

THE WOOD CYLINDER METHOD OF MEASURING FOREST INFLAMMABILITY

By H. T. GISBORNE

Northern Rocky Mountain Forest and Range Experiment Station

The wood cylinder method of measuring forest inflammability is now being tested throughout the West and Northwest. It has been adopted at over forty stations in Region 1. Heretofore, there has been no detailed description of this method published for general information.

THE best test of the practicability of any new method or device is the actual trial by numerous users who are interested only in the end product, and who have no special interest in the means employed to reach that end. Such users are not inclined to give the new method the advantage of any doubts, and they are particularly critical of the method or device insofar as it may make more work for them. If, after such a trial, these users extend the use of the new method, of their own volition, or better yet if they do this at some expense to themselves, the verdict is most conclusive.

The wood cylinder method of measuring forest inflammability has been in the course of development at the Northern Rocky Mountain Forest & Range Experiment Station since 1924, but it was not until 1932 that a field trial was made up on a scale sufficient to warrant any decision concerning its practical value. During the 1932 fire season, however, wood cylinders were used at 14 stations on as many different national forests or national parks in Regions 1 and 4 of the Forest Service. Orders for 18 additional stations to be in operation before the opening of the 1933 fire season constitute the verdict from this trial. A detailed description of this method, therefore, seems to be desirable.

The basic reason for measuring forest inflammability is, of course, to determine that factor of fire danger more accurately

than it can be estimated even by experienced men. The duff hygrometer method of making such measurements was early proposed for this use (1) and has been tested in the Northern Rocky Mountain Region since 1923. The hygrometer method alone has not, however, appealed to field men sufficiently to create a very large demand for these instruments. Perhaps this has been due to the somewhat indirect character of the measurement, or it may be that the duff itself is not generally conceded to be a really dangerous carrier of fire. Again, it may be that the fire danger meter was needed to demonstrate the need of such measurements and that by the time the meter was evolved in 1931-32 the wood cylinders had proved their practicability for this purpose. Perhaps the cylinders are now being chosen in preference to the duff hygrometer partly because of the greater apparent simplicity of the cylinders.

In any event, the fire danger meter appears to have been the key to more accurate rating of fire danger which opened the door to measurements instead of estimates of forest inflammability. This meter integrates six of the more important factors of fire danger including 1. Season of the year, 2. Activity of lightning or people, 3. Visibility distance, 4. Wind velocity, 5. Minimum relative humidity, and 6. Fuel moisture content. The end product of the meter is a rating of fire danger into one of seven classes,

"I" indicating no men needed for current fire control, and "VII" indicating the need of every conceivable type of action that can be economically justified by the resources at stake.

The distinctions in fuel moisture shown by this meter as significant are small differences of only 3 per cent to 6 per cent in the amount of moisture. Proved as significant by numerous field tests of inflammability, and by comparison with fire behavior over a period of several years at several stations, these small differences cannot be detected consistently and identified accurately even by experienced forest officers. They can be measured by either the duff hygrometer or the wood cylinders.

As soon as field men attempted to rate fire danger by use of the danger meter they recognized the value of accurate measurements of fuel moisture. The essential function of these measurements was made especially striking on those forests where one or more inflammability stations was in actual operation and where the measured ratings for one ranger district were therefore contrasted with estimates attempted for neighboring districts. The contrast demonstrated the value of the measurements and produced the present demand for many additional sets of wood cylinders and a few duff hygrometers.

Called "wood cylinders" because the pieces of wood are made perfectly cylindrical, these samples are intended to represent the small branchwood that is such a common fuel of forest fires. Three sizes are used at field stations in the Northern Rocky Mountain Region; half inch, one inch, and two inch diameter, all 18 inches long. The material used is ponderosa pine sapwood and the sticks are exposed on wire brackets so that they lie level, ten inches above the ground, with the long axis extending north and south. Each cylinder carries a light

aluminum tag to identify it by number and this tagged end is always placed toward the north with the number right side up. This insures a constant and comparable exposure the same as if the stick lay in a natural position and were not disturbed from day to day.

As the oven dry weight of each cylinder has been previously determined, all that is needed to ascertain the amount of moisture present is a simple weighing on an inexpensive set of balances. The surplus above the oven dry weight then represents the moisture in the wood, and its determination as a percentage of the dry weight is readily made by reference to a single-line chart specially prepared for each cylinder. By this method the daily determination of the moisture content of these samples is easily made, and with far more accuracy than is possible by estimate, even by a most experienced forest officer.

In order to provide comparable measurements representing various stations, exposed to different weather, it is necessary, of course, that the many cylinders be compared or calibrated somehow. Otherwise a report of 10 per cent moisture content from one station, and 6 per cent from another, could not be accepted as proof of a real difference in dryness and inflammability. As a first step to insure dependable comparability the samples are manufactured so that all are perfect cylinders. The use of natural branchwood samples was tried, but the effects of taper, bark, checks, stubs of branches, presence of decay, etc., made these samples less accurate and actually more costly than the manufacture of perfect cylinders truly comparable as to size and shape.

As small branchwood, of less than two or three inches diameter, is all sapwood, these cylinders have been made to resemble this natural feature. And this has been found to be important, as the

presence of even a small amount of heartwood shows an appreciable influence on the hygroscopicity of the sample. The length of the cylinders has been held at 18 inches because this gives sufficient weight to permit accurate measurements of one per cent moisture content in a half inch diameter sample, and does not result in excessive weight of a two inch sample, for the type of scales or balances used. Of the three sizes now being used the half inch is intended to represent the more rapid drying material and the two inch to indicate the rate of change when the core is of sufficient volume to exert an effect on the surface. There is no intention of having these cylinders represent any *exact* size of natural branchwood, the purpose is instead to have them typical of small and moderate sized natural material, approximately one-half inch and approximately two inches in diameter.

The one inch sample perhaps could be eliminated from use at field stations, but it serves so well as a check on the accuracy of weighing the other two that its use is being continued at present. Cylinders of one-and-one-half inch diameter have been tried experimentally but their value appears to lie principally in accumulating a record for later study of moisture gradient by increasing size classes. Diameters of more than two inches have not been used, primarily because it is the moisture content of the outer surface of wood that controls current inflammability, and with larger sizes the ratio of surface to volume decreases markedly. Furthermore, it is very difficult and expensive to obtain ponderosa pine cylinders of more than two inches diameter that have no heartwood.

At least one other investigator of fuel moisture has questioned the effect of end grain exposed at both ends of each cylinder. He has suggested coating these ends with paint or some waterproofing to elim-

inate evaporation from the end grain where it is admittedly the most rapid. The reason for the question and the suggestion is the contention that most of the natural dead branchwood lying on the ground in the forest is in lengths longer than 18 inches and therefore changes moisture content only by surface absorption and evaporation which is a less rapid process than via end grain. The effect of exposed end grain consequently would be to make the sample change moisture content somewhat more rapidly than would be the case if the stick were three feet long instead of 18 inches.

Coating the ends of the cylinders perhaps would be important if the purpose of the work were to represent a precise diameter class of fuel with great accuracy. But that is not the principal objective, and in the opinion of the writer there are several reasons why exact representation of a precise diameter class should be considered as of very minor importance. First is the fact that the few samples that can be operated conveniently, even if six or eight were used instead of three, can never represent exactly all diameters and lengths of natural dead branchwood. The best that can be done economically, and all that is needed for practical application, is some standard that is reasonably typical of existing fuels. The important and useful purpose of this wood cylinder method is to provide a method of measurement that can be applied easily and give dependable, comparable results at numerous stations. Whether the wood samples represent material exactly 0.50 inch in diameter or 0.55 inch or 0.40 inch is of no practical significance.

Two features of far more importance in the use of this method are (1) the elimination of erratic samples which have a greater or much lesser hygroscopicity than the average, and (2) the degree of exposure of the cylinders to the weather,

including the effect of shade of tree crowns and the effect of local weather influences such as lakes, marshes, heat reflecting canyon walls, etc. The writer's experience with the wood cylinder method of measuring forest inflammability, during the past six years, has shown that these factors are decidedly important if accurate comparisons are desired for various stations and for one fire season against another.

In the calibration or standardization of these wood cylinders the present practice at the Northern Rocky Mountain Station is to expose the entire supply of new samples—some 230—side by side with the same conditions of sunshine, air, and earth moisture, wind velocity, etc., affecting all cylinders. (Figure 1.) Moisture contents are determined periodically for each cylinder over a period including both very low moistures such as prevail in early August and high moisture contents such as occur after the fall rains and in the spring when the snow cover

melts and uncovers the cylinders. The records for all cylinders of a single size class are then plotted graphically so that a median line can be drawn for the period, including both high and low moisture contents. All cylinders not varying from this median by more than one half of one per cent above or one-half of one per cent below are then rated as acceptable.

By this comparison some samples are usually found which consistently depart more than 1 per cent from the median, but which can be made to meet the standard by a small correction of the oven dry weight. When this is found to be the case the correction is made and that sample is then accepted. A few specimens, however, exhibit erratic tendencies of various kinds and such degree that no correction is possible. If these samples were used for practical field measurements the moisture contents would at times indicate erroneously the degree of inflammability. Such specimens are therefore destroyed or eliminated from this use. Hence the samples that have passed this exposure test can be distributed to widely separated stations, and if they are not injured in transit or daily use they can be depended upon to produce comparable measurements.

The second factor of fundamental importance in the use of this method of measuring inflammability is the degree of exposure to the weather elements. Twice daily measurements at full sun, half shade, and full shade stations at Priest River for three fire seasons have shown that these different conditions produce decidedly different moisture contents in the wood cylinders. Likewise a comparison of records from 14 wood cylinder stations in various parts of the region indicates that some of the differences may be due to the local exposure of the cylinders including the effects of lakes, marshes, reflecting canyon walls, as well



Fig. 1.—The exposure of 230 wood cylinders to eliminate erratic samples and thereby insure comparable measurements.

as the shade of neighboring trees.

Naturally, the effects of lakes, marshes, etc., produce actual differences in fire danger by contributing to maintain a higher moisture content in all adjacent hygroscopic materials. But if this condition is recognized as restricted, and not applicable to a majority of the area for which measurements of inflammability are desired, then the wood cylinders are not properly located and the trouble is not with the method of measurement but is with the site. If, however, the station is located in an area practically covered by green timber, and the effect of this timber cover is indicated by records of somewhat higher moisture contents, then that is exactly what is desired. The essential feature is to expose the wood cylinders to local weather and topographic influences that are truly representative. Very often this is not simple, because the ranger station or other headquarters may by chance or past purpose be located advantageously for the personnel but not under site conditions that represent the surrounding district.

Even when the general site is typical of the district, extreme care also must be used in selecting the exact spot for exposing the cylinders. A few extra hours of shade, either from low vegetation, trees, or precipitous canyon walls will surely produce a slower rate of drying than will occur if the samples are exposed on a ridge top to the maximum possible hours of sunshine, wind, etc. Likewise tree crowns directly overhead will intercept an appreciable part of the precipitation and thereby prevent the cylinders from reaching the highest possible moisture contents, such as are actually attained by natural branchwood more fully exposed. The problem then is to select arbitrarily some standard degree of exposure and to maintain this standard at all stations.

At experimental centers, or at any sta-

tion where information is desired concerning the full range of moisture conditions, it is possible to expose cylinders in the full sun, half sun, and full shade. At the ordinary field stations, however, and especially in the preliminary stages of development of such a method, measurements at a single site are all that can be justified. Hence either one extreme or a gradation between extremes must be selected. In the Northern Rocky Mountain Region an exposure is selected possibly halfway between full sun and half shade, but always with the cylinders sufficiently removed from sheltering objects of any kind so that precipitation falling vertically or at any angle up to about 45° from the vertical will strike the samples. They are then placed so that they will be shaded from full solar insolation between approximately two o'clock to three o'clock in the afternoon in mid-July. Such an exposure produces moisture contents in the cylinders that represent not the extreme of either safety or danger but a condition not too far behind extreme danger to give ample warning.

The selection of such an exposure at numerous stations, in different topography and timber types, and at various elevations is not at all simple. At present nearly all of the exposures in this Region have been personally selected by the writer, with the studied purpose of having them as nearly alike as possible. Until a very detailed series of site measurements can be evolved and described this personal selection method appears to be the best guarantee of comparability of station records. Whether another forest protective organization would decide to use the present slightly less than full exposure site or to eliminate all shade and expose the cylinders in full sun would depend upon the desire to obtain measurements of average bad conditions or of the very worst.

In addition to these factors already

mentioned, any forest protective organization attempting to use this method should also appreciate the need of annual calibration, the desirability of using cylinders of the same age since manufacture, and the advantages and dangers in exposure throughout the winter. The need of annual calibration is especially apparent in the cylinders of half-inch diameter. Naturally there is some leaching, weathering, and possibly some decay taking place in all the cylinders when exposed continuously to the weather. While the loss in weight due to these conditions seldom amounts in one season to more than 1 per cent of the oven dry weight of two inch diameter stock, it has been found that the half inch cylinders may lose more weight than this in one year. Consequently, in present practice all the cylinders are redried and the oven dry weights redetermined after 12 to 18 months' exposure. Theoretically each oven drying effects the hygroscopicity of the wood fibers, but the amount of this effect does not appear to be material in this work.

The age class of the cylinders is another factor that has been found to be important if accurate comparisons of cylinders are desired. While this effect has not yet been studied in sufficient detail the data available indicate that all cylinders in use should have been exposed or used for the same length of time rather than attempting to compare results from some samples in use for the first season with others previously exposed throughout four or five seasons. Furthermore, after use for more than four seasons these cylinders lose enough sensitivity to warrant the manufacture of new ones.

At the Northern Rocky Mountain Station the cylinders are usually re-calibrated in October or November and then returned to their respective brackets for exposure throughout the winter. The purpose of this is to permit a measurement in the early spring showing the effects of

winter snows and spring rains in moistening the samples and thereby indicating whether or not the fire season will be delayed by the presence of much moisture in the core or center of this class of fuel. From the measurements of this kind, made to date, it appears that precipitation in the form of snow, including the snow blanket that may cover the cylinders for three months, has very little effect in raising the moisture content of these fuel samples. Fall and spring rains, when the temperature is above the freezing point, apparently are the important factors in wetting the fuels sufficiently to delay the opening of the fire season.

Experience in these winter exposures, with the cylinders under deep and often crusted snow, has shown that the samples should rest upon the ground rather than upon their bracket supports, in order to avoid serious marring or even breakage. After the snow has melted to uncover the sticks they should be replaced on their brackets to insure uniform exposure.]

The product of this method of measuring forest inflammability is illustrated by Figure 2 which shows graphically the record of half inch and two inch wood cylinder moisture at one of the actual field stations operated during the 1932 fire season. This figure shows the type of information obtained by the wood cylinder method of measuring forest inflammability. This record reveals the fact that on June 20, when the measurements were commenced, the two inch cylinder still retained (undoubtedly in the center core) an appreciable amount of moisture supply by spring rains. The half inch sample on the other hand was very nearly as dry and inflammable then as at any time during the entire fire season. Rains on July 3 and 4 raised the moisture contents of both samples temporarily. By July 9 and 10 they were practically as dry and inflammable as before the rains. The function of this method is obvious

in revealing such changes and in permitting a forest officer to be definite not only in his own knowledge, but also in his reporting of such conditions.

As a method of comparing one fire season with another these wood cylinders measure the peak of danger, as in Figure 2, by showing $8\frac{1}{2}$ per cent for the half inch cylinder on July 22 and August 5. No days are shown drier than this for 1932 which has been rated as a season of about average danger. In 1931, however, a very critical season, the half inch cylinder at this same station dried to less than $8\frac{1}{2}$ per cent on 33 days; and

reached an absolute minimum of $6\frac{1}{2}$ per cent on two days. This difference between $6\frac{1}{2}$ per cent and $8\frac{1}{2}$ per cent represents one of the reasons for the great difference in fire danger in 1931 as compared to 1932. The possibility of detecting and recording such differences more accurately than is possible by experienced estimate is the characteristic of practical value in this method.

REFERENCES

1. Gisborne, H. T. Measuring forest fire danger in northern Idaho. U. S. D. A. Misc. Publ. No. 29. October, 1928.

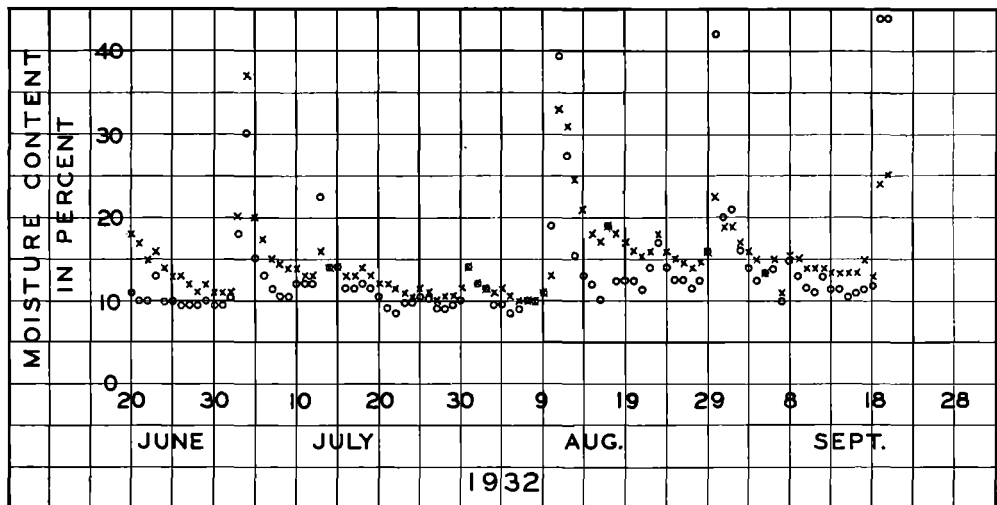


FIG. 2.—Wood cylinder moisture contents at Twin Creeks R. S.

x=2" Cylinder

o= $\frac{1}{2}$ " Cylinder