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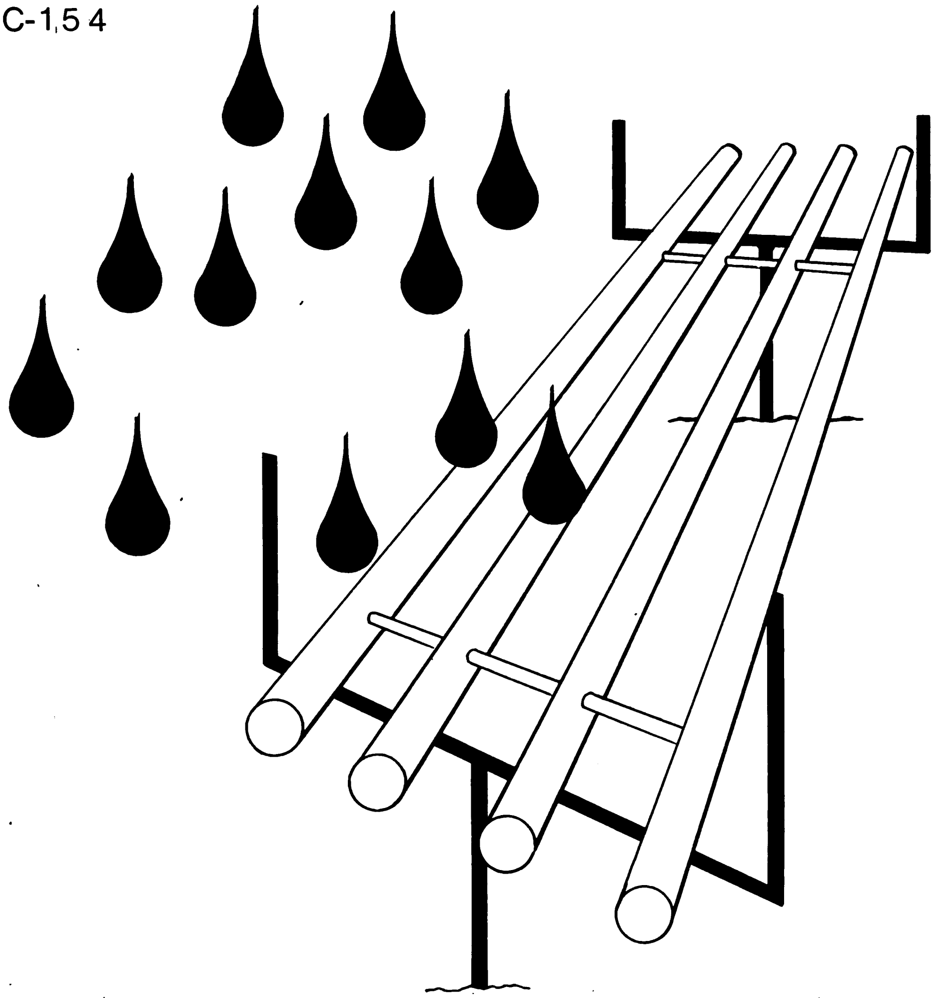

WEATHERING EFFECTS on fuel MOISTURE STICKS: corrections and recommendations.

DONALD A. HAINES AND JOHN S. FROST

NORTH CENTRAL FOREST EXPERIMENT STATION
FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

North Central Forest Experiment Station
John H. Ohman, Director
Forest Service—U.S. Department of Agriculture
1992 Folwell Avenue
St. Paul, Minnesota 55108

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WEATHERING EFFECTS ON FUEL MOISTURE STICKS: CORRECTIONS AND RECOMMENDATIONS

Donald A. Haines, *Principal Research Meteorologist*
and **John S. Frost,** *Meteorological Technician*
East Lansing, Michigan

APPLICATION

The National Fire-Danger Rating System (NFDRS) (Deeming *et al.* 1977) and other systems require measurement of fuel moisture to evaluate potential fire behavior and fire danger. Currently, ½-inch diameter, 100 gram, ponderosa pine dowels are used in the NFDRS to measure fuel moisture in the 10-hour timelag class. We found that the magnitude of moisture content error increases as these sticks weather.

HOW TO CORRECT MOISTURE CONTENT OBSERVATIONS

You can correct moisture content readings of ½-inch, 100 gram, ponderosa pine dowels exposed to the atmosphere at the usual 10-inch height above the ground as follows: (1) Weigh the stick and observe its moisture content; (2) Find the observed moisture content along the horizontal axis of figure 1: (3) Extend a line vertically from this axis to the line on the graph that corresponds to the number of months that the stick has been exposed (fig. 1); and (4) Extend a line horizontally to the vertical axis and read the corrected value.

RECOMMENDATIONS FOR USE OF FUEL MOISTURE STICKS IN NFDRS

Uncorrected readings of moisture content in fuel sticks that have weathered for a month or more can affect NFDRS final values, especially in the Energy Release Component (ERC) and the Burning Index (BI). In order to obtain more accurate results we recommend the following: (1) If you primarily require a grass or timber fuel model in your fire protection area, use a single stick throughout a fire season, unless the stick collects excessive dust, dirt, or other atmospheric pollutants. Observation corrections can be made by following the procedures listed above. (2) If you primarily require a brush or slash fuel model in your protection area, replace the stick once or twice during the fire season if wet or very humid conditions cause rapid weathering, or if the stick collects excessive dust, dirt, or other atmospheric pollutants. In all cases make corrections before observations are entered into the NFDRS. (3) Regardless of fuel model, replace sticks if they have checks, cracks, or damage by rodents or fungi. Also, discard all fuel moisture sticks after one season's use.

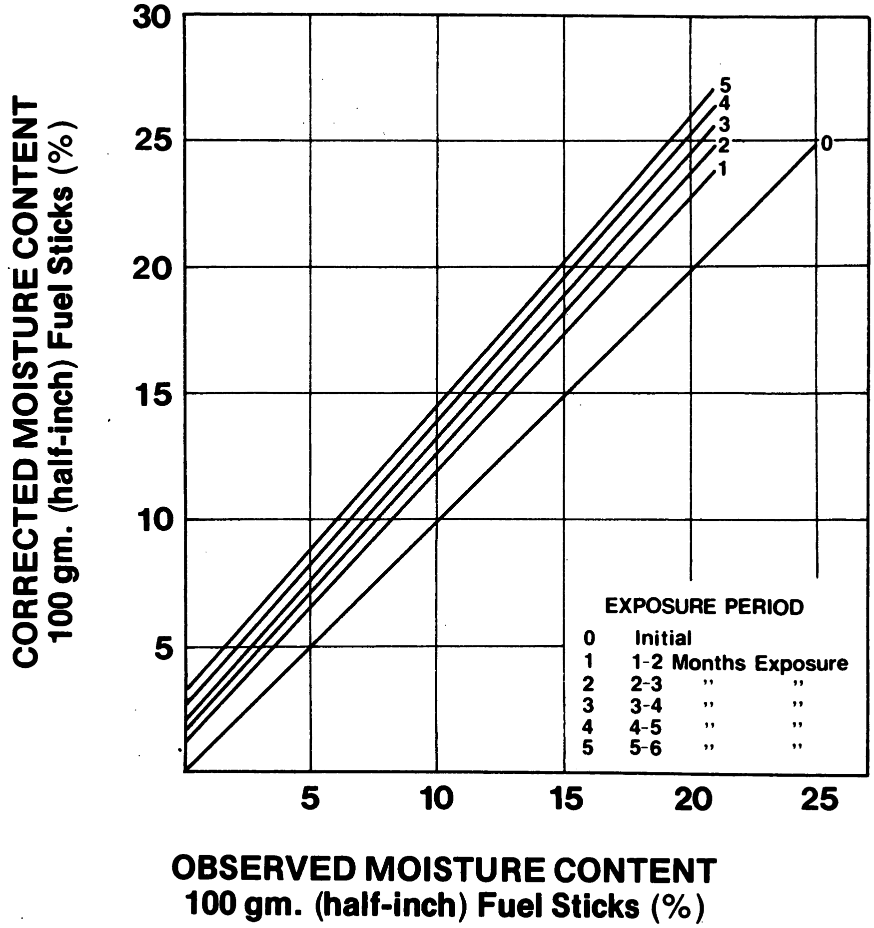

Figure 1.—*Chart for correcting the observed moisture content of fuel sticks [located 10 inches above the ground] according to the exposure period. To use, find stick weight reading at observation on the horizontal axis; extend a line vertically to the curve corresponding to the exposure period of the stick; extend a line horizontally to the vertical axis and read the corrected value.*

DOCUMENTATION

In the National Fire-Danger Rating System (NFDRS) dead fuels are delineated by their moisture timelag, as defined by Deeming *et al.* (1977), and grouped by 1-, 10-, 100-, and 1,000-hour classes. Values of the 10-hour class, usually determined by measurement of 100-gram (½-inch) fuel moisture sticks (Gisborne 1933), enter all components of the System but are especially important in computing the Energy Release Component (ERC) and Burning Index (BI). However, exposed fuel sticks used to determine fuel moisture are subject to processes that could induce measurement errors. These errors include dry-weight changes, timelag changes, and perhaps changes in the characteristic relation between equilibrium moisture content and temperature-relative humidity.

Weight loss induced by weathering of basswood slats used as 1-hour fuel moisture analogues in earlier Danger Systems received much attention from both operational and research personnel. As a result, suppliers included a time-weight correction card with each basswood analogue (Nelson 1965). No such elaborate precautions were devised for the presently used ½-inch ponderosa pine dowels. Thus, it became necessary to determine the rate of change of these wooden fuel moisture analogues in relation to their environment and to develop weathering corrections for them.

METHODS

From May 1 to November 1, 1975, standard 100-gram wooden dowel sets were exposed over a natural litter fuel bed located in East Lansing, Michigan. At the beginning of this period four sets of sticks were exposed, two in direct contact with the litter and two on wire racks at the standard 10-inch height. Four additional sets, two on the racks and two on the ground, were sequentially exposed every 4 weeks. All sticks were of similar manufacture. Weights of all sticks and routine, supplementary weather data were taken daily at 1300 local standard time (l.s.t.). At the end of the 6-month period all sticks were ovendried and their weight loss recorded. Although there was discoloration of the wood in relation to the length of exposure, no checking, cracking, or exceptional fungal activity was evident.

ANALYSIS AND DISCUSSION

Weather

Principal weather factors affecting fuel-moisture during the exposure season are listed in table 1. Rain amounts were below average each month except for an extremely wet August. On the other hand, days with rain were near average over the course of the season. More importantly, almost every night had rain, dew, or both. The dew observations aren't complete for May and June, but available records indicate that these 2 months were equally wet. In a study of weathering effects on accuracy of fuel-moisture indicator sticks in the Pacific Northwest, Morris (1959) concluded that heavy dew, regardless of rain, caused the greatest weathering observed west of the Cascades. Therefore, the frequent dew-rain nights in the East Lansing area would also tend to increase the

Table 1.—*Summarized weather records, May to October 1975 for East Lansing, Michigan*

	Mean temperature: 30 years	Mean temperature: 1975	Precipitation amount: Mean	Precipitation amount: 1975	Days ≥ 0.01 inches precipitation: Mean	Days ≥ 0.01 inches precipitation: 1975	1975 Dew &/or rain nights[1]	Possible sunshine: Mean	Possible sunshine: 1975	1975 Relative humidity departure from average (hours): 0100	0700	1300	1900
	Degrees F		*Inches*		*Number*			*Percent*					
May	56.8	61.3	3.51	2.81	11	12	--	62	64	+13	+12	+ 3	+ 4
June	67.1	68.4	3.80	2.38	11	10	--	65	53	+ 8	+ 9	+ 8	+ 8
July	70.9	70.6	2.88	1.92	9	9	29	70	67	+ 6	+ 7	0	0
Aug	69.5	69.6	3.27	8.23	10	14	28	66	46	+ 5	+ 6	+10	+10
Sept	61.7	56.2	2.48	2.05	10	7	29	58	49	- 5	- 6	- 3	- 2
Oct	51.6	52.2	2.38	0.93	8	6	25	54	61	-11	- 9	-12	-11

[1]Includes all morning observations with dew of any amount on the Durderani Dew Gage.

weathering effect relative to many other regions of the country. Another important factor in the present study is the high humidity observed during the first 4 months of record. It may have caused a more intense weathering season.

References

Daily observations of fuel moisture were compared to two "references", one for ground sticks and one for elevated sticks. Reference sticks were defined as "the most recently exposed fuel moisture sticks", since these were assumed to give the most accurate and true value of fuel moisture conditions. All moisture values of dowels that had been exposed longer were taken as a departure from either the ground or the elevated reference. As additional sets of sticks were exposed every 4 weeks, they automatically became the new references. Because of the method of analysis (using references), departures could not be computed until after a second set of sticks was installed.

Ground-Exposed Fuel Moisture Sticks

Because weathering effects vary with current stick moisture content, daily readings of moisture content in the reference sticks were divided into six convenient groups covering 171 days that weather allowed observations as shown below:

Reference sticks	*Frequency of occurrence*	
Moisture content	*Ground-exposed*	*Elevated*
	-----(percent)-----	
6 to 7	13	
8 to 10	30	17
11 to 13	20	44
14 to 16	14	16
17 to 24	12	14
25+	11	9
	100	100

No ground-stick fuel moistures below 6 percent were observed for the references on any day during the period of record. Consequently we interpolated through the 0 to 6 percent moisture range during analysis. Because sticks weigh 100-grams, all weights are directly convertible to percent moisture.

Interestingly, the ovendry weights of the ground sticks (fig. 2) showed nearly the same weight loss at the end of the season as the elevated sticks (fig.3). However, at various time intervals over the exposure period there were distinct differences. Ground sticks displayed more erratic changes.

Through the first 2 to 3 months of exposure the ground fuel moisture groups were separated by weight loss. Differentiation and pattern identity of the ground groups were not distinct in the following months of exposure except for the 17 to 24 percent fuel moisture group. This would indicate that if ground-exposed sticks are used in the future, they should be replaced at 2- or 3-month intervals.

Elevated Fuel Moisture Sticks

These stick weights, also recorded at the daily observation, showed a lesser range of moisture contents than the ground-exposed sticks.

Weight loss, when sticks were ovendried, varied from almost 1 gram for sticks exposed for 1 month to over 3 grams for those exposed during the entire 6 months (fig. 3). Graphing of other fuel moisture groups showed a well delineated family of curves with the 8 to 10 percent fuel moisture group having the least departure from reference and the 17 to 24 percent group having the most. Unlike the ground stick fuel moisture groups, differentiation and pattern identity were not lost.

IMPLICATIONS

During ambient exposure, either at the standard 10-inch height or in contact with duff, wooden fuel moisture sticks lose weight. This loss is probably due to erosion of water solubles, fungal activity, and perhaps sublimation of woody materials. Data show that the resultant error increases with the length of stick exposure and higher average moisture content. This error is consistently negative; i.e., old sticks indicate a lower 10-hour moisture content than new sticks. During analysis of these data we emphasized time change in stick moisture content. A discussion of this change as applied to select NFDRS fuel models is given in this section.

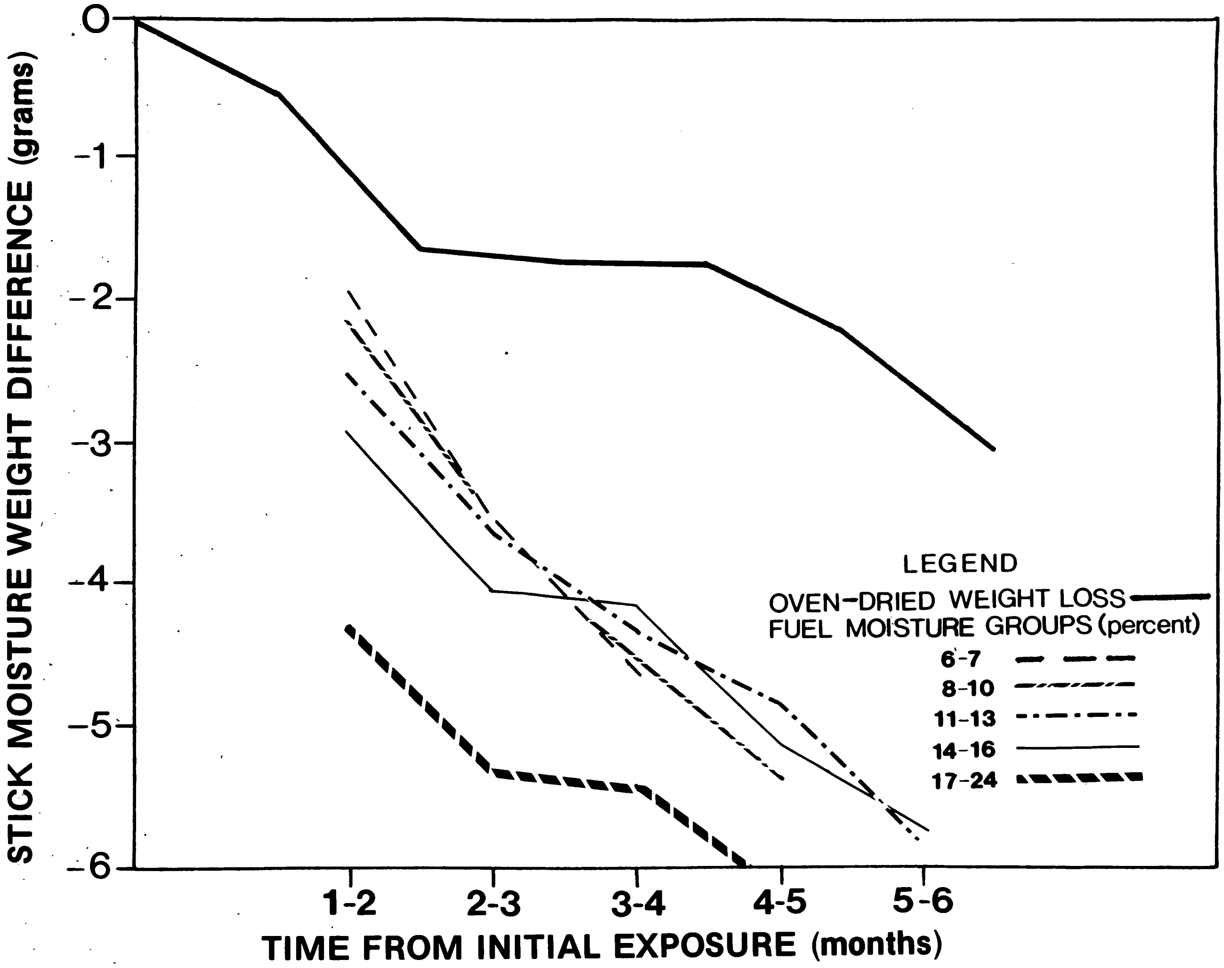

Figure 2.—*Ground stick weight loss with exposure time. Weight reading differences are relative to weight readings of the most recently exposed sticks [the reference]. Ovendried weight was determined by gravimetric analysis, 105 C for 24 hours.*

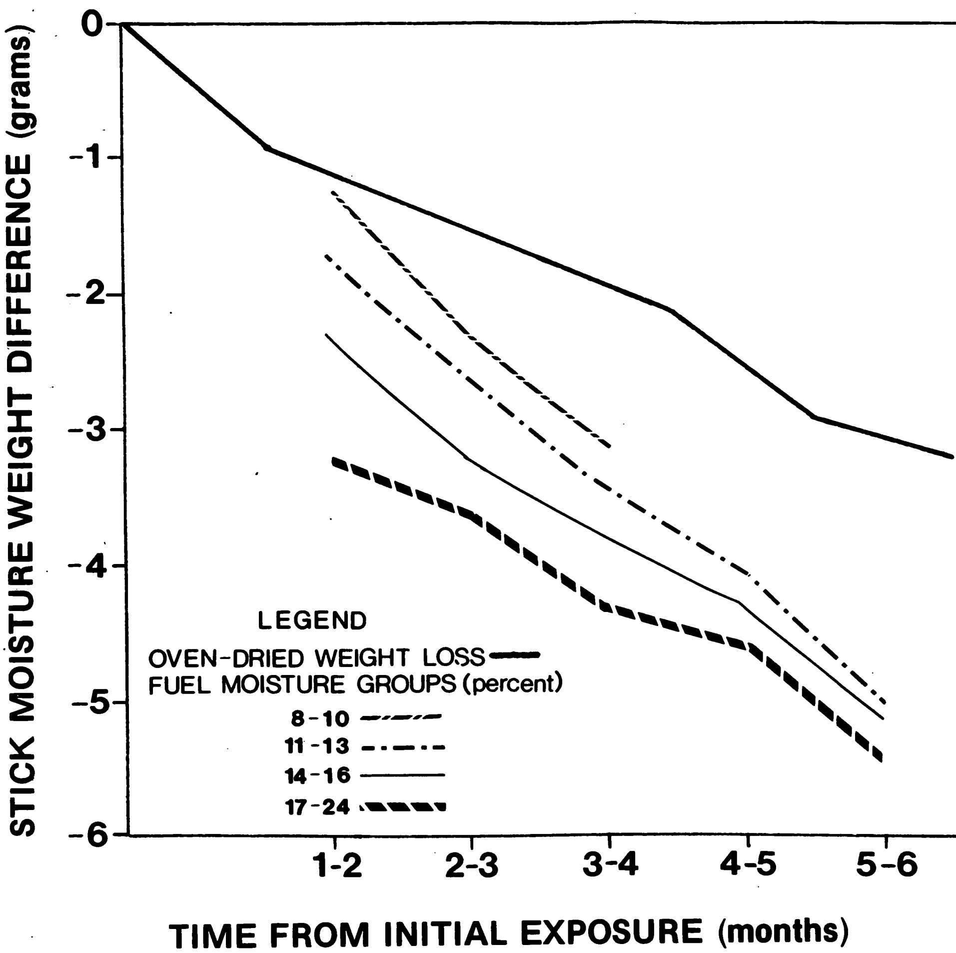

Figure 3.—*Elevated stick weight loss with exposure time. Weight reading differences are relative to weight readings of the latest exposed sticks* [*the reference*].

Previous studies of stick weight change with time considered only ovendry weight loss (Morris 1959). Therefore, it is difficult to estimate the differences from our moisture group values that one might expect in other regions of the country. Our ovendry weights showed an average loss of 0.53 gram per month over the season. Morris found the following average monthly losses in areas of the Northwest: Coastal strip of Oregon, 0.67 gram; west slope of the Cascades, 0.45 gram; east slope of the Cascades, 0.35 gram; Ochoco Mountain and northeast Oregon, 0.27 gram.

As a first approximation we believe our data are fairly representative for the country. Treating the elevated stick departures from reference as linear trends produce a graph of observed versus corrected weights (fig.1). In areas with moist climates, such as the coastal mountains of the Pacific Northwest, the departures between observed and actual should be somewhat greater than shown. In areas with dry climates, such as the Southwest, they will be somewhat less.

Because moisture values of elevated fuel sticks are an integral part of the NFDRS, the use of uncorrected readins from aged sticks could affect the final values of the System, especially the ERC and BI. To show the magnitude of errors in ERC and BI caused by different weathering times of sticks, representative values were assigned to four fuel models (tables 2 and 3).

Table 2.—*Effect of exposure of the 100-gm fuel moisture sticks on the Energy Release Component values of the NFDRS, using four fuel models*[1]

Fuel model	Time of exposure (months) 0	1-2	2-3	3-4	4-5	5-6
B	25	27	30	33	35	39
G	42	42	43	43	44	44
H	21	22	22	23	23	24
J	144	152	156	160	165	174

[1]For this illustration, the following representative values were assigned: fine fuel moisture, 6 percent; reference 10-hour class, 9 percent; 100-hour class, 12 percent; 1,000-hour class, 15 percent.

Table 3.—*Effect of exposure of the 100-gm fuel moisture sticks on the Burning Index values of the NFDRS, using four fuel models*[1]

Fuel model	Time of exposure (months) 0	1-2	2-3	3-4	4-5	5-6
B	31	32	34	35	37	38
G	44	44	44	45	45	45
H	17	18	18	18	18	18
J	149	159	161	163	166	177

[1]The constants assigned are the same as those in table 2, plus: wind speed, 20 mph; slope, class I; herbaceous vegetation, zero percent green.

The magnitude, and therefore the importance, of weathering error depends on the type of fuel model used because the ratio of the 10-hour class fuel loading to total loading varies with model (Deeming *et al.* 1977). Timber types are not heavily weighted toward 10-hour timelag fuels. For example, in model G the ratio of 10-hour class fuel loading to total loading is 9 percent, while the loading ratio of models I,J,K, (slash) are 26 or 27 percent.

Stick weathering caused relatively small changes with time in the ERC and BI for timber fuels (models G and H): there is a difference of 2 or 3 units in the ERC and 1 unit in the BI over the fire season (tables 2 and 3). On the other hand, there is an ERC change of 14 and a BI change of 7 for brush-type fuel model B and corresponding changes of 30 and 28 units for slash-type fuel model J. These data lead to the recommendations given in the Application section.

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