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The extensive use of frame construction in the Atlantic Provinces of Canada makes the subject of paint performance on wood sidings of particular interest in that region. The problem of peeling is related to the presence of water but the source of the water is not particularly well understood. In April 1961 one of the authors conducted a detailed examination of the exteriors of 278 wood clad houses in the region. These and subsequent studies on other houses of similar age and construction type suggested that paint failure by peeling is more probably due to exterior weathering factors than to the condensation of moisture originating behind the paint film. The most serious peeling was observed to occur most often on walls exposed to wind-driven rain. There was some evidence that roof overhangs protected top portions of walls but building orientation remained the most important factor.

Generally, north walls were free from the type of failure common to other exposures. The most severe paint failures occurred on south and east walls. (Most wind-driven rain in the region comes from southerly directions.) Even on unheated unoccupied buildings having the same exposures failure by peeling has been observed. It was decided to investigate how rain and outdoor humidity affected the moisture content of wood behind painted surfaces. Any effect humidity in wall spaces and heat loss from typical occupancies might have on drying of wetted wood siding from the back was ignored.

Accordingly, twelve panels, made of the same wood siding but applied in three different methods, were painted and instrumented so that the wood moisture contents could be recorded regularly. Panels of each of the three types were exposed outdoors in four directions at the DBR/NRC Regional Station in Halifax, Nova Scotia, in April 1965.

DETAILS OF PANELS AND SENSING ELEMENTS

Bevelled cedar siding was applied $5\frac{1}{2}$ inches to the weather over $\frac{3}{4}$-inch fir plywood on 2- by 3-inch studs for a panel width of 16 inches. All structural elements of the panels, including the sheathing, were painted before the siding was applied. There were three methods of siding application but only two structural types of panels. Of the application methods, No. 1 had a ventilated space between the sheathing and siding, No. 2 had the siding applied directly to the sheathing (over #15 asphalt sheathing paper), and No. 3 was the same as No. 2 except the siding was backprimed. Panels were assembled in sets of three before exposure by bolting to a common drip cap and base strap (Fig. 1).

Following its application the siding was painted indoors with a good quality oil type primer and two topcoats for a 4 to 5 millimetre film thickness. Caulking was done with a one part sealant after the primer had dried (Fig. 2).

Sensing pins were assembled for each panel, care being taken to ensure that the wire leads and lucite holders for the pins were moisture proof (Fig. 3). The pins were fixed with epoxy resin in the holders and centered behind the third piece of siding from the bottom of each panel, penetrating 1/8 inch where the siding was $\frac{1}{4}$ inch thick.

PANEL ASSEMBLY AND INSTRUMENTATION

The clad panels were assembled in sets of three in an existing frame on the laboratory roof with sides facing north, east, south, and west (Fig. 4). Leads from the sensing pins were taken through a wiring harness to connections in a waterproofed junction box (Fig. 5); additional leads were taken from the box to the selector switch of a resistance type of moisture meter inside the building. Because the pins were "permanently" installed, meter voltages were only applied long enough to obtain individual readings. A check was made for possible thermal effects on a typical installation subjected to the anticipated temperature range. Periodic checks with a portable meter were made during the exposure period. All metered readings were corrected for temperatures obtained simultaneously with thermocouples installed in the panels using the chart in ASTM D2016-65 (1).

During the twelve-month exposure period that began on 1 April 1965, the wood moisture contents were recorded only once a week. The possibility of recording automatically was investigated, and in consultation with a company specializing in this type of equipment, instrumentation involving a meter, timer, and chart recorder was developed to record the moisture content of each panel at preselected intervals of one hour to one day (Fig. 6).

In July 1966 the automatic equipment was put into operation; it took readings every six hours, coinciding with the times that temperatures and humidities were observed by the local Meteorological Station. Initially, readings were taken more frequently than this, during periods of heavy rains, to observe the rates of change in moisture content.

The study consisted of two phases. During Phase I moisture contents were obtained by manual switching on a weekly basis for twelve months beginning April 1965. During Phase II, moisture contents were automatically recorded every six hours for twelve months beginning July 1966. During this latter period, weekly readings were also taken manually until 19 December 1966.

Rain cups on the frame provided the rainfall amounts noted in this report. Information on rainfall, outdoor temperature and humidity was provided by the Shearwater Naval Air Station, $4\frac{1}{2}$ miles east and $1\frac{3}{4}$ miles south of the panel installation.

OBSERVATIONS FROM PHASE I

For the twelve-month period beginning 1 April 1965, meteorological data and rain cup measurements were compiled (Fig. 7). Shown in this graph are the equilibrium moisture contents (EMC) based on relative humidity and in accordance with established tables (2), the plotted humidities and a bar graph to illustrate the monthly rainfall totals. No attempt was made to correlate raincup collections with meteorological totals but in general the variations over the period are similar.

Monthly averages of wood moisture contents, based on weekly readings recorded from the three panel types for four exposures, were plotted in association with the relative humidities for the same times (Fig. 8). It is apparent that the vented panel (No. 1) attained a higher moisture content for all exposures than did the non-backprimed (No. 2) and the backprimed (No. 3) types in that order.

Table I relates panel types to exposure in decreasing moisture contents. For this location the north exposure is, for all panel types, the one with the lowest wood moisture content as the result of wind-driven rain. With the exception of a drying period during February 1966 there appeared to be a progressive accumulation of wood moisture content over the exposure period.

The graphs in Figures 9 and 10 show the raincup measurements for the four exposures and the related directional effects. They also show how the direct readings of wood moisture content differ from the EMC calculated from relative humidity records; although the patterns are similar, the table-derived EMC are higher than the measured values of wood moisture content.

DISCUSSION OF PHASE I

Raincup totals confirm field observations in demonstrating that most of the wind-driven rain in this region comes from southerly directions. There were some obvious departures from this over the exposure period: in June 1965 most rain came from the north and east in medium amounts, and in July 1965, when maximums were low for all exposures, rain was from the west.

Although the open rain screen effect of a vented panel may, in theory, prevent rain in association with wind pressure from penetrating the cladding, it is evident that the vented panels contained more moisture for all exposures over the entire period than did the other types. This may be due to the combined effects of surface wetting and simultaneous gains from relative humidity increases at the back surface. The higher moisture contents of the non-backprimed type suggests that backpriming the siding is beneficial.

It is assumed that increases in wood moisture during a rain are due to water penetrating the paint film. As an added precaution and to ensure that rain from one direction did not penetrate the back of panels opposite (although this is improbable due to the thickness of the plywood sheathing which was painted both sides), the backs of all panel assemblies were covered with plastic.

Weekly readings do little to explain rates of wetting or drying during and immediately following a rain. They serve a useful purpose, however, in indicating cumulative effects during prolonged periods of rainfall.

The backprimed panels (No. 3) had the lowest moisture content for all exposures. Although the vented panels (No. 1) had the highest content for south and east exposures, the other two types were not substantially influenced by exposure. The lowest moisture gains in all panels were in those exposed to the north - substantiating previous field studies of houses.

OBSERVATIONS FROM PHASE II

To complete the rather limited picture produced by the readings taken manually each week, automatic recording equipment was connected to the panel sensing elements in July 1966, and was checked by the original method until 19 December 1966. The automatic equipment was kept in service for an additional twelve months (until July 1968). Although this paper refers only to records collected during one year by the automatic method, those taken during a second year revealed a similar pattern when weather variations are taken into account and gave no evidence that paint weathering had materially influenced moisture readings. This study is not concerned with paint performance but rather with wood moisture contents behind the film, but it may be noted that there were no obvious defects in the film after three years.

From records taken every six hours during May 1967, a graph illustrating moisture variations in the south-exposed vented panel was prepared (Fig. 11). In addition to the graph of relative humidity for that period, the amount of rainfall (in inches) is noted and appears to relate directly to maximum wood moisture contents. Moisture contents increased very rapidly during a rain and decreased at about the same rate when the rain stopped. It is not known whether the recorded decreases are due to moisture leaving the panel or, in part, to moisture redistribution within the panel causing lower readings at the sensing elements.

Weekly averages based on readings recorded every six hours were plotted for all panels for July 1966 to July 1967, along with the relative humidities and monthly rainfall totals for the same period. The graphs in Figures 12, 13 and 14 show the relative humidities and the wood moisture content for each panel over this period.

DISCUSSION OF PHASE II

Examination of moisture contents recorded at six-hour intervals indicated that many variations occur which could not be anticipated from weekly observations. Significant changes were observed over short periods of time; for example, the relative humidity increased from 65 to 100 percent, and with less than $\frac{1}{2}$ inch of rain, the moisture increased from 7 to 20 percent within a twelve-hour period. Generally a relative humidity of 100 percent did not cause the moisture content to exceed 20 percent unless there was also rain. Increases and decreases in moisture content of 10 percent in twelve hours were common. Although weekly readings indicated cumulative effects over a twelve-month period, they provided no indication of the many cycles of wetting and drying within that period.

When the weekly averages based on daily readings for the vented panel are compared with the daily averages for the same period, the variations are levelled out to such an extent as to eliminate any indication of moisture contents exceeding 15 percent. As might be anticipated, there is very little indicated lag between humidity changes and changes in wood moisture content.

Although the weekly averages based on daily readings are more detailed than the weekly readings observed in Phase I, an appreciation of the extremes of change in reflecting what actually happens over short time periods depends on an examination of records obtained every six hours or at even shorter intervals.

As in Phase I, the vented panels had the highest moisture content followed by the non-backprimed and backprimed types respectively, but in the second Phase, only small differences could be observed to relate to orientation. Maximum values for limited periods occurred for south and west exposures.

CONCLUSION

In general, the panels exposed in a southerly direction had the highest moisture content, and those facing north had the lowest moisture levels. The vented panels had the highest moisture contents for all exposures followed by the non-backprimed and the backprimed panels in descending order.

Measured wood moisture contents rarely exceeded 20 percent, except for short periods when high relative humidities were accompanied by rain. It was observed from readings acquired every six hours that substantial increases and decreases could occur in less than twelve hours.

Average wood moisture contents for one-year periods departed very little from field measurements that had been made in April 1961 when over 500 moisture readings were taken from sidings of 278 houses in the region. The majority of field readings were less than 15 percent but moisture contents near butt joints, window details, and corner boards were found to be 10 to 12 percent higher than at other locations on the walls.

This study of panels exposed outdoors suggests that weekly readings provide insufficient detail when attempting to relate frequency and rate of change of wood moisture contents to relative humidity and rainfall. It is assumed that wetting by rain is due to penetration of the paint film, and although rapid increases can be noted during a rainfall, it is possible that similar decreases that occur when the rain stops might be due in part to moisture redistribution.

The problems of moisture redistribution, the depth of penetration while there is a continuous film of water over the face of the panels, and the possibility of indoor moisture and temperature having an influence on the moisture content of the siding are under review for detailed investigation at the Halifax Station.

REFERENCES

1. American Society for Testing and Materials, 1965. Standard Methods of Test for Moisture Content of Wood. ASTM D2016-65.

2. Canadian Woods; Their Properties and Uses. Second Edition, May 1951. Forestry Branch, Forest Products Laboratories Division. Queen's Printer, Ottawa, Canada.

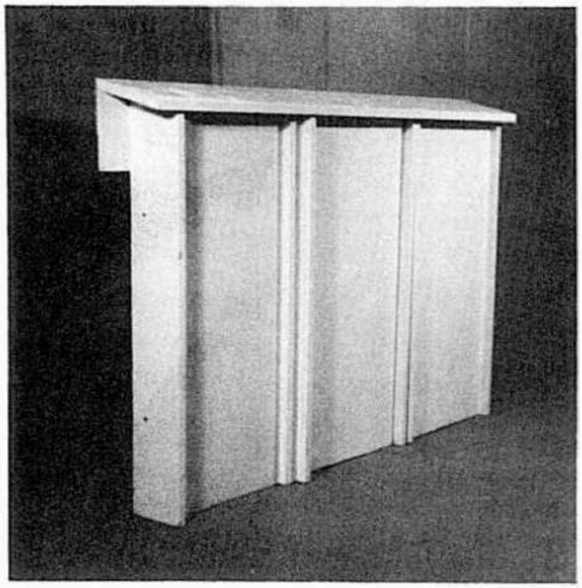


Figure 1. Front view of panel assembly before siding application — furred panel at left.

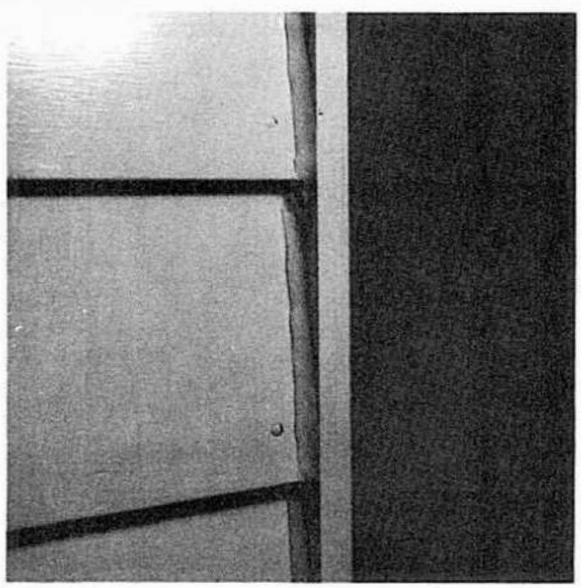


Figure 2. Caulking at ends of siding — over prime coat.

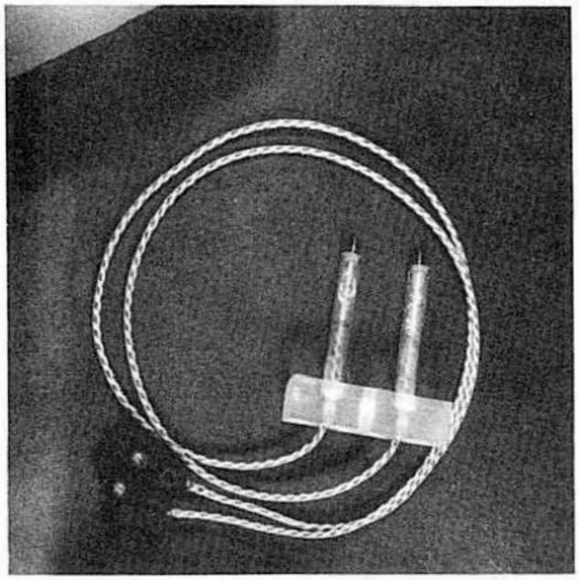


Figure 3. Moisture sensing assembly.

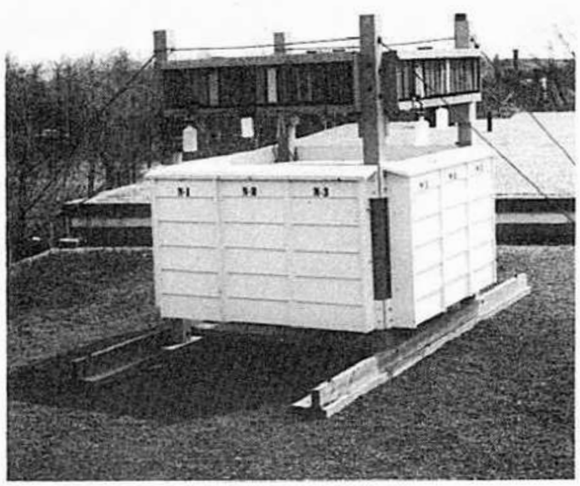


Figure 4. Completed assembly showing North and West exposure — rain cups above panels.

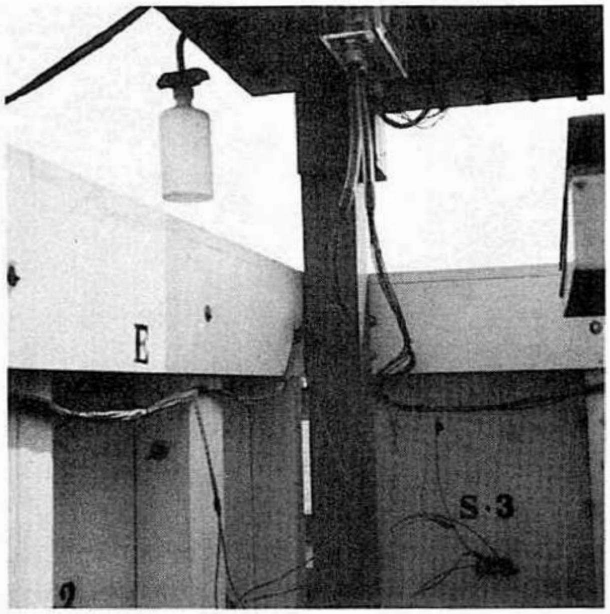


Figure 5. Wiring harness for assembled panels — waterproof junction box at top.

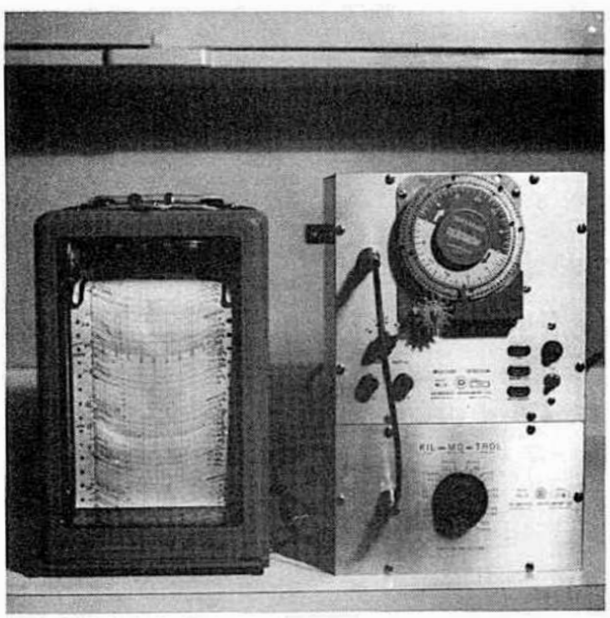


Figure 6. Automatic metering and recording assembly.

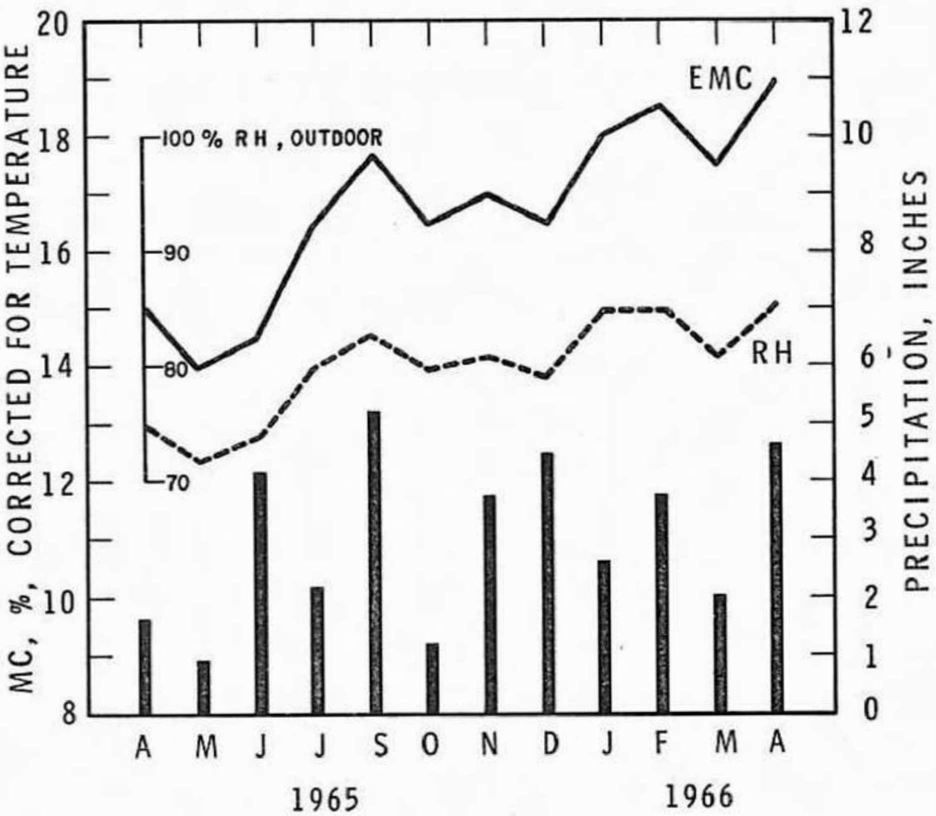


FIGURE 7

EQUILIBRIUM MOISTURE CONTENTS, RELATIVE HUMIDITIES AND INCHES OF RAINFALL FROM DOT WEATHER RECORDS, AND RAINFALL FOR FOUR EXPOSURES FROM RAINCUPS INSTALLED AT PANEL LOCATION.

BR 4385-1

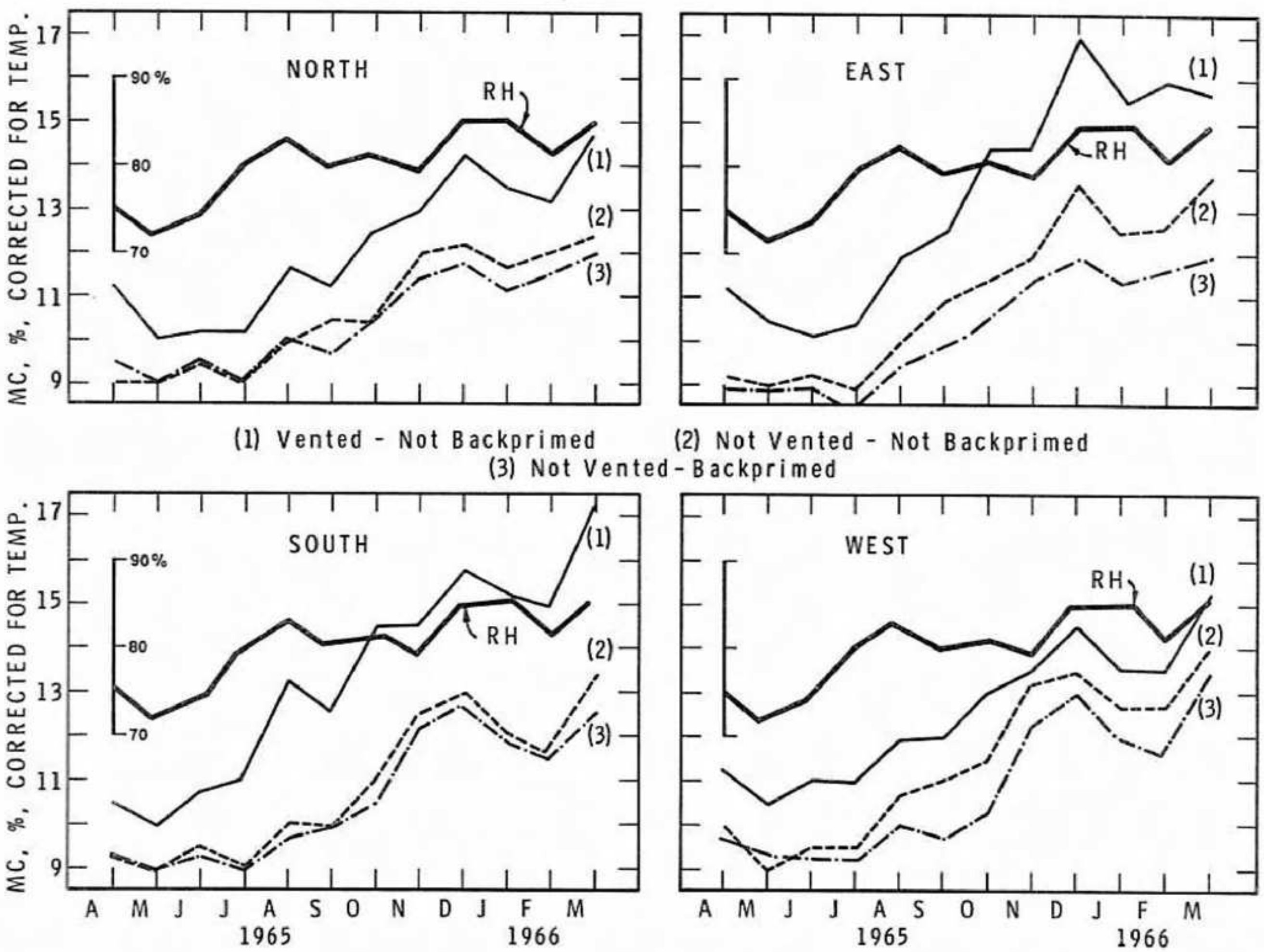


FIGURE 8

MONTHLY AVERAGES OF WEEKLY MOISTURE READINGS FOR THREE PANEL TYPES WITH FOUR EXPOSURES, AND RELATIVE HUMIDITY READINGS.

BR 4385-2

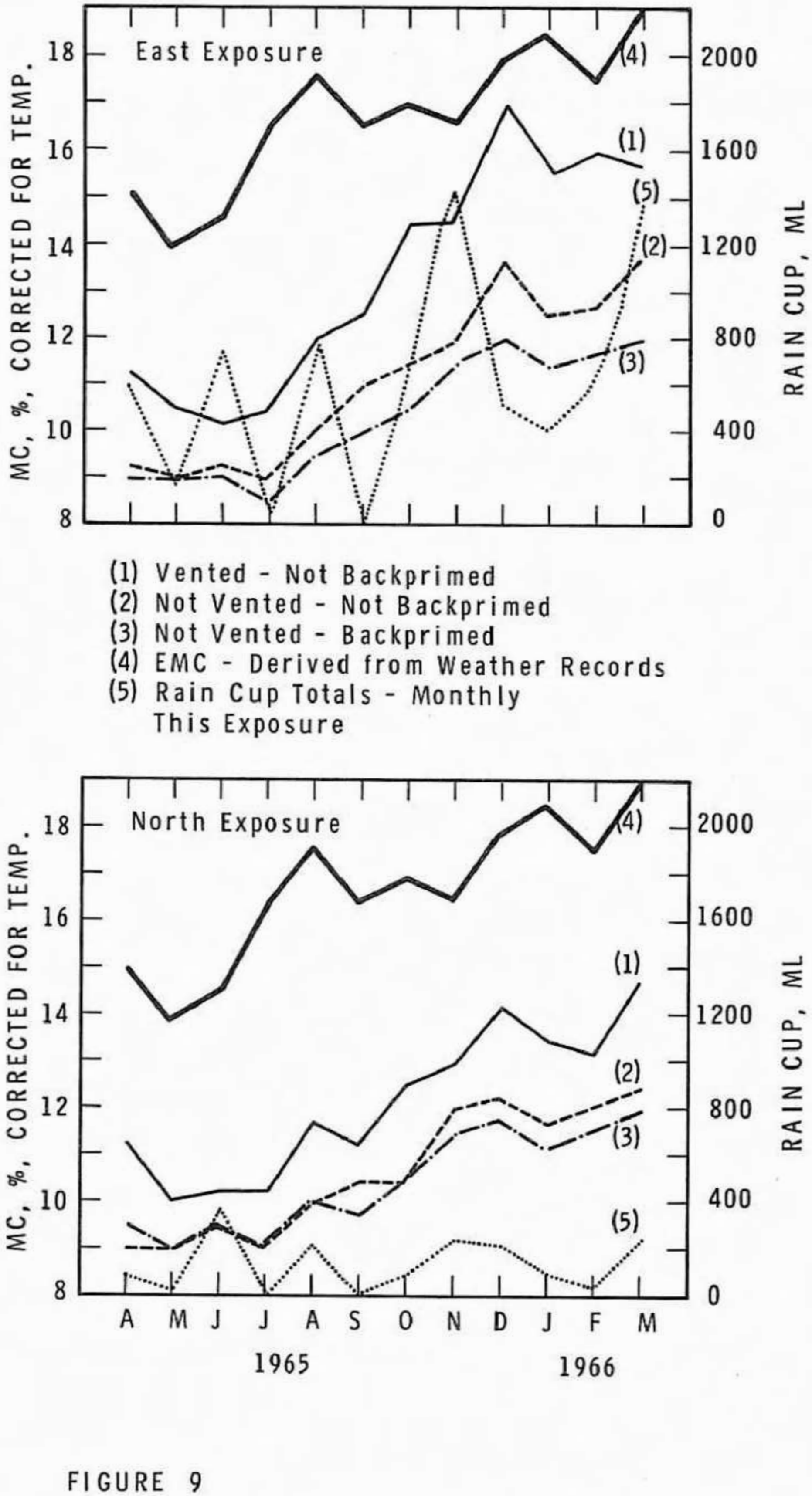
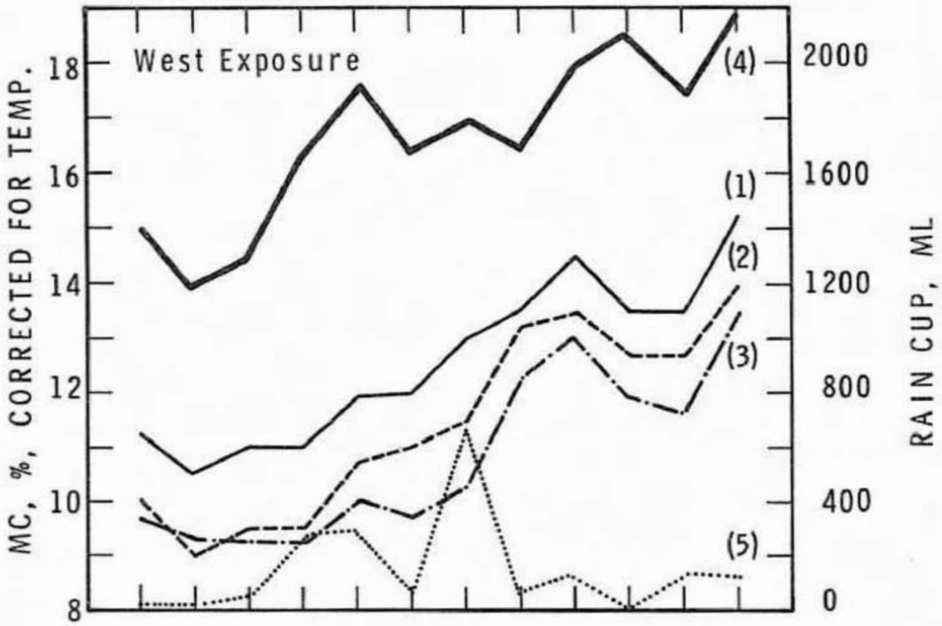


FIGURE 9

MOISTURE READINGS FOR EAST AND NORTH EXPOSURES FOR THREE PANEL TYPES WITH RELATIVE HUMIDITY READINGS AND RAINCUP TOTALS.

BR 4385-3



(1) Vented - Not Backprimed
(2) Not Vented - Not Backprimed
(3) Not Vented - Backprimed
(4) EMC - Derived from Weather Records
(5) Rain Cup Totals - Monthly
This Exposure

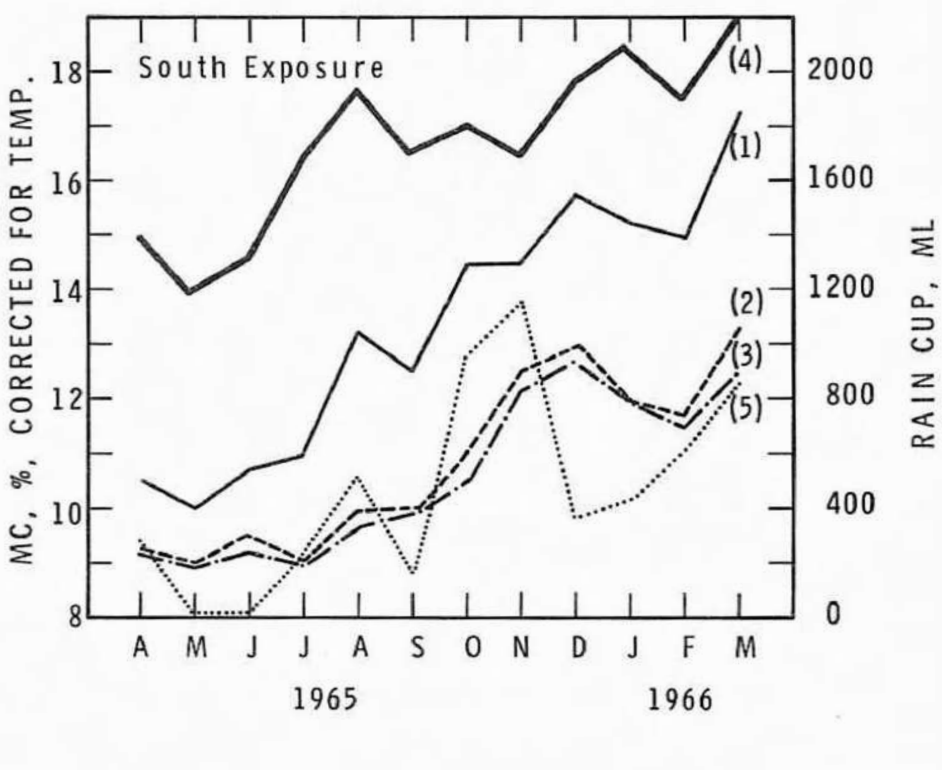


FIGURE 10

MOISTURE READINGS FOR WEST AND SOUTH EXPOSURES FOR THREE PANEL TYPES WITH RELATIVE HUMIDITY READINGS AND RAINCUP TOTALS

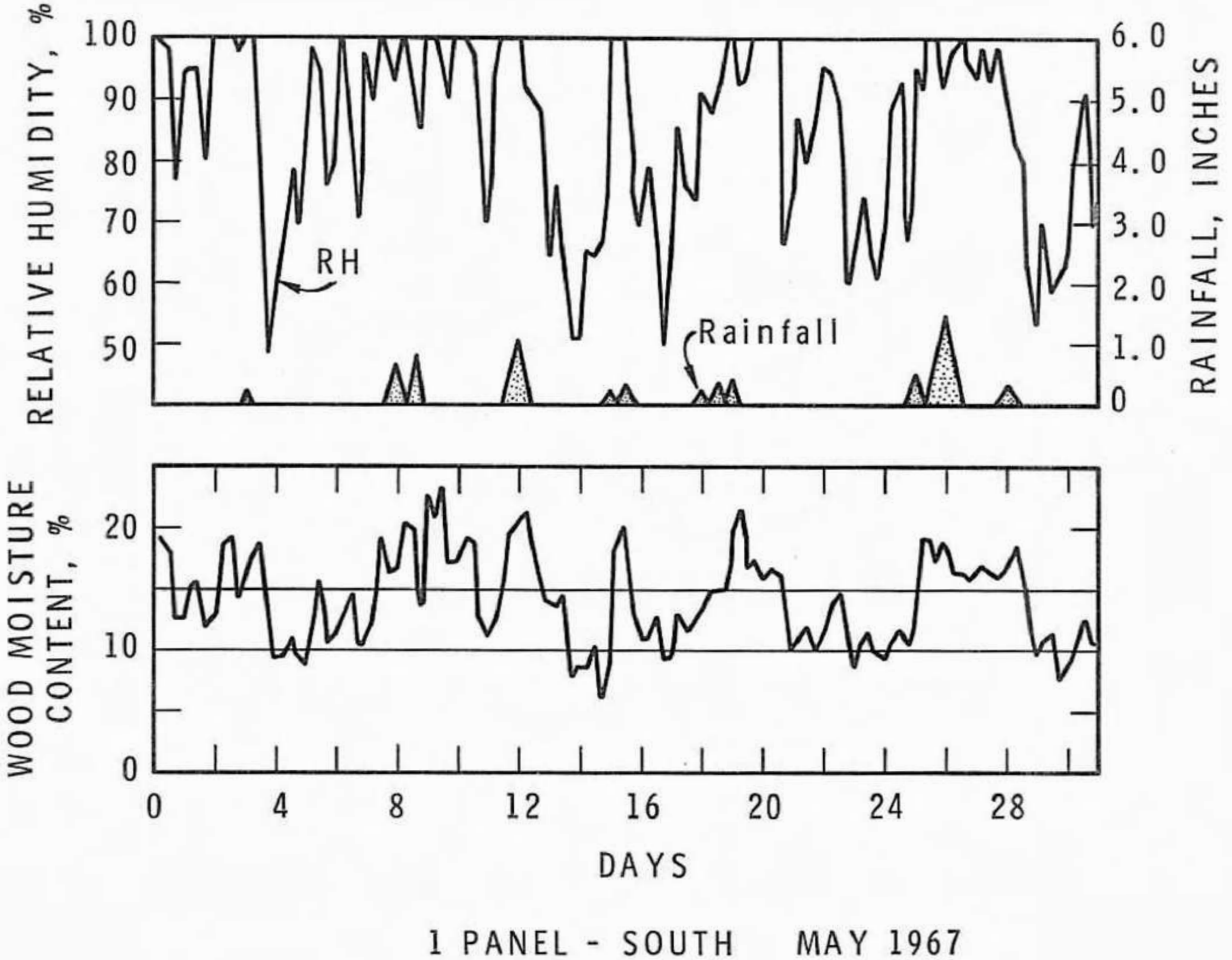


FIGURE 11

HUMIDITY AND RAINFALL DATA FROM DOT WEATHER RECORDS, HALIFAX FOR MAY 1967, AND THE MOISTURE CONTENT OF THE VENTED SOUTH FACING PANEL BASED ON READINGS TAKEN EVERY SIX HOURS.

BR 4385-5

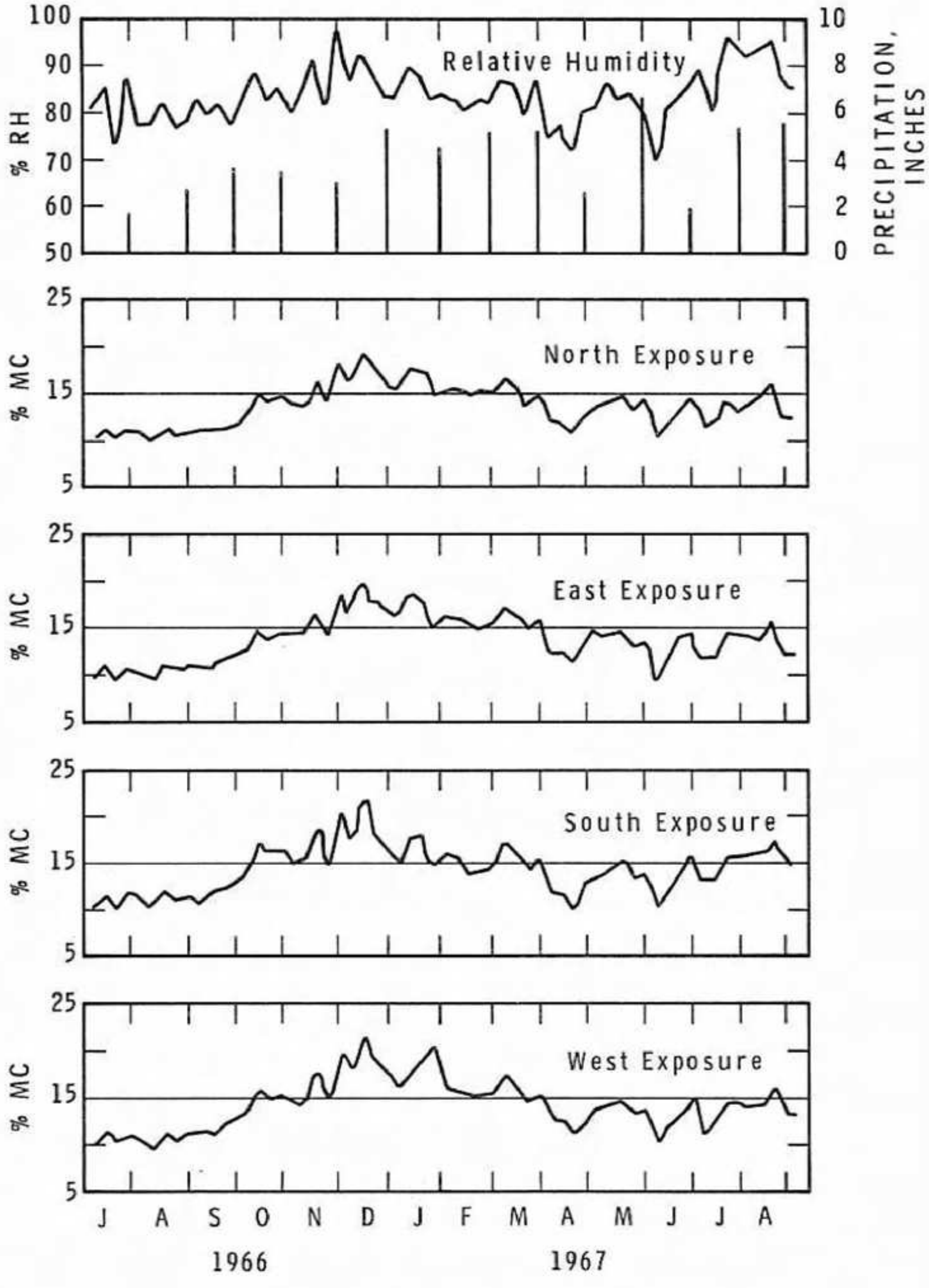


FIGURE 12

HUMIDITY AND RAINFALL DATA WITH WEEKLY AVERAGE MOISTURE CONTENT BASED ON DAILY READINGS FOR FOUR EXPOSURES OF VENTED PANELS (NO. 1).

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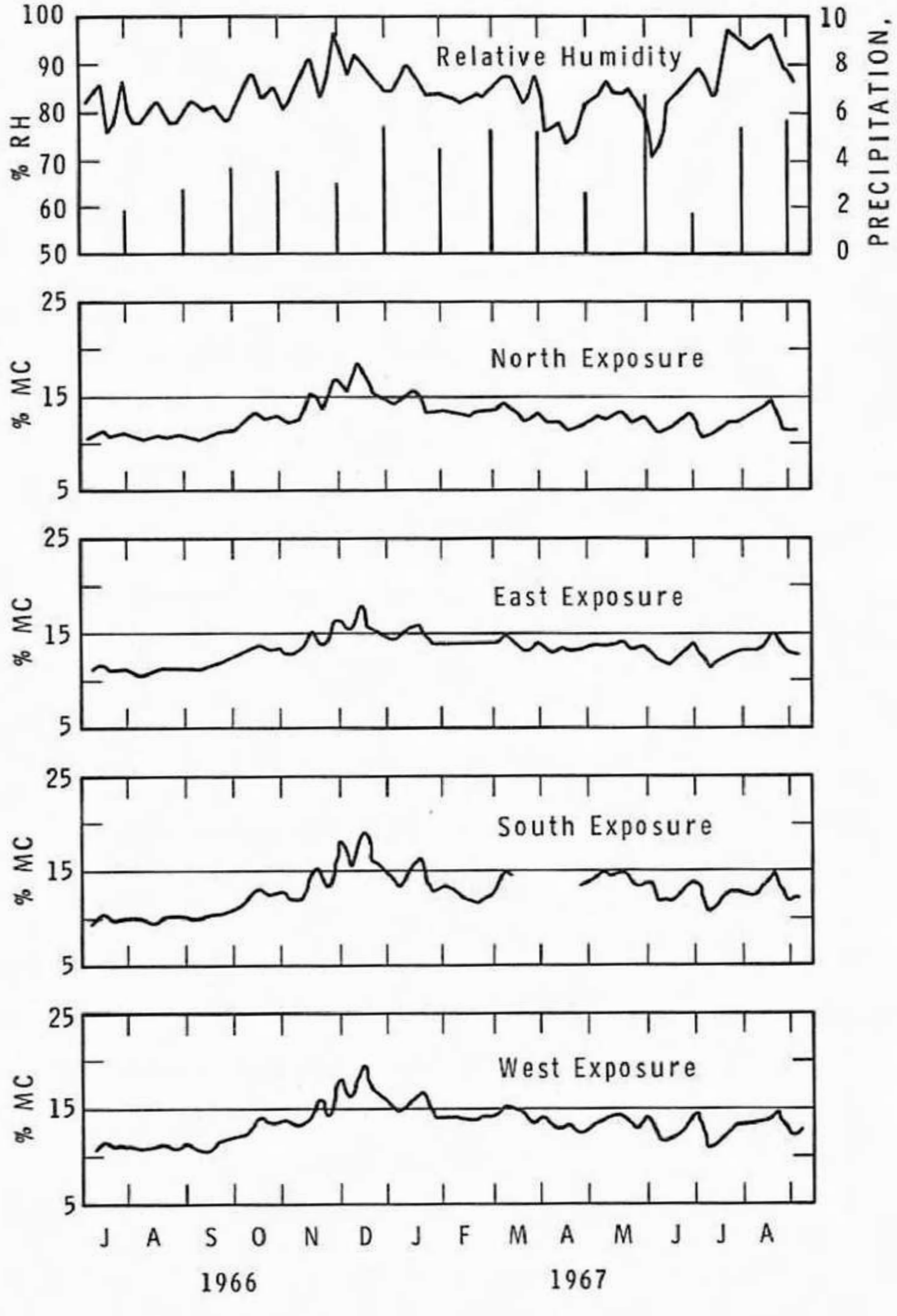

FIGURE 13

HUMIDITY AND RAINFALL DATA WITH WEEKLY AVERAGE MOISTURE CONTENTS BASED ON DAILY READINGS FOR FOUR EXPOSURES OF NON-BACKPRIMED PANELS (NO. 2).

BR 4385-7

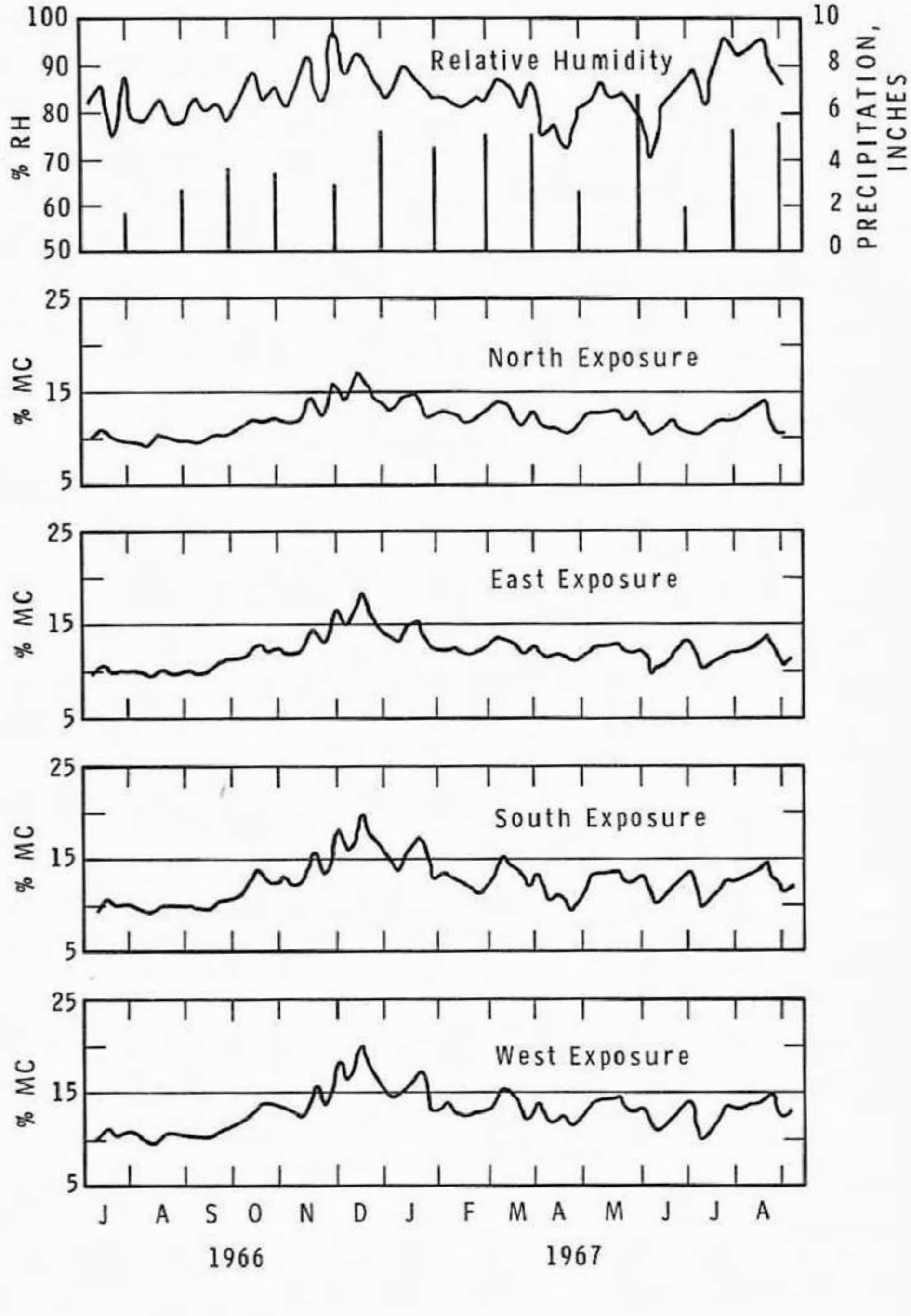

FIGURE 14

HUMIDITY AND RAINFALL DATA WITH WEEKLY AVERAGE MOISTURE CONTENTS ABSED ON DAILY READINGS FOR FOUR EXPOSURES OF BACKPRIMED PANELS (NO. 3).

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Table 1. - Panels related to direction of exposure in order of decreasing moisture content.

Panel Type	No.	Exposed Direction
Vented	1	South-East-West-North
Non-backprimed	2	West-East-South-North
Backprimed	3	West-South-East-North