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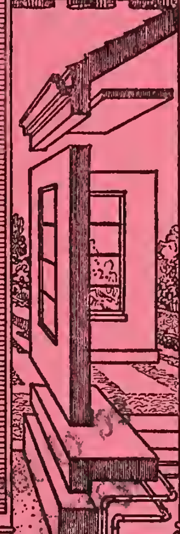


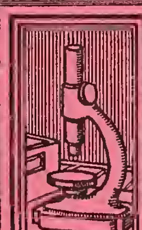
BUILDING MATERIALS AND STRUCTURES

REPORT BMS56

A Survey of Humidities in Residences

by

THOMAS D. PHILLIPS



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BUILDING MATERIALS *and* STRUCTURES

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ISSUED OCTOBER 9, 1940

The National Bureau of Standards is a fact-finding organization; it does not "approve" any particular material or method of construction. The technical findings in this series of reports are to be construed accordingly.

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Foreword

As a part of the investigation of low-cost housing being conducted by the National Bureau of Standards, data on the atmospheric conditions prevailing in occupied houses were needed. It was known that, in general, the relative humidity in heated houses during cold weather was likely to be rather low, and many means of increasing the humidity have been devised and advocated. However, there has been a lack of specific information on the conditions actually prevailing, and such information could be obtained only by a rather extensive survey. Such a survey can be made efficiently and economically by the cooperation of a considerable number of observers located in various parts of the country. The Bureau was fortunate in obtaining the cooperation of the physics faculties of a considerable number of colleges, who generously contributed to the success of the project.

LYMAN J. BRIGGS, *Director.*

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ABSTRACT

This report presents the results of a survey of the relative humidities prevailing in occupied houses during the winter. The observations were made by students of colleges cooperating in the survey, working under the supervision of the physics departments of the colleges, and data were obtained from 26 localities in the northern part of the United States. In general, in the occupied houses, the moisture content of the air was sufficient to make the interior condition from 10- to 15-percent relative humidity higher than would have resulted from heating outside air to 70°F without change in moisture content.

I. INTRODUCTION

Problems which involve the effects of moisture or water vapor on either the occupants or the structure of dwellings call for some definite information as to the humidity conditions which exist within the buildings under normal conditions of occupancy. Such information is not generally available, as measurements of humidity in dwellings have been made only sporadically and at isolated points. Such observations do not well serve the purpose of estimating the inside humidities which may be expected, on the average, over periods of either winter or summer weather conditions in a variety of dwellings.

During the winter, the outdoor air usually has a fairly high relative humidity, but because the temperature is low, the moisture content is also low. When cold air with its low moisture content is brought into a house, and heated to 70° F, for example, without adding or removing moisture, its relative humidity becomes very low, even though its moisture content is unchanged. The relative humidity that would be expected in a house under various conditions in winter, if the air in the house had the same moisture content as the outdoor air, is shown in table 1.

TABLE 1.—*Calculated indoor relative humidities at indoor temperatures of 70° and 80° F for outdoor relative humidities of 100 percent and 50 percent*

Outdoor temperature	Indoor temperature 70° F. Outdoor relative humidity—		Indoor temperature 80° F. Outdoor relative humidity—	
	100%	50%	100%	50%
° F	%	%	%	%
40	33	17	24	12
30	22	11	16	8
20	14	7	10	5
10	9	4	6	3
0	5	3	4	2
−10	3	2	2	1
−20	2	1	1	1

Relative humidities as low as those shown in table 1 are rather rare, because there are many sources from which moisture may be supplied to the air in a house, for example, the occupants and their activities, plants, woodwork, furnishings, humidifying systems, etc. The extent to which the relative humidity in any house is raised above that indicated in table 1 will depend upon the amount of moisture added and upon the ventilation, that is, upon the rate at which fresh air of low moisture content comes into the house and air of higher moisture content escapes. Since such effects are not readily subject to calculation, the only way to determine the relative humidities actually prevailing in occupied houses is by measurement.

II. SOURCE OF DATA

To provide these measurements, a number of colleges located in the Northern States were asked to cooperate. The data presented in this report are based on observations made by students or by the physics faculties of the following colleges:

Whitman College, Walla Walla, Wash.
Cornell College, Mt. Vernon, Iowa.
Parsons College, Fairfield, Iowa.
Doane College, Crete, Nebr.
Friends University, Wichita, Kans.
Lake Forest College, Lake Forest, Iowa.
Earlham College, Richmond, Ind.
Western State Teachers College, Kalamazoo, Mich.
Findlay College, Findlay, Ohio.
Marietta College, Marietta, Ohio.
Bethany College, Bethany, W. Va.
Allegheny College, Meadville, Pa.
Haverford College, Harverford, Pa.
Waynesburg College, Waynesburg, Pa.
Alfred University, Alfred, N. Y.
Hamilton College, Clinton, N. Y.
Hobart College, Geneva, N. Y.
Mount Holyoke College, South Hadley, Mass.
Wellesley College, Wellesley, Mass.
University of Vermont, Burlington, Vt.
Ricker Classical Institute and Junior College, Houlton, Maine.
Oregon State College, Corvallis, Oreg.
University of Idaho, Moscow, Idaho.
Montana State College, Bozeman, Mont.
Milton College, Milton, Wis.
Ripon College, Ripon, Wis.

The instrument data consisted of wet- and dry-bulb readings taken with sling psychrometers. Each observation included an outdoor reading and one taken within the residence. In all, 3,050 such observations were made, involving 215 residences.

Owing to the fact that the convenience of the observers and of the residents had to be served, no fixed time of observation was set. In general, two observations per day were made, one between nine and eleven o'clock in the morning and another between three and five o'clock in the afternoon. Also, in many cases, observations were made in several rooms in the house at one visit.

In addition, the observers furnished a brief description of the heating system and of any provision for humidification. Also note was taken of any readily observed characteristics of the structure or conditions of occupancy which might be expected to affect the interior humidity.

III. TABULATION OF DATA

The data have been tabulated with the intent of putting them into forms in which they may best be available for immediate use. No causal relationship is assumed or implied in the choice of method of grouping them.

The houses were divided into two groups on the basis of their description. One group is called "unhumidified" and includes 73 houses. The other group is called "humidified" and includes 142 houses. The houses forming the unhumidified group are those which have no provision whatever in the heating system for adding moisture to the air. The houses in the humidified group include those in which some sort of humidifying appliance is included in the heating system. Houses with such devices as water pans on radiators or water tank in a warm-air furnace were placed in this group as well as the very few houses provided with humidification under instrument control. In this group also were included houses in which the heating system consisted of open, natural-gas stoves without flue connections, since such a heating system is equivalent to one with a humidifying appliance.

As the data given later show, the amount of humidification was not very great in some of the houses described as humidified. However, no attempt has been made to evaluate the various methods of humidification, since the conditions under which observations were made were not controlled.

IV. GRAPHS OF RELATIVE HUMIDITIES

It is to be expected from the information given in table 1, and it was at once apparent from the data, that the outside dry-bulb temperatures formed a convenient means of grouping the relative humidities of the interiors. The bar graphs in figure 1 show the distribution of relative humidities for various outside temperatures. The method of obtaining these graphs was as follows: The data were separated into two groups as previously described, those for the humidified houses being placed in one group and those for the unhumidified in the other. On the graphs the data for the humidified are represented by solid bars and those for the unhumidified by shaded bars. In cases where observations were made in more than one room of the house at the same time, only one value was chosen, that in the living room or other room most nearly equivalent to the living room in method of use.

Considering only the humidified houses, the observations of relative humidity were grouped according to the outside dry-bulb temperature. For example, there were 45 observations of interior relative humidities that were made when the outside dry-bulb temperature was 60° F or higher. These 45 observations were used as the data for plotting the solid bars of the top graph of figure 1. For the other brackets of outside temperature a similar procedure was followed. The resulting groups are listed in table 2.

TABLE 2.—*Observations of interior humidities of humidified houses at various ranges of outside temperature*

Outside dry-bulb temperature	Number of observations of interior relative humidity
F	
60° or higher	45
50° to 59°	109
40° to 49°	258
30° to 39°	337
20° to 29°	128
19° or lower	21

Considering, for example, those observations made when the outside temperature lay between 30° and 39° F, figure 1 and table 2, there was a total of 337 observations of interior relative humidity. These 337 observations were then divided into subgroups according to the interior relative humidity. The number in each subgroup was counted and percentages computed. The results are given in table 3.

The dark bars in the part of figure 1 captioned "Outside temperature 30°–39° F"—represent the data in the last column of table 3.

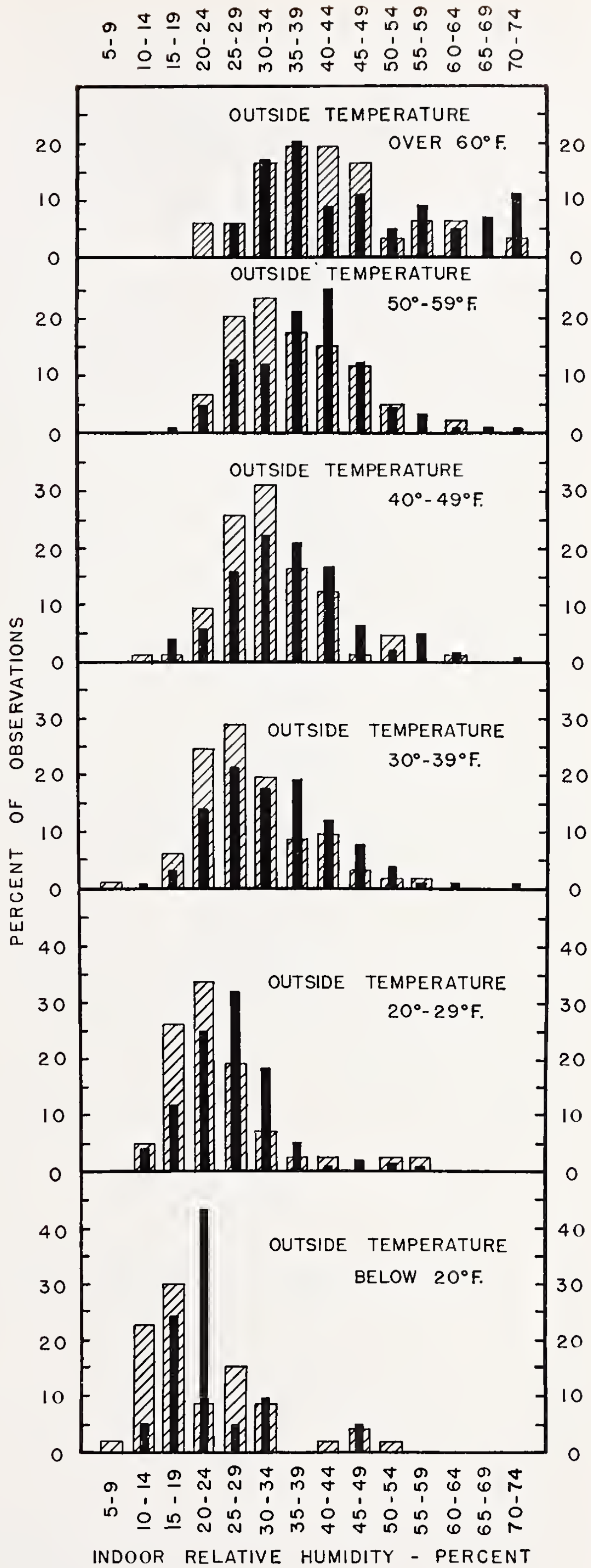

FIGURE 1.—*Distribution of interior relative humidities grouped according to outside dry-bulb temperatures.*

The height of a bar represents the percentage of the total number of observations in that temperature group which gave the indicated relative humidity. The data for the humidified houses are represented by solid bars and those for unhumidified houses by shaded bars.

Table 3.—*Distribution of interior relative humidities in the humidified houses when the outside dry-bulb temperature was 30° to 39° F*

Interior relative humidity (in groups) (percent)	Number of observations for which this relative humidity was found	Percentage of observations for which this relative humidity was found
		Percent
10 to 14	2	0.6
15 to 19	10	3.0
20 to 24	49	14.5
25 to 29	73	21.6
30 to 34	59	17.5
35 to 39	65	19.3
40 to 44	38	11.3
45 to 49	25	7.4
50 to 54	11	3.3
55 to 59	2	0.6
60 to 64	2	.6
65 to 69	0	.0
70 to 74	1	.3
Total	337	100

Following a similar procedure, the graphs for the other outside temperature ranges and also for the unhumidified houses were constructed, completing the set shown in figure 1. At outside temperatures above 60° F, the graph is irregular, particularly for the humidified houses. At outside temperatures below 60° F, the graphs of the interior relative humidities are of a more definite pattern and have fairly well defined maxima. Upon comparison of the graphs of figure 1, it will be noted that the position of the maximum shifts to lower values of relative humidity in going to graphs of lower outside temperatures.

The average relative humidities in the humidified houses are plotted against the outdoor dry-bulb temperature in curve 1 of figure 2, using the data shown in figure 1, and curve 2 of figure 2 gives the corresponding data for the unhumidified houses. It may be seen from these curves that the average relative humidities fall to rather low values for outside temperatures below 20° F.

Figure 3 shows the differences between the average relative humidities observed in the

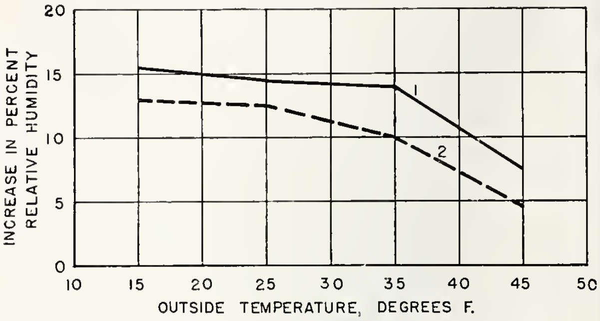

Figure 3.—*Effective humidification of humidified and unhumidified houses shown by the difference between the averages of the observed relative humidities and the relative humidity which would have resulted if outdoor air of 70-percent relative humidity had been heated to 70° F without change in moisture content.*

Curve 1, in humidified houses; curve 2, in unhumidified houses.

survey and the relative humidity of outdoor air of 70-percent relative humidity after heating to 70° F without gain or loss of moisture. Curve 1 is for the humidified houses and curve 2 for the unhumidified houses. It may be seen that at outdoor temperatures below 35° F the relative humidity in unhumidified houses ranged from 10- to 13-percent relative humidity above that corresponding to no addition of moisture, while in the houses classed as humidified the corresponding figure was about 15-percent relative humidity. In other words, the average effect of all sources of additional moisture in the unhumidified houses was to raise the relative humidity some 10-percent relative humidity

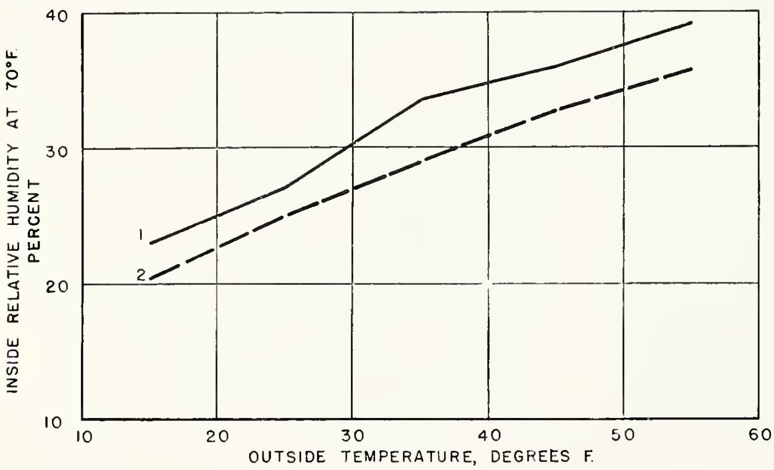

Figure 2.—*Mean relative humidities in humidified and unhumidified houses.*

Curve 1, mean relative humidity in humidified houses; curve 2, mean relative humidity in unhumidified houses.

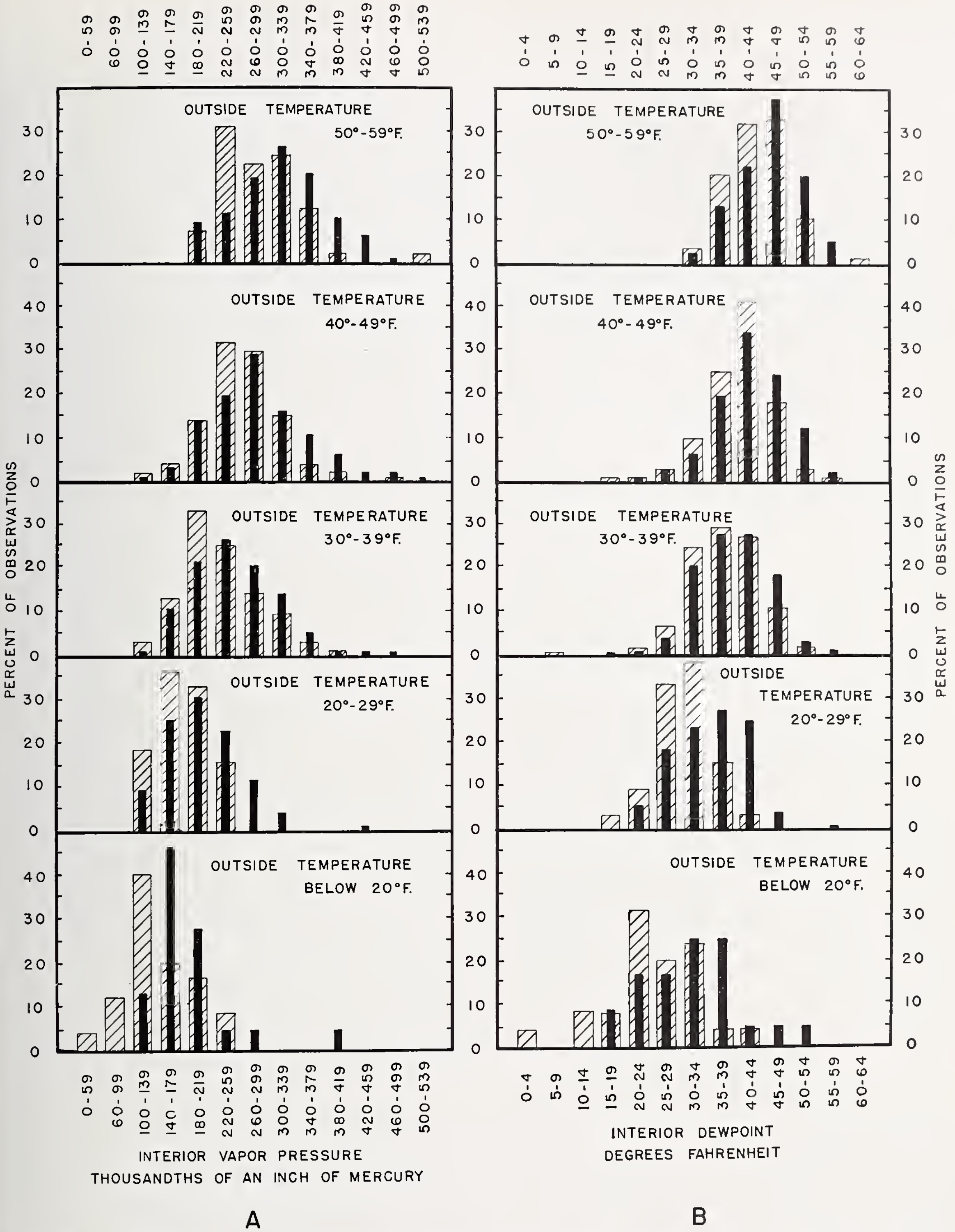

FIGURE 4.—*Distribution of (A) interior vapor pressures and (B) interior dew points grouped according to outside dry-bulb temperature.*

The height of a bar represents the percentage of the total number of observations in that temperature group which for figure 4 (*A*) gave the indicated vapor pressure or, for figure 4 (*B*) the indicated dew point. The data for the humidified houses are represented by solid bars and those for unhumidified houses by shaded bars.

above what it would be in a house which was heated but not occupied. In the houses classed as humidified there was a corresponding increase of 15-percent relative humidity. This is a comparatively small difference between the two classes of houses, which is probably acco nted for by the fact that most of the houses classed as humidified had no really effective means of adding moisture to the air.

In any use that is made of these data it should be noted that the outside temperatures were taken for the most part during the warmer hours of the day, between 9 a. m. and 5 p. m.,

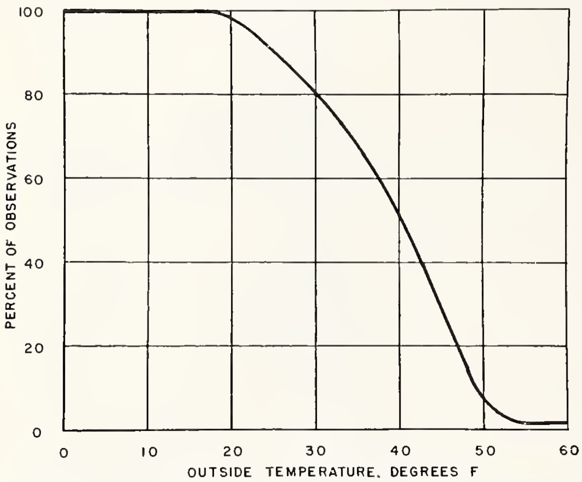

FIGURE 5.—*Percentage of observations for which the interior dew point in unhumidified houses was higher than the outside dry-bulb temperature.*

and in particular that they are not the minimum for the day which is the temperature most frequently mentioned in other publications. The winter of 1937–38, when the observations were made, was a comparatively mild one, which accounts in part for the comparatively small number of observations of outdoor temperatures below 20° F.

V. DISTRIBUTION OF VAPOR PRESSURES

Figure 4 (*A*) gives the distribution of interior vapor pressures in the two groups of houses with reference to the outside dry-bulb temperature. The bar graphs were constructed in a manner similar to that used for figure 1. It is again apparent that the maximum points of each graph go to lower vapor pressures in progressing to graphs for lower outside temperatures.

VI. DISTRIBUTION OF INTERIOR DEW POINTS

Figure 4 (*B*) gives the distribution of interior dew points. The data are divided into five groups according to the outside dry-bulb temperature. The method of obtaining these graphs was similar to that used for the relative humidities shown in figure 1. Figure 5 gives, for the unhumidified houses, the percentage of cases for which the interior dew point was higher than the outside temperature.

VII. EFFECT OF CONTINUED COLD WEATHER OR LOW EXTERIOR ABSOLUTE HUMIDITY

Observations taken after an extended period of cold weather or weather of low exterior absolute humidity show much lower interior vapor pressures than those on days similar at the time of observation but preceded by warmer weather. This points to a large contribution by the house and furniture to the interior humidity by the absorption and release of water vapor. The data are too scattered to permit any estimate of the lag introduced in this way.

VIII. CONCLUSIONS

1. The relative humidity in occupied houses decreases as the outside air temperature decreases.

2. The average effect of all sources of additional moisture in unhumidified houses is to raise the relative humidity some 10-percent relative humidity above what it would be in a house which was heated, but not occupied.

3. In houses with some provision for humidification, on the average the humidity was some 5-percent relative humidity higher than for unhumidified houses.

4. Conditions in individual houses may depart widely from the average.

This survey was made possible by the cooperation of a large number of observers who supplied the basic data. Some of the preparation of the manuscript for publication was undertaken by E. F. Mueller and H. V. Cottony.

WASHINGTON, May 17, 1940.

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