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CYCLICAL MOISTURE DESORPTION/ABSORPTION BY BUILDING CONSTRUCTION AND FURNISHING MATERIALS

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ABSTRACT

A common procedure for commercial buildings is to operate the air-conditioning equipment only during the daytime and to ventilate with outside air at night when the building is normally not occupied. While nighttime ventilation air achieves some sensible cooling, it is frequently of high relative humidity. The resulting moisture absorption by the building construction and furnishing materials represents a significant latent heat load that is added to the next cycle of the air-conditioning equipment.

An investigation of the dynamic latent heat storage effects of fifteen common building construction and furnishing materials was sponsored by the Department of Energy. The materials were subjected to three different dynamic daily humidity cycles and to four different constant humidity exposures. Weight changes of the materials, as they lost or gained moisture, were monitored by sensitive load cells.

Dynamic and constant-condition moisture loss/regain data for the fifteen materials are presented. With a diurnal change in relative humidity from 90 percent to 40 percent RH, the materials comprising a typical single office were calculated to experience a cyclical moisture weight change of 13.4 pounds.

The materials have been classified into three major classes:

1. Low moisture load materials, such as vinyl floor tile and drapery materials, which lose less than 0.004 lb/ft^2 when subjected to a 90 percent to 40 percent relative humidity cycle.
2. Moderate moisture load materials, such as wood materials and concrete and gypsum materials, which lose between 0.008 and 0.016 lb/ft^2.
3. High moisture load materials, such as newspapers and letters, which lose more than 0.018 lb/ft^2.

The materials have been characterized further as either slow or rapid absorbing and desorbing. The slow desorbing materials; such as the wood materials, concrete and concrete block and the gypsum board; give up the absorbed moisture throughout the entire low humidity portion of the daily cycle. The rapid desorbing materials; such as the cotton and wool cushions, the ceiling tile and the carpet; give up most of the moisture during the first two to three hours of the low humidity portion of the cycle.

A simple calculation of the dynamic latent heat load represented by the materials in a typical office shows that the latent heat load of the materials can be as much as ten times the latent heat load of the airspace alone. With a daily cyclical change in relative humidity from 90 percent to 40 percent, the materials were calculated to yield 13.4 pounds of water and the airspace moisture load was calculated to be 1.4 pounds. In a typical office building, with an air-conditioning system capacity of one ton per 320 ft^2 of floor area, the latent heat load imposed by the materials would take about one hour and forty minutes to remove, compared with about ten minutes for the airspace.

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INTRODUCTION

One strategy for the management of the air-conditioning systems in buildings is to operate the cooling system during the daytime. At night the air-conditioning system may be shutdown and the building ventilated with outside air. Since the nighttime outside air is usually at a lower temperature than that inside, sensible cooling can be achieved by this procedure. However, when the nighttime air relative humidity is high, as is frequently the case, the ventilation can introduce a significant quantity of moisture into the building airspace.[1] The excess moisture can be absorbed by the building in both the construction and furnishing materials. The absorption process releases substantial thermal energy, approximately equal to the heat of condensation of water. This provides local heating, which will counteract the sensible cooling benefits provided by the lower temperature of the nighttime ventilation air. Others have investigated various aspects of related moisture problems in buildings.[2-5]

When the air-conditioning system is restarted, the system reduces the relative humidity of the building airspace by condensing the excess moisture. As the airspace relative humidity is reduced, the moisture previously absorbed by the building materials will be desorbed into the building airspace, and subsequently removed by the air-conditioning system. The desorption process requires substantial thermal energy, approximately equal to the heat of evaporation of water. This in turn provides local cooling. However, the moisture previously absorbed by the building materials and stored on a cyclical basis must be removed by the system. This will be shown to represent an appreciable latent heat load during the initial or restart portion of the operation.

When nighttime ventilation is used in humid climates, the assumption had been made prior to this study that the significant latent heat load was that represented by the moisture in the humid air of both the building airspace and the ventilation and infiltration air. The moisture absorbed and later desorbed by the construction and furnishing materials had been considered to be small when compared with the moisture in the air. Until now there were little data available on the moisture load that was represented by moisture absorption by the building materials.

Current moisture sorption data available on building materials are for equilibrium conditions. These are typically equilibrium moisture content (EMC) data for both absorption and desorption as a function of relative humidity. Usually a hysteresis effect has been observed, with the desorption values resulting in a higher EMC than for absorption.[6] Also, at least for textiles, the time required to reach equilibrium is substantially slower for desorption than for absorption.[7] While interesting and useful, EMC data do not apply specifically to the dynamic conditions considered in this study where relative humidity cycles during the daily operation of the HVAC system.

Various detailed models have been developed to calculate the sensible and latent loads in buildings.[8-11] The primary moisture response data of the selected materials obtained through this study will be useful in these models. The data will also be valuable in developing optimum energy conservation strategies for daytime air-conditioning and nighttime ventilation strategies.

EXPERIMENTAL INVESTIGATION

This investigation developed primary data on the dynamic moisture response of selected building construction and furnishing materials subjected to cyclical changes in relative humidity at constant temperature. The testing was performed on fifteen different construction and furnishing materials in a controlled temperature and humidity chamber. The materials were subjected to three different dynamic daily humidity cycles for at least two weeks and to four different constant exposures for up to two weeks. Weight changes of the materials as they gained or lost moisture were monitored by sensitive load cells. The materials tested, the equipment used, and the techniques used to analyze the data obtained are detailed in the following sections.

Material Selection and Preparation

The test specimens were prepared to simulate as closely as possible exposure to the conditioned air that would be found in a commercial application. A summary of the test specimens is presented in Table 1. The intention was to moisture seal the edges that normally would not be exposed because the sample represented a small element of a larger area. The faces that normally would be exposed in a typical construction were left open. For example, the nominal 2 x 10 dimension lumber represented a joist. One long edge and the two short ends were sealed, leaving one long edge and two flat faces exposed. For the precast concrete and the concrete block masonry unit test specimens, the four edges were sealed, leaving the two faces exposed. Non-exposed edges were sealed with multiple coats of spray applied epoxy paint.

Table 1. Summary of Test Sample Data

		Test specimen			
No.	Test material Description	Dimensions no. @	in. x in. x in.	Weight lb	Area ft^2
1	2 x 10 Dimension Lumber		1.5x9.25x36	8.50	5.00
2	T & G Plywood	2	0.75x15.8x15.6	6.50	3.43
3	Reinforced Concrete		3.9x12.1x24.1	97.2	4.03
4	Concrete Block		7.6x15.6x16.4	81.9	3.55
5	Painted Gypsum Board	2	0.5x18.0x24.0	10.50	6.00
6	Prefinished Plywood Panel	2	0.41x15.0x48.0	11.2	10.0
7	Prefinished Parquet Floor	2	0.32x12.0x24.0	5.82	4.00
8	Vinyl Floor Tile	2	0.12x12.0x24.0	5.19	4.00
9	Acoustical Ceiling Tile	2	0.62x23.75x47.75	10.34	15.75
10	Carpet-on-Pad	2	12.0x24.0	2.58	4.00
11	Wool Cushion		4.6x20.4x20.6	4.75	8.46
12	Cotton Cushion		4.7x19.5x19.5	4.25	7.81
13	Polyester/Cotton Drapery		40.4x47.9	0.95	13.4
14	Newspaper		15.1x11.4	0.72	1.19
15	Letters		8.5x11	0.24	0.65

For materials that typically would have only one face exposed, such as plywood, plywood paneling, acoustical ceiling tile, and painted gypsum board, test specimens were prepared by fastening together two pieces back-to-back with a sheet of 6-mil polyethylene film between and moisture sealing the four edges.

Typically; parquet flooring, floor tile, and carpet are installed on a substrate such as plywood or concrete. Because of weight limitations of the test load cells, the plywood substrate was selected. Two pieces of 0.75 in. plywood were fastened back-to-back with a sheet of 6-mil polyethylene film between the pieces. The four edges were moisture sealed. The flooring materials were fastened to the plywood using the manufacturer's recommended procedures. No attempt was made to moisture seal the edges of the flooring materials.

The upholstered cushions and the drapery test specimens were suspended so that all six faces were exposed. The newspaper, folded to half-page size, and the stack of letters, with interleaved envelopes, were laid on plastic carriers so that one face and the four edges were exposed. Prior to testing, all materials were conditioned at 75°F and 45 percent RH.

Equipment

The test chamber used for the exposure of the test materials was designed to perform environmental testing at controlled and time-programmable temperature and humidity conditions. The chamber was operated to simulate the daily cycles of high humidity followed by low humidity. The dehumidification capacity of the moisture condensing surface was found to be insufficient to reduce the relative humidity in the chamber to the desired level in less than three hours. Rather than adding more chilled surface to increase the humidity pull down rate, the humid air in the chamber was exchanged with the much drier air outside of the chamber. The response time for humidity reduction was decreased to approximately one hour. This was a reasonable pull-down time that would simulate the response in a building to cyclical changes in humidity.

The test materials were hung on wires attached to strain gauge load cells. The load cells were mounted on a 5 foot high steel channel frame located in the middle of the test chamber. Weight changes of each sample, in response to the cyclical humidity changes in the chamber, were detected by monitoring the output signals of the load cells. The load cells had a nominal sensitivity of 3 parts in 10,000.

The voltage output signal of each load cell and the power supply voltage were measured by a digital voltmeter. The voltmeter signal monitoring was controlled by a data acquisition/control unit driven by a multi-tasking program of a computer system. The multi-tasking program used an internal date and time-of-day clock to take data readings at user defined time intervals of fifteen minutes. The digitized voltage signals were converted into calculated load cell weights, power supply voltage, dry and wet bulb temperatures, and relative humidity. These digitized data were logged into data files by the computer. These raw data files were subsequently used for analysis of the response of the materials to the cyclical humidity exposures.

The calibration for each load cell was checked by using known weights. The mean difference between the actual weight and the load cell measurement was less than 0.4 percent of the actual weight.

The temperature and humidity of the air space in the vicinity of the test materials was monitored using thermocouples. The dry bulb temperature was measured by a bare type T (copper/constantan) thermocouple. The wet bulb temperature was measured by a separate type T thermocouple covered with a cloth wick. The wick was kept wet by contact with water contained in a small bottle reservoir. The voltage signals from the thermocouples were measured and converted to temperature readings in degrees Fahrenheit by the digital voltmeter and the resulting temperatures were logged into data files by the computer system along with the load cell readings.

The relative humidity was calculated using a simple algorithm relating the dry bulb and wet bulb temperatures to humidity. The mean error was found to be +/-1.5 percent RH with a maximum error of 4 percent RH.

The rate of moisture movement into or out of a material is dependent, in part, on the movement of the air in contact with the surface of the material. The air velocity in the vicinity of the fifteen samples was measured by a handheld thermal anemometer. The average air velocity adjacent to the samples was about 68 ft/min.

Test Program

Prior to testing in the controlled temperature and humidity chamber, the materials were stored a minimum of 14 days in a standard conditioning room maintained at approximately 75^{o}F and 50 percent RH. The samples were weighed to determine the specimen weight for each material. The total weight of the sample and attachments hung on the load cell was used as the basis weight for subsequent computer data reduction and analysis of the load cell weight data.

The entire set of samples was exposed to the temperature and humidity conditions outlined in Table 2. Before each dynamic exposure cycle, the materials were exposed to constant temperature and humidity conditions to establish "equilibrium" moisture contents at different relative humidities. The dynamic exposure cycles simulated eleven hours of air-conditioning at constant temperature and low humidity followed by thirteen hours of ventilation at constant temperature and high humidity. Dynamic cycles A and B were identical except for the initial conditions of relative humidity.

Table 2. Nominal Exposure Conditions

Exposure No.	Exposure Type	Temperature (°F)	Humidity (%RH)	Cycle time (hr)	Exposure (days)
1	Steady	75	45	Continuous	8
2	Dynamic Cycle A	75 75	40 90	11 13	28
3	Steady	75	90	Continuous	7
4	Dynamic Cycle B	75 75	90 40	13 11	14
5	Steady	75	75	Continuous	11
6	Dynamic Cycle C	75 75	75 40	13 11	15
7	Steady	75	60	Continuous	15

TEST RESULTS

Dynamic Exposure Conditions

The weight change data resulting from the exposure conditions were converted as described above and then plotted as weight change of the sample versus time from the start of exposure. A typical plot of the temperature and humidity in the test chamber is shown in Figure 1. A typical plot of the response of the 2 x 10 dimension lumber is shown in Figure 2.

From the plot of temperature and humidity for each exposure, the average temperature and humidity for each portion of the cycle was determined. From each plot of the weight change of the individual materials, the daily moisture loss from the samples was determined. The daily moisture loss represents the latent heat load on the air-conditioning system. The moisture load is the difference between the highest weight level at the end of the high humidity exposure and the lowest weight level at the end of the low humidity exposure. An overall summary of the dynamic exposure test results is shown in Table 3.

Table 3. Overall Summary of Dynamic Exposure Tests

		Average Weight loss, lb/ft^2		
		Relative humidity difference, (% RH)		
		Cycle A	Cycle B	Cycle C
	Test material	52%	47%	36%
1	2 x 10 Dimension Lumber	0.015	0.014	0.009
2	T & G Plywood	0.011	0.011	0.007
3	Reinforced Concrete	0.011	0.007	0.006
4	Concrete Block	0.014	0.014	0.012
5	Painted Gypsum Board	0.017	0.011	0.008
6	Prefinished Plywood Panel	0.011	0.010	0.008
7	Prefinished Parquet Floor	0.012	0.012	0.010
8	Vinyl Floor Tile	0.003	0.003	0.003
9	Acoustical Ceiling Tile	0.013	0.011	0.007
10	Carpet-on-Pad	0.016	0.016	0.011
11	Wool Cushion	0.014	0.013	0.009
12	Cotton Cushion	0.010	0.009	0.007
13	Polyester/Cotton Drapery	0.004	0.004	0.003
14	Newspaper	0.027	0.029	0.023
15	Letters	0.019	0.018	0.018

Steady Exposure Conditions

Prior to each dynamic exposure cycle, and following the last dynamic exposure cycle, the materials were subjected to steady humidity exposure conditions as outlined above in Table 2. The response of the materials to these steady exposure conditions is summarized in Table 4.

In steady exposure number 1, the materials were exposed to a nominal 45 percent relative humidity before the start of the dynamic exposure, number 2. This was to condition the materials to the lower humidity portion of the dynamic cycle. In the steady exposure, number 3, the materials were exposed to a nominal 90 percent relative humidity before the start of the dynamic exposure, number 4. This was to condition the materials to the upper humidity portion of the dynamic cycle, which was to be the same as in exposure number 2.

Differences in the response of the materials to the same dynamic exposure cycle would indicate that there was a hysteresis effect and that the initial conditioning could have an impact on the latent heat loads in a system. The steady exposure, number 5, was at a nominal 75 percent relative humidity, the upper humidity level of the dynamic exposure, number 6, which followed. Finally, the steady exposure, number 7, was at a nominal 60 percent relative humidity.

FIGURE 1.

DYNAMIC CYCLE A - CHAMBER TEMPERATURE AND RELATIVE HUMIDITY

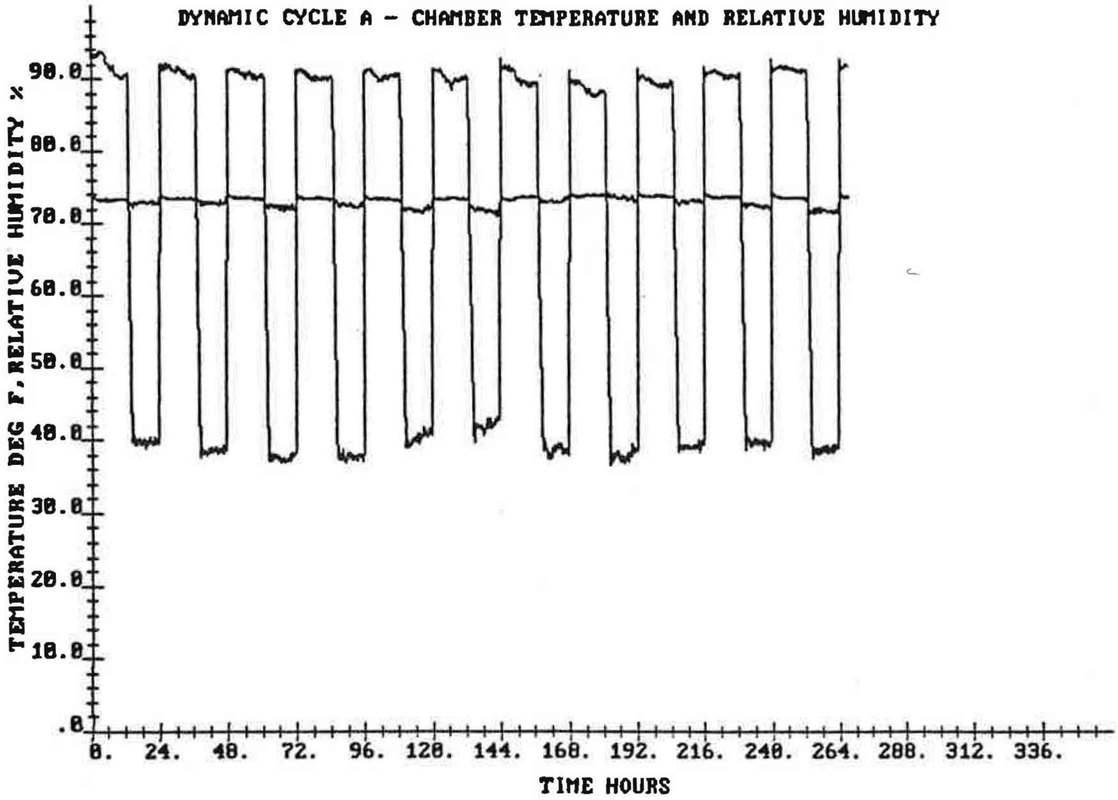

FIGURE 2.

DYNAMIC CYCLE A: MATERIAL 1 - 2X10 DIMENSION LUMBER

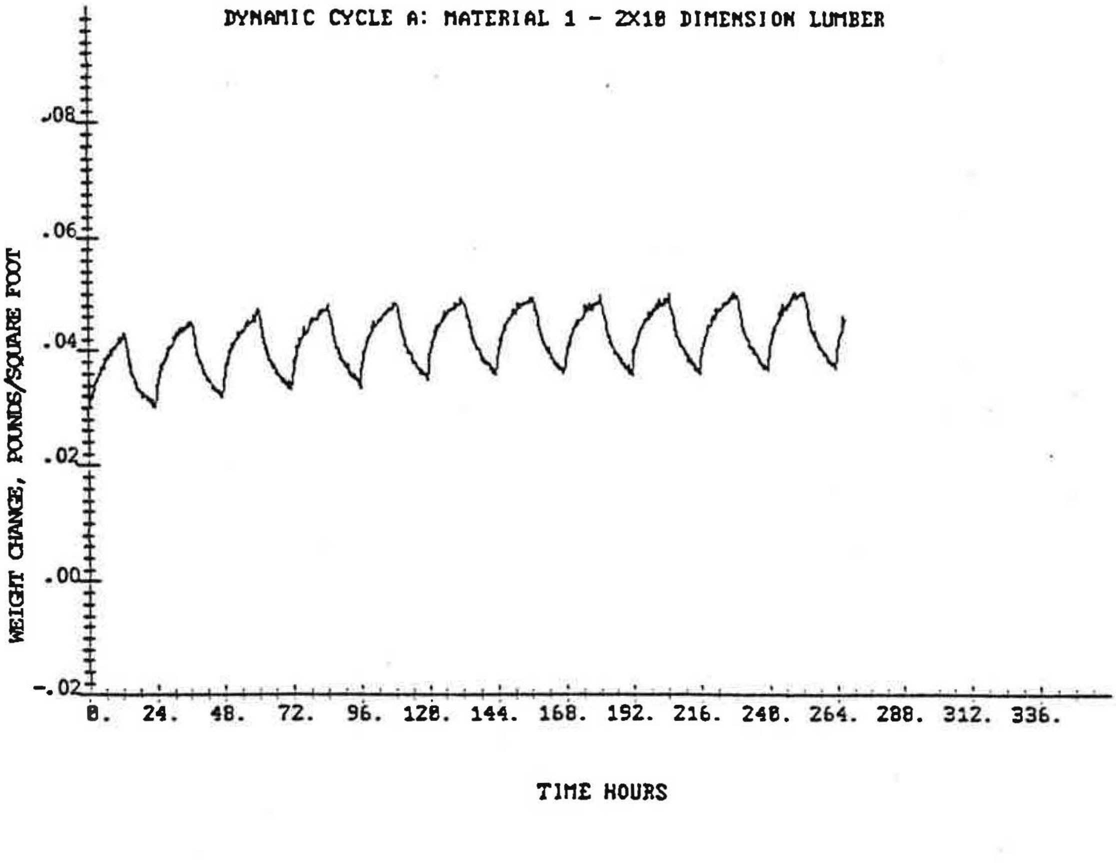

Table 4. Overall Summary of Steady Exposure Tests

	Test material	Average Moisture difference, lb/ft² (relative to exposure 1 74°F 45%RH) Exposure 3 74°F/89%	Exposure 5 74°F/77%	Exposure 7 74°F/58%
1	2 x 10 Dimension Lumber	0.080	0.057	0.013
2	T & G Plywood	0.088	0.080	0.045
3	Reinforced Concrete	-0.016	-0.049	-0.109
4	Concrete Block	0.105	0.084	0.031
5	Painted Gypsum Board	0.018	0.010	0.004
6	Prefinished Plywood Panel	0.041	0.029	0.006
7	Prefinished Parquet Floor	0.078	0.070	0.025
8	Vinyl Floor Tile	0.041	0.047	0.031
9	Acoustical Ceiling Tile	0.012	0.007	0.000
10	Carpet-on-Pad	0.096	0.088	0.043
11	Wool Cushion	0.016	0.011	0.003
12	Cotton Cushion	0.011	0.008	0.003
13	Polyester/Cotton Drapery	0.004	0.003	0.001
14	Newspaper	0.039	0.027	0.002
15	Letters	0.031	0.039	0.013

RESULTS AND CONCLUSIONS

Discussion of Results

The moisture loss from the test materials during the low humidity portion of the daily cycle will be shown to be a significant latent heat load on an air-conditioning system. In Table 5 the data presented in Table 3 has been fitted with the "best fit" straight line forced to include 0.000 lb/ft² at 0 percent RH difference. This fit through zero means that for no change in humidity there should be no moisture loss from the material. This analysis also assumes that the moisture loss response of the materials is directly proportional to the difference in relative humidity between the high and low levels of the daily cycle. This assumption appears to be valid for upper exposures of 90 percent relative humidity or less according to the work of Cunningham and Sprott.[6] Table 5 includes both the slope, or proportionality relating moisture loss and humidity difference, and the predicted moisture loss of each material for a humidity difference of 50 percent RH. The materials are presented in descending order of predicted moisture loss.

Table 5. Ranked Summary of Dynamic Exposure Tests

	Test material	Weight loss, (lb/ft²) Calculated slope	50% RH
14	Newspaper	0.00057	0.029
15	Letters	0.00040	0.020
10	Carpet-on-Pad	0.00032	0.016
4	Concrete Block	0.00030	0.015
1	2 x 10 Dimension Lumber	0.00028	0.014
5	Painted Gypsum Board	0.00027	0.014
11	Wool Cushion	0.00026	0.013
7	Prefinished Parquet Floor	0.00024	0.012
9	Acoustical Ceiling Tile	0.00024	0.012
6	Prefinished Plywood Panel	0.00022	0.011
2	T & G Plywood	0.00022	0.011
12	Cotton Cushion	0.00019	0.010
3	Reinforced Concrete	0.00018	0.009
13	Polyester/Cotton Drapery	0.00008	0.004
8	Vinyl Floor Tile	0.00007	0.003

Figure 3 shows the predicted response for all of the materials, subject to the assumptions stated above. The response of the materials to the humidity cycles is different for the various materials and can be described in three classes; low moisture load materials, moderate moisture load materials, and high moisture load materials.

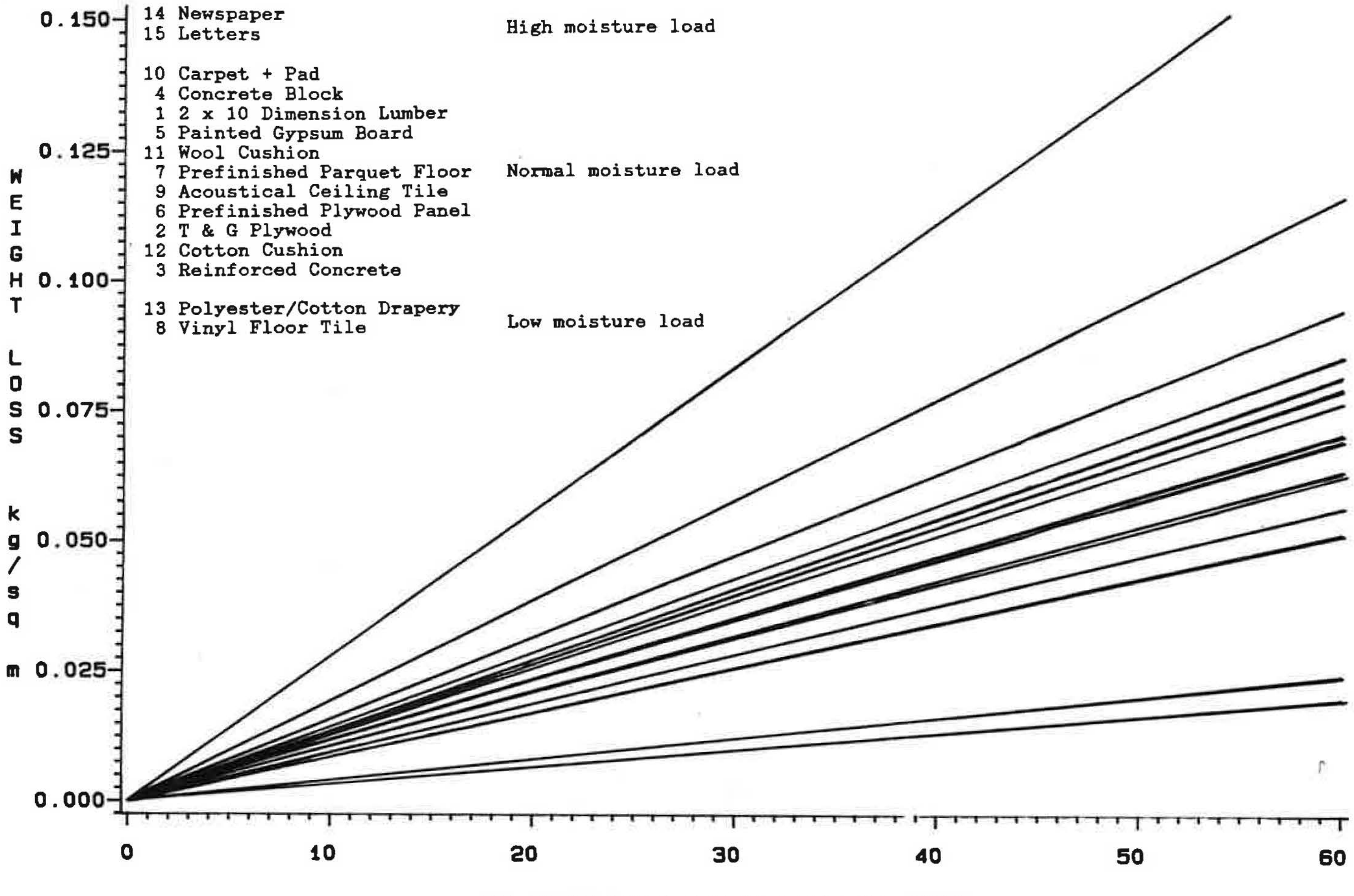

Figure 3. Predicted response of the test materials.

Low Moisture Load Materials

Materials 8 and 13, the vinyl floor tile and the polyester and cotton drapery, absorb and desorb relatively little moisture when compared with the other test materials. They both represent less than 0.004 lb/ft^2 moisture loads even up to 50 percent differences in humidity between the high humidity level and the low humidity level. Material 8, the vinyl floor tile, is probably hydrophobic and probably has a water impermeable surface. The water that is absorbed probably is absorbed primarily on the surface and does not penetrate very far into the interior of the sample. Thus, the vinyl floor tile responds slowly to the changes in the humidity in the chamber. Material 13, the polyester/cotton drapery, unlike the vinyl floor tile, absorbs and desorbs moisture very quickly, but there is very little mass to the material so that the capacity of the material for moisture absorption and desorption is relatively small.

In these low moisture load materials either the moisture does not penetrate the surface, as in the case of the vinyl floor tile, or, there is little moisture storage capacity in the material, as in the case of the polyester/cotton drapery. These materials could be present as a large exposed area in a building and even with the low load capacity per unit area still may represent a significant latent heat load.

Moderate Moisture Load Materials

Materials 1 through 7 and 9 through 12; the wood materials, masonry block, concrete, gypsum board, wool and cotton cushions, and the ceiling tile all respond to the changes in humidity to a similar extent. The moisture loads represented by these materials range from 0.0088 lb/ft^2 for the reinforced concrete to 0.016 lb/ft^2 for the carpet-on-pad.

The rate of moisture absorption and desorption can be determined qualitatively by inspecting the dynamic weight change curves (Figure 2) for each material. Sharp curvature indicates rapid absorption and desorption. Additional investigations should be performed to determine the initial time rate quantitatively.

The wood materials, the reinforced concrete and concrete block and the painted gypsum board respond slowly to the changes in humidity but have significant moisture storage capacity. These response characteristics are typical of low air contact surface area materials with diffusion controlled absorption and desorption. These materials probably absorb and desorb moisture rapidly at the surface of the material but the rate of moisture movement into or out of the interior of the sample is controlled by diffusion. These materials potentially represent a substantial latent heat load during the entire daily cycle.

The cotton cushion, the wool cushion, the acoustical ceiling tile, and the carpet-on-pad respond to the changes in humidity very rapidly and have significant storage capacity. These response characteristics are typical of high air contact surface area materials with diffusion controlled absorption and desorption. In contrast to the other materials the air contact surface area is quite large so that a significantly larger quantity of moisture is absorbed or desorbed at the start of each humidity cycle. Once this early moisture has been absorbed or desorbed, the moisture movement is controlled by diffusion into or out of the interior of the sample. These materials potentially will represent a substantial latent heat load at the start of the daily cycle.

High Moisture Load Materials

Materials 14 and 15, the newspaper and the letters, both absorbed and desorbed significantly higher amounts of moisture than the other materials. The moisture load represented by the letters was 0.020 lb/ft^2 and by the newspaper was 0.029 lb/ft^2. Both of these materials respond quickly to the changes in humidity and have very significant moisture storage capacity. This is probably a characteristic of hygroscopic materials, such as paper, with very high surface areas as a result of the pulping operation to make the paper products from wood fibers. The large storage capacity is probably a result of the inclusion of absorptive fillers into the paper composition. Like the previous materials, these response characteristics are typical of high air contact surface area materials with diffusion controlled absorption and desorption. These materials potentially represent a substantial latent heat load at the start of the daily cycle.

Estimate of Dynamic Latent Heat Load in a Typical Office

The significance of the dynamic latent heat load represented by the building construction and furnishing materials was estimated by considering the moisture load associated with a typical office. The moisture load was estimated by assuming a typical single office of 16 ft x 13 ft x 10 ft with some of the construction and furnishing materials of this study. If the office is subjected to daily humidity cycles from 90 percent to 40 percent relative humidity (e.g. daytime temperature of 70°F and RH of 40 percent followed by nighttime temperature of 70°F and RH of 90 percent), the moisture load represented by the materials was calculated as shown in Table 6 using the results previously tabulated in Table 4. Also included in Table 6 is the moisture load of the airspace.

Table 6. Calculated Moisture Load for 90% to 40% Relative Humidity
Daily Cycle for a Typical Office
16 ft x 13 ft x 10 ft office, air at 75°F

	Test material	Location	Size ft	Moisture load, (lb)
5	Painted Gypsum Board	two walls	16x10	2.2
			13x10	1.8
6	Prefinished Plywood Panel	one wall	13x10	1.4
9	Acoustical Ceiling Tile	ceiling	16x13	2.6
10	Carpet-on-Pad	floor	16x13	3.5
11	Wool Cushion	six chairs	65 ft^2	0.8
13	Polyester/Cotton Drapery	one wall	16x10	0.7
14	Newspaper	table	11 ft^2	0.3
15	Letters	desk	5 ft^2	0.1

total moisture load of the materials = 13.4 pounds
moisture load of the airspace = 1.4 pounds
(from psychometric chart)

The total moisture load of the materials considered in this typical office is 13.4 pounds of water per cycle. This amount of water contributed by the materials in the office is very large when compared with the 1.4 pounds of water in the airspace of the office. This does not include the latent heat load required for dehumidification of any outside ventilation air superimposed.

If this typical building has an installed air-conditioning capacity of one ton per 320 ft^2 of floor area, the removal of the latent heat load of 13.4 pounds represented by the building materials would take approximately one hour and 40 minutes. The removal of the 1.4 pounds latent heat load from the airspace would take approximately 10 minutes. If the building is very energy efficient with an installed air-conditioning capacity of one ton per 750 ft^2, the calculated times would be 4 hours for the moisture load from the materials and 24 minutes for the airspace. These times are consistent with the observation made earlier in which the condensing coil of the test chamber was found to be inadequate to remove the moisture given up by the test materials in less than 3 hours.

RECOMMENDATIONS

The results of this study should be incorporated into models of building system performance to determine the impact of the inclusion of the substantial latent heat loads determined in the course of this study. The large latent heat loads could change the way in which air-conditioning systems are designed to include more moisture control with less sensible heating or cooling capacity.

This study was limited to fifteen typical materials used in commercial construction and furnishing. Further studies should include additional commercial materials and materials typical of residential construction and furnishing. Additional samples of some of the materials should be tested to determine if there are different responses for similar materials from different sources.

Further testing should include a closer look at the time rate of moisture desorption to determine the latent heat impact of the initial hour or two of each low humidity cycle.

The major portion of the moisture loss from many of the samples occurred during the first two to three hours of the cycle and represents a huge latent heat load based on load per unit time. This load could result in a system design requiring a large capacity for moisture removal for a short time period and decreased capacity for the remainder of the cycle. Proper selection or treatment of the materials for use in a building might reduce this "instantaneous" load. Different surface treatments of the materials, such as vapor retarding paint on gypsum board, should be tested to determine if the latent heat effects can be reduced or distributed throughout the entire cycle rather than occurring just at the beginning of the cycle.

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Copies of the complete final DOE report are available from Oak Ridge National Laboratory.[12]

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