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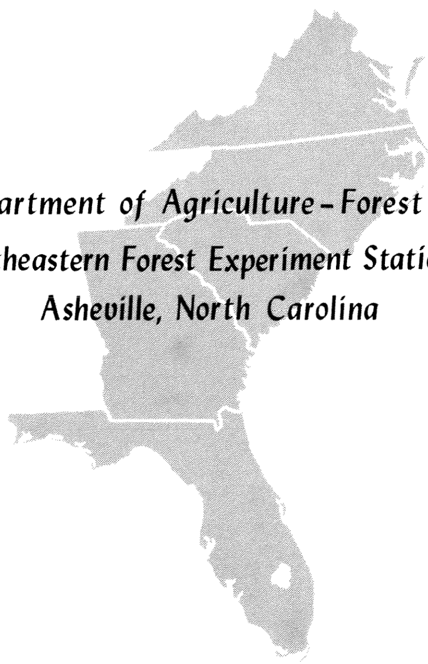

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Southeastern Forest Experiment Station
Asheville, North Carolina

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INTRODUCTION

Moisture content is one of the more important fuel conditions affecting forest fire behavor, and it can be estimated from samples of fuel collected from the forest stand. For fire danger prediction or the prediction of favorable conditions for prescribed burning, however, this is usually impractical because of the time and work that it requires.

Although the prediction of fuel moisture through its correlation with certain weather factors is convenient, it may be inaccurate for two reasons. First, fuel particles and fuel complexes vary so widely in their response to the influence of weather that the relationship of fuel moisture to weather is not completely understood. Second, there is a lack of reliable instruments which can intensively sample the important meteorological parameters and then integrate these measurements into accurate estimates of fuel moisture content.

Most of the fine fuel on the forest floor consists of cured leaves and small woody stems from a variety of plant species (except in plantations). These materials vary in the way their moisture content responds to fluctuating relative humidity. Their EMC's[1] differ as a result of inherent differences in the chemical and physical nature of each kind of fuel. Their EMC's also differ according to whether they are approached from a previously dry or wet condition.

The moisture content of forest fuels does not often reach equilibrium because atmospheric humidity is seldom constant. The rate at which fine fuel particles gain or lose moisture depends on their degree of exposure to agents such as wind, solar radiation, and precipitation which influence the

[1] The equilibrium moisture content (EMC) of a fuel is that moisture content which the fuel will attain after prolonged exposure to an atmosphere of constant relative humidity and temperature.

exchange of moisture between the fuel particle and atmosphere. The complex arrangement of fine fuel particles on the forest floor can produce wide variations in the moisture content throughout the fuel layer because of varying degrees of exposure of individual fuel particles to wetting and drying forces.

Equilibrium moisture content data have been reported for many kinds of cellulosic materials. Most of these are for wood or wood products[2] and textile fibers.[3] The EMC's of most cellulosic materials vary from 0 to about 30 percent of their dry weight. This is true for relative humidities from 0 to about 99.5 percent. Between 99.5 and 100 percent relative humidity, EMC's may reach as high as 150 percent.[4] Few EMC data have been reported for materials that make up the fine fuel complexes of the forest floor. However, King and Linton[5] have reported EMC data for eight different natural fuels found in Australian forests. These include pine needles, eucalyptus leaves and bark, brachen fern, and grass.

METHODS

Dead leaves from the following plant species:

Loblolly pine (Pinus taeda L.)

Slash pine (Pinus elliottii Engelm.)

Longleaf pine (Pinus palustris Mill.)

Southern red oak (Quercus falcata Michx.)

Post oak (Quercus stellata Wangenh.)

Mockernut hickory (Carya tomentosa Nutt.)

Wiregrass (Aristida stricta Michx.)

Broomsedge (Bromus secalinus L.)

and sawdust from a freshly cut loblolly pine log were subjected to stepwise changes in relative humidity at a constant temperature of $80° \pm 1.5°$ F. The equilibrium moisture content of the fuel materials was determined at each relative humidity.

Bulk samples of each fuel material were first dry-homogenized and dried to approximately 1 percent moisture content in an oven at 130° F. Homogenization should not affect the EMC since the amount of surface available for adsorption of water molecules inside the fuel particles is negligibly affected by such treatment. The bulk samples were

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[2] Stamm, Alfred J. Wood and cellulose science. 549 pp. New York: Ronald Press Co. 1964.

[3] Urquart, A. R. Sorption isotherms, pp. 14-32, ch. III. In J. W. S. Hearle and R. H. Peters, Moisture in textiles. New York: Textile Book Publ., Inc. 1960.

[4] Stamm, loc. cit.

[5] King, A. R., and Linton, M. Report on moisture variation in forest fuels: equilibrium moisture content. Commonwealth Sci. & Ind. Res. Organ. Australia, Melbourne, 9 pp. 1963.

then placed in a controlled-atmosphere chamber (fig. 1) and subjected to stepwise increases in relative humidity ranging from 3 to 92 percent. The bulk samples were then soaked in water for 48 hours and subjected to stepwise decreases in relative humidity from 92 to 1.5 percent.

Figure 1.--Bulk samples of fuel material were conditioned at constant relative humidity and temperature in this controlled-atmosphere glove box. Subsamples were collected to determine the moisture content at each level of relative humidity.

We maintained constant relative humidity at each step by recirculating the air in the chamber through a reagent bottle (fig. 2) containing a saturated salt solution. The salts used were selected from the list in the Handbook of Chemistry.[6] We measured the relative humidity in the chamber with wet and dry bulb precision thermometers which were mounted in the return air duct. Temperature in the glove box was held constant by a small heat element mounted in the incoming air duct. By keeping the temperature in the laboratory slightly below 80° F., the heat element was able to maintain the glove box temperature at 80° ± 1.5° F.

[6] Lange, Norbert A. Solutions for maintaining constant humidity, p. 1420. In Handbook of chemistry. Ed. 10. New York: McGraw-Hill Book Co., Inc. 1961.

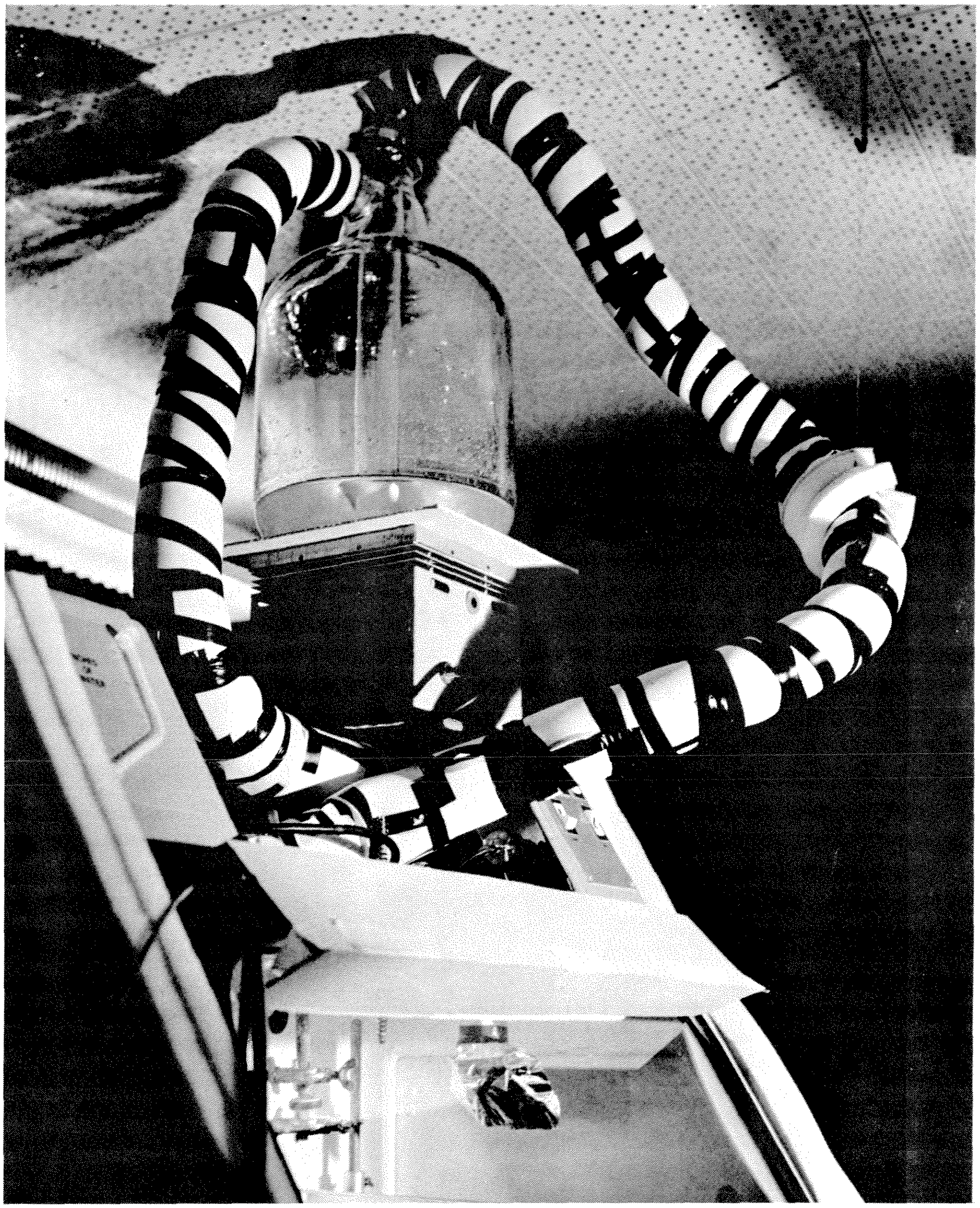

Figure 2.--Constant relative humidity was maintained in the glove box by recirculating air through the reagent bottle containing a saturated salt solution.

The EMC of each fuel was estimated at each level of relative humidity by determining the moisture content of two subsamples which were removed from the chamber after they had reached a constant weight. This usually required about 2 to 3 days. The subsamples were weighed on a balance inside the chamber. The sample moisture content was determined by drying the material in a vacuum oven for 18 hours at 212° F.

RESULTS AND DISCUSSION

The EMC curves in figure 3 illustrate how the moisture content of fine forest fuels is influenced by relative humidity. These curves should be a useful guide for comparing the response of different fuels to relative humidity, and for estimating fuel moisture levels at specific relative humidities. However, certain limitations in the data should be kept in mind. First, the EMC's at any given relative humidity vary slightly with changes in air temperature.[7] Within the range of air temperatures that occur around forested areas, the EMC of forest fuels decreases as air temperature increases. This is due to the natural tendency for adsorbed molecules to vaporize from a surface more readily as temperature increases, even though the relative humidity remains constant. However, under natural conditions, the relative humidity of the atmosphere does not usually remain constant as changes in temperature occur. Increases in temperature are usually accompanied by a corresponding decrease in relative humidity.

Second, the samples used to obtain these curves were freshly fallen leaves collected in the fall of the year. Weathering of these materials from prolonged exposure to the elements may alter their EMC's slightly. Third, constantly changing weather does not often permit fuel moisture to reach equilibrium with the surrounding atmosphere. Furthermore, the "time lag" characteristics of fine fuels vary considerably. For example, Simard[8] found that the time lag constant described by the National Fire Danger Rating System[9] varies considerably with the degree of weathering of the needles of white spruce, white pine, jack pine, and red pine. We have also observed variation in time lag characteristics of slash pine needles, depending on whether they were collected in the fall or in the spring. Freshly fallen, dead needles take on and lose water vapor much slower than needles that have weathered in the open for several months.

With these limitations in mind, the data still provide useful information about the response of these fuel materials to changes in relative humidity. To compare the EMC's of one fuel with another, we chose a range of moisture contents, 8 to 15 percent, which is accepted by fire use specialists as suitable for many applications of prescribed fire in southeastern pine forests.[10] The shadowed areas in figure 3 delineate the range of relative humidities which would produce EMC's between 8 and 15 percent, regardless of whether the EMC is approached from a dry or wet condition. By comparing the shadowed area for each fuel, one can rank each kind of fuel according to the range of relative humidities which produces EMC's between 8 and 15 percent. At any specific relative humidity, hardwood leaves tend to have relatively high EMC's, pine needles are somewhat lower, and the grasses and loblolly pine wood have the lowest EMC's.

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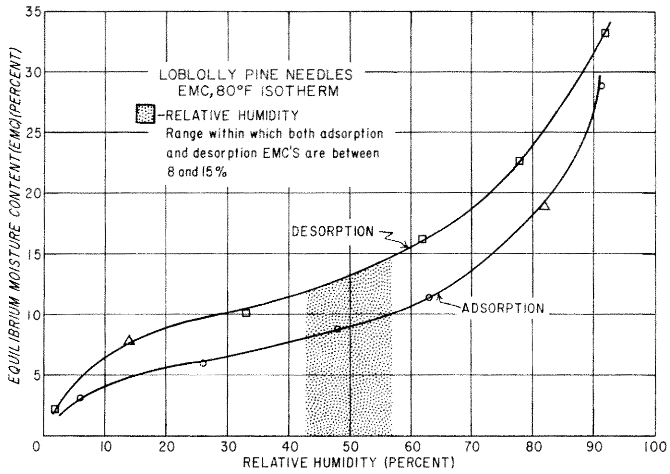
[7] Stamm, loc. cit.

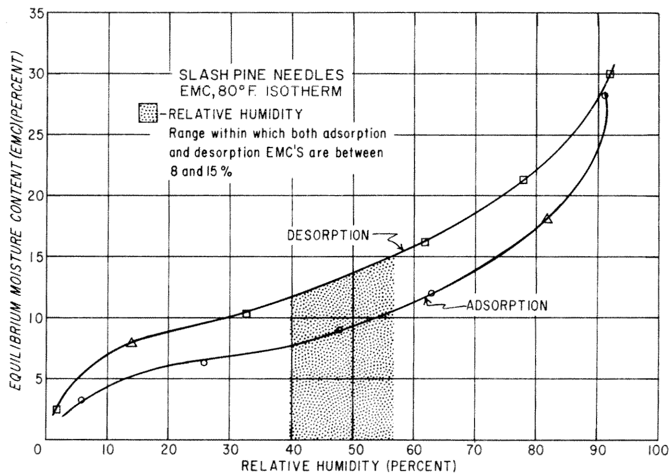
[8] Simard, Albert J. The moisture content of forest fuels - II; Comparison of moisture content variations above the fibre saturation point between a number of fuel types. Forest Fire Res. Inst., Dep. Forest & Rural Develop., Ottawa, Ontario. Inform. Rep. FF-X-15, 68 pp. 1968.

[9] USDA Forest Service. National Fire-Danger Rating System handbook. Category 2 Handbook, FSH2 5123.3. Washington, D. C. 1964.

[10] Cooper, R. W. USDA Forest Serv. Southeast. Forest Exp. Sta. Personal communication. 1969.

Figure 3.--Equilibrium moisture content (EMC) of fine fuel materials found in forests of the southeastern United States. (□ = EMC's obtained during desorption cycle, O = EMC's obtained during adsorption cycle, Δ = EMC's obtained on a second adsorption-desorption cycle following the one used to obtain all other points.)





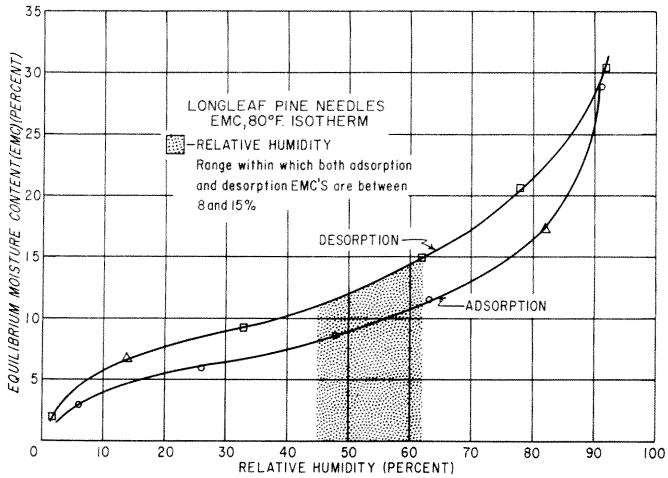
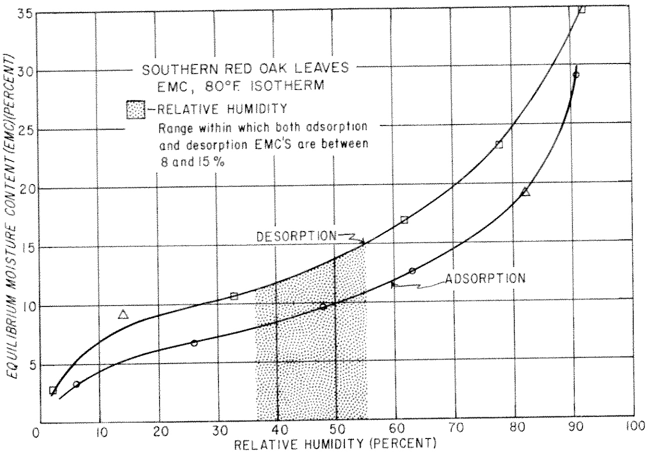
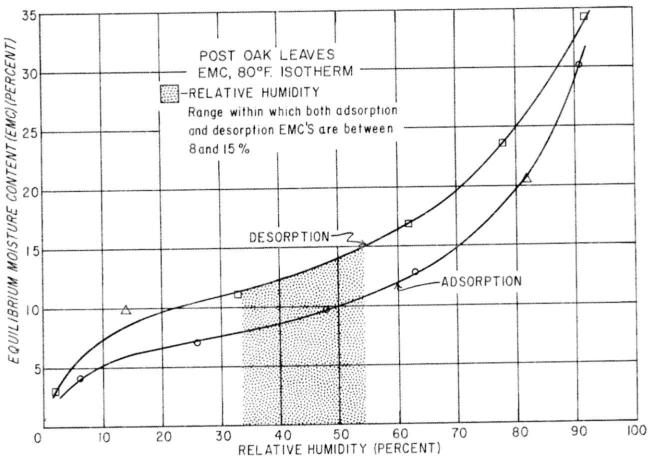
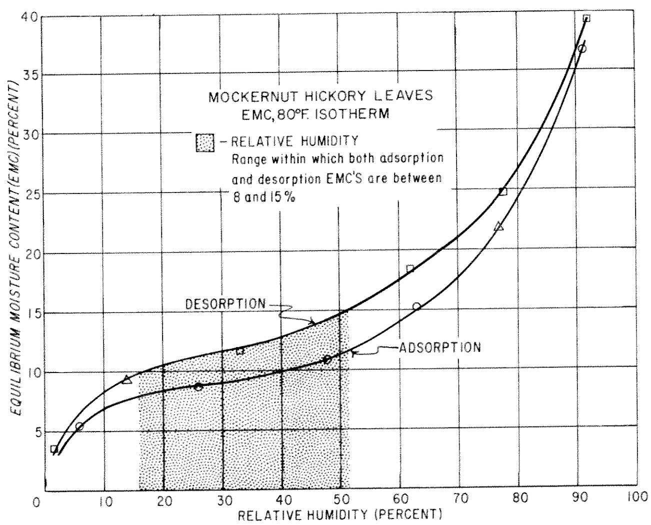


Figure 3.--(Continued)







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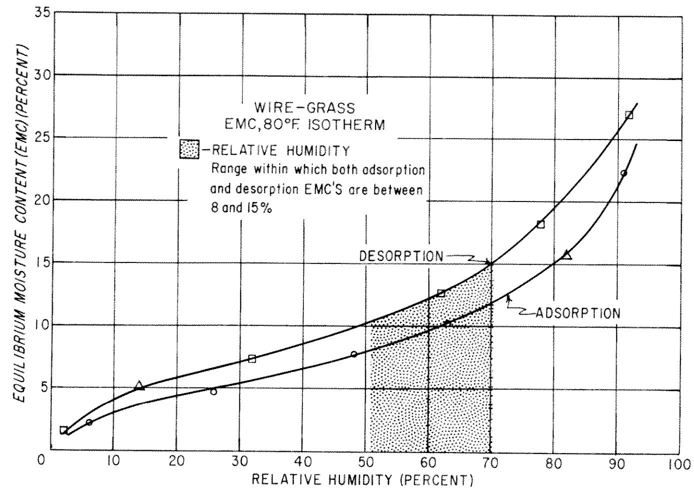

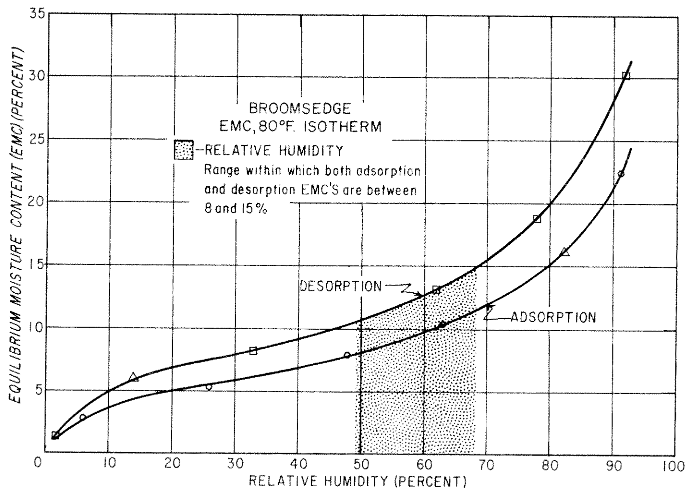

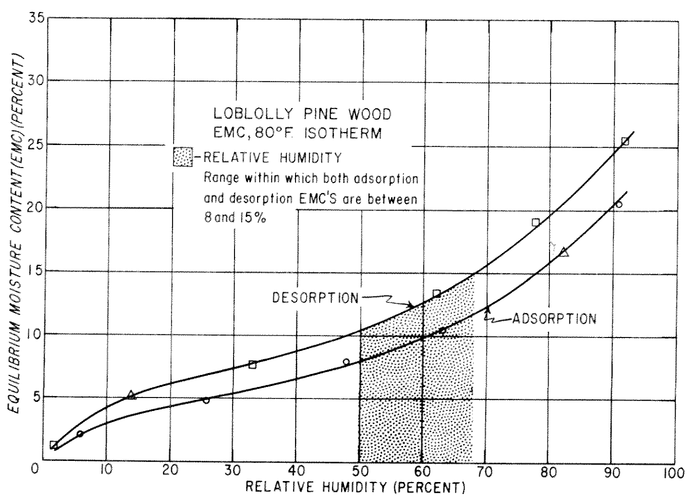

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1971. Equilibrium Moisture Content of Common Fine Fuels Found in Southeastern Forests. Southeast. Forest Exp. Sta., USDA Forest Serv. Res. Pap. SE-74, 8 pp.

Nine different kinds of forest litter found in ground fuel complexes of southeastern forests were subjected to stepwise changes in relative humidity to determine their equilibrium moisture content (EMC) at different levels of relative humidity.

The adsorption and desorption EMC curves for these fuels exhibited the typical hysteresis loop. At any given relative humidity, hardwood leaves usually had the highest EMC's, pine needles were somewhat lower, and grasses and loblolly pine wood had the lowest EMC's.

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