REGULATORY INFORMATION DISTRIBUTION SYSTEM (RIDS)

ACCESSION NBR:8407250381 DOC.DATE: 84/07/17 NOTARIZED: NO DOCKET #
FACIL:50-397 WPPSS Nuclear Project, Unit 2, Washington Public Powe 05000397
AUTH.NAME AUTHOR AFFILIATION
SORENSEN,G.C. Washington Public Power Supply System
RECIP.NAME RECIPIENT AFFILIATION
SCHWENCER,A. Licensing Branch 2

SUBJECT: Discusses replacement of vinyl asbestos tiled floor w/carpeting to enhance control room condition & improve human performance.Proposed carpeting meets or exceeds critical radiant flux rating,per ASTM E-648 test.

DISTRIBUTION CODE: A003S COPIES RECEIVED:LTR 1 ENCL 1 SIZE: 8
TITLE: OR/Licensing Submittal: Suppl 1 to NUREG-0737(Generic Ltr 82-33)

NOTES: 05000397
OL:12/20/83

	RECIPIENT ID CODE/NAME	COPIES LTTR	COPIES ENCL	RECIPIENT ID CODE/NAME	COPIES LTTR	COPIES ENCL
	NRR LB2 BC	7	7			
INTERNAL:	IE/DEPER/EPB	3	3	NRR PAULSON,W	1	1
	NRR/DHFS/HFEB	5	5	NRR/DHFS/PSRB	1	1
	NRR/DL/ORAB	1	1	NRR/DL/ORB5	5	5
	NRR/DSI/CPB	1	1	NRR/DSI/ICSB	1	1
	NRR/DSI/METB	1	1	NRR/DSI/RAB	1	1
	NRR/DSI/RSB	1	1	REG FILES	1	1
	RGN5	1	1			
EXTERNAL:	LPDR	1	1	NRC PDR	1	1
	NSIC	1	1	NTIS	1	1

TOTAL NUMBER OF COPIES REQUIRED: LTTR 34 ENCL 34

Washington Public Power Supply System
P.O. Box 968 3000 George Washington Way Richland, Washington 99352 (509) 372-5000

July 17, 1984
G02-84-427

8407250381 840717
PDR ADOCK 05000397
P PDR

Docket No. 50-397

Director of Nuclear Reactor Regulation
Attention: Mr. A. Schwencer, Chief
Licensing Branch No. 2
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Schwencer:

Subject: NUCLEAR PLANT NO. 2
CONTROL ROOM FLOOR: ENHANCEMENT OF

Review of the WNP-2 control room design has indicated the desirability of replacing the present vinyl asbestos tiled floor covering with carpeting. Enhancement of the work area to create a pleasant and comfortable setting is advantageous and desirable in view of the long hours and confining aspects of the control room operator's job. Beneficial features to be realized by this replacement include at a minimum, the following:

1) Background noise reduction
2) Ambience and comfort
3) Minimize fatigue of personnel
4) Overall improvement of control room appearance.

This control room enhancement/improvement has been adopted effectively by other operating plants such as Susquehanna, Diablo Canyon, Trojan and LaSalle.

With construction completion and a marked decrease in control room traffic, this improvement is being scheduled at this time to enhance control room conditions and improve human performance.

Current NRC regulations establish carpet flammability criteria on the basis of the ASTM E-84 "tunnel" test, specifying a maximum flame spread index of 25 and a maximum smoke developed value of 50. Submitted for your review is a comparative analysis of the subject floor covering using the "Critical Radiant Flux" test in accordance with ASTM E-648, NVLAP Code 03/F04, and the NFPA 258, ASTM E-662, 79 test for "Specific Optical Density of Smoke Generated".

Since about 1981 carpet manufacturers have used the Floor Radiant Panel Test (ASTM E-648 or NFPA 253) as the nationally recognized standard for evaluating carpet used on floors. This test more adequately tests the carpet in its actual installation configuration and is recognized in the 1981 Life Safety

A003
1/1

Code (NFPA 101), Section 6-5.2, Interior Floor Finish. Per this section, a Class I Interior Floor Finish will have a minimum critical radiant flux of 0.45 watts per square centimeter or greater. The life safety requirement of 0.45 watts per square centimeter is also recognized by the Department of Health, Education, and Welfare standard on flammability of floor coverings (Chapter 8-40, Attachment 1) paragraph 8-40-40, "Standard for Flammability". Part A states that "Floor coverings used in corridors and means of egress in health care facilities shall have a minimum critical radiant flux of 0.45 watts per square centimeter as determined by the Floor Radiant Panel Test".

Since the Radiant Panel Test does not include a smoke value, the ASTM E-662 Smoke Density Chamber (NFPA 258) Test has been used to regulate carpets to a maximum optical density. Using this test, the Department of Health, Education, and Welfare set a standard of 450 or less in paragraph 8-40-50, "Standard for Smoke Developed". Per attachment 2, NBS Technical Note 757, "The Smoke Density Chamber Method for Evaluating the Potential Smoke Generation of Building Materials", vinyl asbestos tile has a flaming smoke development of 325.

As stated in Attachment 3, the carpet that is proposed to be used in the control room at WNP-2 meets or exceeds the critical radiant flux rating of 0.45 watts per square centimeter per the ASTM E-648 Test. Per the manufacturer, the carpet has a critical radiant flux of 1.01 watts per square centimeter. The carpet also has a smoke value of less than 250 per the ASTM E-662 Test. Both of these values are well within the requirements set by the Department of Health, Education, and Welfare for health care facilities and the smoke value of the carpet is less than that for vinyl asbestos tile which the NRC has already accepted as non-combustible and acceptable for use in the WNP-2 control room. It is the Supply System position that the proposed carpet meets and exceeds the NRC requirements. Additionally, a review in accordance with 10 CFR 50.59 has been completed and the Supply System considers that no significant hazards or unreviewed safety questions will result from the change.

The WNP-2 Plant Staff's schedule for implementation of this improvement is quite restricted. Your cooperation with expeditious review and concurrence in this matter is appreciated. If you have any further questions concerning this matter, please contact Mr. P. L. Powell, Manager, WNP-2 Licensing.

Very truly yours,

G. C. Sorensen, Manager
Regulatory Programs

SIS/tmh
Attachments (3)

cc: R Auluck - NRC
WS Chin - BPA
D Kubicki - NRC
AD Toth - NRC Site

ATTACHMENT 1

CHAPTER 8-40

Safety Standard for Flammability of Floor Coverings

8-40-00 Purpose

To establish a Department of Health, Education, and Welfare safety standard on the flammability of floor coverings.

8-40-10 Policy

It is the policy of the Department of Health, Education, and Welfare to assure a safe and healthful environment insofar as practicable, for its employees in the performance of their assigned responsibilities and to those members of the public whose environments may be affected by activities or programs of the Department, through the establishment of appropriate Departmental safety and health standards, criteria, policy and guidance for uniform and consistent use on a Department-wide basis.

8-40-20 Applicability

This standard is applicable to all types of floor coverings and surfacings used in all facilities owned or operated by the Department of Health, Education, and Welfare and to all program areas of the Department including Federally aided and grant programs.

8-40-30 Effective Date

This standard is effective on January 1, 1977: floor coverings installed prior to the effective date of this standard may be continued in use. In those cases where a purchase contract or similar commitment to install floor coverings was entered into prior to January 1, 1977, but for installation to commence after that date, the policy standards in this chapter should be adhered to if it is feasible to renegotiate the contract or

8-40-30 (continued)

similar commitment.

8-40-40 <u>Standard for Flammability</u>

A. Floor coverings used in corridors and means of egress in health care facilities shall have a minimum critical radiant flux of 0.45 watts per square centimeter as determined by the Flooring Radiant Panel Test (FRPT). See Exhibit X-25.

B. Floor coverings used in corridors and means of egress in facilities other than health care shall have a minimum critical radiant flux of 0.22 watts per square centimeter as determined by the Flooring Radiant Panel Test (FRPT). See Exhibit X-25.

C. Carpets and rugs used in spaces other than corridors and means of egress of all facilities (including health care) are required by Federal Law to meet "Standard for the surface Flammability of Carpets and Rugs" DOC FF-1-70 (Pill Test).

See Federal Register, April 10, 1970. Only those floor coverings installed after April 10, 1970 are required to meet DOC FF-1-70. Floor coverings of other materials used in spaces other than corridors and means of egress of all facilities <u>may</u> be required to meet the interior finish requirements of the "Life Safety Code," 1973 edition as published by the National Fire Protection Association as determined by the authority having jurisdiction.

D. When floor coverings are composed of multi-layered materials, such as a carpet over a separate pad, the minimum criteria above shall apply to the entire assembly.

E. When an additive or process has been applied to either the basic material or to the final floor covering material which significantly decreases the flammability of the floor covering and enables it to meet the acceptance criterion of this standard, the test method calls for a washing or other determination that such treatment or process is not easily removed by normal maintenance procedures.

F. Special treatments, such as carpet shampoo which may render a floor covering less flammable, shall not be used to comply with above criteria. The use of such treatments requires judgment on the part of the enforcing official as to the acceptability of such treatments for previously installed floor coverings.

8-40-50 Standard for Smoke Developed

Floor coverings, installed throughout any facility, after the effective date of this standard shall possess a "smoke developed" rating of 450 or less as determined by the standard "Smoke Generated by Solid Materials".
(Note: This standard is currently National Fire Protection Association's No. 258T and was developed as National Bureau of Standards Technical Note No. 708. The smoke developed rating is intended to permit hardwood floors and most resilient (vinyl, asbestos, etc.) floor coverings).

8-40-60 Standard for Static Build-up

Floor coverings, unless in conflict with another safety or medical standard, installed after the effective date of this standard, shall not build-up a static level exceeding 3.5 kV when tested by the AATCC Test Method 134-1969. In locations where flammable liquids, vapors, gases, and highly combustible solids are present, there should be no measurable build-up of static electricity charges.

8-40-70 Standard for General Safety

Floor coverings, installed throughout any facility after the effective date of this standard, shall be of types which do not present an unusual slipping or tripping hazard to those persons traveling over them.

8-40-80 Standard for Use by Handicapped

All carpeting in areas subject to use by handicapped individuals shall, in addition to meeting other requirements of these standards, be specified as high density, low uncut pile, and non-absorbent. Underlayments are permissible provided they are specified as firm or hard and do not exceed 3/8 inches in depth. Carpets,and underlayments if used, shall be installed stretched taut and securely anchored at all edges to the floor. Edging strips shall not project higher than 3/8 inches above the floor line.

8-40-90 Previous Standards for Departmental Facilities

Floor coverings in use in Department owned or operated health care facilities prior to the effective date of this standard and installed after May 17, 1973 are required to have a flame spread rating of 75 or less as determined by ASTM E-84 test method (Steiner Tunnel).

(Note: This ASTM E-84 standard will no longer apply to floor coverings installed after the effective date of this standard.

8-40-100 Previous Standards for Program Facilities

Floor coverings in use in facilities under a Department funded or grant program were required to meet various standards according to the particular program. These floor coverings may be continued in use, provided they met the applicable standards of the specific program (Hill-Burton, Medicare, Medicaid, etc.) at the time of installation.

(Note: These program standards will no longer apply to floor coverings installed after the effective date of this standard.)

8-40-110 Exceptions

When deviations from the basic intent of this standard are required to meet specific conditions or problems, justifications supporting such determinations may be submitted to the official possessing waiver authority for the specific program or facility involved. In the case of Departmental owned or operated facilities justifications shall be submitted via appropriate organizational channels to the Director, Office of Safety Management, in accordance with 8-00-40 of the Safety Management Manual, DHEW.

ATTACHMENT 3

BIGELOW-SANFORD, INC.

P. O. BOX 3089

GREENVILLE, S. C. 29602

PHONE (803) 299-2630

PRODUCT IDENTIFICATION: CV01963 Revision 1 Remake DATE: June 5, 1984

Flooring Radiant Panel: This is to certify that a carpet sample identified as above was tested for critical radiant flux in accordance with ASTM Test Method ASTM E-648, NVLAP Code 03/F04, Bigelow-Sanford Test T-232.

TEST ASSEMBLY: Specimens were mounted as part of:

	Meets or exceeds: Average Critical Radiant Flux, Watts/sq. cm.
A direct Glue Down System using NuBroadlok Adhesive.	.45
A Carpet Flooring System using Standard 50 oz. rubberized jute/hair cushion.	-
A Carpet Module Loose Lay System without any adhesive.	-
A Carpet Module Release System using 3M Blue Glue.	-

This laboratory is accredited by NVLAP of the U. S. Department of Commerce as having the competence to perform above tests in accordance with prescribed test method and accreditation criteria.

NVLAP

NBS Smoke: This is to certify that a carpet sample identified as above was tested for "Specific Optical Density of Smoke generated by solid materials" in accordance with NFPA 258, ASTM E-662, 79, Bigelow-Sanford Test T-219.

The Maximum Average Specific Optical density is:

Non-Flaming - 250 or less than 250
Flaming - 250 or less than 250.

Approved by:

Bigelow-Sanford, Inc.

Reference: Report Number 28800

Report Date 5/29/84

BIGELOW-SANFORD, INC.
P.O. BOX 3089
GREENVILLE, S.C. 29602
PHONE (803) 299-2646

REPORT NO. 28800 DATE 6/5/84

SUBJECT Electrostatic Propensity of Carpets

MANUFACTURER Bigelow-Sanford, Inc.

PRODUCT IDENTIFICATION: CV 01963 Revision 1 Remake

This is to certify that a carpet sample identified as above was tested for electrostatic propensity in accordance with AATCC-134 Test Method.

TEST ASSEMBLY: Test specimen was mounted as part of carpet flooring system comprised of a rubberized jute/hair cushion.

The maximum static voltage generated at 20% RH and 70°F was less than 2000 volts.

Approved By:

BIGELOW-SANFORD, INC.

Reference: Report Number 28800

Date 5/29/84

Electrostatic propensity of Carpets AATCC 134/CRI 102, NVLAP Code 03/E01, Bigelow-Sanford Test T-213.

This laboratory is accredited by NVLAP of the U.S. Department of Commerce as having the competence to perform specified tests in accordance with prescribed test method and accreditation criteria.

NVLAP

ATTACHMENT 2

A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NBS TECHNICAL NOTE 757

The Smoke Density Chamber Method For Evaluating The Potential Smoke Generation Of Building Materials

U.S.
DEPARTMENT
OF
COMMERCE
National
Bureau
of
Standards

The Smoke Density Chamber Method For Evaluating the Potential Smoke Generation of Building Materials

T. G. Lee

Center for Building Technology
Institute for Applied Technology
National Bureau of Standards
Washington, D.C. 20234

NBS Technical Notes are designed to supplement the Bureau's regular publications program. They provide a means for making available scientific data that are of transient or limited interest. Technical Notes may be listed or referred to in the open literature.

U.S. DEPARTMENT OF COMMERCE, Peter G. Peterson, *Secretary*
NATIONAL BUREAU OF STANDARDS, Lawrence M. Kushner, *Acting Director*,

Issued January 1973

THE SMOKE DENSITY CHAMBER METHOD FOR EVALUATING THE POTENTIAL SMOKE GENERATION OF BUILDING MATERIALS

T. G. Lee

The paper reviews the Smoke Density Chamber Test Method and illustrates its use and application to assess smoke generation of building materials in fire situations. It shows how test results may aid the Fire Services and code authorities in evaluating and reducing the potential light-obscuration hazard of smoke in buildings. An example is given for calculating visibility in a simplified fire situation involving material of known smoke generation. The smoke generation of some common interior finish and construction materials are given.

Key words: Building Codes; building materials; fire; Fire Services; smoke; smoke density chamber; smoke generation; test method; visibility.

The Smoke Density Chamber Method for Evaluating

The Potential Smoke Generation of Building Materials

1. Introduction

There is a well known adage, "where there's smoke, there's fire." Fire is one of the foremost causes of accidental injury and we suffer the consequences of its by-product, smoke.

Statistics show that "smoke inhalation" and "asphyxiation" rather than burn injury cause a majority of the fire fatalities in this country. It is not accurately known how many people are trapped by decreased visibility due to dense smoke and who eventually succumb to the direct effects of fire and smoke in the immediate vicinity of the fire. Smoke can also cause apprehension, panic, or even death to occupants in other parts of a building because of smoke movement induced by natural convection or by mechanical ventilating systems. Furthermore, property losses are greatly increased because smoke also impedes fire fighting efforts. A smoke logged building often requires venting, in order to clear out smoke and hot gases. This generally increases the fire severity, but allows the fire fighting to be accomplished more effectively. The extent of these difficulties depends on the amount and rate of smoke generation in a given fire.

The increased use of plastics in coatings insulations, furnishings, and other materials of construction has changed the type and volume of smoke

generated and thereby broadened the fire problem. Chemical treatments or retardants added to reduce flammability of material may also increase the smoke generated in a fire.

One way to reduce problems associated with smoke is to provide reliable and meaningful information on the smoke generation of common materials. Such data may then be used by building designers, owners, or code officials in selecting materials of construction and furnishings at various levels of risk. For example in certain locations where smoke is critical such as in shafts, heating plant rooms and enclosures, exitways, duct linings, and filters in air conditioning systems, material of low smoke potential may be selected.

We have come to understand the concept and the application of fire load[1] in the design of fire resistive walls, columns, and floors. We should now begin thinking in terms of a smoke load[2] so that a rational building design will allow control of smoke by automatic venting, dilution, and/or shaft (i.e. stair and elevator shaft) pressurization in high rise buildings.

---

[1] Fire load: the total heat which could be liberated by the complete burnout of combustible materials in a prescribed area. Commonly expressed in terms of weight of combustibles per square foot of floor area in a compartment on the basis of a calorific value of 8000 Btu/lb.

[2] Smoke load: the total smoke which could be liberated by the combustion of furnishings and finish materials in a compartment under prescribed exposure conditions. It may be based on the summation of the product of specific optical densities and the area of smoke producing materials associated with a given volume. The specific optical densities are determined by measurements of sample specimens in the standardized Smoke Density Chamber.

At the present time very little meaningful data on quantitative smoke production are available to those who wish to design low-risk facilities such as nursing homes.

2. Requirements of a Meaningful Test Method

To date, smoke requirements have been used only sparingly; this is due partly to a lack of knowledge on how to apply smoke limitations, and partly to a lack of a meaningful test method. The need for a quantitative means for smoke measurement, based on flaming and nonflaming modes of exposure was clearly apparent to fire research workers, in both government and private organizations.

The Smoke Density Chamber meets all the following essential requirements of a good laboratory test method for measuring smoke generation of materials:

1. It must give relevant and useful results. Exposure conditions in the test should simulate important and typical parameters experienced in a real fire. For example, the amount and rate of smoke generation for most materials depends on whether the specimen is exposed to flame or just radiant heating.
2. The method must provide reliable and quantitative results. The degree of reproducibility (among laboratories) and repeatability (within a laboratory)

of the test results, determined by interlaboratory evaluations of the test method, must be acceptable.

3. The method must provide a continuous scale of measure and have sufficient resolution to cover the common materials. It should be capable of measuring the total smoke generated as well as the amount released over a specified time period.

4. The result must be understandable to various user groups (Fire Service, code official, architect, engineer, etc.) and fit the concept of performance criteria in building code enforcement. A building designer should be able to use the data to design for the possible smoke load. He should, for example, be able to select a material with moderate potential smoke generation to cover small parts of a room (or its furnishings), and a material of very low potential smoke in the rest of the room; so that the total smoke generation does not exceed some agreed upon limit.

3. The Test Method, Reliability, and Limitation

3.1 The Test Method

The test method, using the Smoke Density Chamber, was developed in 1966 by the Fire Research Section at the National Bureau of Standards (NBS) for the measurement of smoke potential of solid materials.[1] [1] Several

---

[1] The original work was supported by the Federal Housing Administration as part of a technical study of test methods and performance criteria for wall systems.

TABLE 1

Smoke Generation of Selected Specimens

Specimens	Thickness inch	Density lb/ft^3	Density oz/yd^2	Smoke (D_m) Non-Flam.	Smoke (D_m) Flaming
Wall & Ceiling Material					
Asbestos Cement Board	0.187	125		0	0
Gypsum Board (unfinish, paper)	0.375	51		35	10
Plywood	0.17	32		305	45
Fiber Board	0.5	16		230	75
PVC Veneer on Gypsum	0.5	51		109	110
(Veneer)	(0.01)				
Flooring					
Red Oak Flooring	0.75	39		505	300
Vinyl Asbestos Tile	0.062	93		240	325
Polyamide (aromatic) carpet	0.22		49	175	105
Nylon (foam backing) carpet	0.39		86	310	270
Acrylic carpet	0.375		82	470	220
Polymer Sheet					
Polyvinyl Chloride	0.01	87			100
Polyvinyl Chloride	0.015	87			210
Polyvinyl Chloride	0.03	87		120	430
Acrylonitrile-Butadiene-Styrene	.022	66		188	
Acrylonitrile-Butadiene-Styrene	.032	66		220	450
Glass-Reinforced Polyester	.110	48		420	720
Wood					
Elm	0.05	40		150	35
Elm	0.125	40		270	
Elm	0.185	40		390	65
Elm	0.24	40		510	
Insulation					
Glass Fiber Insulation	1.0	3.5		25	25
Polystyrene Foam (Rigid)	1.0	1.8		25	390

of the early applications of the Smoke Density Chamber were the measurement of smoke produced by aircraft interior finish materials [1] and the effect of ventilation on the smoke produced by wood and plastic materials [2]. References [3] and [4] give the complete theory, construction details and the test method procedures of the Smoke Density Chamber. The Chamber is an 18 ft^3 closed cabinet in which a specimen three inches square is supported vertically in a holder and is exposed to heat under one of two conditions, designated as "flaming" or "nonflaming" (smoldering). The thickness and mounting of the test specimens should match the end use (installation) thickness and mounting. For each specimen, the combustion generated smoke accumulates within the chamber and the reduction of light transmission during the test is reported in terms of optical density of the smoke. The principle of smoke measurement in the chamber is based on application of the law of light absorption through solid or liquid aerosols commonly referred to as the Beer-Lambert Law [3]. Optical density is the single measurement most characteristic of a "quantity of smoke." The data from the chamber gives both the maximum optical density and the rate of increase in optical density during the test. To simplify use of the test results, however, only the maximum optical density, D_m, may be used to estimate the potential smoke generation of materials in building fires. The range of the instrument is between 0 and 800 units which adequately covers the D_m levels for most building finish materials.

Table 1 shows the maximum specific optical density of some common materials under flaming and nonflaming exposure conditions. In general,

TABLE 2

Combined Results of Interlaboratory Evaluation of
Smoke Density Chamber (AMINCO) Test

Specimen	Thickness in.	Mean D_m(corr.)	Reproducibility		Repeatability	
			Standard Deviation	Coefficient of Variation %	Standard Deviation	Coefficient of Variation %
Non-flaming Exposure						
Linoleum	0.125	725	49	6.7	46	6.4
Polypropylene Rug	0.22	621	52	8.4	28	4.5
Red Oak	0.25	552	40	7.2	18	3.2
ABS/.022	0.022	188	20	11	12	6.4
α-Cellulose	0.03	162	4.7	2.9	4.2	2.6
PVC-Gypsum	0.5	109	6.6	6.0	3.5	3.2
Polystyrene Foam	1.0	23	6.3	27	6.7	29
Flaming Exposure						
GRP	0.062	719	49	6.8	36	5.0
ABS/.032	0.032	451	17	3.8	20	4.5
Polystyrene Foam	1.0	391	52	13	32	8.0
Polypropylene Rug	0.22	292	24	8.3	20	6.9
PVC-Gypsum	0.5	109	29	27	12	11
Acoustic Tile	0.75	23	2.7	12	3.4	16

specimens from wood products gave higher smoke values under the non-flaming than under the flaming exposure condition while for solid plastic materials, the reverse was true.

Although not a part of the smoke density measurement and not discussed in this paper, the Smoke Density Chamber can also be used for the simultaneous measurement of the concentration of potentially toxic gases and vapors.

3.2 Reliability

The reproducibility of the test result from one laboratory to another compares favorably with other fire test methods. Several interested laboratories constructed their own chambers based on the published drawings and used the method to measure the smoke produced by a variety of materials [5,6]. This led, in 1970, to the production of a commercial version of the chamber incorporating a number of refinements by the American Instrument Company (AMINCO).

Twenty-two laboratories (18 with identical AMINCO chambers, four with "home-made" chambers) have participated in an inter-laboratory evaluation of the method involving eight common building materials under the prescribed flaming and nonflaming exposure conditions [4]. Several recommendations for procedural changes by the participants were accepted and are included in the latest test method standard; see Appendix II, NBS Technical Note 708 [4]. Table 2 shows a summary of these results

including supplemental flaming tests by twelve laboratories. The median reproducibility (among laboratories) for a variety of materials under the two exposure conditions was on the order of 8%.

Two standard reference materials to check the performance of the chamber are available from the Office of Standard Reference Materials, National Bureau of Standards.

3.3 Limitations

This test, in common with some other fire tests, does not measure an inherent property or "smoke characteristic" of a material; what the test does measure is the light obscuration characteristic of smoke generated by a particular material or assembly (of prescribed density, thickness, moisture content, etc.) under two stipulated conditions of fire exposure. At the present time, it is not possible to predict smoke production from a specimen without testing. For a solid uniform material, the smoke generated increases proportionally with thickness up to a certain thickness depending on its density and thermal properties. Specimens submitted for testing should be identical in all respects including thickness to that to be used in the field. The test specimen holder can handle specimens up to one inch thick.

4. How to Use the Data to Estimate Relative Smoke Hazard

In practical situations where no information is available on the disposition of interior finish material in the building, D_m may be used to

estimate the comparative light-obscuration hazard of smoke from burning different specimens. A simple specification, for example, could require that the surface finish materials of a room or other space not exceed a value of D_m based on the average of flaming and nonflaming exposure conditions, or alternately based on the higher value. However, to be accurate, information on the volume of the room or building, and the size, and type of the material should be used by designers to calculate the potential smoke load. Consideration should also be given to the effect of air dilution in the room or building as a basis of estimating possible smoke levels in the event of fire.

The maximum optical density D_m is a property of the particular specimen, its thickness and type of backing. If the identical material were to be similar exposed in a room, visibility, through the smoke generated in that room neglecting eye irritation, may be estimated from data based on the laboratory tests. To do this, we take into account the three geometrical factors affecting smoke density:

- the exposed <u>area</u> of material producing smoke, (A)
    - Greater area, more smoke;
- the <u>volume</u> of the room in which the smoke is accumulating (V)
    - Greater volume, lower density (concentration);
- the <u>length</u> of vision path (L)
    - Greater length, reduced visibility.

The estimated density of smoke (D/L) in a room can be calculated from the (D_m) value in the test chamber by the following equation:

$$D/L = D_m \times A/V \qquad \text{Equation (1)}$$

The relation between visual distance and smoke density is determined experimentally. Figure 1 is based on data from Jin [7] for smoke of various types. It represents the visual threshold response for several observers situated outside the room viewing through a window either a back-lighted sign or a side illuminated placard. These results show that for a given smoke density, the visual distance is affected primarily by the brightness of the sign and only slightly by the color of the smoke, burning conditions and type of material used. However, other studies have indicated variability in the relationship between visual distance and smoke density as summarized in the review by McGuire et al [8]. All of this work has ignored the irritant and lachrymatic effect that the smoke may have on an occupant located within the room.

The following example shows how data from the Smoke Density Chamber may be used to estimate the visibility in a hypothetical situation. It is desired to estimate the visibility in a 3200 ft^3 room where a 32 ft^2 area of material is exposed to fire over its entire surface and is the only material producing smoke. A test specimen of thickness identical to that of the panel is tested in the Smoke Density Chamber and the measured maximum specific optical density (D_m) is 100.

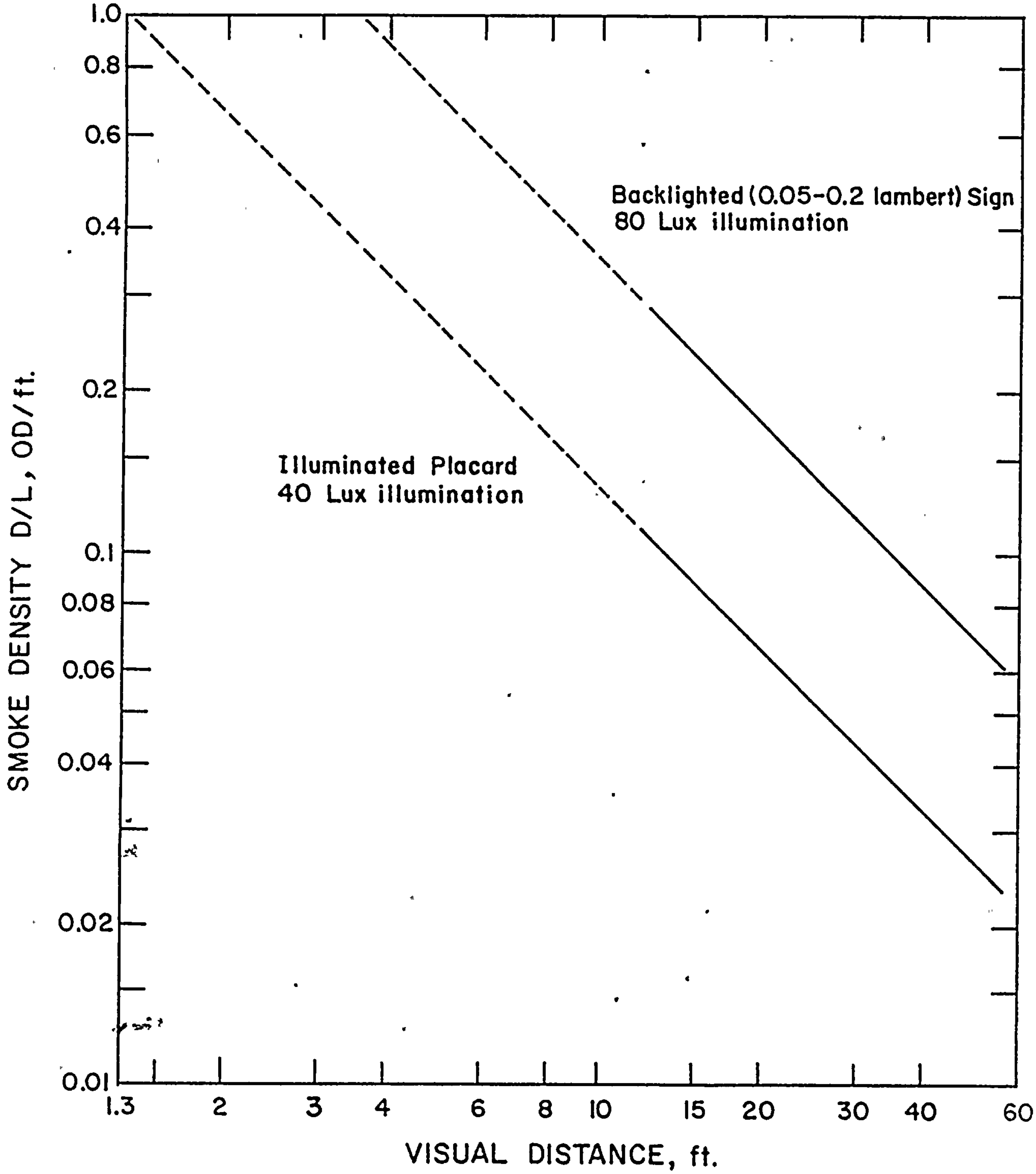

Fig. 1. Smoke Density and Visual Threshold of Signs Based on Data Ref. [7].

Substituting these numbers in equation (1), the smoke concentration (optical density per unit length) in the room will be:

D/L = 100 x 32/3200 = 1.0 per foot

Though experimental data on visibility in the 1.0 optical density per foot range was not given by Jin, extrapolation of the curves in Figure 1, (for illustration purposes) may be used to estimate visibility. D/L = 1.0 corresponds to a visual distance of only 3.5 ft for a back lighted (exit) sign under a typical light level of 80 lux* (without smoke) and 1.3 ft for a side illuminated placard under a light level of 40 lux.

However if the smoke were diluted from the room by natural convection due to stack effect or by a forced air ventilating system into the whole building with a volume of 45,000 ft^3, the smoke concentration assuming no losses will be:

D/L = 100 x 32/45,000 = .071 per foot

From Figure 1, D/L = .071 corresponds to a threshold visual distance of about 50 ft for the back lighted (exit) sign and about 18 ft for the side illuminated placard under the same lighting conditions.

5. How the Smoke Density Chamber Can Aid the Fire Services and Building Code Officials

The Fire Services in various jurisdictions have realized the critical nature of the problem of smoke in high density public occupancy buildings

* NFPA No. 101-1970 standard for exit sign calls for a minimum of 5 foot-candle or approximately 54 lux on the illuminated surface.

such as nursing homes, apartment buildings, and hotels. Some jurisdictions have enacted ordinances for its control. The Smoke Density Chamber is offered as a tool to evaluate the potential smoke generation which may occur in a room, a corridor, or a building caused by either surface finishes or by contents.

A test method based on the use of the Smoke Density Chamber has been submitted to ASTM for consideration and possible promulgation as a voluntary standard. At the present time over 70 chambers of the commercial type are being used by industrial, research and testing laboratories in this country and abroad. The following commercial testing laboratories have reported that they can provide the test service for the public:

American Instrument Company
Silver Spring, Maryland 20910

Underwriters' Laboratories, Inc.
Northbrook, Illinois 60062

Southwest Research Institute
San Antonio, Texas 78228

U. S. Testing Company
Hoboken, New Jersey 07030

6. Summary and Conclusion

The Smoke Density Chamber is a method for the measurement of the smoke generation of materials based on common fire exposure situations. A large number of industrial and government research laboratories have used the method to develop information on the smoke generation of a wide variety of materials. Tests are also being performed by several

commercial testing laboratories. Reduction of visibility by smoke without consideration of its irritant effect may be calculated based on the results of laboratory tests. The precision of the method has been determined by inter-laboratory evaluation using typical materials. Standard reference materials are available for the test calibration. The concept of the Smoke Density Chamber method is proposed as a suitable first step in evaluating the production of smoke and as a basis for future code requirements. Limitation on the use of materials on the basis of smoke production or smoke load in building may vary, however, depending on fire experience, type of occupancy, level of risk, and type of built-in protection used. These factors should be considered in any requirement to be established.

7. References

[1] Gross, Loftus, Lee, and Gray, "Smoke and Gases Produced by Burning Aircraft Interior Materials," NBS Building Science Series BSS 18, 1969.

[2] Gaskill, "Smoke Development in Polymers During Pyrolysis of Combustion," Journal of Fire and Flammability, 1, pp. 183-216, 1970.

[3] Gross, Loftus, and Robertson, "A Method for Measuring Smoke from Burning Materials," ASTM Special Technical Publication STP 422, 1967.

[4] Lee, T. G., "Interlaboratory Evaluation of Smoke Density Chamber," NBS Technical Note 708, December 1971.

[5] Brenden, J. J., "Usefulness of a New Method for Measuring Smoke Yield from Wood Species and Panel Products," Forest Product Journal 21, pp. 23-28, 1971.

[6] Gaskill and Veith, "Smoke Opacity from Certain Woods and Plastics," Fire Technology, 4, pp. 185-195, 1968.

[7] Jin, T., "Visibility Through Fire Smoke," Report of Fire Research Institute of Japan 31 33 (1971).

[8] McGuire, Tamura, and Wilson, "Factors in Controlling Smoke in High Buildings," ASHRAE Symposium: Fire Hazards in Building, pp. 8-13, January 1970.

☆ U. S. GOVERNMENT PRINTING OFFICE : 1973—511-322/146

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS TN-757	2. Gov't Accession No.	3. Recipient's Accession No.
4. TITLE AND SUBTITLE The Smoke Density Chamber Method for Evaluating the Potential Smoke Generation of Building Materials			5. Publication Date January 1973
			6. Performing Organization Code
7. AUTHOR(S) T. G. Lee			8. Performing Organization
9. PERFORMING ORGANIZATION NAME AND ADDRESS NATIONAL BUREAU OF STANDARDS DEPARTMENT OF COMMERCE WASHINGTON, D.C. 20234			10. Project/Task/Work Unit No.
			11. Contract/Grant No.
12. Sponsoring Organization Name and Address Same as 9			13. Type of Report & Period Covered
			14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

The paper reviews the Smoke Density Chamber Test Method and illustrates its use and application to assess smoke generation of building materials in fire situations. It shows how test results may aid the Fire Services and code authorities in evaluating and reducing the potential light-obscuration hazard of smoke in buildings. An example is given for calculating visibility in a simplified fire situation involving material of known smoke generation. The smoke generation of some common interior finish and construction materials are given.

17. KEY WORDS (Alphabetical order, separated by semicolons) Building materials; fire; fire services; smoke; smoke density; chamber; smoke potential; test method; visibility.

18. AVAILABILITY STATEMENT	19. SECURITY CLASS (THIS REPORT)	21. NO. OF PAGES
☒ UNLIMITED.	UNCLASSIFIED	20
☐ FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.	20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED	22. Price 45 cents

USCOMM-DC 66244-P71

[illegible]