NOAA TECHNICAL MEMORANDUM NWS CR-62

DEPARTMENT OF COMMERCE
UNITED STATES OF AMERICA

DESIGN WEATHER CONDITIONS FOR PRESCRIBED BURNING

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Scientific Services Division
Central Region Headquarters
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INTRODUCTION

Significant use of prescribed burning as a management tool by USFS and Department of Interior began in the late 1960's. It became apparent that the guidelines of design weather conditions for efficient and safe burns were needed if the goals of the burns were to be achieved. The following guidelines are presented based on our experience and data for the prescribed burning projects in Missouri and Illinois.

USFS Ranger Districts in the Mark Twain and Clark National Forests and the Department of Interior, Crab Orchard Lake Refuge were requested to send a copy of the report on their burns which stated weather, success of burns and any problems. The basic data included temperature, relative humidity, wind direction and speed, sky conditions, buildup index (BUI), purpose of burn, fuel types and results. Data for 43 cases have been gathered although reports were not received for every burn.

A study of the data suggests that the design weather conditions for an efficient and safe prescribed burn depend on the objective of the burn. In the following, all weather parameter values are for burning time.

LIGHT SUSPENDED FUEL

A burn of this nature would have as its objective the reduction of light fuels which have one hour timelag fuel moisture; including standing weeds, top leaves and light dead bushes and brush. Most of the data for burns in this category are based on projects by the Crab Orchard Lake Refuge in southern Illinois and on Clark National Forests, Cedar Creek Unit. The purpose of the burns was for the wildlife management and for fire hazard reduction.

The desirable design weather conditions for light suspended fuels are:

Relative humidity, optimum 25 to 45 percent
Wind speed 3 to 10 miles per hour on a 10-minute average

It is desirable to have the humidity less than 50 percent for several hours especially before the start of the burn. However, at times with full sunshine and/or on south slope fuels, a higher prevailing humidity could be tolerated for a good burn. None of the fires for this purpose were conducted when humidity was below 25 percent, because wildfire experience shows that when humidity is below 25 percent, a dangerous fire hazard is likely.

We found that an ideal set of weather conditions for burning these flashy fuels is to have humidity values 40 percent or less within 24 hours after a soaking rain or over saturated soil conditions.

For this situation control problems are a minimum since the heavier fuels would still be too damp or the fuels close to the soil are too wet to burn intensely. If the burn happens to be an open field surrounded by forests, the forest would act as a natural fire line since drying and wind speed would be less in the forest than in open fields.

GENERAL PURPOSE BURNS

A variety of fuel types are included such as slash, herbicide kill, brush, duff and dead light vegatation. Fire hazard reduction is usually a primary goal and at times seed bed preparation, depending on the amount of duff present.

Data for these burns are from USFS Ranger Districts in Mark Twain and in Clark National Forests. Since these burns involve a wide range of fuel type of varying sizes and arrangements, the antecedent weather conditions along with the weather conditions on the day of the burn are important factors.

The desirable design weather conditions are:

Antecedent Weather...BUI 25 or more, or 100-hour fuel moisture of 15% or less or number of days since rain 6 or more.
Day before Burn......RH below 40% and wind speed 10 mph or greater.
Day of Burn..........10 hour timelag fuel moisture 6.5% to 10%.
Relative Humidity....20% to 40%.
Winds................3 to 10 mph, sky partly sunny.

At least one of the items listed under Antecedent Weather should be available to the forest manager. The BUI is the buildup index which is a measure of antecedent dryness used in the National Fire Danger Rating System 1964. The number of days since rain would have meaning provided that drying conditions occurred. Obviously, if fog were present for six days prior to the burn date, no drying would occur and the number of days since rain would be valueless as far as a measure of drying of heavier fuels. One-hundred-hour timelag fuel moisture is moisture content of fuels ranging in size one to three inches in diameter or roughly the moisture of litter extending from approximately 3/4 inch to 4 inches below the surface. This parameter is calculated for selected fuel models of the National Fire Danger Rating System 1972.

A summary of the results of the burns for corresponding calculated 10-hour timelag fuel moisture (sticks) is given in the following table:

Table 1. BURN RESULTS VERSUS CALCULATED 10-HOUR TIMELAG FUEL MOISTURE (Deeming,)

CALCULATED 10-HOUR STICK MOISTURE IN PERCENT

Burn Results	4	5	6	7	8	9	10	11	12	13	14	15	16
Excellent		1	5	3	3	1							
Good			2	1	2	6							
Fair					1	2							
Poor-Fair							2	2	15				
Poor							1		2	2			1
Hard Hold/ Spotting	1	2	1										

The data clearly show that for a successful burn the 10-hour fuel moisture of the sticks should be 9 percent or less. The four cases of hard to hold or spotting were on projects which were started in late morning when 10-hour moisture values were 7 to 9, but dropped to 6 or less in the mid-afternoon. These burns were in the fall with abnormally hot afternoon temperatures and low humidity.

From this it was concluded a safe desireable range would be 6.5 to 10 percent. Apparently if 10-hour stick moisture drops below 6.5 percent, a control problem is a good possibility. These calculated values of stick moisture vary considerably at times with the observed values. Using later data, a cursory study comparing Salem Missouri District Ranger calculated 10-hour timelag fuel moisture to the observed values shows wide seasonal differences, as well as day-to-day differences. It was noted that the largest differences occur when the weather elements change radically in the 12 hours prior to 1300 CST. The reason for this is that the tables used for calculating the 10-hour timelag fuel moisture are for conditions observed at 1300 CST while the observed stick moisture are the net result of the effects of all weather elements in the preceding time period. However, it was noted in periods which have no abrupt changes in weather elements or which have normal diurnal trends, the calculated values are close to the observed values within several percent.

Usually prescribed burns are planned in periods when the weather trends are considered normal and consequently the given calculated values should still serve as a useful guide until observed data becomes available.

In studying burn data and in evaluating our experience, it became apparent that the weather on the day before a planned burn was a very important factor in the achievement of the goals in prescribe burns involving heavier fuel types and/or where the fire had to carry on the heavier ground fuels. Our initial look at the data showed that if the humidity was below 40 percent the day before the burn, a good success rate was attained. Additionally, if the wind speed was moderate or higher at the same time the humidity was in good drying range (40 percent or less), it was almost a certainty the project burn would be a success. Therefore, it is inserted as a guideline for design weather conditions.

Physically this makes sense since moderate or stronger wind speed creates turbulence and more movement of air in the close vicinity of the fuels and thus provides aeration of the protected or shaded fuels, and thus a more uniform drying of the fuels over a large area. This is especially true close to the earth's surface or in protected brush and slash piles or in the woods.

The idea and conclusion above is supported by the work done by Kucera. He found that for a given vapor pressure deficit (humidity) that the evaporation rate in close proximity of vegetation (fuels) increases with increasing wind speed in the vicinity of fuels. He found that the greatest increase was when the wind speed in the close proximity of vegetation increased from calm to the 0.5 mph to 2 mph range. Such a change could enhance the evaporation rate 100 percent.

Fire weather stations measure wind speed at a 20 ft standard above the surface roughness. It was found using the standard wind profile for sunny days that a wind speed of 10 mph or more at 20 ft standard would be associated with wind speeds 1 mph or greater in the vicinity of fuels or close to the earths' surface. Therefore in order to have good homogenous drying in fuel arrays or protected shaded areas at least 10 mph wind speed is needed at the observation site.

The 10-hour timelag fuel stick moisture values presented were not observed since stick moisture was not a parameter used in Missouri at the time of the burns in this study. However, enough data were available to calculate it using the table given for the National Fire Danger Rating System 1972.

BURNING DUFF LAYER TO EXPOSE MINERAL SOIL

Weather conditions for this type of burn are the hardest to achieve because significant continuous duff is usually present in protected or shaded sites and is not directly exposed to radiation from the sun and/or effects of wind.

Generally the same conditions for a general purpose burn should be present, plus knowledge about duff moisture. Studies by others give some help as far as what time of year this type of burning would likely be possible.

How much of the duff layer which should be burned in order to achieve satisfactory pine seed bed preparation cannot be adequately answered for all cases.

The experience of forest managers in Missouri is that a burn which depletes or reduces the duff to the bottom ½ to 1 inch is very satisfactory and results in a good stand of pine seedlings. They also have found that if only the top leaves are burned, germination is high, but if a dry period sets in, the seedlings wither because they have only rooted in the loose top layer of the duff which drys out rapidly.

Assuming a considerable amount of the duff layer is to be disposed of, the following are some guidelines. Loomis found that the duff layer in a well-stocked, 40-year oak stand at Sinkin Experimental Station, Salem, Missouri, is likely to have duff moisture in the burnable range (20 to 30%) in the late summer and fall. Generally, soaking rains would override these conditions. Late summer and fall are the normal times when the moisture in the soil and duff is depleted because of high evaporation due to hot summer temperatures and high transpiration by the growing vegetation. It was noted that all the burns reported as excellent in previous tables were performed in late summer and fall. The ones reported as good for the same values of calculated 10-hour stick moisture were in the winter or spring.

Work by Morris on prescribed burning data from Cascade National Forests used the moist or dry appearance of duff as a parameter in prescribed burnings. This visual feature was not reported with the burns in Missouri. Morris found that if the lower duff appeared moist, about 25 percent of the duff would be burnt exposing mineral soil, and if the lower duff layer was dry about 50 percent of the duff would burn exposing mineral soil. Other weather parameters were suitable to carry out a safe fire.

SMOKE MANAGEMENT

In all prescribed burning operations smoke dispersal has to be considered. This paper will not go into details of this problem, but, in general, in the central part of the country poor dispersion days are poor prescribed burning days, since cloudiness is often present and fuels are often too moist to burn efficiently. Planners of prescribed burns will always have to consider the locations of busy roads and cities with respect to the location of fire site for a given wind direction. Each prescribed burn site along with weather conditions on the burning date will have to be evaluated with respect to local, state and Federal air pollution control laws in order to be in compliance.

DISCUSSION AND HINTS

A forest manager in planning prescribed burning projects should always try to take advantage of diurnal weather changes which make his job easier. An example of this is the fact that the relative humidity normally has its highest values late at night and around sunrise and drops rapidly in the morning reaching its minimum in mid-afternoon. As the temperature falls the humidity begins to rise again. The most rapid rise usually occurs in the late afternoon and early evening.

Exhibit 1 is a hygrothermograph trace which clearly shows the diurnal trends of temperature and humidity. November 10, 11, and 12 are good drying days. Assuming no significant precipitation occurred for six days prior to November 10, and wind was in a favorable range, November 10 would be a good day for burning light suspended fuels. November 11, for heavier fuels and November 12, and 13 would be quite favorable for general purpose burns and duff removal.

Wind speeds also show diurnal changes, with a minimum around sunrise and a maximum in the early afternoon. However, if weather systems e.g., fronts, intensifying lows, thunderstorms, etc., are affecting the area, the diurnal changes are distorted and/or not in phase with what we would expect. Knowledge of expected changes help in planning the ignition of the fire and also in the mop up. Consequently a forest manager should know in advance what changes can be expected for his project burn.

Another factor which is an important consideration in prescribed burning is the slope or aspect of the area to be burned. On a sunny day east and south slopes heat and dry out earlier and/or more than other aspects. This fact may allow for earlier ignition or even produce a lower humidity which would permit a burn in a weather situation which would not be favorable for other aspects such as level ground or north slopes.

The best source of forecast weather conditions is the fire weather meteorologist responsible for the area. The information he can provide will minimize risks and maximize the efforts in prescribed burning.

Local ranger district's fire danger weather records can provide valuable information about local weather changes. Beaufait and Fischer have discussed the use of fire danger weather records for prescribed burning.

The above guidelines have been presented for efficient and safe prescribed burning for Missouri and southern Illinois. However, they should be applicable in typical mixed hardwood stands in other sections of the United States.

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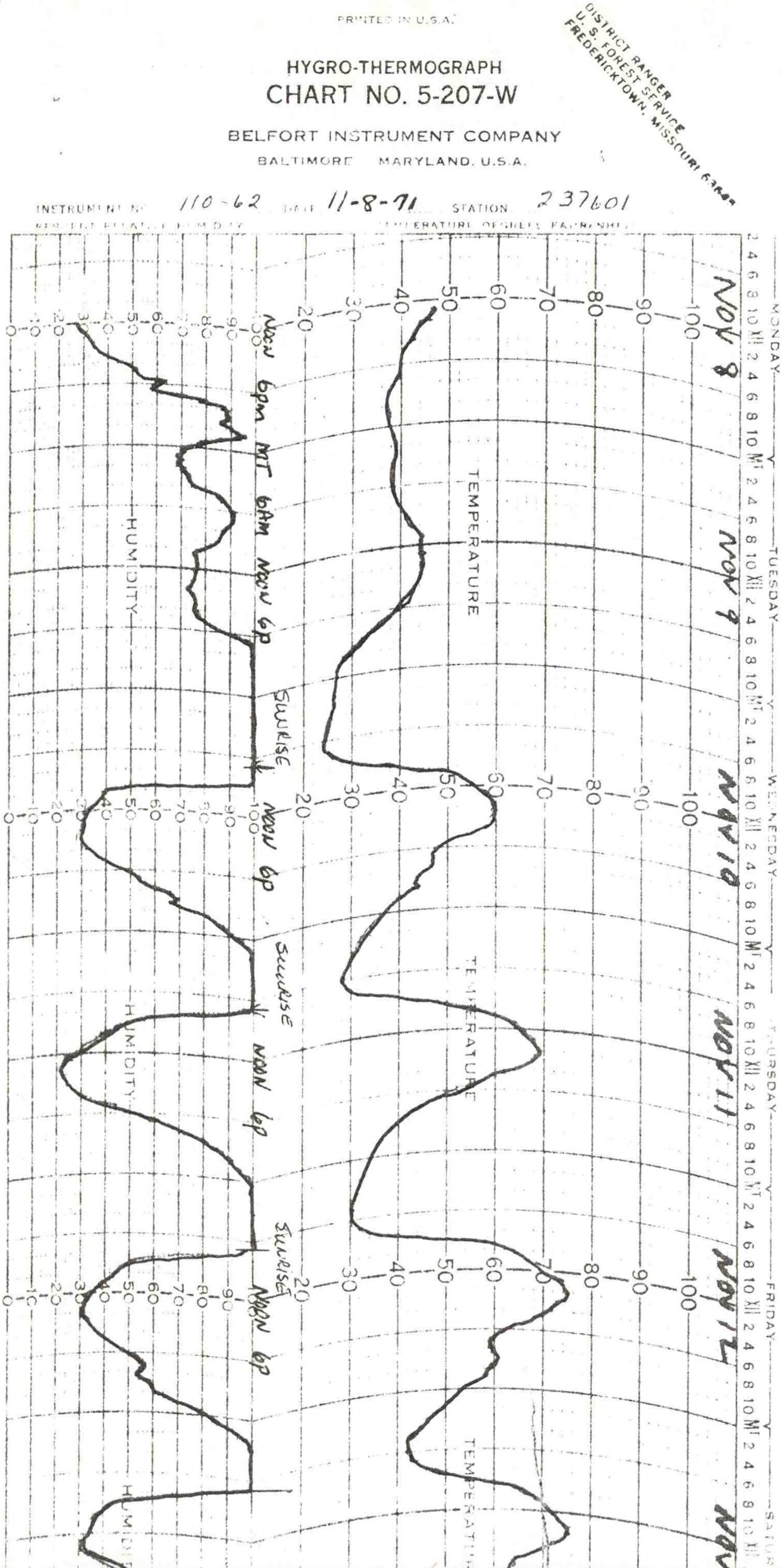

EXHIBIT 1 HYGROTHERMOGRAPH TRACE DEPICTING TYPICAL DIURNAL TEMPERATURE AND HUMIDITY TREND FOR A FAVORABLE PRESCRIBE BURNING DAY

APPENDIX/GLOSSARY

Ambient - Surrounding, enveloping conditions. As it pertains to weather at the earth's surface, the conditions measured in the instrument shelter are considered as ambient.

Buildup Index - A number directly related to the dryness of 10-day timelag fuels. It is used in the National Fire Danger Rating System of 1964. The larger the value the drier the larger fuels.

Dead Fuels - Naturally occurring fuels in which the moisture content is governed almost entirely by atmospheric moisture (relative humidity and precipitation).

Diurnal - Daily; pertains to daily cycles of temperature, relative humidity, wind and stability.

Duff - The partially decomposed organic material of the forest floor beneath the litter of freshly fallen twigs, needles and leaves. (The F and H layers of the forest floor.)

Equilibrium Moisture Content (EMC) - The moisture content that a fuel particle would attain if exposed for an infinite period in an environment of specified constant temperature and humidity. When a fuel particle has reached its EMC there is no net exchange of moisture between it and its environment.

Fuel Moisture Content (also fuel moisture) - The quantity of water in a fuel particle expressed as a percent of the ovendry weight of the fuel particle.

Litter - The top layer of the forest floor, composed of loose debris including dead sticks, branches, twigs and recently fallen leaves or needles; little altered in structure by decomposition. (The L layer of the forest floor.)

One-Hour Timelag Fuel Moisture (1-Hr. TL FM) - The moisture content of the 1-hour timelag fuels.

One-Hour Timelag Fuels - Fuels consisting of dead herbaceous plants and roundwood less than about one-fourth inch in diameter. Also included is the uppermost layer of needles or leaves on the forest floor.

One-Hundred Hour Timelag Fuel Moisture (100-Hr. TL FM) - The moisture content of the 100-hour timelag fuels.

One-Hundred Hour Timelag Fuels - Dead fuels consisting of roundwood in the size range of 1 to 3 inches in diameter and very roughly the layer of litter extending from approximately three-fourths inch to 4 inches below the surface.

Slash - Branches, bark, tops, chunks, cull logs, uprooted stumps and broken or uprooted trees left on the ground after logging; also debris resulting from thinnings, wind or fire.

Slope - The variation of terrain from the horizontal; the number of feet rise or fall per 100 feet measured horizontally, expressed as a percentage.

Ten-Hour Timelag Fuel Moisture (10-Hr. TL FM) - The moisture content of the 10-hour timelag roundwood fuels.

Ten-Hour Timelag Fuels - Dead fuels consisting of roundwood in the size range of one-fourth to 1 inch and very roughly the layer of litter extending from just below the surface to approximately three-fourths inch below the surface.

Timelag (TL) - The time necessary for a fuel particle to lose approximately 63 percent of the difference between its initial moisture content and its equilibirum moisture content.

Windspeed - Wind, in miles per hour, measured at 20 feet above the ground or the average height of the vegetative cover, and averaged over at least a 10-minute period.

CENTRAL REGION TECH MEMOS

(Continued from front inside cover)

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