 Aug. 1931): 150.

[56] Harry Mortimer Spring, *Boiler Operator's Guide: Construction, Operation, Inspection, and Maintenance of Steam Boilers, with 310 Typical Steam Engineer's Examination Questions and Answers* (New York, 1940), 312.

[57] J. H. Walker and Sabin Crocker, *Piping Handbook*, 4th ed. (New York, 1945), 712.

[58] Alan Osbourne, *Modern Marine Engineer's Manual* (Cambridge, Md., 1947), 5-11; and Clifford Strock, *Engineering Databook: Selected Tables and Charts for Supplying Engineers and Contractors with Essential Data on the Design, Operation and Maintenance of Equipment and Systems for Air Conditioning, Refrigeration, Piping, Heating, Air Sanitation and Ventilation in Buildings* (New York, 1948), 3-54.

[59] "Keeping the Heat In," 124.

[60] Games Slayter, "Strength and Physical Properties of Fine Glass Fibers and Yarns," *Journal of the American Ceramic Society* 19 (Jan. 1936): 335-36; T. D. Callinan, T. D., "Glass and Ceramic Fibers—They Beat the Heat," *Product Engineering* 29 (1958): 70-72; M. R. Piggott and J. C. Yokom, "The Weakening of Silica Fibres by Heat Treatment," *Glass Technology* 9 (1968): 172-75; and "Standard Specifications for Cellular Glass Thermal Insulation for Pipes, ASTM Designation C 381-58," in American Society for Testing and Materials, Committee C-16 on Thermal Insulating Materials, *ASTM Standards on Thermal Insulating Materials (with Related Information) Specifications, Methods of Test, Recommended Practices, Definitions*, 2d ed. (Philadelphia, 1962), 165-67.

lished in 1965, all boiler insulations listed as approved for marine use contained asbestos.[61] The 1967 (fifth) edition of the standard industry manual, the *Piping Handbook*, ranked the asbestos-with-diatomaceous-earth insulation assembly at the top of its table of thermal insulations, with the highest K factor.[62]

When engineers realized, first in Britain and later in the United States, that health issues associated with asbestos would make it necessary to find alternative materials, they expressed serious concerns about what it would mean to drop all but one of the tested and proven insulation assemblies. Asbestos, as a British engineer pointed out in 1969, was "unique and indispensable"; it did not fuse or soften even at temperatures of 2100°F, while glass fiber, to this day, begins to fail at just over 1700°F. Engineers were understandably reluctant to give up this significant margin of fire safety.[63] The New York State Commissioner of the Division of Housing and Community Renewal ruled in June 1988 that "Fiberglass should not be used as a firestop in locations requiring noncombustible firestopping materials due to its tendency to burn, diminish in size and eventually melt-down" [sic].[64]

Because the heating industry was, of course, familiar with these national standards, some manufacturers of boilers and furnaces supplied kits with their equipment that enabled contractors, plumbers, and other building trades professionals to make efficient code-compliant installations on site. Counterintuitive as it may seem, it is this history of providing materials for compliance with local, state, and federal law, plus the use of code-compliant asbestos gaskets and seals, that has resulted in billions of dollars in claims against heating equipment manufacturers since 1973.[65] As the complaint I quoted earlier asserts, the mere facts of having provided asbestos-containing materials and not having developed alternatives to them, are held to be reprehensible in the moral economy of asbestos litigation.

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[61] Alan Osbourne and A. Bayne Neild, *Modern Marine Engineer's Manual*, 2d ed. (Cambridge, Md., 1965), 19-3.

[62] Wesemann, "Thermal Insulation," 6-1 to 6-21.

[63] "Asbestos Is Unique and Indispensable," *Engineer* (London), 24 April 1969, p. 40; L. McLain, "Seeking Alternatives to Hazardous Asbestos," *Engineer*, 20 May 1976, pp. 30-31 and 34; L. McGinty, "Risk Equations: A Ban on Asbestos?" *New Scientist*, 14 July 1977, pp. 96-97; and N. Gupta, "Searching for the Asbestos Substitute," *Engineer*, 22 Nov. 1979, p. 41.

[64] "Code Section: 717.4(b)(2)–Prevention of Interior Fire Spread—Firestopping—Materials—Fiberglass Insulation," New York (State), Division of Housing and Community Renewal, and New York State Fire Prevention and Building Code Council, *Commissioner's Interpretations of the NYS Fire Prevention and Building Code* (Albany, N.Y., 1990), CI-443, date of issue 9 June 1988, v. 1, p. 458.

[65] The first significant case in the historical avalanche of asbestos litigation was *C. Borel v. Fiberboard Paper Products et al.*, 493 Fed. 2nd 1076 (1973).

The Search for Alternatives

The organizations that contributed to the development of the Table of Clearances were, of course, mainly interested in fire safety, not occupational health. Nonetheless, several of them, including the American Society of Heating and Ventilating Engineers (later the American Society of Heating, Refrigerating and Air-Conditioning Engineers), the American Gas Association, and the U.S. Public Health Service, routinely noted in their publications that asbestos dust in ambient air was an inhalation hazard and proposed measures to reduce it.

In asbestos litigation, much is typically made by counsel for plaintiffs of the USPHS' 1935 report on the hazards of asbestos dust, omitting mention of the same agency's endorsement of the mineral for hospital safety and in the *National Plumbing Code* of 1962.[66] It was not, in fact, unusual for twentieth-century U.S. regulatory agencies and safety organizations to affirm both that asbestos dust was toxic and that the use of asbestos was nevertheless required by safety codes. The U.S. Public Health Service, and later OSHA, took this position.

Among state governments, California, for example, was aware by 1936 that asbestos dust in ambient air was an inhalation hazard, but nevertheless required the mineral in many types of fire resistive, thermal, and electrical insulations.[67] In the California Housing Code of 1963, for example, asbestos was specified 127 times.[68] The Commonwealth of Pennsylvania has an asbestos regulatory history very similar to California's.[69] The New York State *Multiple Dwelling Law* still (as of winter 2011)

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[66] John Jacob Bloomfield and J. M. DallaValle, *The Determination and Control of Industrial Dust*, U.S. Public Health Service, Public Health Bulletin no. 217 (Washington, D.C., 1935), is often cited as warning against the use of asbestos, which it in fact does not do. For the asbestos specifications in the *National Plumbing Code,* see U.S. Public Health Service, Technical Committee on Plumbing Standards, *Report of Public Health Service Technical Committee on Plumbing Standards: A Proposed Revision of the National Plumbing Code ASA A40. 8-1955* (Washington, D.C., 1962), 22-24, 27, 29, and 91.

[67] California Department of Industrial Relations, Division of Industrial Safety, *Dusts, Fumes, Vapors and Gases: Safety Orders Effective December 28, 1936, with Appendix A Revised July 20, 1945* (Sacramento, Calif., 1945), 16.

[68] California Dept. of Industrial Relations, Immigration and Housing Division, *State Housing Law and Building Regulations, Applicable to Apartment Houses, Hotels, Dwellings* (San Francisco, 1963).

[69] On the dust hazard, see Pennsylvania Dept. of Labor and Industry, Bureau Industrial Standards, and W. B. Fulton, "Asbestosis Part II: The Effects of Exposure to Dust Encountered in Asbestos Fabricating Plants on a Group of Workers," *Bureau of Industrial Standards Special Publication No. 42* (1935). For an example of a type of service in which the Commonwealth required asbestos, see Pennsylvania, Dept. of Labor and Industry, *Regulations for Protection from Fire and Panic: Class II buildings, Theatres and Motion Picture Theatres* (Harrisburg, Pa., 1952), plate 1.

specifies asbestos as a fire-resistive material.[70] South Carolina still incorporates by reference a safety standard requiring the use of asbestos on boilers (see Fig. 2).[71]

Figure 2
American Insurance Association (AIA), Successors to the National Board of Fire Underwriters, Table of Clearances to Combustible Construction, 1967

Table 2.3.b.
Clearances, Inches, With Specified Forms of Protection.*

Type of Protection	Where the required Clearance with not protection is:											
	36 inches			18 inches			12 inches		9 inches	6 inches		
Applied to the combustible material unless otherwise specified and covering all surfaces within the distance specified as the required clearance with no protection. (See Fig. 2.3). Thicknesses are minimum.	Above	Sides & Rear	Chimney or Vent Connector	Above	Sides & Rear	Chimney or Vent Connector	Above	Sides & Rear	Chimney or Vent Connector	Above	Sides & Rear	Chimney or Vent Connector
(a) ¼ in. asbestos millboard spaced out 1 in.†	30	18	30	15	9	12	9	6	6	3	2	3
(b) 28 gauge sheet metal on ¼ in. asbestos millboard	24	18	24	12	9	12	9	6	4	3	2	2
(c) 28 gauge sheet metal spaced out 1 in.†	18	12	18	9	6	9	6	4	4	2	2	2
(d) 28 gauge sheet metal on ⅛ in. asbestos millboard spaced out 1 in.†	18	12	18	9	6	9	6	4	4	2	2	2
(e) 1½ in. asbestos cement covering on heating appliance	18	12	36	9	6	18	6	4	9	2	1	6
(f) ¼ in. asbestos millboard on 1 in. mineral fiber batts reinforced with wire mesh or equivalent	18	12	18	6	6	6	4	4	4	2	2	2
(g) 22 gauge sheet metal on 1 in. mineral fiber batts reinforced with wire or equivalent	18	12	12	4	3	3	2	2	2	2	2	2
(h) ¼ in. asbestos cement board or ¼ in. asbestos millboard	36	36	36	18	18	18	12	12	9	4	4	4
(i) ¼ in. cellular asbestos	36	36	36	18	18	18	12	12	9	3	3	3

* Except for the protection described in (e), all clearances shall be measured from the outer surface of the appliance to the combustible material disregarding any intervening protection applied to the combustible material but in no case shall the clearance be such as to interfere with the requirements for combustion air and for accessibility.

For the protection described in (e), the clearance shall be measured from the outer surface of the protective covering to the combustible material.

† Spacers shall be of noncombustible material.

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Note: The same table appeared in the 1976 edition.

Source: American Insurance Association, *National Building Code* (New York, 1967), Table of Clearances to Combustible Construction, table 2.3.b.

[70] New York (State), *Multiple Dwelling Law*, Section 33 of Article 3 Title 1, paragraph 3b: "In every kitchen and kitchenette, all combustible materials immediately underneath or within one foot of any apparatus used for cooking or warming of food shall be fire-retarded or covered with asbestos at least three-sixteenth of an inch in thickness and twenty-six guage [sic] metal. . . ."

[71] For South Carolina, see *Code of Laws of South Carolina, 1976, Annotated, Containing Permanent Public Statutes of General Application to the End of the 2002 Legislative Session* (St. Paul, Minn., 1977), § 5-25-650, 5-25-730, 5-25-740, 5-25-750, and 5-25-760, vol. 2: 191 and 195-96. None of these clauses was amended in the *Cumulative Supplement* of 2008.

The City of Chicago code contained requirements and specifications for asbestos as late as the 1991 (October 1990) edition, although inhalation hazard warnings and asbestos abatement advertising had already begun to appear in the publication.[72] In the 1991 edition, the Table of Clearances appears as Table 13-384-100, on p. 554. Asbestos is specified for more than fifty other types of service as well. Among the electrical requirements for portable switchboards in this edition, for example, is the directive: "Conductors within the switchboard enclosure shall be of the stranded, asbestos-covered type enclosed in metal troughs or properly supported and securely fastened in position."[73] On page 195 of the 1991 code, section 13-56-150, asbestos manufacturing is classified as a "Low Hazard Industrial Unit."

Similarly, the use of asbestos was recommended as best safety practice for dozens of purposes by such organizations as the National Safety Council (NSC), while it was also recommended that, as much as possible, asbestos dust be kept out of the ambient air.[74] The American Gas

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[72] Chicago (Ill.), Ordinances, etc., *City of Chicago Building Code, as of October 31, 1990* (Chicago, 1991). For asbestos-abatement and related advertising, see the spine of the volume and pp. 11, 43, 45, 441, and 867. For inhalation hazard regulations, see sections 11-4-690, 11-4-120 on p. 15 (definition of asbestos), p. 20, section 11-4-670 on p. 42, and sections 11-4-679 and 11-4-680 on p. 44.

[73] *City of Chicago building Code*, 958.

[74] For the views of the National Safety Council (NSC) on the dust hazard, see the following in the NSC's *National Safety News*: L. U. Gardner, "Inhaled Mineral Dusts" (1933), 34-36; A. S. Johnson, "No Half Way Measures in Dust Control" (1935), 17-18 and 48-51; H. B. Meller, "Air Contaminants That Affect Health" (1936), 43-46; J. M. Roche, "Settling the Dust Problem" (1939), 18-19 and 72-74; C. O. Sappington, "Are All Dusts Hazardous?" (1932), 18 and his "Industrial Health" (1931), 46 and 76-77; R. R. Sayers, "Dusts That Harm" (1938), 51-52 and 82-84; National Safety Council, *Supervisors Safety Manual: Better Production without Injury and Waste from Accidents* (Chicago, 1956), 133 and 180; "Respirator [product review]," *National Safety News* 56, no. 6 (1947): 120; A. J. Hayes, "Labor's Stake in Safety," *Transactions of the National Safety Congress* 15, Labor Safety (1957): 16-21; National Safety Council, *Accident Prevention Manual for Industrial Operations*, 3d ed. (Chicago, 1955), 11-9 and 29; 38-19 and 33; 40-1, 7 and 48; 41-4 and 25; and 43-24 and 29; and NSC, *Supervisors Safety Manual; Better Production without Injury and Waste from Accidents*, 3d. ed. (Chicago, 1967), 108 and 163.

For the NSC's endorsement of the use of asbestos in thermal insulation, see Gustav Egloff, "Pioneering with High Pressure Oil Equipment," *Transactions of the National Safety Congress* 21, Current Safety Topics in the Petroleum Industry (1949): 21; NSC, *Accident Prevention Manual* (1955): 13-11, 15-12, 31-14; W. W. Allison, "Nuclear Energy as a Potential Industrial Problem," *Transactions of the National Safety Congress* 16 (1953): 83; and L. E. DeQuine, Jr., "Safety Specifics," *Transactions of the National Safety Congress* 14, Glass & Ceramics and Rubber (1958): 38-42. On electrical safety, see E. G. Meiter, "Control of Health Hazards of Electrical Insulating Materials," *Transactions of the National Safety Congress* 8, Electrical Equipment and Public Utilities

Industries (1957): 13-16; H. K. Sessions, "What the Safety Engineer Should Know about Industrial Health Hazards," *Transactions of the National Safety Congress* 15, Current Topics in Industrial Safety (1949): 87-90; NSC, *Accident Prevention Manual* (1955): 43-33 to 34; Wills MacLachlan, "Modern Practical Methods of Accident Prevention in Small Companies," in *Proceedings of the National Safety Council Seventh Annual Safety Congress* (St. Louis, Mo., 1918), 696. On gaskets, see Darrell D. Frederick, "High Pressure Equipment—Designing for Safety," *Transactions of the National Safety Congress* 16, Industrial Safety (1958): 102-5. On protective clothing see National Safety Council. "5 Minute Safety Talk: Dress for Safety," *Industrial Supervisor* 34, no. 10 (1970): 6-7; National Safety Council, Air Transport Section, *Aviation Ground Operations Safety Handbook*, 2d ed. (Chicago, 1972), 30 and 270; National Safety Council, "Safe Clothing," *Industrial Supervisor* 26, no. 11 (1958): 13; NSC *Accident Prevention Manual* (1955): 12-26; 14-41; 29-27; 29-31; 35-13; 36-34 to 39; NSC, *Supervisors Safety Manual*, 3d ed.,

152, 159, and 177; W. M. King, "Safety and the Human Machine," *Industrial Supervisor* 34, no. 12 (1970): 13; NSC, *Supervisors Safety Manual* (1956): 162, 169, 177, 183-86; NSC Chemical Section. *Personnel Safety in Chemical and Allied Industries* (Chicago, 1979), 95 and 105; NSC, *Safety Manual for Marine Oil-Fired Watertube Boilers* (Chicago, 1955), 49; NSC, "At the Safety Exposition," *National Safety News* 56, no. 5 (1947): 34-35; NSC, "Personal Protection," *Industrial Supervisor* 18, no. 1 (1950): 10-11; R. J. McWilliams, "Aluminum Heat Reflecting Equipment," *Transactions of the National Safety Congress* 14, Glass & Ceramics and Rubber (1958): 6; NSC, "Protective Clothing," *Industrial Supervisor* 18, no. 9 (1950): 11; C. F. Moberg, "Work Gloves: 5 Minute Safety Talk Subject no. 21," *Industrial Supervisor* 19, no. 9 (1951): 4-5. On welding and forging screens and blankets see National Safety Council, *Forging Safety Manual* (Chicago, 1965), 23; NSC, *Accident Prevention Manual* (1955), 28-50, 29-28, 33-16 and 20; NSC, *Supervisors Safety Manual*, 3d. ed., 321; its *Electric Welding*, Safe Practices Pamphlet no. 105 (Chicago, 1941), 12; *Gas Welding and Flame Cutting*, Safe Practices Pamphlet no. 23 (Chicago, 1941), 4 and 10-12; George L. Germain, "How to Make Your Safety Talks Count," *Industrial Supervisor* 33, no. 7 (1964): 13; NSC *Supervisors Safety Manual* (1956), 335; J. C. Stennett, "Analyzing Accident Causes," *National Safety News* 56, no. 6 (1947): 52-54 and 98. On home safety see Myrtle Rudd Tolg and National Safety Council, *Homemaking Can Be Easy* (New York, 1949), 39; and National Safety Council. *Safe at Home* [pamphlet] (Chicago, 1943), 12. On farm safety, see Mrs. Roy C. F. Weagley, "A Safety Program for Farm Women," *Transactions of the National Safety Congress* 31, Current Topics in Farm Safety (1948): 15.

On air filtration see NSC, *Accident Prevention Manual* (1955): 28-14 and 43-42. On other safety applications of asbestos, including construction materials, see NSC, *Accident Prevention Manual* (1955): 32-14, 32-33; NSC, "Paper Products," *Transactions of the National Safety Congress* 24, Current Safety Topics in the Pulp and Paper Industry (1948): 44; NSC, "Reaching Officers and Obtaining their Cooperation," in *Proceedings of the National Safety Council Seventh Annual Safety Congress* (St. Louis, M0., 1918), 1941; NSC, "Safety Suggestions for Tire Repair Shops," *National Safety News* 56, no. 5 (1947): 105; F. A. Van Atta, "Perchloric Acid: Industrial Data Sheet D-Chem 44," *National Safety News* 56, no. 6 (1947): 42; A. C. Leigh, Clyde M. Leavitt, and F. W. Atchison, Jr., "Safety in Shipbuilding and Ship Repairs," 18, and Jones F. Devlin, "Accidents to Passengers and Personnel on Passenger Ships," 34, both in *Transactions of the*

Association's *Gas Engineer's Handbook*, 1965 edition, mentions asbestos twice as an inhalation hazard, but goes on to specify it seventy-eight times as a safety material.[75] Like the City of Chicago, the National Safety Council, and the state governments of California, Pennsylvania, and New York, the AGA regarded asbestos as one of a number of commonly used industrial materials that required safety precautions, but its use was nevertheless recommended as best practice, as well as being required by federal, state, and local codes.

Failure-to-warn issues, as in our representative complaint, are central to asbestos litigation. The federal, state, and local jurisdictions that specified asbestos in approved assemblies did not require such warnings, and it is difficult to imagine how it might have occurred to anyone to put a warning on an assembly that was approved by all three levels of government. Even the Occupational Safety and Health Administration (OSHA) approved the use of asbestos in both thermal and electrical insulation in the 1970s, and prohibited leaving hot surfaces uninsulated in workplaces.[76] The *Code of Federal Regulations (CFR)* (29 CFR 1910) sections enforced by OSHA incorporated into the *CFR* by reference a national standard, NFPA 54, that included the Table of Clearances as well as other specifications for asbestos.[77]

In the 1940s, when the Table of Clearances was first published, more than eleven thousand Americans a year were dying in fires, a rate of more than seven per hundred thousand. By 1990, a number of factors, including, but by no means limited to, asbestos in building codes, had reduced this rate to two per hundred thousand. But in the meantime, *Borel vs Fibreboard* (1973) had begun the process of putting a new frame around the use of asbestos: litigation and the risks of mesothelioma. As far as can be determined by medical and litigation statistics, the incidence of the former was many times that of the latter. More than forty thousand claims were filed in the period from September 30, 2006, to September 30, 2007, but there were only about 2,500 cases of mesothelioma and

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National Safety Congress 16, Current Safety Topics in the Maritime Industries (1949).

[75] American Gas Association, Curt George Segeler, and Pacific Coast Gas Association Gas Engineers' Handbook Committee, *Gas Engineers Handbook: Fuel Gas Engineering Practices* (New York, 1965). The inhalation hazard references are on p.1/31 and 35.

[76] *Code of Federal Regulations* 1910.261 (k)(11) and 1910.261 (k)(11). See list of national consensus standards incorporated by reference into the CFR in 1971 at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&rgn=div5&view=text&node=29:5.1.1.1.8&idno=29#29:5.1.1.1.8.1.33.6, accessed 14 Feb. 2011.

[77] U.S. Congress, Occupational Safety and Health Act of 1970, 29 CFR §1910.110(b)(20)(iv)(a), incorporating National Board of Fire Underwriters and National Fire Protection Association, *Standard for the Installation of Gas Appliances and Gas Piping as Recommended by the National Fire Protection Association: NBFU/NFPA 54*, NBFU no. 54 (New York, 1969).

about 300 deaths from asbestosis per year in 2006.[78] As of December 31, 2009, the U.S. District. Court 875 Multi-District Litigation docket in Philadelphia, into which all federal asbestos cases have been consolidated, consisted of "42,076 cases, consisting of 2,337,692 individual claims (all diseases), 50,889 (pending, all diseases)."[79] Because mesothelioma was not separately classified as a reportable disease until 1999, we do not have reliable figures on its incidence before that date. The reported mortality rate for this disease, however, is thought to have risen slightly between 1990 and 2005, but the rate per million population was stable, and may be declining.[80]

Both the litigation and the perceived occupational health risk drove strenuous efforts in the late 1970s and the decade of the 1980s to produce a Table of Clearances that would pass the standard test (exposure of combustibles to no more than 160°F) without the use of asbestos. This proved so challenging that the Table of 1988 changed the wording but not the assemblies themselves, substituting the words "insulating" and "mineral" for "asbestos," although no other material was then available that would pass the standard test (see Fig 3).[81]

Going on behind this struggle to accommodate new views of risk was a massive effort to overcome technological barriers that had already been shown, during World World II, to be formidable. Efforts to relieve wartime asbestos shortages by mineral fiber innovation in the United States and Europe between 1939 and 1945 had been largely unsuccessful.[82] Engineers knew by 1980 that the world of high-temperature thermal insulation

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[78] Disease statistics are from U.S. Centers for Disease Control, *Worker Health Chartbook, 2000* (Sept. 2000), DHHS (NIOSH) Publication no. 2000-127, Figure 3-2. Asbestos filings in 2006-07, acknowledged by the authors to almost certainly undercount new claims, are from Asbestos Liability Risk Analysis Group, *Asbestos Claims And Litigation: Update and Review: 2007 New Case Filing Summary and Analysis* (2008), 4.

[79] Asbestos Liability Risk Analysis Group, *Asbestos Claims and Litigation: Update and Review: 2009 New Case Filing Summary and Analysis* (2010), 5.

[80] K. M. Bang et al., "Malignant Mesothelioma Mortality—United States, 1999-2005," *Morbidity and Mortality Weekly Report* 58, no. 15 (2009): 393-96.

[81] International Conference of Building Officials, *Uniform Mechanical Code* (Whittier, Calif., 1988), 39-40. On p. 246, the "mineral" is declared to be asbestos.

[82] U.S. Congress, Senate, Committee on Military Affairs, *Strategic and Critical Materials: Hearings before a Subcommittee of the Committee on Military Affairs, United States Senate, Seventy-seventh Congress, First Session, Relative to Strategic and Critical Materials and Minerals May 15, 19, 21, 26, June 4, 11, 16, and July 1, 1941* (Washington, D.C., 1941); Oliver Bowles and F. M Barsigian, "Asbestos," *Minerals Yearbook*, ed. C. E. Needham (Washington, D.C., 1942), 1423-34; R. W. Fisher and R. L. Thorne, "Paligorskite, a Possible Asbestos Substitute," *U.S. Bureau of Mines Informational Circular* 7313 (1945), 5; and *The German Mineral Wool and Heat Insulation Industries, British Intelligence Objectives Sub-Committee Final Report no. 916* (1947).

was changing rapidly, and that materials other than asbestos would have to be identified or invented for this purpose. Mineral and rock wool, glass fiber, and a few other man-made fibrous materials had been available for decades and were code-compliant as insulations for cold pipes, warm-air

Figure 3
Table of Clearances from Uniform Mechanical Code of 1988, Table 4-2, from NFPA 31

INSTALLATION OF OIL BURNERS AND OIL-FIRED UNITS 31-27

Table 4-2 Clearances (Inches) With Specified Forms of Protection*

Type of Protection Applied to the combustible material unless otherwise specified and covering all surfaces within the distance specified as the required clearance with no protection. (*See App.B.*) Thicknesses are minimum.	Where the required Clearance with no protection is: 36 inches			18 inches			12 inches		9 inches	6 inches	
	Above	Sides & Rear	Chimney Connector	Above	Sides & Rear	Chimney Connector	Above	Sides & Rear	Chimney Connector	Above	Sides & Rear
(a) 1/4 in. insulating millboard** spaced out 1"† ...	30	18	30	15	9	12	9	6	6	3	2
(b) 28 gage sheet metal on 1/4" insulating millboard**	24	18	24	12	9	12	9	6	4	3	2
(c) 28 gage sheet metal spaced out 1"†	18	12	18	9	6	9	6	4	4	2	2
(d) 28 gage sheet metal on 1/8" insulating millboard** spaced out 1"†	18	12	18	9	6	9	6	4	4	2	2
(e) 1/4" insulating millboard** on 1" mineral wool bats reinforced with wire mesh or equivalent	18	12	18	6	6	6	4	4	4	2	2
(f) 22 gage sheet metal on 1" mineral wool bats reinforced with wire or equivalent	18	12	12	4	3	3	2	2	2	2	2
(g) 1/4" insulating millboard**	36	36	36	18	18	18	12	12	9	4	4

*All clearances shall be measured from the outer surface of the equipment to the combustible material disregarding any intervening protection applied to the combustible material.
**A factory fabricated board formed with noncombustible materials, normally fibers, and having a thermal conductivity in the range of 1 Btu inch per square foot per °F, or less.
†Spacers shall be of noncombustible material.

For SI Units: 1 in. = 25 mm.

ductwork, walls, and roofs, but, except for the rock wool reinforced with asbestos, described earlier, none of these materials could be used on heating or power boilers, furnaces, hot pipes, or on any other surface that exposed combustible construction to operating temperatures greater than 160°F.[83]

[83] On operating temperatures, see Labes, “Safe Mounting, Clearances,” 80. Some authors have argued that these “substitutes” for asbestos were kept off the market by the same “conspiracy” of asbestos insulation producers that they claim suppressed information regarding the dangers of asbestos. As we have seen, this was not the case; the materials were available but were not code-compliant for high temperatures because they did not pass the standard tests. See, for example, Castleman and Berger, *Asbestos: Medical and Legal Aspects* (2005), 28-29, and Berger’s chap. 6, “Alternatives to Asbestos Insulation,” 437-513; and Jock McCulloch and Geoffrey Tweedale, *Defending the Indefensible: The Global Asbestos Industry and Its Fight for Survival* (New York, 2008), 22-23, 26, 115,

Research and testing of possible substitute materials began in the 1970s and had by the mid-1980s reached a frenetic level, as insulation manufacturers urged their engineers to devise insulation assemblies that could capture a significant share of the rapidly emerging market for asbestos-free substitutes.[84] Ceramic fibers and aramid were considered especially promising candidates. Article after article in the engineering literature proclaimed victory or near-victory, but all contenders eventually failed either the alkali-resistance test, the Steiner tunnel test (ASTM E-84), the hot-surface performance test (ASTM C-411), the heat transfer performance test devised by Achenbach and Cole at the National Bureau of Standards in 1962, or some other critical performance-standard test.[85] In addition to the anticipated health benefits of asbestos-free materials, there was a significant economic incentive to innovate as well: two of the proposed substitute insulation materials (rock wool and fiber glass) were much less expensive than asbestos. In 1984, for example, code-compliant asbestos-containing pipe covering cost $2.72 per square foot installed, whereas 4-inch-thick rock wool and 2-inch-thick glass fiber batts were, respectively 58 and 32 cents per square foot. Boiler insulation consisting of asbestos in calcium silicate was even more costly than pipe covering, at $12.04 per square foot.[86]

Even the government was at a loss for substitutes. At the National Bureau of Standards, for example, fire safety engineers were charged in

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195. For a different view of the "conspiracy theory," see Maines, *Asbestos and Fire*, 160-68.

[84] Dale C. Swanson, "Asbestos Substitutes for High Temperatures," *Materials Engineering* 92, no. 7 (1980): 36-38; "Asbestos Users Step Up Search for Substitutes," *Chemical Engineering* 93, no. 20 (1986): 18-19, 21; Karlheinz Hillermeier, "High-Performance Fibres as Substitutes for Asbestos," *Textile Month* (1983), 25, 27-28, and the same author's "Prospects of Aramid as a Substitute for Asbestos," *Textile Research Journal* 54, no. 9 (1984): 575-80; and Christel Hemman and Mariano Pelagalli, "Moeglichkeiten der Asbestsubstitution [Possibilities of Asbestos Substitution]," *Chemische Technik* (Leipzig) 37, no. 7 (1985): 303-5.

[85] Tamami Kusuda and W. M. Ellis, "Boiling Tests of Thermal Insulation in Conduit-Type Underground Heat Distribution Systems," in *Thermal Insulation, Materials, and Systems for Energy Conservation in the '80s: A Conference*, ed. F. A. Govan, D. M. Greason, J. D. McAllister, ASTM Committee C-16 on Thermal Insulation, United States Dept. of Energy and Oak Ridge National Laboratory (Philadelphia, Pa., 1983), 802-18; Les Stanwood, "Asbestos Substitutes: Exploring the Options," *Construction Specifier* 40, no. 4 (1987): 112-19; Peter Steinau, "Austauschfasern fuer Asbest [Fibers for Asbestos Substitution]," *Gummi, Fasern, Kunststoffe* 37, no. 11 (1984): 567-68; Alasdair Crewe, "Asbestos Substitutes Take Off," *Engineering Materials and Design* 30, no. 11 (1986): 36, 38, 41-36, 38, 41; and Gary R. Teague, "How to Select an Asbestos Substitute," *National Safety and Health News* 133, no. 5 (1986): 45-47.

[86] R. S. Means Company, *Building Construction Cost Data* (Kingston, Mass., 1984).

1979 with the unenviable task of developing new asbestos-free thermal insulation standards that would help reduce the alarming increase in wood-heating fires, which were rising rapidly from 66,800 with 290 deaths in 1978 to 112,000 with 350 deaths in 1980.[87] NBS engineers Joseph Loftus and Richard Peacock tested twenty-three wall protection assemblies in 1979, observing ruefully that “All of the codes studied specified the use of two materials—asbestos millboard in various thicknesses and sheet metal—as acceptable for wall protection. Yet the current health concerns over the use of asbestos limit the available alternatives for wall and floor protection.”[88] The U.S. Navy, which had been the asbestos industry’s largest single customer in 1969, was still struggling with acceptable substitute materials in 1982; their troubles were compounded by the fatally poor fire performance of some of the materials eventually adopted by both the American and the British Navy, as well as health concerns regarding some of the proposed substitute materials (see Fig. 4).[89]

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87 Richard D. Peacock, “Wood Heating Safety Research: An Update,” *Fire Technology* 23, no. 4 (1987): 292-312.

88 Joseph J. Loftus and Richard D. Peacock, “Evaluation of Wall Protection Systems for Wood-Burning Appliances,” *Fire Journal* 77, no. 5 (1983): 23-25, 28, 39.

89 U.S. Congress, House Committee on Education and Labor, Subcommittee on Labor Standards, *Occupational Health Hazards Compensation Act of 1982: Hearings before the Subcommittee on Labor Standards of the Committee on Education and Labor, House of Representatives, Ninety-Seventh Congress, Second Session, on H.R. 5735 , on March 4; April 21, 22, 1982* (Washington, D.C., 1983), 249; U.S. Congress, House Committee on Armed Services, *Investigation into the Attack on the U.S.S. Cole* (Washington, D.C., 2001); U.S. Congress, Senate Committee on Armed Services, *Lessons Learned from the Attack on U.S.S. Cole . . . : Hearing before the Committee on Armed Services, United States Senate, One Hundred Seventh Congress, First Session, May 3, 2001* (Washington, D.C., 2002), 107-609; C. A. Pinkstaff, D. L. Sturtz, and R. F. Bellamy, “USS Franklin and the USS Stark—Recurrent Problems in the Prevention and Treatment of Naval Battle Casualties,” *Military Medicine* 154, no. 5 (1989): 229-33; and Jeffrey L. Levinson and Randy L. Edwards, *Missile Inbound: The Attack on the Stark in the Persian Gulf* (Annapolis, Md., 1997). On health concerns regarding potential substitutes, see P. T. Harrison et al., “Comparative Hazards of Chrysotile Asbestos and Its Substitutes: A European Perspective,” *Environmental Health Perspectives* 107, no. 8 (1999): 607-11; V. Cavaseno, “Latest Word on Asbestos Won’t be the Last,” *Chemical Engineering* 85 (1978): 76ff; A. M. Pye, “A Review of Asbestos Substitute Materials in Industrial Applications,” *Journal of Hazardous Materials* 3, no. 2 (1979): 125-47; and Arthur Furst and Shirley B. Radding, “Toxicological Evaluations of Asbestos Substitutes,” in *Proceedings of the International Conference on Thermal Insulation* (Millbrae, Calif., 1981), 249-56. On the Navy’s substitution efforts, see A. Winer and W. D. Holtgren, “Asbestos—A Case Study of the U.S. Navy’s Response to Upgraded Safety and Health Requirements,” presented at the Annual Technical Symposium (13th), Association of Scientists and Engineers of

Figure 4
Fire in the Post-Asbestos Era: The *U.S.S. Cole*, 2000

Asbestos-free electrical insulation on the *U.S.S. Cole* burned for 96 hours.

Source: Jim Watson/AFP/U.S. Navy.

The 1990 Table of Clearances shows how formidable the engineering challenges still were at that time; it lists no approved assembly that could be directly applied to hot metal surfaces as asbestos had been (see Fig. 5).[90] All required construction of some type of enclosure that included dead air space, as no sufficiently heat-resistant material performed in insulation as asbestos had done. The options set forth in the 1990 Table were so much more space-intensive than those of the 1943 Table that much existing construction could not accommodate it, a difficulty overcome by the New York City jurisdiction by simply keeping the old Table alongside the new as approved assemblies in its building code.[91] No jurisdiction required the removal of the older approved assemblies as long

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the Naval Air and Sea Systems Commands, 12 March 1976 (Alexandria, Va., 1976).

[90] Building Officials and Code Administrators International, *The BOCA National Mechanical Code*, 7th ed. (Country Club Hills, Ill., 1990), 93-94.

[91] New York (City) Bureau of Buildings, *Building Code of the City of New York: Titles 26, 27, and 28 of the Administrative Code: Including Building Code Reference Standards and Rules of the City of New York* (Binghamton, N.Y., 2002).

Figure 4: "Reduced Clearance to Combustibles," from Uniform Mechanical Code of 1990

Table M-1101.2
REDUCED CLEARANCE TO COMBUSTIBLES

Reduced clearance protection[a] (described from the device to the combustible surface)	Minimum air space between the device and the protection listed below (inches)[b] Reduced clearance based on required clearance to combustibles (inches)[b]			
	36	18	9	6
1/8-inch unpainted aluminum plate, spaced 1 inch off the wall	3	3	3	3
1/8-inch painted aluminum plate, spaced 1 inch off the wall	28	9	3	3
Unpainted galvanized sheet metal, minimum nominal thickness of 0.019 inch (No. 28 Gage), mounted on 1/2-inch inorganic insulating board attached directly to the wall	3	3	3	3

Reduced clearance protection[a] (described from the device to the combustible surface)	Minimum air space between the device and the protection listed below (inches)[b] Reduced clearance based on required clearance to combustibles (inches)[b]			
	36	18	9	6
Unpainted galvanized sheet metal, minimum nominal thickness of 0.019 inch (No. 28 Gage), spaced 1 inch off the wall	3	3	3	3
Painted galvanized sheet metal, minimum nominal thickness of 0.019 inch (No. 28 Gage), spaced 1 inch off the wall	24	6	3	3
Two layers of painted galvanized sheet metal, minimum nominal thickness of 0.019 inch (No. 28 Gage), having a 1-inch air space between layers, spaced 1 inch off the wall	3	3	3	3
1/4-inch inorganic insulating board having painted galvanized sheet metal, minimum nominal thickness of 0.019 inch (No. 28 Gage), attached on both sides spaced 1 inch off the wall	3	3	3	3
1/4-inch inorganic insulating board, spaced 1 inch off the wall	30	9	3	3
Two layers of painted galvanized sheet metal, minimum nominal thickness of 0.028 inch (No. 24 Gage), having 1 inch of fiberglass insulation between layers, spaced 1 inch off the wall	3	3	3	3
3 1/2-inch-thick brick wall, spaced 1 inch off the wall	18	5	3	0

Source: Building Officials and Code Administrators International, *The BOCA National Mechanical Code*, 7th ed. (Country Club Hills, Ill., 1990), 93-94

as they were still in functional condition, except when the equipment was replaced, or when the building underwent substantial renovation.

The perceived need to remove asbestos from the Table of Clearances and from other long-established engineering systems of fire safety, such as high-temperature gaskets, necessitated a systemic shift that took decades to accomplish.[92] Despite demand from both consumers and makers of intermediate goods, the technological obstacles to devising a substitute for a naturally occurring mineral proved far more formidable than even the engineers themselves had anticipated. The processes of innovation, testing and adoption of asbestos-free thermal insulation materials into engineering standards were complicated by the interlocking and inherently conservative character of consensus code development, with some standards incorporating other standards with different testing requirements for each.[93]

After more than half a century of assiduous testing and approvals for thermal insulation assemblies had resulted in consensus in 1943 on the superiority of asbestos for high-temperature insulation, the engineering and code-development community was thrown into disarray by a dramatic change in the risk framing of fire safety and asbestos. The persistence of asbestos in twentieth-century engineering codes and standards was a measure of both the complexity of code development and the technological obstacles to innovation when a widely used and accepted naturally occurring material is newly perceived as a health hazard.

[92] Asbestos is still specified in some types of gasket service; see American Society of Mechanical Engineers, Boiler and Pressure Vessel Committee, "Seal Technology," in *ASME Boiler and Pressure Vessel Code* (New York, 1995), 636-37.

[93] As, for example, NFPA 54, 90, and 211, incorporated NFPA 89M.