NATIONAL BUREAU OF STANDARDS REPORT

10 327

SPREAD OF FLAME TESTS ON FIVE MATERIALS
ISO/TC 92 WG4

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards [1] was established by an act of Congress March 3, 1901. Today, in addition to serving as the Nation's central measurement laboratory, the Bureau is a principal focal point in the Federal Government for assuring maximum application of the physical and engineering sciences to the advancement of technology in industry and commerce. To this end the Bureau conducts research and provides central national services in four broad program areas. These are: (1) basic measurements and standards, (2) materials measurements and standards, (3) technological measurements and standards, and (4) transfer of technology.

The Bureau comprises the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Radiation Research, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of an Office of Measurement Services and the following technical divisions:

> Applied Mathematics—Electricity—Metrology—Mechanics—Heat—Atomic and Molecular Physics—Radio Physics [2]—Radio Engineering [2]—Time and Frequency [2]—Astrophysics [2]—Cryogenics.[2]

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; develops, produces, and distributes standard reference materials; relates the physical and chemical properties of materials to their behavior and their interaction with their environments; and provides advisory and research services to other Government agencies. The Institute consists of an Office of Standard Reference Materials and the following divisions:

> Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations in the development of technological standards, and test methodologies; and provides advisory and research services for Federal, state, and local government agencies. The Institute consists of the following technical divisions and offices:

> Engineering Standards—Weights and Measures — Invention and Innovation — Vehicle Systems Research—Product Evaluation—Building Research—Instrument Shops—Measurement Engineering—Electronic Technology—Technical Analysis.

THE CENTER FOR RADIATION RESEARCH engages in research, measurement, and application of radiation to the solution of Bureau mission problems and the problems of other agencies and institutions. The Center consists of the following divisions:

> Reactor Radiation—Linac Radiation—Nuclear Radiation—Applied Radiation.

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in the selection, acquisition, and effective use of automatic data processing equipment; and serves as the principal focus for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

> Information Processing Standards—Computer Information — Computer Services — Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System, and provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world. The Office consists of the following organizational units:

> Office of Standard Reference Data—Clearinghouse for Federal Scientific and Technical Information [3]—Office of Technical Information and Publications—Library—Office of Public Information—Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

[2] Located at Boulder, Colorado 80302.

[3] Located at 5285 Port Royal Road, Springfield, Virginia 22151.

NATIONAL BUREAU OF STANDARDS REPORT

NBS PROJECT 4212229

August 24, 1970

NBS REPORT 10 327

SPREAD OF FLAME TESTS ON FIVE MATERIALS
ISO/TC 92 WG4

by

D. Gross

IMPORTANT NOTICE

NBS

U.S. DEPARTMENT OF COMMERCE

NATIONAL BUREAU OF STANDARDS

SPREAD OF FLAME TESTS ON FIVE MATERIALS
ISO/TC 92 WG4

by

D. Gross

1.0 TEST PROCEDURE

The same test procedure was used for these tests as previously described in test report "Preliminary Spread of Flame Tests - ISO/TC 92 WG4."

The panel was operated at a blackbody temperature of 750 °C, corresponding to a radiation intensity of 6.3 w/cm^2. No canopies or skirts were used. The edges of all specimens were coated with sodium silicate, and all specimens were conditioned to constant weight at 23 °C and 50% relative humidity.

2.0 TEST MATERIALS

The test materials comprised the five materials supplied by ISO member countries, as listed below, plus two carpeting materials for test in the "floor" orientation only.

Material No.	Designation	Supplied By	Thickness (nominal)		Density	
			in	mm	pcf	kg/m^3
1	Panel Board (Hardboard)	Denmark	1/2	12	41	660
2	Melamine-faced Chipboard	U. K.	11/16	18	50	800
3	Red Oak	U. S. A.	3/4	20	42	680
4	Rigid Polystyrene (FR)	Germany	3/4	20	1.0	16
5	Rigid Polyurethane	Belgium	7/8	26	2.4	38
6	Acrylic Shag Carpet	---------	79.5 oz/yd^2 (2.70 kg/m^2)			
7	Nylon Twist Carpet/Hair Pad	---------	63.8 oz/yd^2 (2.16 kg/m^2)			

3.0 RESULTS

Typical results are shown graphically for the four orientrations in Figures 1, 2, 3 and 4. The distance-time plots are on semilogarithmic coordinates which had previously resulted in generally straight lines, except for the "wall" position.

The floor position gave the greatest discrimination (or difference) between polyurethane foam and the other materials. The polystyrene foam sustained flame near the pilot flame, and burned to 85 mm on the molten portions, but otherwise only melted out to a distance of 675 mm. On acrylic shag carpet, the flames traveled to the limit of the specimen in less than 6 minutes. Typical results are listed in Table 1.

The ceiling position was the only position to give measurable flame spread for all five materials. Due to the increased contribution from flaming combustion in this position, flaming generally extended furthest. This position gave the greatest discrimination between hardboard and red oak. The plots were linear or very nearly so.

The wall position test reversed the ranking of the melamine-faced chipboard compared to the floor and ceiling positions. The polystyrene foam melted but did not burn. The flame advance was greater at the top of the specimen, and the distance-time plots were generally non-linear.

In the incline position, the differences between materials was not as great as in the other positions.

The ranking order of the materials was consistent (polyurethane most rapid spread; melamine-faced chipboard least rapid spread) for four materials (polystyrene excluded) in all positions except the wall position.

4.0 DISCUSSION

In the absence of any discrete suggestions as to how to express the performance of materials by this test, the following may be considered:

(A) (1) Plot distance (mm) versus time (min) on semilogarithmic coordinates.

(2) Draw a straight line through the data points if possible; a curve where appropriate.

(3) Read the value of distance at a time of 1 minute (extrapolate the straight line or curve, if necessary).

(B) Calculate a flame spread index based on the following:

$$FSI = 1 + \frac{1}{t_{75}} + \frac{1}{t_{150}-t_{75}} + \frac{1}{t_{225}-t_{150}} + \ldots.$$

where t_{75}, t_{150}, t_{225}, ... represent time in minutes for flames to reach the 75, 150, 225, ... mm mark. This represents a sum of progressive flame spread rates, in which the contributions are added from all segments which propagate flames.

Using the "1 minute distance" as a test criterion, the distances ranged from 60 mm for the melamine chipboard to 350 mm for the polyurethane foam and acrylic carpet in the floor position. Similar measurements can readily be made for the ceiling, wall and incline positions.

Using the "flame spread index" as a test criterion, the floor position values ranged from 1.0 for the fire-retardant polystyrene foam which did not yield a flame front, to 2.0 for the melamine chipboard to 51.4 for the polyurethane foam. The acrylic carpet, on which the flame front traveled the full length, received an index of 43.1. It did not spread flames initially as rapidly as the polyurethane foam.

Flame spread index values for the five round-robin materials in all four positions are listed in Table 2. The index is, with few exceptions, highest in the ceiling position, next highest in the incline position, and lowest in the floor position.

USCOMM-NBS-DC

Table 1. Flame Spread Data

FLOOR POSITION

Distance mm	TIME, min						
	Panel Board MFT*=525	Melamine Chipboard MFT=135	Red Oak MFT=360	Polystyrene Foam (FR)	Polyurethane Foam MFT=430	Acrylic Carpet MFT=1000	Nylon Carpet MFT=760
Sustained Flame	.16	.24	.20	.02	.02	0	.02
75	.72	1.46	.85		.05	.09	.47
150	1.63	4.36**	2.30		.10	.32	1.39
225	3.29		4.52		.27	.50	2.88
300	5.73		8.65		.62	.77	5.54
375	9.08		15.00**		1.23	1.09	9.43
450	13.56					1.50	14.35
525	19.56					2.07	23.00
600						2.74	32.88
675						3.46	44.76
750						3.92	58.93
825						4.65	
900						5.39	
975						5.83	
Flame Spread Index	5.14	2.02	3.71	1.0	51.38	43.13	6.1
1-min distance, mm	105	60	85	---	350	350	120

* MFT = maximum flame travel
** Time to MFT

Table 2. Flame Spread Index Values

$$\text{Index} = 1 + \Sigma \frac{1}{\Delta t}$$

	Position			
	Floor	Ceiling	Wall	Incline
Panel Board	5.1	25.3	7.4	12.2
Melamine Chipboard	2.0	8.2	6.1	8.3
Red Oak	3.7	10.5	5.2	8.8
Polystyrene Foam (FR)	1.0	58.6	1.0	1.0
Polyurethane Foam	51.4	130.2	33.7	27.5

Figure 1

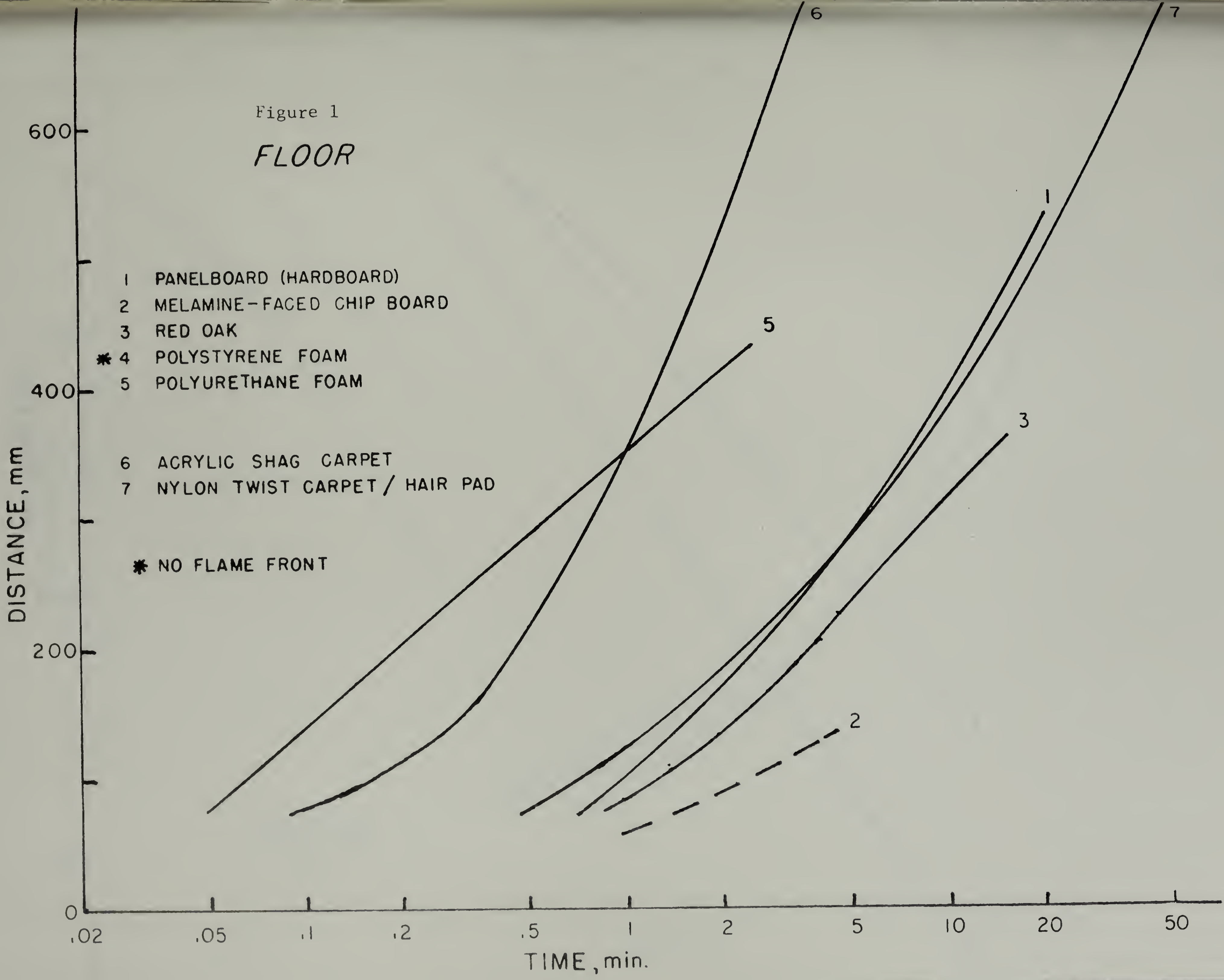
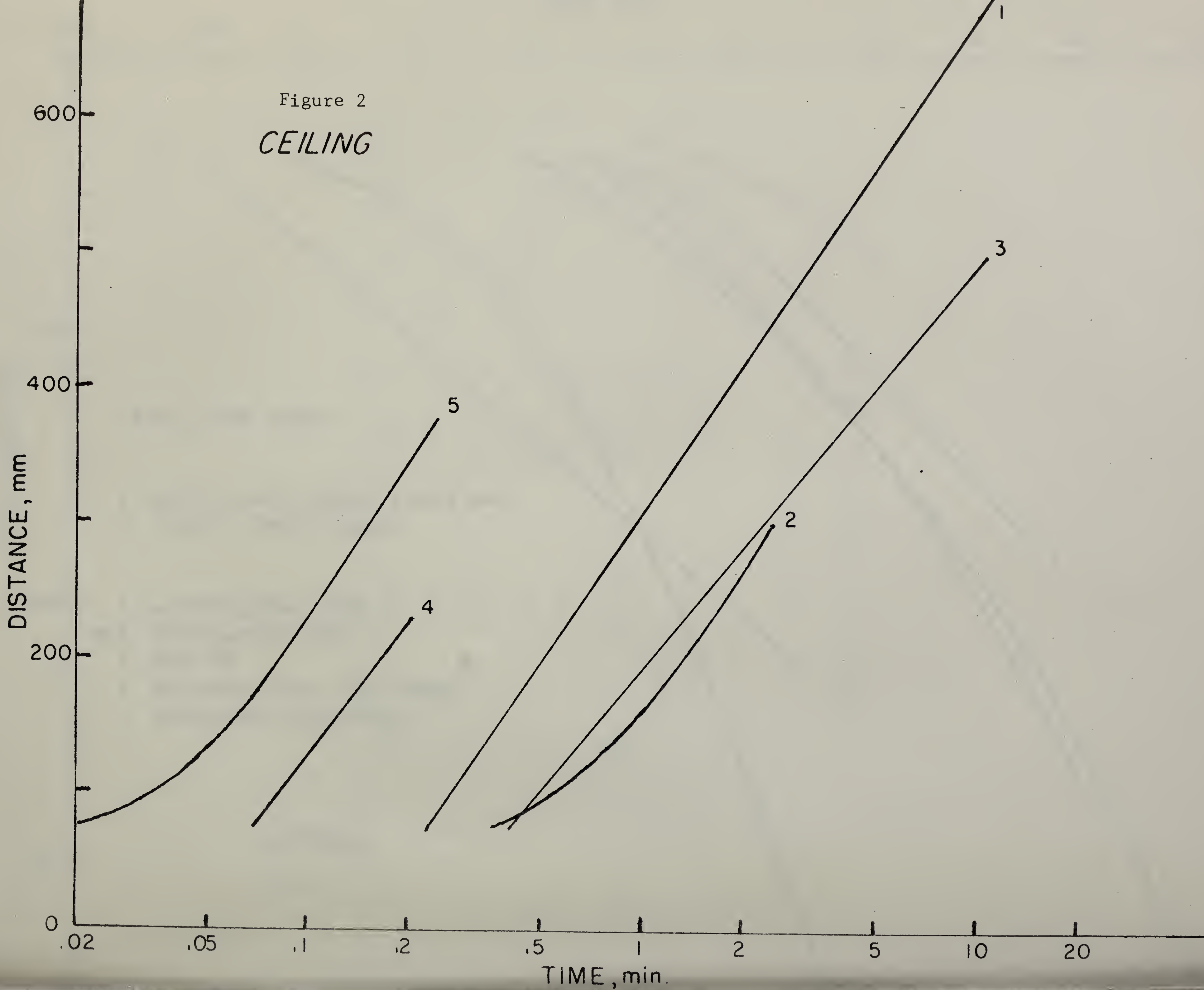

FLOOR
1 PANELBOARD (HARDBOARD)
2 MELAMINE-FACED CHIP BOARD
3 RED OAK
* 4 POLYSTYRENE FOAM
5 POLYURETHANE FOAM
6 ACRYLIC SHAG CARPET
7 NYLON TWIST CARPET / HAIR PAD
* NO FLAME FRONT
DISTANCE, mm
0
200
400
600
TIME, min.
.02
.05
.1
.2
.5
1
2
5
10
20
50
1
2
3
5
6
7

Figure 2


CEILING
DISTANCE, mm
0
200
400
600
TIME, min.
.02
.05
.1
.2
.5
1
2
5
10
20
1
2
3
4
5

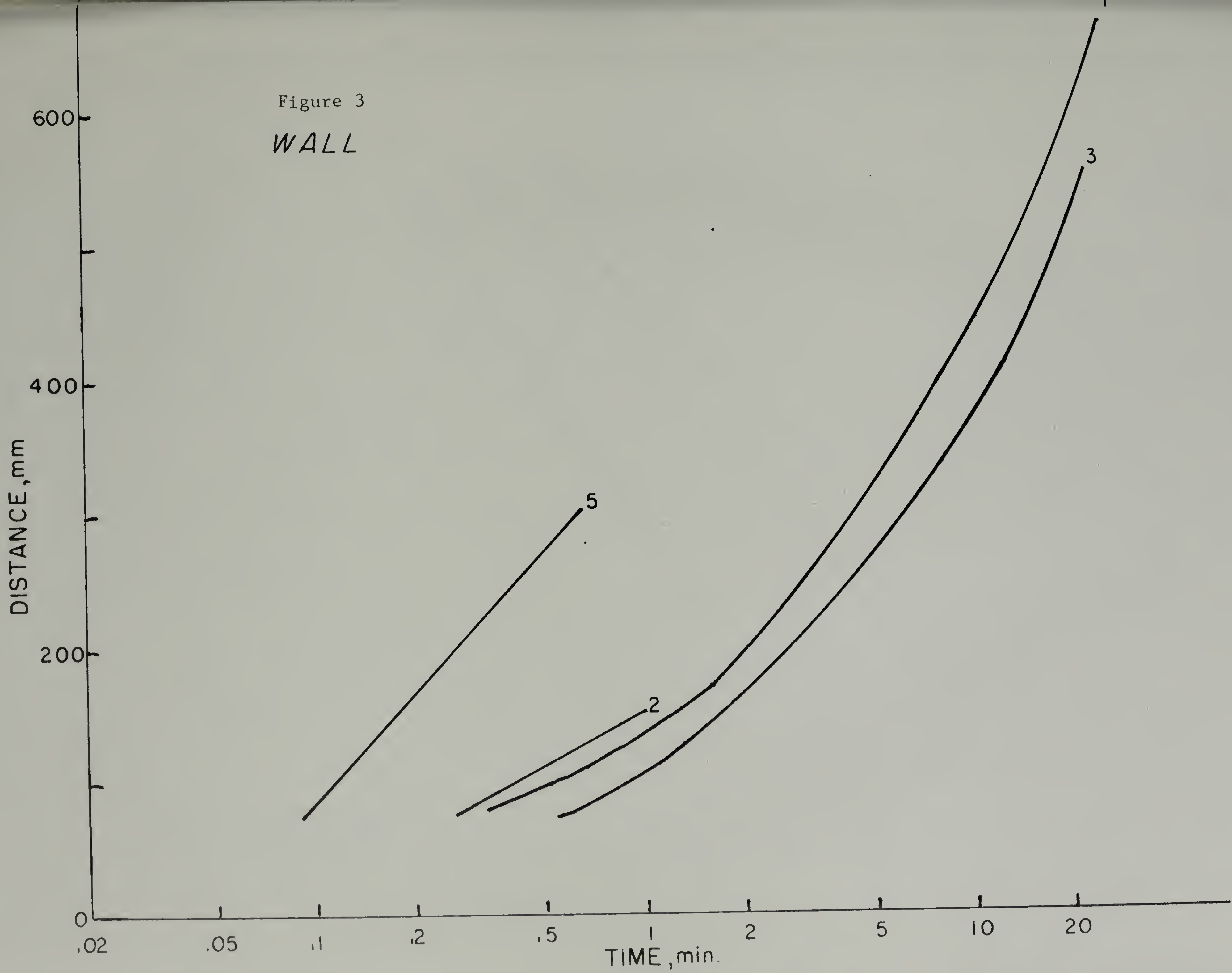
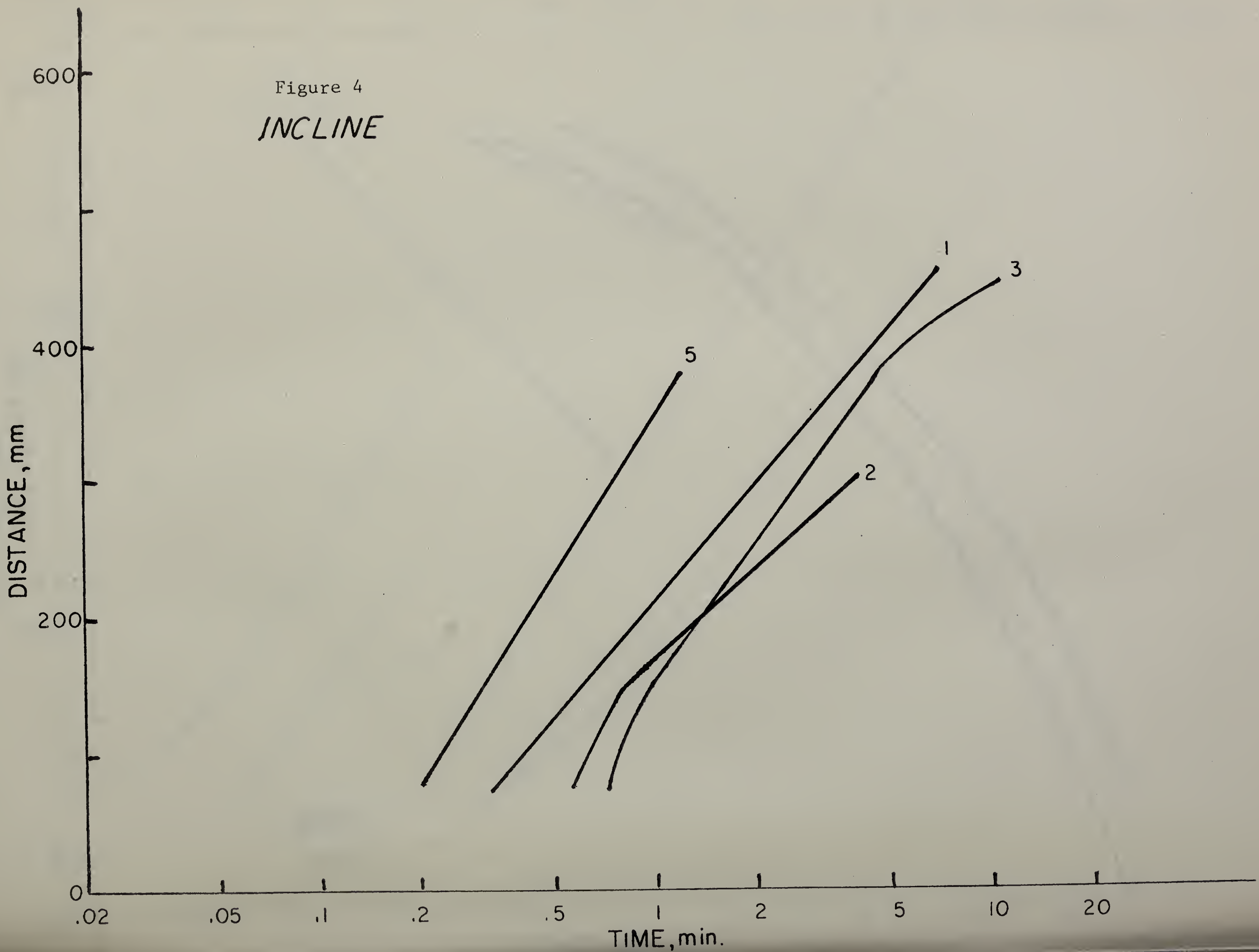


Figure 3
WALL
600
400
200
0
DISTANCE, mm
5
2
3
.02
.05
.1
.2
.5
1
2
5
10
20
TIME, min.

Figure 4



INCLINE
DISTANCE, mm
600
400
200
0
.02
.05
.1
.2
.5
1
2
5
10
20
TIME, min.
1
2
3
5