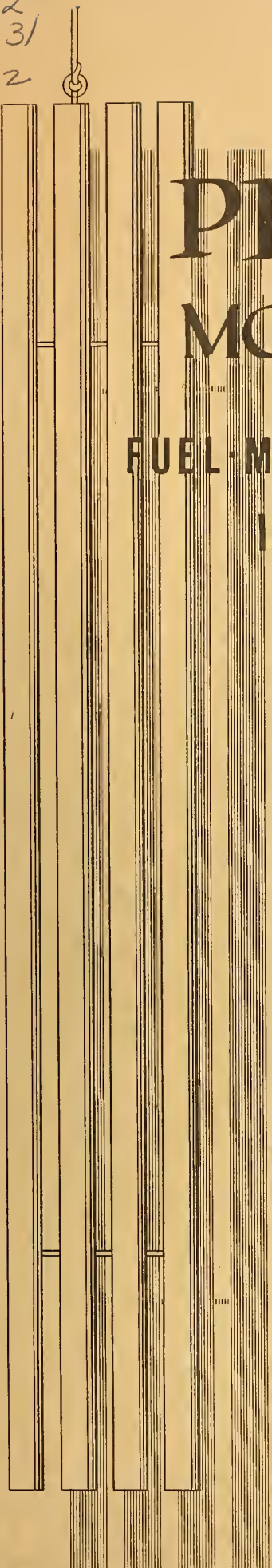


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PREDICTING MOISTURE CONTENT

FUEL MOISTURE INDICATOR STICKS IN THE PACIFIC NORTHWEST

BY OWEN P. CRAMER

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SUMMARY

Successful day-to-day planning of presuppression activities requires accurate prediction of burning index. In the Pacific Northwest, forecasts of burning index are prepared by the fire-control man and are based on predictions of windspeed and fuel moisture. Although fuel moisture is affected by a number of weather elements and is consequently difficult to predict, the fire-control man can make satisfactory forecasts of fuel moisture by using the method described here.

This paper includes aids with which 4:30 p.m. fuel moisture can be predicted from forecast relative humidity and observed fuel moisture. Aids are provided for both morning and evening use, with separate morning aids for peak stations and valley stations. Corrections are suggested for certain weather conditions, and a procedure is given for determining error in observed fuel-moisture values. By means of a special chart, fuel moisture can be approximated for any station for which only 4:30 p.m. humidity is known. A special verification and adjustment procedure for morning aids is suggested to take into account any unusual station exposure effects.

These instructions for predicting 4:30 p.m. moisture in half-inch fuel-moisture-indicator sticks supersede those appearing in "Methods for estimating future burning index from fire-weather forecasts and local weather observations," issued by the Pac. NW. Forest & Range Expt. Sta. in 1950.

PREDICTING MOISTURE CONTENT
OF FUEL-MOISTURE-INDICATOR STICKS
IN THE PACIFIC NORTHWEST

by

Owen P. Cramer

May 1961

PACIFIC NORTHWEST
FOREST AND RANGE EXPERIMENT STATION
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FOREST SERVICE

U. S. DEPARTMENT OF AGRICULTURE

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INTRODUCTION

What will the fuel moisture be at 4:30 p.m. tomorrow? Fire-control agencies need a daily answer to this question. The clue lies in this afternoon's fuel moisture and tomorrow afternoon's predicted relative humidity.

Usually, current moisture content of fuel-moisture indicator sticks can be observed and individual station humidity predicted.^{1/} ^{2/} Moisture content of the half-inch-diameter fuel sticks can then be predicted from these two values by use of one of the aids prepared for that purpose. This paper describes these aids and tells how to verify and use them. Separate aids are provided for use with afternoon and morning observations of fuel moisture. With correct humidity forecasts, the fuel-moisture prediction for the next afternoon based on today's 4:30 p.m. fuel moisture will be within 1 percent of the correct value 90 percent of the time. Similarly, based on the 8 a.m. moisture observation, the prediction made for 4:30 p.m. the same day will average about 96 percent correct. This compares with 80-percent-correct estimates using forecasts of no change in fuel moisture.

These aids for predicting fuel moisture are composites of similar charts prepared for 14 individual stations in various parts of Oregon and Washington. They help predict the moisture content of 100-gram (dry weight), half-inch-diameter cylinders of ponderosa pine sapwood fully exposed to sunlight and weather 6 inches above the

^{1/} Cramer, Owen P. Adjustment of relative humidity and temperature for differences in elevation. 1960. (In preparation for publication, Pac. NW. Forest & Range Expt. Sta., U.S. Forest Serv., Portland, Oreg.)

^{2/} Cramer, Owen P. Using fire-weather forecasts and local weather observations in predicting burning index for individual fire-danger stations. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Paper 28, 33 pp., illus. 1958. (Processed.)

ground. The aids are used for rainless weather between July 1 and September 15 in Oregon and Washington and apply to sticks first exposed June 25.

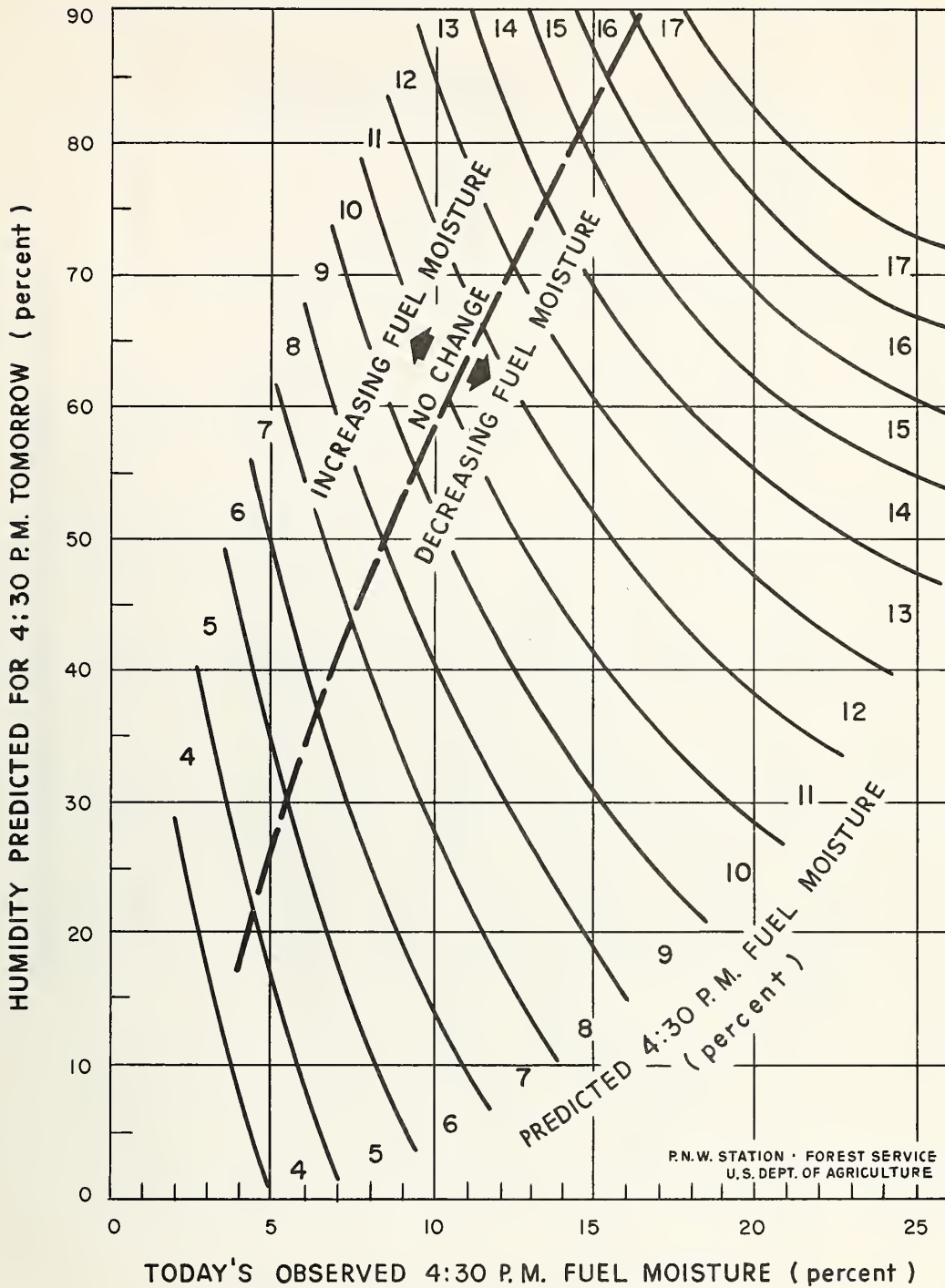
When this method was first proposed,^{3/} it seemed that differences in exposure of sticks were great enough to require separate aids for each station. Although some stations will require individually prepared fuel-moisture aids for morning use, the composite charts presented here will provide estimates accurate within 1 percent fuel moisture for the majority of stations.

The afternoon composite fuel-moisture aid (fig. 1) is ready for use without adjustment. The fuel moisture expected at 4:30 p. m. tomorrow for any combination of predicted 4:30 p. m. relative humidity and current 4:30 p. m. fuel moisture is shown by the sloping zones. Combinations that result in no change are indicated by the "no-change" line. Although this line merely marks the intersection of observed and predicted fuel moistures of like value, it also approximates the average relation between fuel-stick moisture content and relative humidity at 4:30 p. m. Use of this relation to detect incorrect fuel-moisture values is explained later.

The two aids for morning use (figs. 2 and 3) are composites based on less uniform conditions than the afternoon aid. This greater variation is due to local exposure differences affecting nighttime fuel-moisture recovery, particularly through cold air drainage and outgoing radiation. This variation is reduced as much as possible by recognizing two groups with similar exposure characteristics: the peak and the valley stations. The remaining station-to-station differences within each group may require still further refinement for some stations. Therefore, the morning aids must be considered approximate until verified for each station or adjusted as necessary.

^{1/} Cramer, Owen P. Methods for estimating future burning index from fire-weather forecasts and local weather observations. U.S. Forest Serv. Pac. NW. Forest & Range Expt. Sta., 25 pp. 1949. (Processed.)

**AFTERNOON COMPOSITE AID
FOR PREDICTING TOMORROW'S 4:30 P.M. FUEL MOISTURE**



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Figure 1. --Fuel-moisture aid for afternoon use for all stations.

**MORNING PEAK-STATION AID
FOR PREDICTING TODAY'S 4:30 P.M. FUEL MOISTURE**

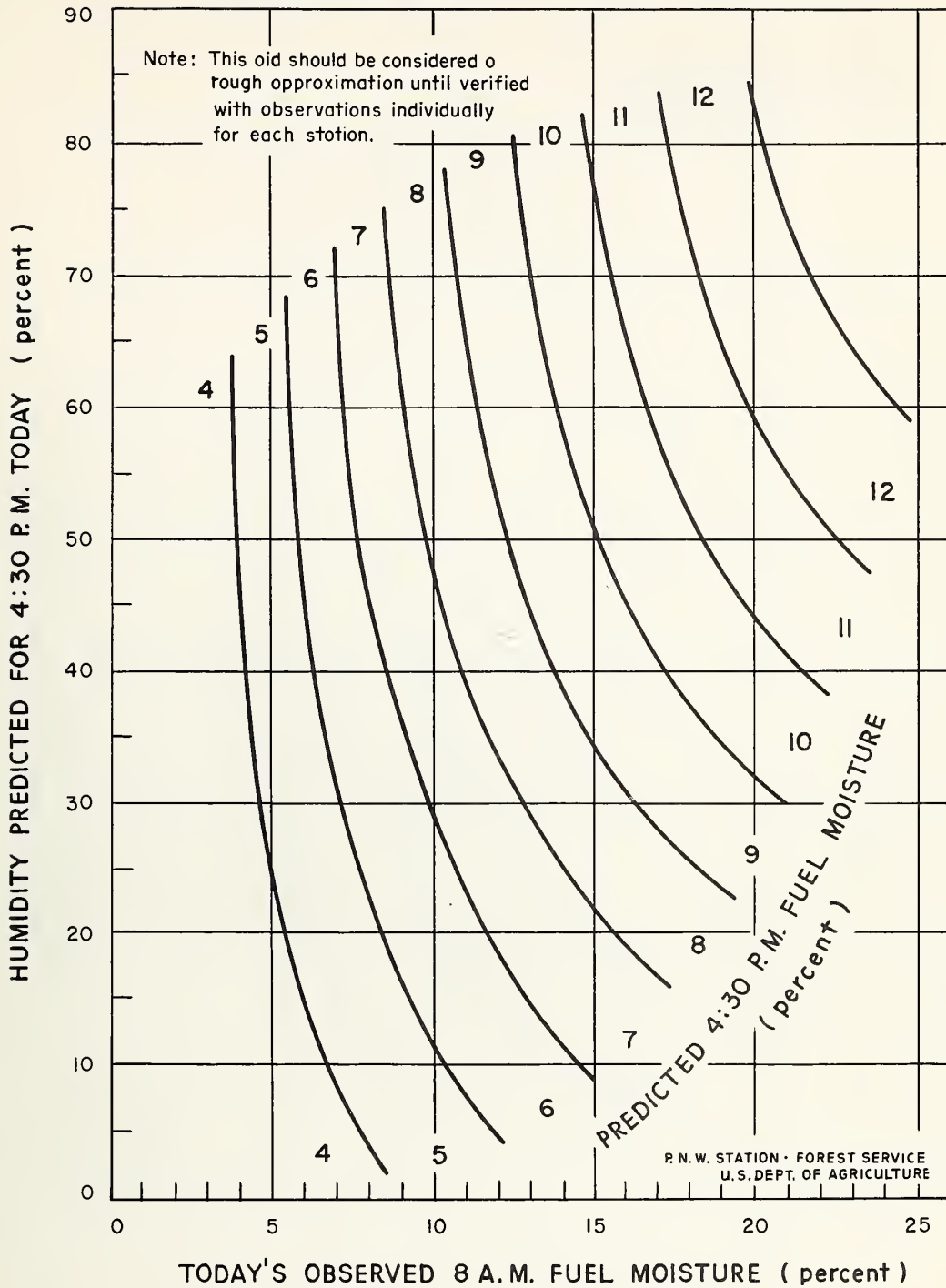


Figure 2. -- Fuel-moisture aid for morning use for peak stations.

**MORNING VALLEY-STATION AID
FOR PREDICTING TODAY'S 8 A.M. FUEL MOISTURE**

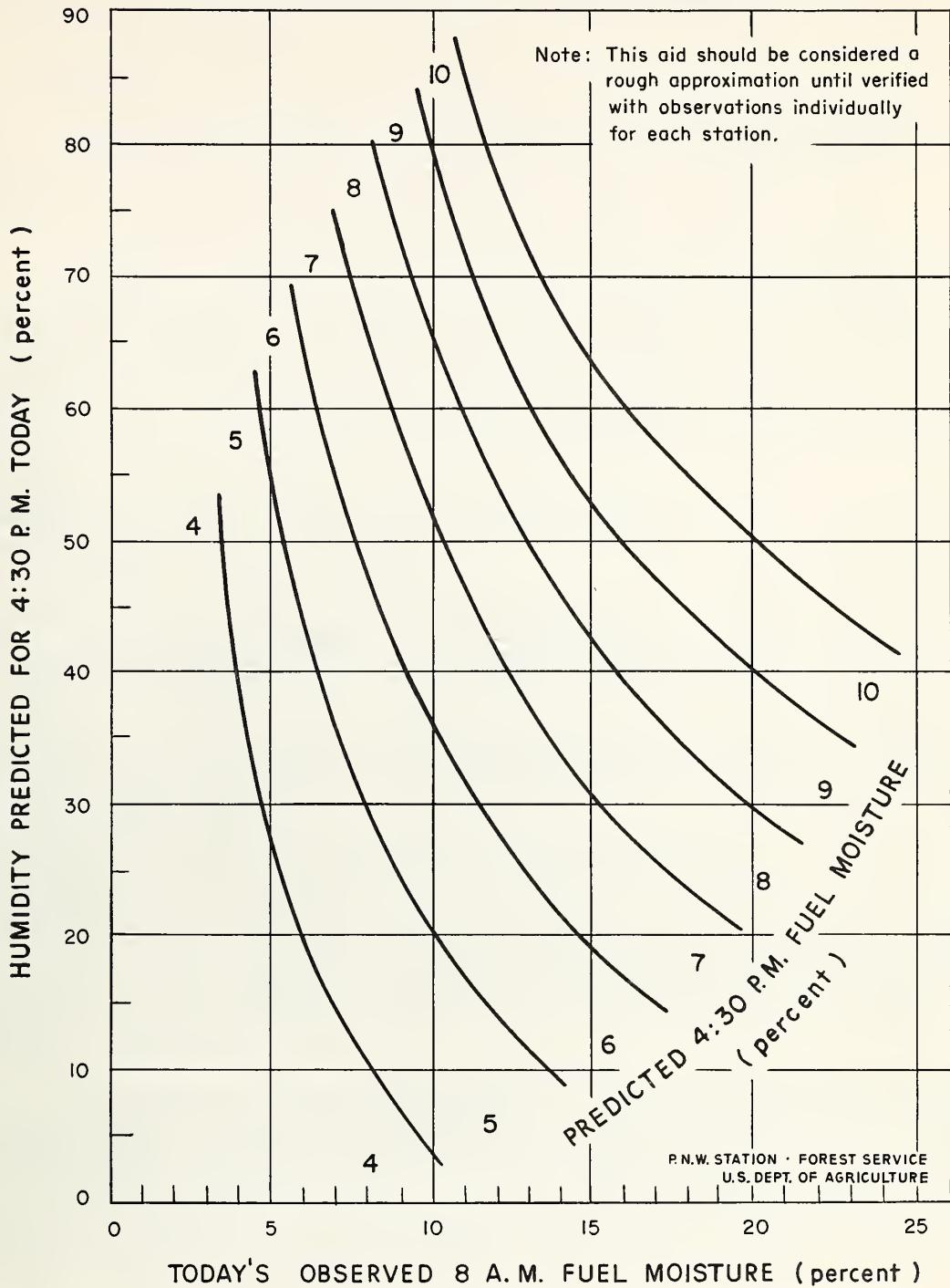


Figure 3. -- Fuel-moisture aid for morning use for valley stations.

PROCEDURE FOR USING AIDS

To Estimate Tomorrow's 4:30 p.m. Fuel Moisture

When. -- 4:30 p.m. or later.

Information needed. -- (1) Today's 4:30 p.m. fuel moisture; (2) prediction of tomorrow's 4:30 p.m. relative humidity for the station.

How. -- The chart (fig. 1) shows zones of "Predicted 4:30 p.m. Fuel Moisture." The zone that includes the intersection of today's fuel moisture and the predicted relative humidity is the predicted fuel moisture. For example, with a predicted humidity of 32 percent and a current fuel moisture of 8, the predicted fuel moisture is 7. Adjustment for special predicted weather conditions is described later.

To Estimate Today's 4:30 p.m. Fuel Moisture

When. -- 8 a.m. or later.

Information needed. -- (1) Current 8 a.m. fuel moisture; (2) prediction of today's 4:30 p.m. relative humidity for the station.

How. -- Same as for estimating tomorrow's 4:30 p.m. fuel moisture. Separate charts are used for peak stations (fig. 2) and valley stations (fig. 3).

To Adjust Estimates for Special Predicted Weather

The aids are based on mostly clear weather, no precipitation, and usual summer 24-hour variation of humidity, temperature, and wind. Aid values therefore require adjustment for certain other weather conditions.

Estimates with rain predicted. -- The relation between rainfall amount and 4:30 p.m. fuel moisture is complicated by differences in intensity and duration of the rain and variation in drying conditions after the rain and before 4:30 p.m. A further difficulty is the uncertainty in predictions of precipitation. For these reasons, forecasts of rain should be handled as follows:

1. Scattered or local showers: use aid with no adjustment.

2. Intermittent light rain: predict a 4:30 p.m. fuel moisture of either 11 or 4 higher than the previous day, whichever is higher.
3. Occasional rain or showers: predict a 4:30 p.m. fuel moisture of 13 to 15.
4. Rain: predict a 4:30 p.m. fuel moisture of 16 to 25.

Estimates with unusual variation predicted for humidity, temperature, and wind. --Suggested adjustments for some special predicted conditions are as follows:

A. Aid value too high--subtract one from the routine estimate

1. Temperature more than 15° above normal.
2. Night or morning humidity substantially lower than usual for the predicted afternoon minimum: for example, during dry east winds.
3. Night cloudiness or night windiness that prevents dew formation (afternoon estimates only).

B. Aid value too low--add one to the routine estimate

1. Temperature more than 15° below normal.
2. Night or morning humidity substantially higher than usual for the predicted afternoon minimum: for example, with a change during the afternoon to drier conditions.
3. Cloudy during the day.
4. Fog or heavier-than-usual dew (afternoon estimates only).

To Estimate Fuel Moisture for Unmanned Stations

Fuel moisture for an unmanned station can be roughly predicted with the aids by first approximating fuel moisture at the most recent 4:30 p.m. observation time (fig. 4). This may be done as follows:

Information needed. --The approximate 4:30 p.m. relative humidity for 2 successive days. (Estimate from nearby stations, if available, or from forecasts.)

FUEL MOISTURE APPROXIMATOR

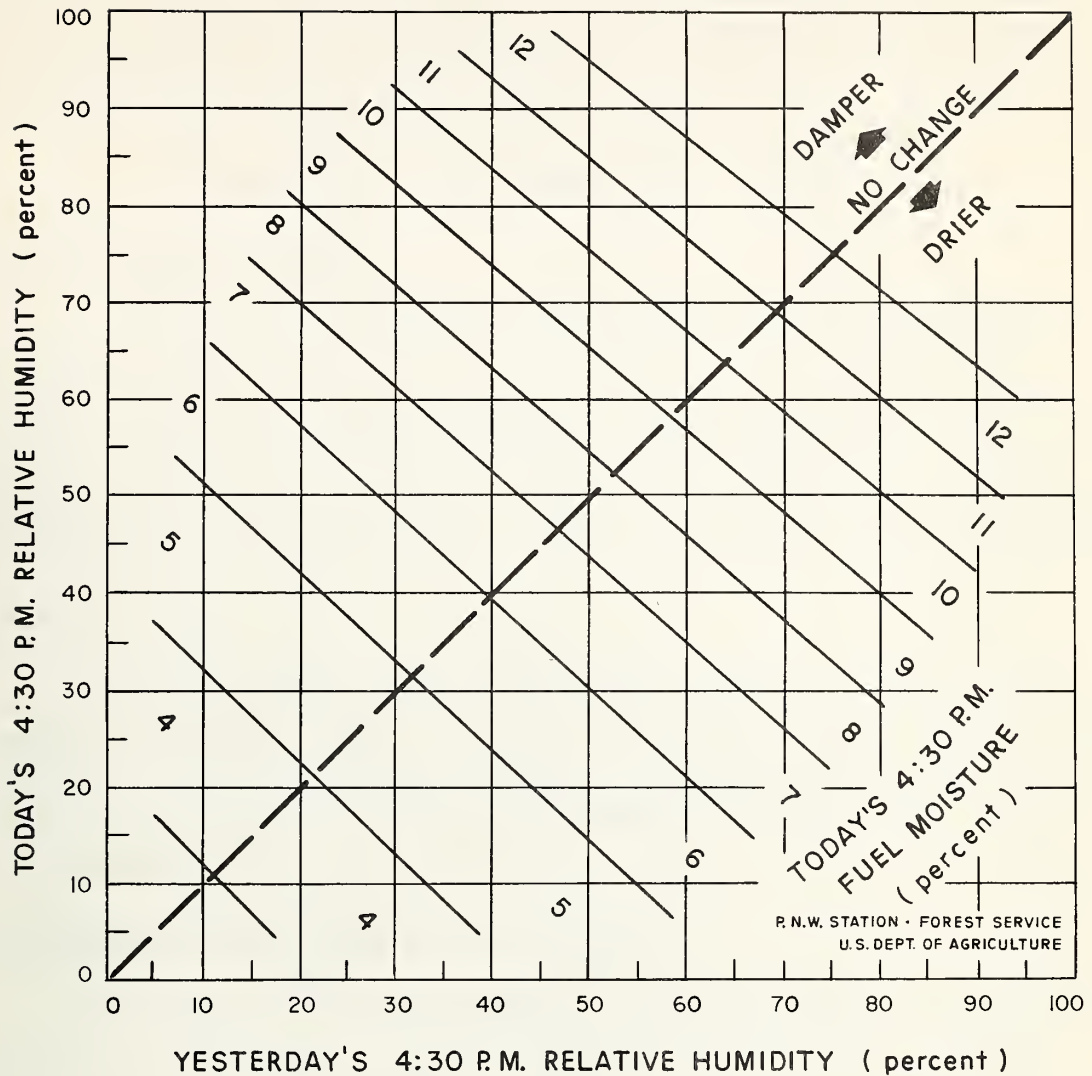


Figure 4. -- Aid for approximating current fuel moisture for localities where no fuel moisture observations are available but for which 4:30 p.m. relative humidities can be estimated.

How. -- The chart shows zones of "Today's 4:30 p.m. Fuel Moisture." The zone that includes the intersection of yesterday's and today's 4:30 p.m. relative humidities is today's approximated fuel moisture. Predicted fuel moisture can be obtained from the afternoon fuel-moisture aid using today's approximated 4:30 p.m. fuel moisture and predicted humidity. Usual adjustments must be made for special predicted weather.

INCORRECT FUEL-MOISTURE VALUES

Effect of Station Exposure

Fuel-moisture-indicator sticks are sensitive to variations in sheltering from sun, wind, and outgoing radiation. To minimize station-to-station differences in exposure, the sticks must be fully exposed in the open. Where sticks are not fully exposed, as in a partially forested area, the aids will not predict moisture accurately. Where exposure is not complete, fuel sticks should be relocated with full exposure before any attempt is made to use the fuel-moisture aids.

Effect of Season

Because of shorter days and lower angle of the sun in winter and fall, moisture predictions during those seasons may require additional correction. Hence, higher fuel-moisture values than the aids indicate can be expected before March 21 and after September 21. The amount of adjustment will have to be determined by experience for each station.

Detecting Incorrect Fuel-Moisture Values

The afternoon fuel-moisture aid may be used to check values that appear out of line. An error may have been caused by faulty scale readings or by erosion of the fuel sticks. Erosion of sticks causes low moisture estimates and this error increases as the season progresses. At the end of the season, sticks at a station where heavy dew occurs frequently during the summer may give readings as much as three points low.^{4/}

^{4/} Morris, William G. Effect of weathering on accuracy of fuel-moisture-indicator sticks in the Pacific Northwest. U. S. Forest Serv. Pac. NW. Forest & Range Expt. Sta. Res. Note 171, 6 pp. 1959. (Processed.)

Error in observed fuel-moisture value is most readily detected during periods of little day-to-day change. The approximate error is the difference between observed 4:30 p.m. moisture and the fuel moisture indicated by the intersection of observed 4:30 p.m. humidity and the "no-change" line. For example, during a period of normal fire-season weather with little day-to-day change, an observed 4:30 p.m. humidity of 37 percent would give a predicted fuel moisture of 6. The observed fuel moisture should be within one point of 6.

STATION VERIFICATION OF MORNING FUEL-MOISTURE AIDS

Because of variation between station exposures, both morning aids must be verified for each station to determine if they need to be adjusted. Verification of the afternoon aid is not necessary because variation at this time of day is slight. Verification of morning aids for any station may be based either on past observations (not more than 5 years old) or on current observations as they become available. At least 2 years' record will usually be necessary.

Verification is a comparison of the mean curves of the given aid with actual observations for a particular station. The observations are plotted to show the 4:30 p.m. fuel moisture produced by the day's drying conditions (measured by the 4:30 p.m. humidity) operating on the nighttime accumulated moisture (indicated by the 8 a.m. fuel moisture). This is the same method that was used to prepare the composite aids.

To verify a morning aid, observed 4:30 p.m. fuel moistures are plotted on a separate worksheet (overlay) at the intersection of 8 a.m. fuel moisture and the observed 4:30 p.m. humidity for the same day. Rainy days and obviously out-of-line observations are omitted. Special weather conditions that affect fuel moisture (page 9) are identified on the worksheet.

When sufficient data have been plotted to show the pattern of unit zones of 4:30 p.m. fuel moisture, lines are drawn to separate zones of different average values (fig. 5). Within each band there should be a balance between higher-than-band-value and lower-than-band-value figures. Values which are different because of unusual conditions should be ignored. Final bands will be similar to those on the aid being verified, but may differ in spacing and orientation

VERIFICATION OF MORNING VALLEY-STATION FUEL-MOISTURE AID

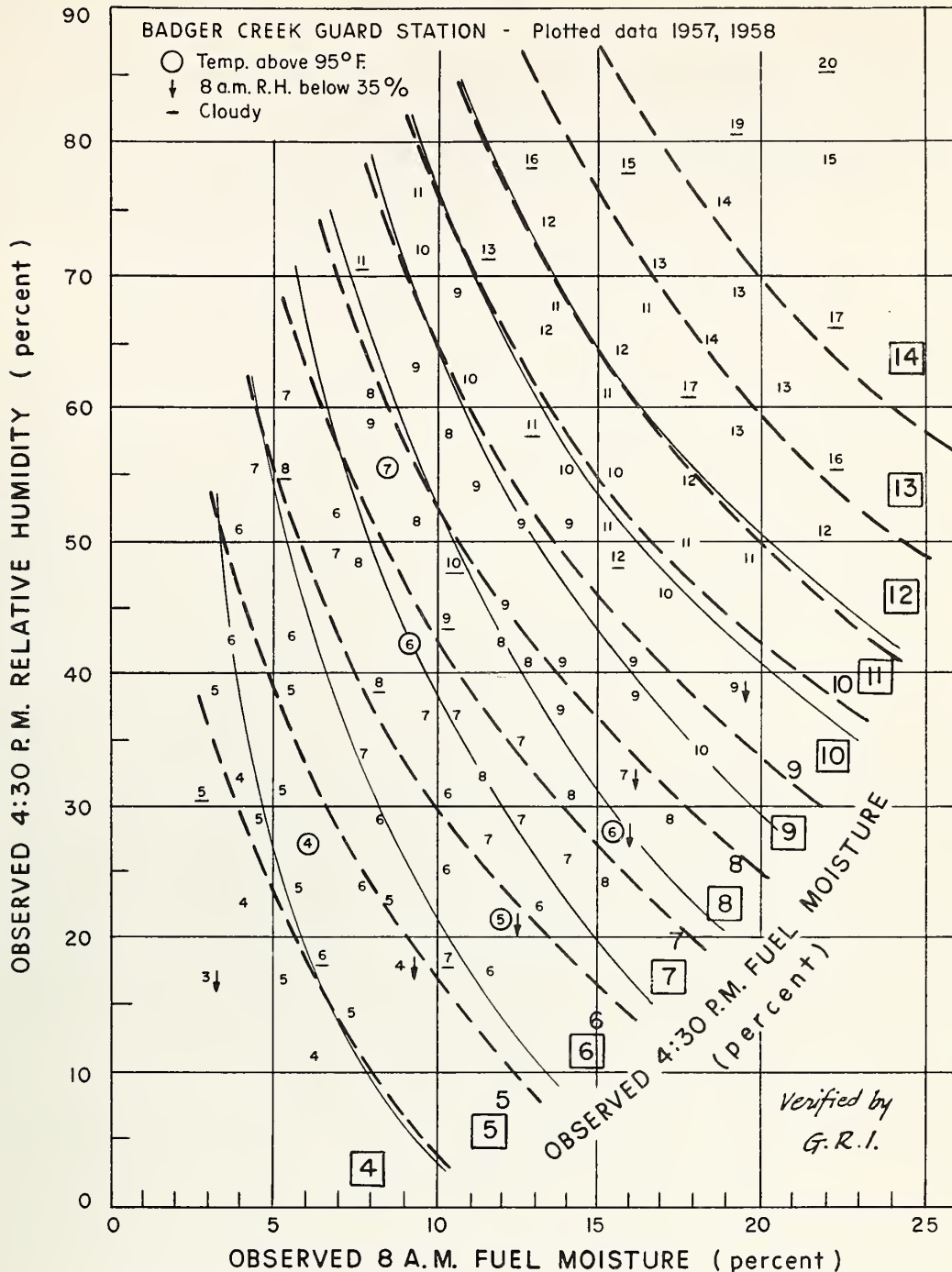


Figure 5. -- Verification worksheet, showing revision of a morning valley-station fuel-moisture aid. Light lines are from the morning aid for valley stations. Heavier, dashed lines delineate 4:30 p.m. fuel moisture for this particular station. Because of the variation shown, the aid for this station will be based on the revised lines.

from one station to another. Curves separating bands of unit value should be smooth and of graded spacing.

If the fuel-moisture bands on the verification chart are nearly identical to those on the aid, the aid is correct for use for the particular station. If, on the other hand, there is a difference of one-half point or more in any part of the chart, the revised curves should be used for this particular station.

