U. S. DEPARTMENT OF COMMERCE

BUILDING MATERIALS AND STRUCTURES

REPORT BMS85

Dimensional Changes of Floor Coverings with Changes in Relative Humidity and Temperature

by

PERCY A. SIGLER
ROBERT I. MARTENS, *and*
ELMER A. KOERNER

NATIONAL BUREAU OF STANDARDS

BUILDING MATERIALS AND STRUCTURES REPORTS

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Dimensional Changes of Floor Coverings with Changes in Relative Humidity and Temperature

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PERCY A. SIGLER, ROBERT I. MARTENS, *and* ELMER A. KOERNER

ISSUED JULY 15, 1942

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Foreword

Investigations of important properties of floor coverings have been made at the National Bureau of Standards as part of a research program on building materials suitable for low-cost house construction. This report contains information and data on the effects of changes in relative humidity and temperature on the dimensions of floor coverings.

LYMAN J. BRIGGS, *Director.*

Dimensional Changes of Floor Coverings With Changes in Relative Humidity and Temperature

by PERCY A. SIGLER, ROBERT I. MARTENS, and ELMER A. KOERNER

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ABSTRACT

The effects of changes in atmospheric conditions on the dimensions of floor coverings were investigated. The floor coverings tested included such general types as linoleum, cork, rubber, felt base, asphalt, strip wood, plywood, fiberboard, and several monolithic compositions, such as cement mortar and magnesium oxychloride. Dimensional changes due to a variation in relative humidity from 8 to 86 percent and those due to a variation in temperature from 32° to 90° F were determined. The floor coverings, testing equipment, and procedure are described, and the results are presented in graphic form.

Changes in relative humidity affect the dimensions of many floor coverings to a much greater extent than do changes in temperature within the range usually encountered in structures. Such floor coverings as strip wood, linoleum, and felt base show a much greater dimensional change in the across-grain or across-machine direction than in the grain or machine direction. The several monolithic compositions showed relatively small changes in dimensions.

I. INTRODUCTION

The tendency of floor coverings to expand or contract with changes in moisture content and temperature is an objectionable characteristic. These changes are most commonly dependent upon the relative humidity and temperature of the surrounding air and thus have a limited range in many locations. However, in some locations extreme conditions are often encountered, such as large temperature changes near heating equipment or prolonged exposure to water in basements.

Excessive expansion or contraction of floor coverings after being installed is likely to result in one or more of the following objectionable conditions: loosening of bond to subfloor, separation within floor covering, buckling, curling, separation at joints, or splitting. Small dimensional changes may cause appreciable buckling or curling, and therefore these conditions are frequently encountered in many floor coverings. This can be readily understood if one considers the small difference which exists between the lengths of an arc typical of a distortion, and its subtended chord. Unequal dimensional changes of the top and bottom surfaces due to difference of exposure are contributing factors, especially with floor coverings installed in small units.

The dimensional changes of subfloors, especially those of strip wood, due to seasonal changes in indoor relative humidity are undoubtedly often the principal cause of a premature failure or unsatisfactory performance of a floor covering. The expansion or contraction of strip wood in the across-grain direction with change in moisture content is considerable. A felt underlay is frequently used with thin floor cover-

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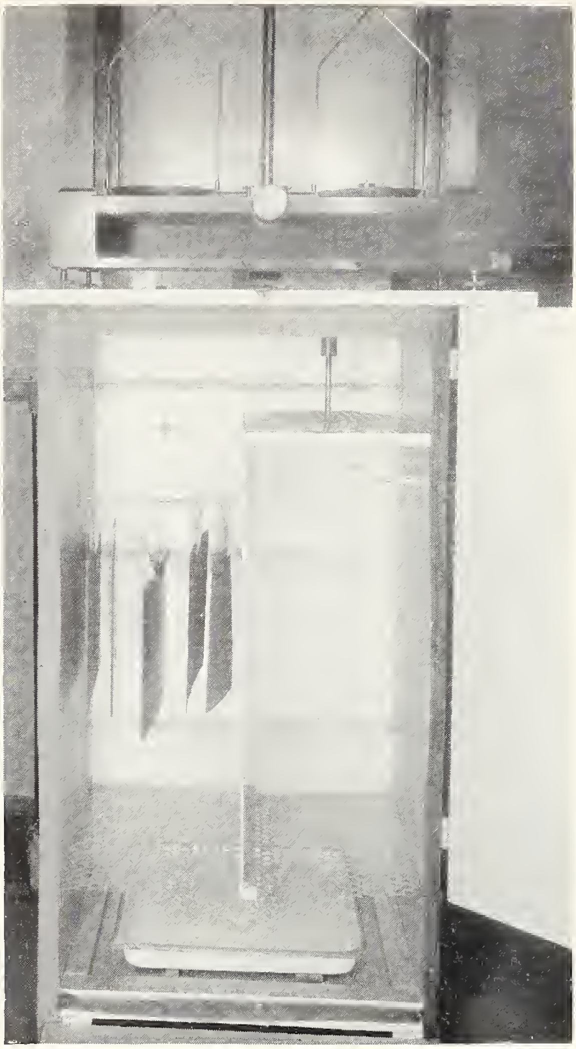

FIGURE 1.—*Conditioning cabinet and balance.*

ings over strip-wood subfloors. It acts as a yielding cushion between the subfloor and floor covering, and aids in maintaining an even surface and thus uniform distribution of wear.

Except for the test method and limit for curling included in Federal Specification SS-T-306 for asphalt tile, little attention has been paid in specifications for flooring materials to dimensional changes. A study was therefore made of the effects of relative humidity and temperature on the dimensions of floor coverings. Such information should be of interest to the manufacturers and installers of floor coverings in the proper recommendation and installation of their merchandise, and also of aid to the consumer in the selection and care of floors, especially where unusual conditions may prevail.

The results of studies of other properties of floor coverings and adhesives have been published in Building Materials and Structures Reports BMS14, BMS34, BMS43, BMS59, BMS68, BMS73, and BMS80. (See cover pp. II and III.)

II. TEST PROCEDURE AND EQUIPMENT

1. Specimens Exposed to Different Relative Humidities

For determining the dimensional changes of floor coverings with changes in the relative humidity of the surrounding air and thus changes in the moisture content of the floor coverings, specimens were conditioned and measured first at 65-percent, then at 8-percent, again at 65-percent, and finally at 86-percent relative humidity. The temperature was maintained at approximately 72° F throughout these determinations. With the exception of the strip-wood flooring, the specimens were 9 by 9 in. The strip-wood specimens were 1⅞ by 9 in. The specimens were weighed from time to time under each of the atmospheric conditions as an indication of the approach to and attainment of moisture equilibrium. An exposure of at least 2 weeks was found necessary for most of the floor coverings to reach equilibrium. Some required a much longer time.

A conditioning room at the Bureau provided an atmosphere maintained at 65-percent relative humidity and 72° F. Atmospheres of 8 ± 3 percent and 86 ± 2 percent relative humidity were obtained in a small cabinet especially constructed for the purpose. (See fig. 1.) The size of the cabinet was sufficient to hold several specimens, with one specimen at a time suspended by a wire from the weighing pan of an analytical balance. By means of baffles and a motor-driven fan, air was circulated around the specimens and over a tray containing the conditioning medium. Anhydrous calcium chloride was used to obtain 8-percent relative humidity and a saturated solution of zinc sulfate to obtain 86 percent. The atmospheric conditions in the cabinet were determined from the readings of wet- and dry-bulb thermometers placed directly below the fan. In order to measure a specimen conditioned in the small cabinet, it was necessary to move it into an atmosphere of 65-percent relative humidity. Measurements of a specimen were started immediately and were completed within half an hour. The dimensions remained practically unchanged for that length of time, inasmuch as check measurements made at the end of the period were the same as those obtained at the beginning of the period.

The dimensional changes of the 9 by 9-in. specimens were determined from measurements made with a micrometer comparator. (See fig. 2.) The instrument consisted essentially of an Invar-steel bar on which were mounted two low-powered microscopes equipped with filar micrometers. The microscopes were clamped on the bar so that corresponding graduations of the two micrometers were 8 in. apart. The distances between reference marks, approximately 8 in., were measured to the nearest 0.001 in. Twelve separate measurements were made on each specimen—three in the machine or grain direction and three in the across-machine or across-grain direction on both the face and the back of the specimen. In order to be certain that a specimen was flat when being measured, it was placed on a glass plate and weighted down with a steel plate 7 in. square and ½ in. thick.

The dimensional changes of the strip-wood flooring in the across-grain direction were determined from measurements made with a micrometer caliper having a range of 1 to 2 in.

2. Specimens Exposed to Different Temperatures

For determining the dimensional changes of floor coverings with changes in temperature, specimens were conditioned and measured first at 72°, then at 32°, again at 72°, and finally at 90° F. The relative humidity of the surrounding air was maintained at approximately 65 percent throughout these determinations. The variation in relative humidity at 72° and 90° F was ±2 percent; the variation at 32° F was ±4 percent. Various conditioning rooms at the Bureau provided the above atmospheres. The specimens were weighed under each of their various conditions as a check on their moisture content remaining constant. Even though the relative humidity was maintained approximately constant, the weights, and thus the moisture contents, of the materials varied somewhat. In general, the specimens weighed slightly more at 32° than at 72° F and slightly less at 90° than at 72° F. The size of the

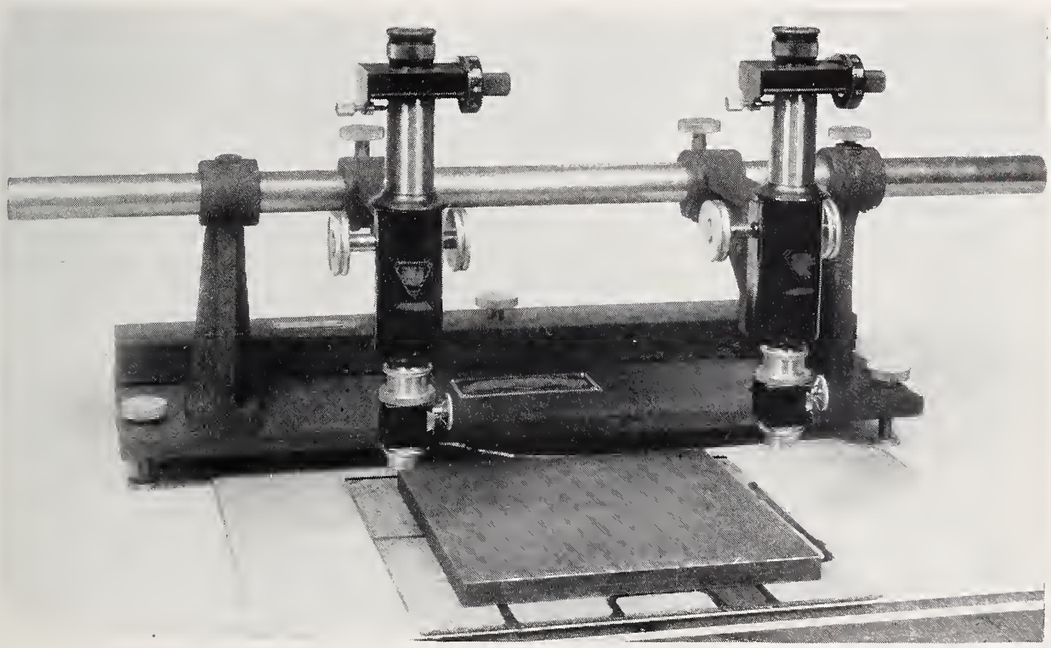

Figure 2.—*Micrometer comparator.*

specimens and the manner of measuring were similar to those used in the exposures to different relative humidities.

III. DESCRIPTION OF MATERIALS TESTED

The floor coverings tested included such general types as linoleum, cork, rubber, felt base, asphalt, strip wood, plywood, fiberboard, and several monolithic compositions. They are listed in table 1, along with their changes in weight in conditioning from 65- to 8-percent relative humidity and from 65- to 86-percent relative humidity at 72° F. The generous cooperation of various manufacturers in furnishing materials for test is gratefully acknowledged.

TABLE 1.—*Floor coverings tested and the effect of change in relative humidity on their weight*

Sample number	Floor covering: Type and description [a]	Floor covering: Nominal thickness	Change in weight from 65-percent relative humidity at 72° F to— 8-percent relative humidity	Change in weight from 65-percent relative humidity at 72° F to— 86-percent relative humidity
		in.	%	%
1	Battleship linoleum; plain pattern, brown	1/8	−2.26	+2.08
2	Battleship linoleum; plain pattern, gray	1/8	−1.80	+1.79
3	Battleship linoleum; plain pattern, green	1/8	−1.98	+1.70
4	Marbleized linoleum; marbleized pattern, tan	1/8	−2.24	+2.30
5	Marbleized linoleum; marbleized pattern, white	1/8	−1.42	+1.82
6	Jaspe linoleum; jaspe pattern, brown	3/32	−2.41	+1.93
7	Inlaid linoleum; molded pattern, gray	5/64	−2.05	+2.06
8	Printed linoleum; block pattern, brown; wearing surface, enamel	5/64	−2.36	+1.78
9	Cork-composition tile; plain pattern, gray	1/8	−1.50	+1.43
10	Cork tile;[b] light shade; density, 30 lb/ft.^{3} [c]	5/16	−1.88	+1.88
11	Cork tile;[d] light shade; density, 37 lb/ft.^{3} [c]	5/16	−2.15	+2.46
12	Felt-base; inlaid pattern, gray; wearing surface, linoleum composition	5/64	------	------
13	Felt-base; inlaid pattern, cream; wearing surface, linoleum composition	5/64	−1.85	+1.86
14	Felt-base; jaspe pattern, brown; wearing surface, cellulose nitrate composition	5/64	−2.56	+2.21
15	Felt-base tile; jaspe pattern, green; wearing surface, cellulose nitrate composition	7/64	−2.18	+2.38
16	Felt-base; mottled pattern, tan; wearing surface, resin and drying oil composition	5/64	−2.60	+2.22
17	Felt-base; mottled pattern, gray; wearing surface, resin-treated cotton-linters sheet	1/16	−1.81	+2.40
18	Felt-base; mottled pattern, white; wearing surface, resin-treated cotton-linters sheet	5/64	−1.89	+1.79
19	Felt-base tile; plain pattern, red; wearing surface, asphalt and pitch composition	5/64	−1.75	+2.11
20	Felt-base; plain pattern, maroon; wearing surface, asphalt and pitch composition	3/32	−1.68	+1.84
21	Felt-base; printed pattern, brown; wearing surface, enamel	5/64	−1.74	+1.88
22	Felt-base; printed pattern, red; wearing surface, enamel	5/64	−1.78	+1.93
23	Sheet rubber; marbleized pattern, brown	1/8	−0.40	+0.31
24	Rubber tile; marbleized pattern, gray	1/8	−.24	+.26
25	Rubber tile; black; contained aluminum oxide aggregate	1/8	−.48	+.55
26	Asphalt tile; plain pattern, black; 1-minute indentation, 0.010 in.[e]	1/8	−.18	+.45
27	Asphalt tile; marbleized pattern, white; 1-minute indentation, 0.006 in.[e]	1/8	−.21	+.55
28	Asphalt tile; plain pattern, mahogany; 1-minute indentation, 0.009 in.[e]	1/8	−.24	+.29
29	Asphalt tile; plain pattern, mahogany; 1-minute indentation, 0.010 in.[e]	3/16	−.21	+.25
30	Asphalt tile; plain pattern, white; 1-minute indentation, 0.008 in.[e]	1/8	−.36	+.73
31	Asphalt tile; plain pattern, white; 1-minute indentation, 0.010 in.[e]	3/16	−.27	+.44
32	Asphalt tile; plain pattern, red; 1-minute indentation, 0.007 in.[e]	3/16	−.18	+.26
33	Asphalt tile; plain pattern, maroon; contained asphalt-roofing material; 1-minute indentation, 0.011 in.[e]	1/8	−.15	+.39
34	1:2 cement-mortar topping; aggregate, Potomac-River sand; density, 137 lb/ft.^{3} [c]	1	−2.33	+1.20
35	Magnesium-oxychloride composition; plain pattern, red; aggregate, calcite dust; density, 108 lb/ft.^{3} [c]	1/2	−1.63	+5.23
36	Magnesium-oxychloride composition; plain pattern, green; aggregate, granite dust; density, 118 lb/ft.^{3} [c]	1/2	−2.61	+5.26
37	Magnesium-oxychloride composition; plain pattern, green; aggregate, marble dust, cotton fiber, and copper powder; density, 108 lb/ft.^{3} [c]	1/4	−1.51	+4.20
38	Alumina cement-rubber latex composition; terrazzo pattern, green; aggregate, marble chips; density 131 lb/ft.^{3} [c]	1/2	−0.05	+0.24
39	Coal-tar mastic composition; plain pattern, gray; aggregate, gravel, sand, and gypsum; density, 128 lb/ft.^{3} [c]	1/2	−.29	+.27
40	Asphalt-impregnated fiberboard tile; plain pattern, dull black; density, 57 lb/ft.^{3} [c]	1/4	−1.23	+1.51
41	Asphalt-impregnated fiberboard tile; plain pattern green; density, 54 lb/ft.^{3} [c]	1/4	−1.45	+1.76
42	Pressed fiberbord tile; brown; density, 67 lb/ft.^{3} [c]	1/8	−4.39	+3.21
43	Rock-elm plywood tile;[b] 3-ply	1/2	−5.66	+5.63
44	Douglas-fir plywood;[d] 5-ply	1/2	−7.70	+5.00
45	Short-strip maple;[d] flat-grained; density, 44 lb/ft.^{3} [c]	25/32	−7.41	+7.64
46	Short-strip maple;[d] flat-grained; density, 47 lb/ft.^{3} [c]	25/32	−6.82	+7.72
47	Strip white oak;[d] flat-grained; density, 40 lb/ft.^{3} [c]	25/32	−6.97	+5.98
48	Short-strip pecan;[d] flat-grained; density, 40 lb/ft.^{3} [c]	25/32	−5.81	+5.18
49	Strip yellow pine;[d] flat-grained; density, 44 lb/ft.^{3} [c]	25/32	−6.10	+5.62
50	Strip Douglas fir;[d] edge-grained; density, 36 lb/ft.^{3} [c]	25/32	−5.07	+5.01
51	Strip Douglas fir;[d] edge-grained; density, 27 lb/ft.^{3} [c]	25/32	−6.03	+3.59
52	Plywood underlay; 3 plies of hardwood veneer with asphalt-saturated paper on both faces	3/16	−6.24	+4.40

[a] Color listed in the predominating color.
[b] Factory-applied finishing material on surface.
[c] At 65-percent relative humidity and 72° F.
[d] No finishing material on surface.
[e] Method prescribed in Federal Specification SS–T–306, Tile; Asphalt.

IV. RESULTS

1. Effect of Relative Humidity on Dimensions

The effects of changes in relative humidity from 65 to 8 percent and from 65 to 86 percent on the dimensions of the floor coverings listed in table 1 are shown graphically in figures 3 to 7, inclusive. The dimensional changes are reported as the percentage change from the dimensions at 65-percent relative humidity and 72° F. The unshaded blocks show the dimensional changes in the machine or grain direction on all samples where the direction could be ascertained. The shaded blocks show the dimensional changes in the across-machine or across-grain direction or at right angles to the first direction. The values reported represent the average of the several separate measurements made on both the face and the back of the specimens.

Dimensional changes occurred in some floor coverings opposite to that which might be expected; the amounts are shown by broken lines in the charts. These reversals occurred only as contractions in the machine direction when the specimens were expanding in the across-machine direction and, to any appreciable extent, only with materials having a fabric backing. Stresses of an opposite nature and of greater magnitude than those due to moisture were probably created in the machine direction

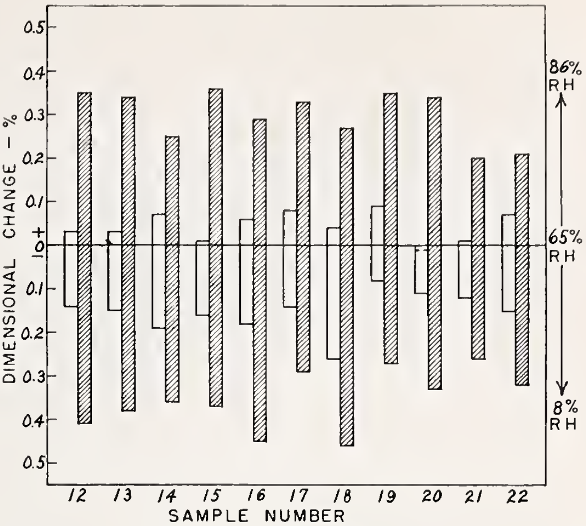

Figure 4.—*Effect of relative humidity on dimensions of felt-base floor coverings having various wearing surfaces.*

Wearing surface of samples 12 and 13, linoleum composition; 14 and 15, cellulose nitrate composition; 16, resin and drying oil composition; 17 and 18, resin-treated cotton-linters sheet; 19 and 20, asphalt and pitch composition; 21 and 22, enamel.

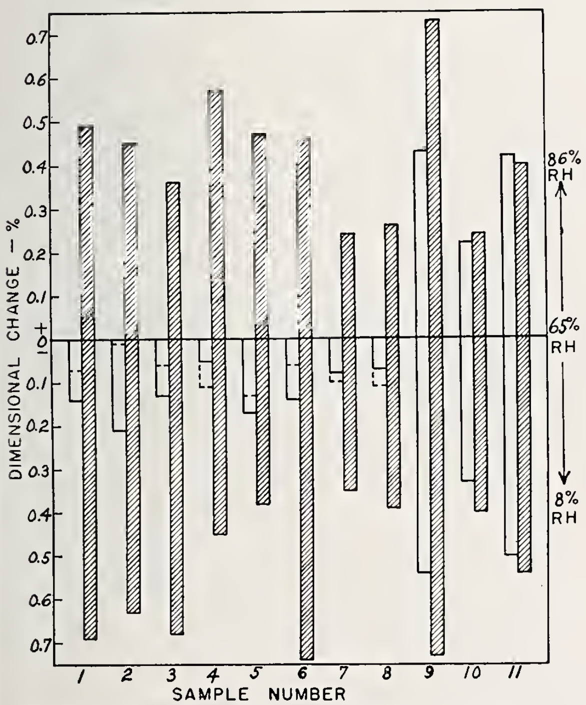

Figure 3.—*Effect of relative humidity on dimensions of linoleums, cork-composition tile, and cork tiles.*

Samples 1 to 8, linoleum; 9, cork-composition tile; 10 and 11, cork tile

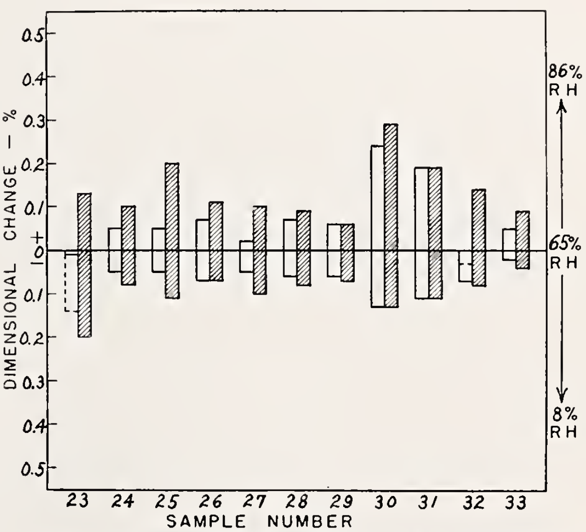

Figure 5.—*Effect of relative humidity on dimensions of sheet rubber, rubber tiles, and asphalt tiles.*

Sample 23, sheet rubber; 24 and 25, rubber tile; 26 to 33, phalt tile.

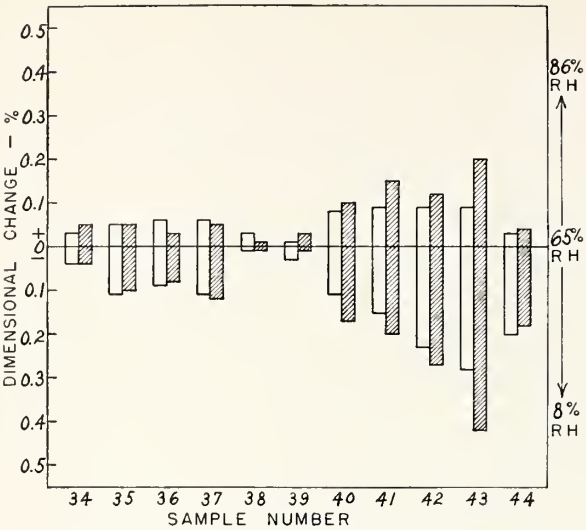

FIGURE 6.—*Effect of relative humidity on dimensions of monolithic compositions, fiberboards, and plywoods.*

Sample 34, cement-mortar topping; 35 to 37, magnesium oxychloride composition; 38, alumina cement-rubber latex composition; 39, coal-tar mastic composition; 40 to 42, fiberboard; 43 and 44, plywood.

of the specimens by the considerable expansion in the across-machine direction. A backing fabric might be expected to aggravate such a condition.

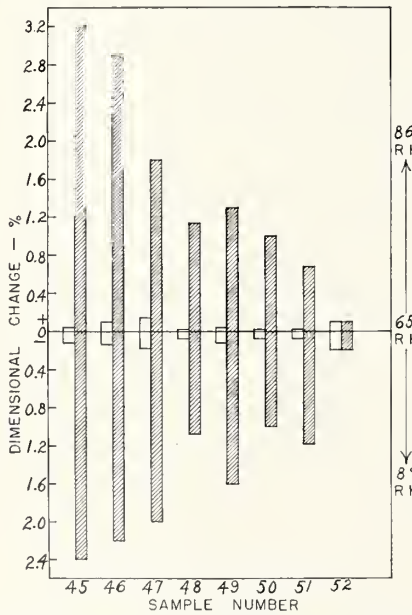

FIGURE 7.—*Effect of relative humidity on dimensions of stripwood floorings and plywood underlay.*

NOTE.—Scale is 4 times that used in other charts. Samples 45 and 46, maple; 47, white oak; 48, pecan; 49, yellow pine; 50 and 51, Douglas fir; 52, plywood underlay.

2. Effect of Temperature on Dimensions

After a number of samples had been tested, it became apparent that the effect of temperature on the dimensions of floor coverings was small in comparison with the effect of relative humidity and from a practical viewpoint was relatively of little importance. In view of this and the difficulty of maintaining the moisture content of the specimens absolutely constant at different temperatures, this phase of the investigation was somewhat curtailed. In order to give a conception of the magnitude of the changes involved, the effects of changes in temperature from 72° to 32° F and from 72° to 90° F on the dimensions of several different floor coverings are shown graphically in figure 8. The dimensional changes are reported as percentage changes from the dimensions at 72° F and 65-percent relative humidity. Dimensional changes in the machine direction for the linoleums and felt-base materials were extremely small and frequently opposite to the changes in the across-machine direction. The amounts were about the same in magnitude as the uncertainty of the measurements—that is, about 0.001 in., or 0.01 percent.

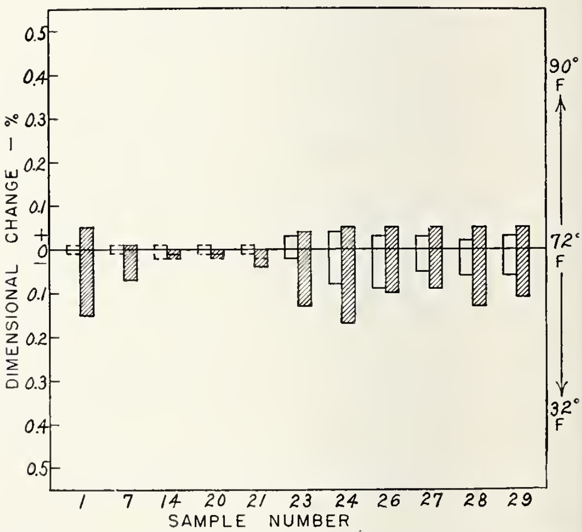

FIGURE 8.—*Effect of temperature on dimensions of floor coverings.*

Samples 1 and 7, linoleum; 14, 20, and 21, felt base; 23 and 24, rubber; 26, 27, 28, and 29, asphalt tile.

V. SUMMARY AND CONCLUSIONS

The magnitude of the expansion or contraction of many floor coverings is much greater for changes in moisture content than for changes in temperature within the limits of ordinary atmospheric conditions. The dimensions of asphalt-tile and rubber floor coverings are not appreciably affected by changes in either relative humidity or temperature.

In many floor coverings there is a pronounced difference in the dimensional change for different directions. For normal changes in moisture content, the dimension in the across-grain or across-machine direction of such floor coverings as strip wood, linoleum, and felt base is affected to an appreciable extent, whereas in the grain or machine direction the change in dimension is negligible. The cork tiles and cork-composition tile did not have distinguishable machine or grain directions. Both of their principal dimensions showed appreciable change.

The dimensional changes of the various monolithic compositions as a whole were small. The fiberboards and plywoods showed much less expansion and contraction in both principal dimensions than the strip-wood floorings in the across-grain direction. Of the strip-wood floors, maple showed the greatest change and edge-grained Douglas fir the least. Among floor coverings in general, dimensional changes of the strip-wood floors in the across-grain direction were by far the greatest.

In order to prevent a large over-all dimensional change from occurring in one direction of a room, some floor coverings are installed in small units, such as tile or unit-block, with the machine or grain direction of alternate units at right angles to each other.

WASHINGTON, May 1, 1942.

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