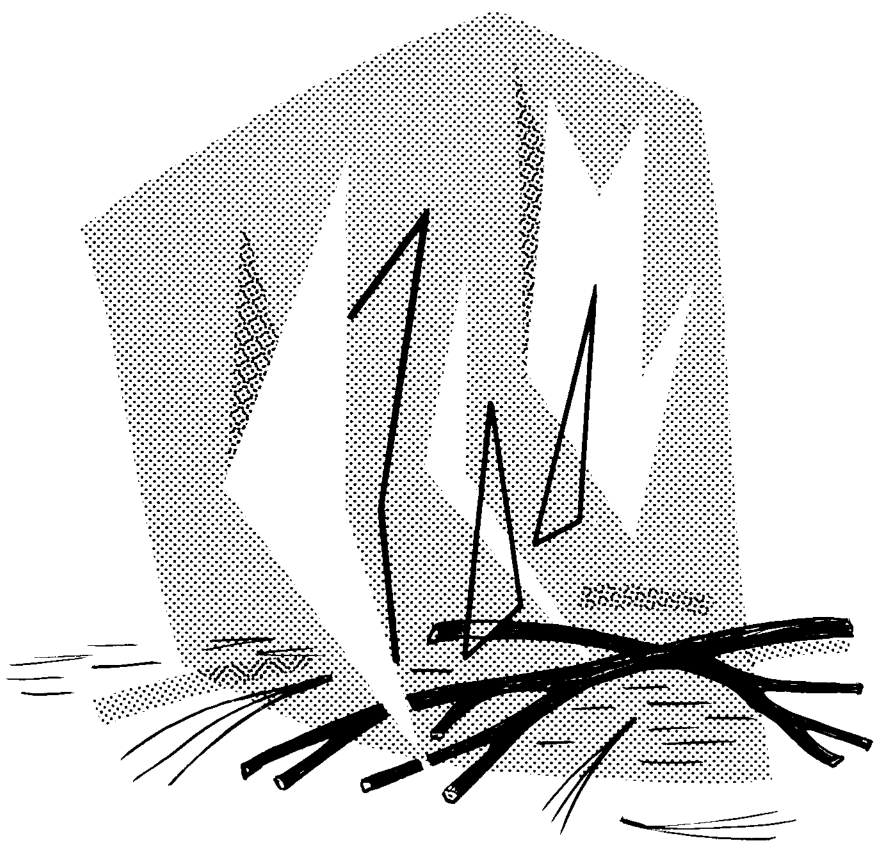
Forest Service - U.S. Department of Agriculture

# Prescribed Burning in the Interior Ponderosa Pine Type of Northeastern California . . .

## *a preliminary study*

Donald T. Gordon



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# Contents

### *The Author*

**DONALD T. GORDON** is doing research on the silviculture of Sierra Nevada forest types, with headquarters at Redding, Calif. Native of Oxnard, Calif., he was educated at the University of California, Berkeley (B. S. in forestry, 1939), and joined the U. S. Forest Service in 1940. He became a member of the Station's research staff in 1946.

## Acknowledgments

I thank Craig C. Chandler for assistance with the fire phases and meteorological monitoring reported; and personnel of the Lassen National Forest—particularly those on the Bogard Ranger District—for their assistance in these experiments.

Perhaps nowhere else has the subject of prescribed burning aroused more debate than in California. For it was here that the controversy had its origin in 1920, when *Sunset* published Stuart E. White's article on "Paiute Forestry."[1] White's advocacy of light burning touched off a cascade of words on the subject. As early as 1924, a cursory literature review yielded more than 30 articles totaling more than 75,000 words on the topic of light burning in California timber stands.

It would seem that in the more than 40 years since the debate on broadcast burning began, nearly every facet of the subject has been exhaustively explored—that no new argument, pro or con, has not been advanced. Yet the use of prescribed burning as a silvicultural or as a fire control tool remains as controversial as ever in California.

What then do we hope to gain by adding an account of a modest set of experiments to an already overflowing literature? Simply that from these experiments we have accrued a reasonable body of objective data from which certain deductions can logically be drawn. Furthermore, detailed descriptions of the trials can add significantly to the data base that must be accumulated before any truly objective analysis of prescribed broadcast burning in California's timber types will be possible. Only rarely in the published results of past experiments has there been enough details on weather conditions, fuel conditions, fire behavior, fire effects, and costs to enable an objective observer to evaluate the practical worth of this management technique.

This paper reports on three experimental prescribed burns in the interior ponderosa pine type on the Blacks Mountain Experimental Forest, northeastern California. Purpose of these trials was fuel hazard reduction or thinning. Information on weather and fuel moisture conditions, timber stands, and results obtained is included.

## Blacks Mountain Experimental Forest

The Blacks Mountain Experimental Forest is typical of the interior ponderosa pine type (Society of American Foresters Forest Cover Type 237),[2] with some inclusions of Jeffrey pine (Cover Type 247). This forest type, locally called eastside pine, occupies about 4 million acres of the northeastern plateau of California. Most of the timbered area has a wealth of advance reproduction. Site quality ranges from medium to poor. Elevations of the test plots varied from 5,800 to 6,150 feet. Precipitation averages about 20 to 25 inches annually. In summer, temperatures usually reach 80° to 85°F. in the afternoon, but drop to about 40°F. by early morning.

Because weather during spring and fall may vary considerably from day to day, it is notably difficult to predict accurately. Relative humidity during summer afternoons may fall as low as 10 percent, and often does not rise above 60 or 70 percent at night. In winter, snow blankets the ground most of the time. In this environment, forest fuels decay slowly—especially where they do not touch the soil.

Merchantable timber volume on the uncut Experimental Forest averaged about 18,000 bd. ft. (Scribner) per acre on 10,000 acres, in 1934. Nearly all the young-growth, much of it in dense sapling and pole groups, is at least 75 years old. Stagnation, and suppression by overstory, has been commonplace. Most of the understory is believed to have originated soon after the vast herds of sheep stopped grazing the land. Presumably the sheep helped prepare a good seedbed by severely reducing the amount of low forms of competitive vegetation. A fire exclusion policy has been in effect since the early 1900's, when the area was placed under the U.S. Forest Service. No evidence of previous fire damage was observed in any of the young-growth in this study. Nor has there been any slash treatment.

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[1]White, Stuart E. *Woodsmen, spare those trees!* Sunset. pp. 23-26, 108, 110, 112, 114-116, illus. Mar. 1920.
[2]Society of American Foresters. *Forest cover types of North America.* Washington, D.C. 67 pp., illus. 1962.

## Three Prescribed Burns

Our investigative work was intended to be preliminary. We had hoped it would lead to a larger program which would study the possible uses of fire to create fuel-breaks, reduce dangerous fuel accumulations, eliminate undesirable vegetation, and thin over-dense young stands. We wanted to observe what occurred during and after burning. As we progressed, our data collection methods were changed to obtain more complete records of results. Our experience in the three burns changed our hopes and limited our actual program.

The data reported apply to four areas; one area was not burned, and half of one was burned a second time. In all but one case, we kept records for a comparative unburned area.

### *First Burn*

The aim of the first burn was to kill abundant and unwanted incense-cedar (*Libocedrus decurrens* Torr.) seedlings and saplings beneath a mature stand of ponderosa pine (*Pinus ponderosa* Laws.). To achieve the desired result, personnel with fire experience prescribed a hot, clean litter burn. A period during fall was judged to be the most satisfactory time to attempt the burn.

The week of September 28, 1959, was tentatively scheduled for the trial. Weather data were recorded continuously during the field season at the Experimental Forest headquarters (about 6 miles distant from the burn site). During the week of September 14, 0.43 inches of rain fell; by the time of the burn—October 2—any practical effects of the storm had pretty much disappeared. Moisture content of pine needles in litter adjacent to the burned area was determined immediately before and after the fire by the xylene distillation technique:

| | Moisture Content *In sun* (percent) | Moisture Content *In shade* (percent) |
|---|---|---|
| Before fire | 5.5 | 9.7 |
| After fire | 5.2 | 8.2. |

Air temperature at ignition time (2:30 p.m.) was 64°F. and burning conditions[3] were as follows:

| | | | | |
|---|---|---|---|---|
| Fuel stick moisture content | vs. | Relative humidity | | Fine fuel moisture factor |
| 8 | | 14 | | 4 |
| Fine fuel moisture factor | vs. | Wind speed | | Spread factor |
| 4 | | 3-5 | | 13 |
| Fuel stick moisture content | vs. | Buildup | = | Intensity factor |
| 8 | | 47 | | 63 |
| Intensity factor | vs. | Spread factor | | *Timber burning index* |
| 63 | | 13 | | 10 |

The perimeter was ignited with a drip torch, lee side first. Some unexpected gusts of wind, perhaps 10-15 m.p.h., caused the fire to burn hotter than desired at times. The hottest areas had to be cooled with water to contain the fire. This fire was secured at 5:30 p.m. On the following day about 2,000 gallons of water were used to douse the smouldering litter and duff.

We obtained the following results:

1. The primary objective — elimination of unwanted cedar reproduction — was accomplished; the understory was reduced from 1,031 to 16 live trees *(fig. 1)*.
2. The overstory was reduced from 31 to 26 live trees. Only small trees (8 to 14 inches d.b.h.) were killed.
3. Total fuel hazard in the area was reduced, but fuels were not measured in this instance.
4. Inflammable dry cedar bark, small pitchy fire scars on some pines, and gusts of wind were responsible for the fire escalating into crowns of a few mature trees.

We concluded that future burning of any kind under such severe conditions would be out of the question. Only the timely and repeated application of water by an alert fire crew kept this experiment from becoming a serious fire.

[3] All expressions of burning conditions in this paper are in terms usable with the *California Fire Danger Rating* (1958), developed by the California Division of Forestry, U.S. Weather Bureau, California Region of the U.S. Forest Service, and California (now Pacific Southwest) Forest and Range Experiment Station. "Fuel stick moisture content" is percent moisture in an assembly of four ½- by 19-inch sugar pine dowels. "Buildup" is an index derived daily from fuel stick moisture content and precipitation data. Basically, buildup increases with days since last precipitation and with progressively lower fine fuel moisture content.

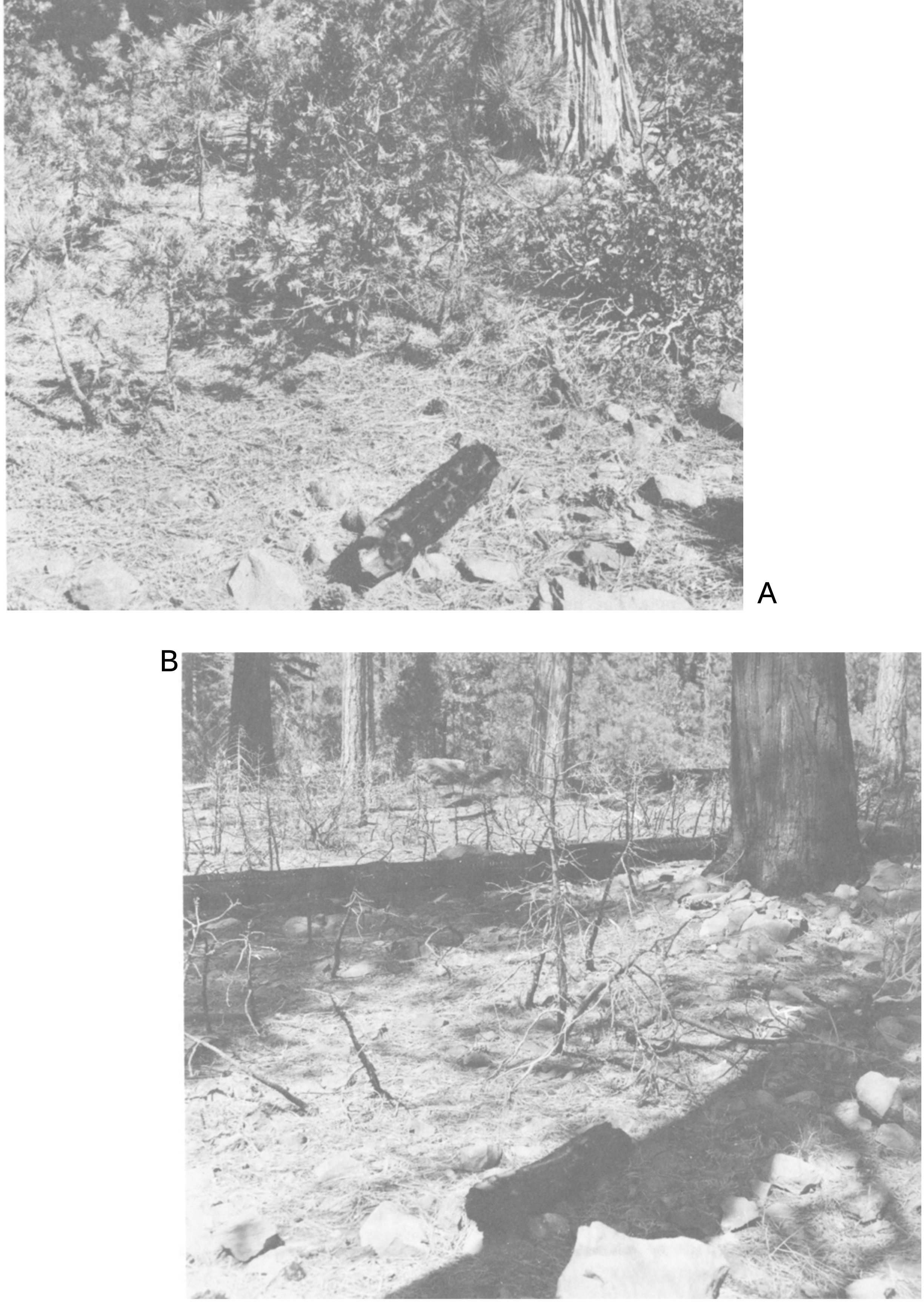


Figure 1. — *First burn, October 2, 1959, Blacks Mountain Experimental Forest. A portion of the area before and 1 year after the burn;* A, *before;* B, *after burn.*

### *Second Burn*

A stand type prevalent in the Experimental Forest consists of dense groups of pine poles. Under the canopy of a closed pole stand, litter—chiefly needles—builds up rapidly, in places to depths of 3 or 4 inches. Also laying on the forest floor, in greatly varying stages of decay, are large dead stems and limbs from the overmature stand which existed when the poles became established.

We decided to try burning for fuel hazard reduction in such a stand. The intent was to secure a light surface burn by backing a fire against a light wind when the surface litter was dry enough to carry fire but when the deeper duff layer was too wet to burn. If this technique succeeded, we thought we would repeat it on the same area—perhaps annually.

The area to be burned was 0.88 acre. Within this uniformly-stocked stand we established a square 1/10-acre sampling unit. The number of trees in each diameter class by crown class and species was tallied *(table 1)*. Stems per acre totaled about 1,200.

Additional trees were sampled within and outside the area to be burned: 20 sets of trees, with four matched individuals in each set. Each set of four trees was picked to be as similar as possible in diameter and crown class; one tree of each set was outside the area to be burned. The 20 sets were chosen to sample the range of diameters and crown classes. All trees were tagged, measured, and described.

Within the burn site, protective treatments were randomly assigned to each of the three trees within a set. One tree was protected by a 3-foot high, .019-inch thick, sheet aluminum collar, with a diameter at least 2 inches greater than that of the tree. Around the second tree, litter was scraped back from the bole for a distance of 6 inches. The third tree received no protection.

When weather and fuel approached the prescribed burning condition *(table 2)*, detailed instrumentation began. A fire weather observation trailer was placed next to the intended burn area. A combination of recording and manual instruments recorded data for 3 days before, and during the early part of the burn.

Fuel samples were collected and "canned" at 1830 hours, a half hour before the burn. Fuel moisture contents determined by solvent distillation techniques were as follows:

| | *Moisture content* (percent) |
|---|---|
| Fuel type: | |
| Surface litter | 10.4 |
| Duff at half-inch depth | 30.2 |
| Half-inch twigs on surface | 10.3 |
| Half-inch dead branches on live trees | 14.0 |
| Two-inch limbs on surface | 19.2 |
| Four-inch limbs on surface | 23.6 |
| Six-inch limbs on surface | 25.6 |

Table 1. - *Distribution of trees, by diameter classes, dominance, and species, 1/10-acre plot, second burn, Blacks Mountain Experimental Forest, 1960*

| D.b.h. (inches) | Dominant | | Codominant | | Intermediate | | Suppressed | | Total | | All species |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pine | White fir | Pine | White fir | Pine | White fir | Pine | White fir | Pine | White fir | |
| | *Number* | | | | | | | | | | |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 1 | 3 | 4 |
| 2 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 3 | 7 | 3 | 10 |
| 3 | 0 | 0 | 0 | 0 | 0 | 0 | 14 | 2 | 14 | 2 | 16 |
| 4 | 0 | 0 | 0 | 0 | 3 | 0 | 15 | 0 | 18 | 0 | 18 |
| 5 | 0 | 0 | 0 | 0 | 7 | 0 | 12 | 0 | 19 | 0 | 19 |
| 6 | 0 | 0 | 2 | 0 | 7 | 0 | 1 | 0 | 10 | 0 | 10 |
| 7 | 0 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 8 | 0 | 8 |
| 8 | 4 | 0 | 10 | 0 | 6 | 0 | 0 | 0 | 20 | 0 | 20 |
| 9 | 2 | 0 | 4 | 0 | 0 | 0 | 0 | 0 | 6 | 0 | 6 |
| 10 | 5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 | 5 |
| 11 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 2 |
| 12 | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 3 |
| 13 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Total | 17 | 0 | 16 | 0 | 31 | 0 | 50 | 8 | 114 | 8 | 122 |

Table 2.--*Trends of weather, fuel moisture conditions, and timber burning index, second burn, Blacks Mountain Experimental Forest, 1960*

| Date and time | Location | Air temperature | Relative humidity | Fuel Stick moisture | Wind speed | Fine fuel moisture index | Spread factor | Buildup | Intensity factor | Timber burning index |
|---|---|---|---|---|---|---|---|---|---|---|
| | | *°F.* | *Percent* | *Percent* | *M.p.h.* | | | | | |
| May 13: | | | | | | | | | | |
| 1430 | Shelter[1] | 52 | 26 | 8.0 | 4 | 5 | 11 | 004.1 | 39 | 5 |
| | Ground[2] | 48 | 27 | 9.5 | -- | -- | -- | -- | -- | -- |
| 1930 | Shelter | 49 | 32 | 8.0 | 1 | 6 | 7 | 004.1 | 39 | 3 |
| | Ground | 45 | 40 | 9.5 | -- | -- | -- | -- | -- | -- |
| 2015 | Shelter | 44 | 40 | -- | -- | -- | -- | -- | -- | -- |
| May 14: | | | | | | -- | -- | -- | -- | -- |
| 0715 | Shelter | 27 | 70 | 9.5 | -- | -- | -- | -- | -- | -- |
| | Ground | 22 | 90 | 11.0 | -- | -- | -- | -- | -- | -- |
| 1530 | Shelter | 60 | 25 | 7.5 | 3 | 5 | 11 | 004.5 | 39 | 5 |
| | Ground | 57 | 28 | 8.5 | -- | -- | -- | -- | -- | -- |
| 1810 | Shelter | 59 | 28 | -- | -- | -- | -- | -- | -- | -- |
| | Ground | 56 | 31 | -- | -- | -- | -- | -- | -- | |
| 1930 | Shelter | 53 | 30 | -- | 2 | -- | -- | -- | -- | -- |
| | Ground | 52 | 35 | -- | -- | -- | -- | -- | -- | -- |
| 2400 | Shelter | 36 | 59 | -- | -- | -- | -- | -- | -- | -- |
| | Ground | 32 | 79 | -- | -- | -- | -- | -- | -- | -- |
| May 15: | | | | | | -- | | | | |
| 0800 | Shelter | -- | -- | 10.0 | -- | -- | -- | -- | -- | -- |
| | Ground | -- | -- | 10.5 | -- | -- | -- | -- | -- | -- |
| 1600 | Shelter | 56 | 33 | 8.0 | 4 | 6 | 9 | 004.9 | 39 | 4 |
| | Ground | 54 | 45 | 9.5 | -- | -- | -- | -- | -- | -- |
| 1930 | Shelter | 49 | 43 | -- | 2 | -- | -- | -- | -- | -- |
| | Ground | 45 | 60 | -- | -- | -- | -- | -- | -- | -- |
| 2200 | Shelter | 44 | 64 | -- | -- | -- | -- | -- | -- | -- |
| | Ground | 39 | 92 | -- | -- | -- | -- | -- | -- | -- |
| May 16: | | | | | | | | | | |
| 0800 | Shelter | -- | -- | 12.5 | -- | -- | -- | -- | -- | -- |
| | Ground | -- | -- | 13.0 | -- | -- | -- | -- | -- | -- |
| 1200 | Shelter | 50 | 13 | -- | -- | -- | -- | -- | -- | -- |
| | Ground | 44 | 30 | -- | -- | -- | -- | -- | -- | -- |
| 1530 | Shelter | 54 | 12 | 8.5 | 3 | 4 | 13 | 005.3 | 35 | 6 |
| | Ground | 51 | 22 | 10.0 | -- | -- | -- | -- | -- | -- |
| 1930 | Shelter | 46 | 23 | 8.0 | 1 | 5 | 8 | 005.3 | 39 | 3 |
| | Ground | 42 | 38 | 9.5 | -- | -- | -- | -- | -- | -- |

[1]Recording instruments in shelter 4.5 feet above ground, moisture stick at 9 inches, wind at 20 feet.
[2]Recording instruments at ground level, moisture stick on litter.

The accumulated fuel moisture and weather information indicated that burning would be appropriate at about 1900 hours, when the relative humidity was just beginning a steep rise from its afternoon low. An hour later, wind velocity could be expected to drop.

At 1930 hours, early in the burn, pertinent conditions were as follows:

| | |
|---|---|
| Air temperature | 46°F |
| Relative humidity | 23 percent |
| Fuel stick moisture | 8 percent |
| Wind speed | 1 m.p.h. |
| Timber burning index | 3 |

The area was fired by a drip torch at 1900 hours, May 16, 1960. The lee side of the perimeter was ignited slowly so that fire behavior could be observed and projected. Strip firing was required immediately to produce enough heat for a continuous burn—even in the surface layer of needles. Therefore, the remainder of the area was fired rapidly by igniting strips 5 to 10 feet apart. Even so, burning was extremely spotty. In many places the fire died by itself, and an unburned strip was left between two torch lines. On the other hand, a few large poles were damaged where fire climbed ladder-like from adjacent smaller trees with low-hanging crowns.

The fire flared up when it reached a prone dead top near the windward edge of the burn. This top was a remnant from logging 2 years previously. It burned hot enough to ignite the crowns of the surrounding trees for 10 or 15 feet. This fire started a crown run that became the most prominent feature of the burn. Embers from the crown fire started numerous smouldering spot fires outside the burned area. All spot fires were extinguished quickly by patrolmen.

The area cooled about an hour after ignition. The fire was watched and allowed to smoulder the following day and night. That this smouldering could go on for several days, at least, became obvious. Pressure of other work required that the fire be secured. Mopup was accomplished on May 18-19, using a 1,100-gallon tanker.

In our estimation, almost ideal conditions existed for this prescribed burn. The top layer of litter was dry, and some of the deeper litter and duff was shiny with free water. A small snowbank still existed on a small part of the area. Weather conditions were good, yet the prescribed burn was disappointing for several reasons. First, litter burned poorly in many places. Second, the major crown fire was an unexpected development. Third, large, rotten, wet fuels were able to carry heat for such a prolonged period that their extinguishment would be a costly necessity.

Part of the crown fire overlapped a portion of the area with the tagged-tree sets. A short time after the fire, when scorched needles had become dry and contrasted with the green, crown damage to all those tagged trees was estimated to the nearest 5 percent of total needle complement. These data were grouped by crown damage classes to reflect certain or probable mortality *(table 3).* Estimation of the possibility of mortality was based solely on results of a study[4] which found a mortality rate of 52 percent for trees when 75 percent of the live crowns were pruned. We had no comparable data for fire-damaged trees in this area.

For several reasons, the protective effect of aluminum shields and litter raking can be only partially evaluated. First, the crown-out killed some trees which might otherwise have been used in the evaluation. Second, hot but slowly smouldering areas had to be mopped up 2 to 3 days after the main burning period; therefore, the fire could not run its natural course. Third, the surface burn in the crown-out area was hotter than elsewhere; in fact, it was hot enough to melt two of the aluminum collars, but the collars did prevent all bark scorching for the 3-foot height.

In spite of these three shortcomings, some treatment effects are discernible (*table 4*).

Proportionately more trees were subject to hot basal burns within the crown-out area than outside that area. Within the crown-out area, there was more than twice as much hot basal burning around untreated trees as there was around trees having aluminum collars or basal cleaning. Contrarily, outside the crown-out area there was twice as much hot basal burning around trees with basal cleaning as around trees with other treatments.

Most of the tagged trees were in the crown-out area; the others were next to it. Because ground fuels generally did not burn well during the main burning period—except in the crown-out area—some of this basal injury undoubtedly was caused by heat generated in the above-average accumulation of fuel at tree bases. These shield-shaped accumulations (or the messes created at fringes of basal cleaning) probably were elevated enough so that the upper portions were drier than surrounding areas; wherever progressive smouldering reached such accumulations during the 2 or 3 days before mopup was completed, combustion became more intense.

While mopping-up we were impressed by the number of large, flattened, decayed old stems which had been hidden by the litter. This material, although seemingly saturated with water, continued to smoulder hotly. Obviously, material like this left within a large burn in the spring would create delayed fire outbreaks as fuels become drier.

Growth measurements were not attempted on the matched tree sets because two-thirds of the tagged trees on the burned area were killed.

Insect activity after this small burn created no problem. Turpentine beetles (*Dendroctonus valens* Lee.) moved into many of the dead and dying trees almost immediately, but did not spread to nearby trees. A number of borers moved into the burned trees. Neither *Ips* nor other *Dendroctonus* beetles made attacks in the vicinity.

Although we thought the prescription and actual burning conditions provided an excellent chance to achieve our objective—fuel hazard reduction—we obtained no generally beneficial results. Our fuel sampling scheme for this fire was inadequate and partly destroyed, so the main evidence of results became a series of before-and-after black-and-white photographs and colored slides. However, we could plainly see that fuels had been reduced only slightly, except in the crown-out area. In-

[4]HaIlin, William E. *Pruning ponderosa and Jeffrey pine.* U.S. Forest Serv. Calif. Forest & Range Exp. Sta. Res. Note 115, 4 pp. 1956.

Table 3.--*Crown damage to tagged trees, second burn, Blacks Mountain Experimental Forest, 1960*

| Crown damage (percent) | Amount of trees | | | |
|---|---|---|---|---|
| | In crown-out area | | Not in crown-out area | |
| | *Number* | *Percent* | *Number* | *Percent* |
| 85-100 | 39 | 95.2 | 1 | 5.3 |
| 35-80 | 0 | -- | 0 | -- |
| 5-30 | 1 | 2.4 | 6 | 31.6 |
| 0 | 1 | 2.4 | 12 | 63.1 |
| Total | 41 | 100.0 | 19 | 100.0 |

Table 4.--*Incidence of hot basal burns*[1] *in litter and duff around sample trees, second burn, Blacks Mountain Experimental Forest, 1960*

| Tree location | Trees in sample area | Trees having hot basal burns when treatment was-- | | | |
|---|---|---|---|---|---|
| | | Untreated | Basal cleaning | Aluminum collar | All |
| | *Number* | *Percent* | | | |
| In crown-out area | 41 | 313 | 14.6 | 12.2 | 58.5 |
| Not in crown-out area | 19 | 5.3 | 10.5 | 5.3 | 21.1 |
| Total sample area | 60 | | | | -- |

[1] 'Hot basal burn' means that litter and duff were completely or mostly consumed by fire; white ash present. Heat which preceded this condition probably caused death of stem cambium and or shallow roots. During mopup, soil under this observable condition was sometimes still hot enough to turn cold water violently to steam.

stead of reducing the hazard, we had created a large amount of standing dead fuel.

During the first fall and winter, many dead needles fell to the ground. In succeeding winters since the burn, increasing numbers of dead trees have fallen. Forbs and grasses have become established in the opening created by the crown-out. These plants have created a competitive environment unfavorable to the establishment and growth of pine reproduction[5,6] *(fig. 2).*

[5] Baron, Frank J. *Effects of different grasses on ponderosa pine seedling establishment.* U.S. Forest Serv. Pacific SW. Forest & Range Exp. Sta. Res. Note 199, 8 pp., illus. 1962.

[6] Roy, D. F. *Effects of ground cover and class of planting stock on survival of transplants in the eastside pine type of California. U.S.* Forest Serv. Calif. Forest & Range Exp. Sta. Res. Note 87, 6 pp. 1953.

From this experiment we learned that if we were to control a fire within reasonable bounds in dense pole-size timber, we had to keep it out of the crowns. Furthermore, we had to use more intensive sampling methods to get better measurements of the many possible results of a burn.

## *Third Burn*

The term "third burn" refers to a particular area where more than an acre was burned in 1961, and about half an acre reburned in 1962. To simplify the presentation of data and comments, the sequence of events at this area will be described first.

The purpose of the third burn was fuel hazard reduction in a pole stand. Selection of the site was based on relative uniformity of the stand. The area

A

B

Figure 2.—*Second burn, view of crown-out area. Intensity of crown fire is evident in comparison of fuels and shade in* A *(pre-burn) and* B *(post-burn).* C *shows newly-fallen litter, falling trees, and competitive vegetation, 2 years later.*

C

comprised 1.50 acres, part of which was used as an unburned check.

The entire area was given a pre-burn treatment designed to keep fire out of the crowns, and in addition to protect bases of selected crop trees. First, potential crop trees were marked. Litter and duff then were scraped from bases of these trees for a distance of 6 to 8 inches. Live and dead limbs were removed to a height of 5 or 6 feet from all but exceptionally short seedlings. In a few instances, small groups of saplings were thinned. In a few places, concentrations of old logging slash were loosely bunched in minor openings with a small bulldozer.

Sampling was by randomly-located 1/100-acre plots, which contained milacre and square-foot sub-plots. Data in Meyer's[7] yield tables indicated that 20 plots would adequately sample trees in the area to be burned (1.10 acres), and that five plots would be necessary in the unburned area (0.40 acre).

On each 1/100-acre plot, crown classes of all trees were recorded. One-foot height classes were used to measure trees up to 10 feet tall; diameter at breast height for trees more than 10 feet tall. Distance from ground level to dead limbs and live limbs was recorded for each tree separately. After burns, fire-killed crown was estimated to the nearest 10 percent of total needle complement. Fire damage to stems (severe bark scorching or worse) was recorded to the nearest 1/10-square foot of external area after measuring with a transparent grid. Only one tree with obviously badly-burned bark was examined in detail. Trees were always tallied as being live or dead. If a tree had any green needles it was considered "live."

We placed a line transect across the middle of each plot. At the surface, condition of soil, rocks, vegetation, and fuel-size classes was recorded to the nearest 1/10-foot. At 18 and 48 inches above the ground transect, additional data were recorded, including vegetation and "overhead" fuels.

Within each 1/100-acre plot, a milacre plot was staked in a specified corner; within each milacre, a 1-foot square litter basket was placed in a specified corner. Each of these sampling units was the area basis for determining weight of a single size-class of fuel.

Fuel weights were recorded by these three size classes: (a) litter—less than 1 inch in diameter; (b) medium-1 to 4 inches in diameter; and (c) large—more than 4 inches in diameter.

[7] Meyer, W. H. *Yield of even-aged stands of ponderosa pine. U*.S. Dept. Agr. Tech. Bull. 630,60 pp., illus. 1938.

Table 5.--*Weather, fuel moisture conditions, and timber burning index, third burn, June 6-8, 1961,*[1] *Blacks Mountain Experimental Forest*

| Date and time | Temperature | Relative humidity | Fuel stick moisture[2] | Wind speed | Fine fuel index | Spread factor | Buildup | Intensity factor | Timber burning index |
|---|---|---|---|---|---|---|---|---|---|
| | *°F.* | *Percent* | *Percent* | *M.p.h.* | | | | | |
| June 6: | | | | | | | | | |
| 1200 | 66 | 37 | 10.0 | 4 | 6 | 9 | 000.5 | 23 | 3 |
| 1400 | 68 | 38 | 8.5 | 5 | 6 | 9 | .5 | 26 | 3 |
| 1600 | 65 | 39 | 9.5 | 5 | 6 | 9 | .5 | 26 | 3 |
| 2000 | 56 | 67 | 10.5 | 0 | 11 | 3 | .5 | 23 | 1 |
| June 7: | | | | | | | | | |
| 1200 | 68 | 32 | 11.0 | 3 | 7 | 8 | .7 | 23 | 2 |
| 1400 | 71 | 34 | 9.5 | 3 | 6 | 9 | .7 | 26 | 3 |
| 1500 | 74 | 37 | 9.5 | 3 | 6 | 9 | .7 | 26 | 3 |
| 1700 | 68 | 45 | 9.0 | 4 | 7 | 8 | .7 | 26 | 2 |
| 2000 | 60 | 65 | 10.5 | 2 | 11 | 3 | .7 | 23 | 1 |
| June 8: | | | | | | | | | |
| 1200 | 66 | 33 | 9.5 | 3 | 6 | 9 | .9 | 26 | 3 |
| 1330 | 69 | 29 | 9.0 | 4 | 6 | 9 | .9 | 26 | 3 |
| 1600 | 67 | 38 | 9.0 | 4 | 6 | 9 | .9 | 26 | 3 |

[1]Hygrothermograph in shelter 4.5 feet above ground, wind at 20 feet, fuel stick moisture at 9 inches.

[2]A fuel moisture stick on litter consistently read one to two percent lower for three days.

**1**

## FINE FUEL MOISTURE

| Fuel Stick Moisture Content | Relative Humidity 0-6 | 7-9 | 10-12 | 13-15 | 16-20 | 21-27 | 28-34 | 35-41 | 42-48 | 49-53 | 54-58 | 59-63 | 64-68 | 69-72 | 73-76 | 77-82 | 83-87 | 88-92 | 93-100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-4.5 | 1.5 | 1.5 | 2 | 2.5 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 8 | 9 | 10 | 11 | 12 | 15 | 16 | 18+ |
| 5-10 | 2 | 2.5 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 10 | 11 | 12 | 14 | 16 | 18 | 18+ |
| 11-15 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 7 | 8 | 9 | 10 | 11 | 11 | 12 | 13 | 15 | 17 | 18+ | 18+ |
| 16-20 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 8 | 9 | 10 | 11 | 12 | 12 | 13 | 14 | 16 | 18 | 18+ | 18+ |
| 21-25 | 5 | 6 | 6 | 7 | 7 | 8 | 9 | 9 | 10 | 11 | 12 | 13 | 13 | 14 | 15 | 17 | 18+ | 18+ | 18+ |
| 26-30 | 6 | 7 | 7 | 8 | 8 | 9 | 10 | 10 | 11 | 12 | 13 | 14 | 14 | 15 | 16 | 18 | 18+ | 18+ | 18+ |
| 31-35 | 7 | 8 | 8 | 9 | 9 | 10 | 11 | 11 | 12 | 13 | 14 | 15 | 15 | 16 | 17 | 18+ | 18+ | 18+ | 18+ |
| 36-40 | 8 | 9 | 9 | 10 | 10 | 11 | 12 | 12 | 13 | 14 | 15 | 16 | 16 | 17 | 18 | 18+ | 18+ | 18+ | 18+ |
| 41-45 | 9 | 10 | 10 | 11 | 11 | 12 | 13 | 13 | 14 | 15 | 16 | 17 | 18 | 18 | 18+ | 18+ | 18+ | 18+ | 18+ |
| 46+ | 10 | 11 | 11 | 12 | 12 | 13 | 13 | 14 | 15 | 16 | 17 | 17 | 18 | 18+ | 18+ | 18+ | 18+ | 18+ | 18+ |

**2**

## SPREAD FACTOR

| Fine fuel moisture | Wind speed (m.p.h.) 0-2 | 3-5 | 6-7 | 8-9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22-23 | 24+ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.5 | 14 | 19 | 23 | 28 | 33 | 37 | 40 | 43 | 47 | 51 | 55 | 61 | 66 | 70 | 74 | 83 | 89 | 100 |
| 2 | 13 | 17 | 21 | 26 | 30 | 34 | 37 | 40 | 43 | 47 | 51 | 56 | 61 | 65 | 70 | 77 | 82 | 92 |
| 2.5 | 12 | 15 | 20 | 24 | 28 | 32 | 35 | 38 | 41 | 44 | 47 | 52 | 56 | 61 | 67 | 72 | 77 | 86 |
| 3 | 11 | 14 | 18 | 22 | 26 | 29 | 32 | 34 | 38 | 41 | 44 | 48 | 52 | 57 | 62 | 67 | 73 | 81 |
| 4 | 10 | 13 | 16 | 20 | 23 | 26 | 29 | 31 | 34 | 37 | 39 | 43 | 47 | 51 | 56 | 60 | 64 | 72 |
| 5 | 8 | 11 | 14 | 17 | 20 | 22 | 25 | 28 | 30 | 33 | 35 | 38 | 41 | 45 | 49 | 53 | 57 | 62 |
| 6 | 7 | 9 | 12 | 14 | 17 | 19 | 21 | 24 | 26 | 28 | 30 | 33 | 35 | 39 | 44 | 47 | 49 | 54 |
| 7 | 6 | 8 | 10 | 12 | 15 | 17 | 19 | 21 | 22 | 24 | 26 | 29 | 31 | 33 | 39 | 42 | 44 | 46 |
| 8 | 5 | 7 | 9 | 11 | 13 | 14 | 16 | 17 | 19 | 20 | 22 | 25 | 26 | 29 | 33 | 36 | 38 | 41 |
| 9 | 5 | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 16 | 17 | 18 | 21 | 22 | 25 | 28 | 30 | 32 | 36 |
| 10 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 13 | 15 | 16 | 17 | 19 | 20 | 24 | 25 | 27 | 29 |
| 11 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 9 | 11 | 12 | 12 | 13 | 15 | 16 | 19 | 20 | 22 | 24 |
| 12 | 2 | 3 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 9 | 10 | 11 | 13 | 14 | 15 | 16 | 18 |
| 13 | 1 | 2 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 14 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 7 | 7 | 8 | 8 |
| 15 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 2 | 3 | 4 | 4 | 5 |
| 16 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 18+ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| II 41-60% | 0-1 | 2-4 | 5-6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | -- | 17 | 18 | 19 | 20+ |
| III 61%+ | 0 | 1-2 | 3-4 | 5-6 | 7 | 8 | -- | 9 | 10 | 11 | 12 | -- | 13 | 14 | 15 | 16 | -- | 17+ |
| Slope Class | Wind speed (m.p.h.) | | | | | | | | | | | | | | | | | |

**3**

## INTENSITY FACTOR--Timber Fuels

| Fuel Stick Moisture Content | Buildup 0-1.9 | 2-3.9 | 4-6.9 | 7-10.9 | 11-16.9 | 17-25.9 | 26-39.9 | 40-61.9 | 62-99.9 | 100+ | Fuel Stick Moisture Content |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1.0 | 57 | 62 | 67 | 71 | 76 | 81 | 86 | 90 | 95 | 100 | 1.0 |
| 1.5 | 54 | 60 | 64 | 68 | 73 | 78 | 83 | 87 | 92 | 97 | 1.5 |
| 2.0 | 51 | 56 | 61 | 65 | 70 | 75 | 80 | 85 | 89 | 94 | 2.0 |
| 2.5 | 49 | 53 | 58 | 63 | 67 | 72 | 77 | 82 | 87 | 91 | 2.5 |
| 3.0 | 46 | 51 | 56 | 60 | 65 | 70 | 75 | 79 | 84 | 89 | 3.0 |
| 3.5-4.0 | 44 | 49 | 53 | 58 | 62 | 67 | 72 | 77 | 82 | 86 | 3.5-4.0 |
| 4.5-5.0 | 40 | 44 | 49 | 54 | 58 | 63 | 68 | 73 | 78 | 82 | 4.5-5.0 |
| 5.5-6.0 | 36 | 40 | 45 | 50 | 54 | 59 | 64 | 69 | 74 | 78 | 5.5-6.0 |
| 6.5-7.0 | 32 | 37 | 42 | 46 | 51 | 56 | 61 | 65 | 70 | 75 | 6.5-7.0 |
| 7.5-8.0 | 30 | 34 | 39 | 44 | 48 | 53 | 58 | 63 | 68 | 72 | 7.5-8.0 |
| 8.5-9.5 | 26 | 31 | 35 | 40 | 45 | 49 | 54 | 59 | 64 | 69 | 8.5-9.5 |
| 10-12 | 23 | 27 | 32 | 37 | 41 | 46 | 51 | 56 | 61 | 65 | 10-12 |
| 13-16 | 19 | 24 | 28 | 33 | 38 | 42 | 47 | 52 | 57 | 62 | 13-16 |
| 17-20 | 16 | 20 | 25 | 30 | 34 | 39 | 44 | 49 | 54 | 58 | 17-20 |
| 21+ | 13 | 17 | 22 | 27 | 31 | 36 | 41 | 46 | 51 | 55 | 21+ |

**4**

## TIMBER BURNING INDEX

| Intensity Factor | Spread Factor 0-2 | 3-4 | 5-6 | 7-8 | 9-10 | 11-12 | 13-14 | 15-16 | 17-19 | 20-22 | 23-25 | 26-28 | 29-31 | 32-34 | 35-39 | 40-44 | 45-49 | 50-54 | 55-60 | 61-67 | 68-74 | 75-81 | 82-90 | 91-100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-12 | 0 | 0 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 6 | 7 | 8 | 9 | 9 | 10 | 11 |
| 13-19 | 0 | 1 | 1 | 2 | 2 | 2 | 3 | 3 | 4 | 4 | 5 | 5 | 6 | 7 | 7 | 8 | 9 | 10 | 12 | 13 | 14 | 15 | 17 | 19 |
| 20-26 | 0 | 1 | 1 | 2 | 3 | 3 | 4 | 4 | 5 | 6 | 6 | 7 | 8 | 9 | 10 | 11 | 13 | 14 | 16 | 17 | 19 | 21 | 23 | 26 |
| 27-32 | 1 | 1 | 2 | 3 | 3 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 13 | 14 | 16 | 18 | 20 | 22 | 24 | 27 | 30 | 33 |
| 33-36 | 1 | 1 | 2 | 3 | 4 | 5 | 6 | 6 | 7 | 8 | 10 | 11 | 12 | 14 | 15 | 17 | 19 | 21 | 24 | 26 | 29 | 32 | 35 | 39 |
| 37-39 | 1 | 2 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 11 | 12 | 14 | 15 | 17 | 19 | 21 | 23 | 26 | 29 | 32 | 35 | 39 | 43 |
| 40-42 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 12 | 13 | 15 | 16 | 18 | 21 | 23 | 25 | 28 | 31 | 35 | 38 | 42 | 47 |
| 43-46 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 10 | 11 | 13 | 14 | 16 | 18 | 20 | 22 | 25 | 28 | 31 | 34 | 37 | 41 | 45 | 50 |
| 47-49 | 1 | 2 | 3 | 4 | 5 | 6 | 8 | 9 | 10 | 12 | 14 | 15 | 17 | 19 | 21 | 24 | 27 | 30 | 33 | 36 | 40 | 44 | 49 | 54 |
| 50-52 | 1 | 2 | 3 | 5 | 6 | 7 | 8 | 9 | 11 | 13 | 15 | 16 | 18 | 20 | 23 | 26 | 29 | 32 | 35 | 39 | 43 | 48 | 52 | 58 |
| 53-56 | 1 | 2 | 4 | 5 | 6 | 7 | 9 | 10 | 12 | 14 | 16 | 18 | 20 | 22 | 24 | 27 | 31 | 34 | 38 | 42 | 46 | 51 | 56 | 62 |
| 57-59 | 1 | 2 | 4 | 5 | 7 | 8 | 9 | 11 | 12 | 14 | 17 | 19 | 21 | 23 | 26 | 29 | 32 | 36 | 40 | 44 | 49 | 54 | 59 | 66 |
| 60-62 | 1 | 3 | 4 | 5 | 7 | 8 | 10 | 11 | 13 | 15 | 18 | 20 | 22 | 24 | 27 | 31 | 34 | 38 | 42 | 47 | 52 | 57 | 63 | 69 |
| 63-66 | 1 | 3 | 4 | 6 | 7 | 9 | 10 | 12 | 14 | 16 | 18 | 21 | 23 | 25 | 28 | 32 | 36 | 40 | 44 | 49 | 55 | 60 | 66 | 73 |
| 67-69 | 1 | 3 | 4 | 6 | 8 | 9 | 11 | 13 | 15 | 17 | 19 | 22 | 24 | 27 | 30 | 34 | 38 | 42 | 47 | 52 | 58 | 63 | 70 | 77 |
| 70-72 | 1 | 3 | 5 | 6 | 8 | 10 | 11 | 13 | 15 | 18 | 20 | 23 | 26 | 28 | 32 | 36 | 40 | 44 | 49 | 54 | 60 | 66 | 73 | 81 |
| 73-76 | 1 | 3 | 5 | 7 | 8 | 10 | 12 | 14 | 16 | 18 | 21 | 24 | 27 | 29 | 33 | 37 | 41 | 46 | 51 | 56 | 62 | 69 | 76 | 84 |
| 77-79 | 1 | 3 | 5 | 7 | 9 | 11 | 12 | 14 | 17 | 19 | 22 | 25 | 28 | 31 | 34 | 38 | 43 | 48 | 53 | 59 | 65 | 72 | 79 | 87 |
| 80-82 | 1 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 17 | 20 | 23 | 26 | 29 | 32 | 36 | 40 | 45 | 50 | 55 | 61 | 68 | 75 | 83 | 91 |
| 83-86 | 2 | 3 | 5 | 7 | 9 | 11 | 13 | 15 | 18 | 21 | 24 | 27 | 30 | 33 | 37 | 42 | 47 | 52 | 58 | 64 | 71 | 78 | 86 | 95 |
| 87-89 | 2 | 4 | 6 | 8 | 10 | 12 | 14 | 16 | 19 | 22 | 25 | 28 | 31 | 34 | 38 | 43 | 49 | 54 | 60 | 67 | 74 | 81 | 89 | 99 |
| 90-92 | 2 | 4 | 6 | 8 | 10 | 12 | 15 | 17 | 20 | 23 | 26 | 29 | 32 | 36 | 40 | 45 | 51 | 56 | 62 | 69 | 76 | 84 | 93 | 100 |
| 93-96 | 2 | 4 | 6 | 8 | 11 | 13 | 15 | 17 | 20 | 24 | 27 | 30 | 33 | 37 | 42 | 47 | 53 | 58 | 64 | 72 | 79 | 87 | 96 | 100 |
| 97-100 | 2 | 4 | 6 | 9 | 11 | 13 | 16 | 18 | 21 | 24 | 28 | 31 | 35 | 38 | 43 | 49 | 55 | 60 | 67 | 74 | 82 | 90 | 100 | 100 |

# TIMBER TABLES

Table 6.--*Burning conditions, prescribed (blocked) and actual (circled), third burn on June 8, 1961; prescription prepared in early May 1961.*

Large fuels on the 1/100-acre plots were measured to the nearest inch of diameter and foot of length. The data were later converted on a volume basis to ovendry weight of ponderosa pine, using a factor of 25 pounds per cubic foot. In fall 1964, all dead trees on the plots were picked up or cut at ground level. Their parts were placed on a tarpaulin, separated into the three fuel size classes, and weighed or measured. Samples of these fuels were ovendried to obtain correction factors for field weights.

Medium fuels were sampled on the milacre plots. They were weighed to the nearest half-pound and put back in their original positions. Samples of similar material off-plot were oven-dried to obtain field weight correction factors. Milacre plots were also used to estimate to the nearest 10 percent that part of the surface of each milacre that had actually burned.

A wire basket 1-foot square by 2-inches deep was used to sample changes in litter weights. Foot-square cores of litter and duff were cut to mineral soil with a square core-cutter or flat spade, lifted intact, and placed in the baskets. Baskets of litter were weighed to the nearest half-ounce and carefully placed so that the cores could be returned to their original positions. During weighing, off-plot fuel samples were collected for ovendrying, to obtain fuel weight correction factors. Litter depth in each basket was measured. After a burn, we also noted whether any litter in a basket had burned. We found no evidence that the litter basket screen inhibited burning.

For about 3 weeks before the burn, fuel moisture was sampled at intervals. When it seemed appropriate, a fire weather observation trailer was installed next to the test area.

As soon as data established the diurnal weather and fuel moisture pattern *(table 5),* we decided to burn in early afternoon. It was estimated that fire then would accomplish the most fuel hazard reduction under the burning prescription *(table 6).*

The Weather Bureau provided a special forecast for the area on the morning of June 8, covering June 8 and 9. Weather and fuel conditions one-half hour before the burn were as follows:

| | |
|---|---|
| Temperature | 69°F. |
| Relative humidity | 29 percent |
| Fuel stick moisture | 9 percent |
| Wind speed | 4 m.p.h. |
| Timber burning index | 3 |

Moisture in fuel samples collected a half-hour before the burn varied widely—from 6.2 percent for litter in the sun to 78.6 percent for a rotten log. Actual fuel moisture content determined by the solvent distillation technique was as follows:

| Fuel type: | *Moisture* (percent) |
|---|---|
| Green needles | 110.0 |
| Lopped needles (from pre-burn treatment) | 75.2 |
| Litter in sun | 6.2 |
| Litter in shade | 10.8 |
| Rotten log | 78.6 |
| Twigs (1/2-1/2 inch) | 7.8 |
| Twigs (1/2-1 inch) | 9.0 |
| Twigs (1-2 inches) | 26.8 |

The area was strip-fired by drip torch according to plans, beginning at 1400 hours, June 8, 1961. Surface litter appeared to burn well. Fire also became established in almost all of the down logs, stumps, and other heavy debris. Flames rose about 12 inches above the ground, but in occasional flareups in small concentrations of slash, flames sometimes reached a height of 3 to 5 feet. Tree crowns near these flareups were sometimes scorched, but nowhere did the fire crown, and there was no difficulty in containing the fire. No spotting was noted.

Relative humidity approached 100 percent by midnight and stayed at that level for the rest of the night. By 0600 hours there were no more than 25 smokes still showing. In most cases, fire which had burned in heavy fuels had gone out by itself during the night. The burned area was patrolled at intervals on June 9 and 10. Mopup consisted mainly of eliminating hot spots on June 11 and 12.

Litter and medium fuels had burned well. Large fuels burned moderately well, considering their relatively high moisture content. There had been no crowning and little evidence of basal scorching, but roughly half of all trees on burned plots were dead by the following spring. No such rate of mortality occurred on unburned plots. Ground fuels had been reduced, but a new condition of standing dead fuels had been created.

Because of this new condition, we decided to reburn about half the area a year later. By so doing we would be able to compare observations of phenomena on adjacent plots burned once and twice.

Weather conditions in spring of 1962 were drier than in the preceding year. Heavy fuels, therefore, had a chance to dry rather well. Our burning prescription was the same as that in 1961. Although we would have preferred a hotter burn, we felt that a higher burning index would result in crown fires becoming started through ignition of dead foliage on trees killed in the previous year.

In 1962 we repeated the 1961 early-season pattern of periodic weather and fuel moisture observations. Subsequently, on May 8, detailed instrumentation at the site began with use of a weather observation trailer *(table 7).* The data established the immediate weather and fuel moisture pattern, and substantiated our judgment of an approaching burning period which would fit our prescription. Weather and fuel conditions immediately before the burn were as follows:

| | |
|---|---|
| Temperature | 48°F |
| Relative humidity | 31 percent |
| Fuel stick moisture | 8.5 percent |
| Wind speed | 2 m.p.h. |
| Burning index | 3 |

Strip firing of the burn began at 1745 hours on May 10, 1962. The fire did not spread well through the litter, mainly because the amount of litter had been reduced by the burn of the previous year. However, the fire became well-established in heavy fuels. Flames reached 12 inches high, with occasional flareups in concentrations of heavy fuels. Crown-scorching from below was not noted, nor did fire flare through any crowns.

We had planned to allow this reburn to smoulder for 2 or 3 days. However, mopup had to be undertaken the following afternoon when the weather changed abruptly and unexpected higher air temperature and wind velocity ( above predicted data) created a hazardous condition. The condition was so obvious that Ranger District personnel appeared, without being called, to assist us with the work.

To describe results of fires on this "third burn" area, we have grouped data various ways. In some instances, data for 20 plots before and after one burn may be compared with five unburned plots. Or, 11 plots, burned and reburned, may be compared with nine plots burned once only, as well as with five unburned plots.

As expected, dominant and codominant trees were least affected by the fires *(fig. 3).* Intermediate and suppressed trees suffered heaviest mortality, probably because of smaller and generally lower live crowns, and thinner bark.

This experiment was accomplished during a 3-year drought which was ended by the Columbus Day storm of 1962. During the drought, foresters in the eastside pine type noticed an increasing but moderate amount of mortality of seedling- and sapling-size pines. Also a study within the three plot groupings in the third burn area showed that trees on the unburned area were slightly smaller and more numerous than trees on the burned and reburned areas. One would therefore expect "natural" mortality on the unburned plots to be greater than that on burned plots. For these reasons, any attempt at a direct comparison of "natural" mortality by plot groups would to a certain degree be misleading.

Table 7. --*Weather, fuel moisture conditions, and timber burning index, reburn of third burn, Blacks Mountain Experimental Forest, 1962*[1]

| Date and time | Temperature | Relative humidity | Fuel stick moisture | Wind speed | Fine fuel index | Spread factor | Buildup | Intensity factor | Timber burning index |
|---|---|---|---|---|---|---|---|---|---|
| | *°F.* | *Percent* | *Percent* | *M.p.h.* | | | | | |
| May 8: | | | | | | | | | |
| 1500 | 55 | 38 | -- | | -- | -- | -- | -- | -- |
| May 9: | | | | | | | | | |
| 1300 | 53 | 28 | 10.0 | 5 | 6 | 9 | 004.6 | 32 | 3 |
| 1530 | 54 | 17 | 8.5 | 3 | 4 | 13 | 004.6 | 35 | 6 |
| May 10: | | | | | | | | | |
| 1130 | 52 | 17 | 10.0 | 4 | 4 | 13 | 004.8 | 32 | 5 |
| 1600 | 51 | 25 | 8.5 | 3 | 5 | 11 | 004.8 | 35 | 5 |
| 1730 | 48 | 31 | 8.5 | 2 | 6 | 7 | 004.8 | 35 | 3 |
| 1915 | 44 | 38 | 9.0 | 1 | 6 | 7 | 004.8 | 35 | 3 |

[1]Hygrothermograph in shelter 4.5 feet above ground, wind at 20 feet, moisture stick at 9 inches.

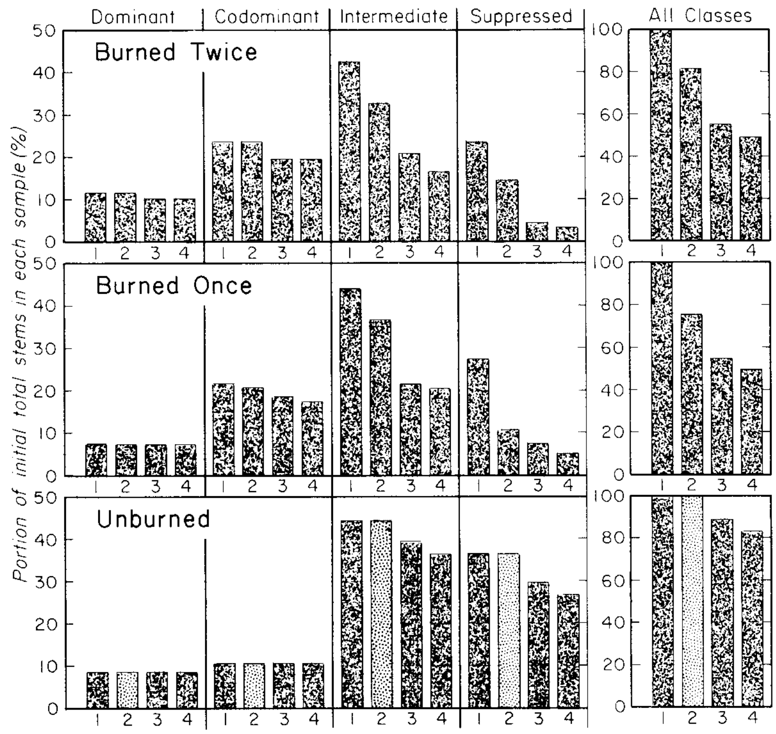


Figure 3. — *Live trees by crown classes on burned and unburned plots, third burn. Numbers below the bars refer to date when plots were examined: 1 - May, 1961 (before first burn); 2 = June, 1961 (after first burn), 3 = May, 1962; 4 = May, 1964 (3 years after first burn). Bar 2 for unburned plots is assumed — no examination.*

Table 8 --*Crown-killing caused* by *fire, by crown classes, third burn, Blacks Mountain Experimental Forest, 1961*

| Portion of crown killed (percent) | Damaged trees by crown classes | | | | |
|---|---|---|---|---|---|
| | Isolated (1)[1] | Dominant (27) | Codominant (67) | Inter-mediate (122) | Suppressed (71) |
| | *Percent* | | | | |
| 0 | 0 | 66.7 | 55.2 | 46.7 | 24.0 |
| 10 | 0 | 14.8 | 8.9 | 8.2 | 1.4 |
| 20 | 0 | 7.4 | 3.0 | 4.9 | 1.4 |
| 30 | 0 | 3.7 | 10.4 | 4.1 | 2.8 |
| 40 | 100.0 | 3.7 | 6.0 | .8 | 0 |
| 50 | 0 | 3.7 | 3.0 | 2.5 | 8.4 |
| 60 | 0 | 0 | 4.5 | 0 | 1.4 |
| 70 | 0 | 0 | 1.5 | .8 | 2.8 |
| 80 | 0 | 0 | 1.5 | 2.5 | 0 |
| 90 | 0 | 0 | 4.5 | 14.8 | 9.9 |
| 100 | 0 | 0 | 1.5 | 14.7 | 47.9 |
| Total | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |

[1] Numbers in parentheses equal total trees in each crown class.

The susceptibility of small trees to the effects of fire was demonstrated in the burn. Where pine pole stands have too many stems, killing the small trees could be considered a modest benefit from the standpoint of competition. And if the smallest trees were of a less desirable species—white fir or incense-cedar, for example—some additional gain could be counted. On the other hand, when all young trees are small (seedlings and saplings), and of a single desired species, total or heavy losses are undesirable.

Total or partial crown-killing by fire occurred during the first burn only *(table 8)*. This condition again illustrates vulnerability of small trees to fire—even when they have been afforded some protection by low pruning.

On the burned areas, the effects of fire raised the average base of live crowns about 2 feet above pruned level *(fig. 4)*. On the unburned plots, live crown bases remained steady at their pruned level. Data on dead limbs probably reflect these factors: (a) more killed limbs at low levels, (b) downward-curling effect of fire on dead limbs, (c) variation in the amount of down-curl caused by differences in moisture content of the limbs at different observation times, and (d) fewer live trees during later examinations.

The lowering of the average level of overhead fuel resulting from killed trees was not measured. But dead poles soon began to bend toward the ground *(fig. 5)*. A significant mass of dry fuel then comes closer to the ground, where it could be ignited easily by accidental fires and carry heat upward, to live crowns.

At the beginning of this experiment there were 45 potential crop trees within the 25 1/100-acre plots. Average diameter of these trees was 7.1 inches. After the second burn, four crop trees on the burned plots were dead. A basal scar was found on only one tree. This injury measured 2.8 square feet. A hot-burning log near the tree caused the damage. The tree later died.

These results show that, silviculturally, fire improved the pole stand—but at a cost. The slightly increased supply of moisture afforded the dominant trees should increase their growth rate—at least moderately.

Only traces of wet (green) fuels on the ground were recorded at the first measurement. These were trimmings from the preburn treatment. Fuels on the unburned area were not remeasured after the first burn. Nor were ground fuels in the over 4-inch class remeasured in the final examination because no measurable change should be expected.

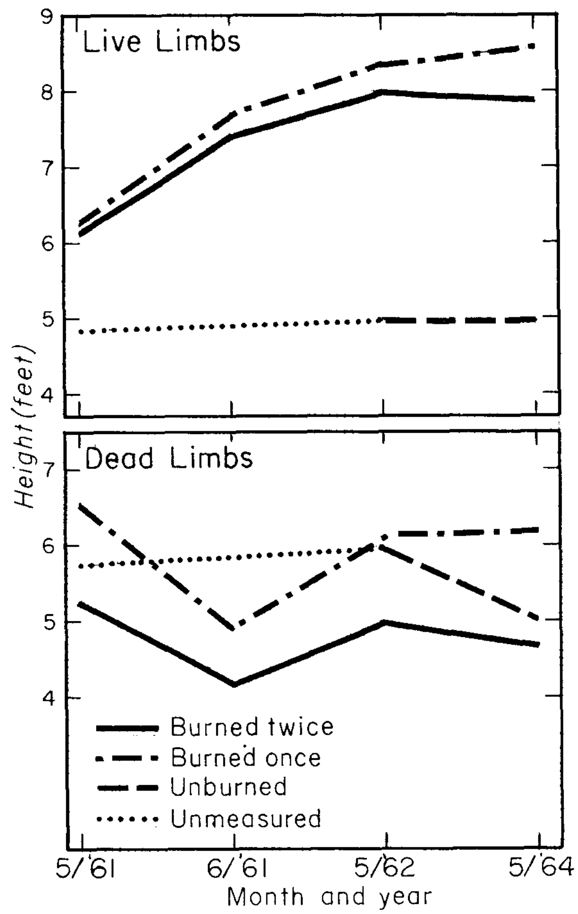


Figure 4. *—Average heights above ground of dead and live limbs at times indicated, for live trees only, third burn.*

The first burn achieved the most over-all fuel reduction. But it also caused most of the mortality which created new fuels *(fig. 6)*. The most striking reduction of fuel occurred in the litter class. Initial litter weight was reasonably comparable between plot groups.

Potential rate of fire spread on the area was therefore at a lower level immediately after the first burn, and was decreased slightly more by the second burn. Description of fire behavior during the reburn supports this judgment.

Medium and large fuels were distributed unevenly over the area, as indicated by grouped plot data in figure 6. Reduction of those original fuels on the burn-reburn area was encouraging, because potential fire intensity was lowered.

Figure 5. — *Site of the third burn as it appeared in 1964. Killed trees bend toward the ground. Forester segregates and weighs fuels.*

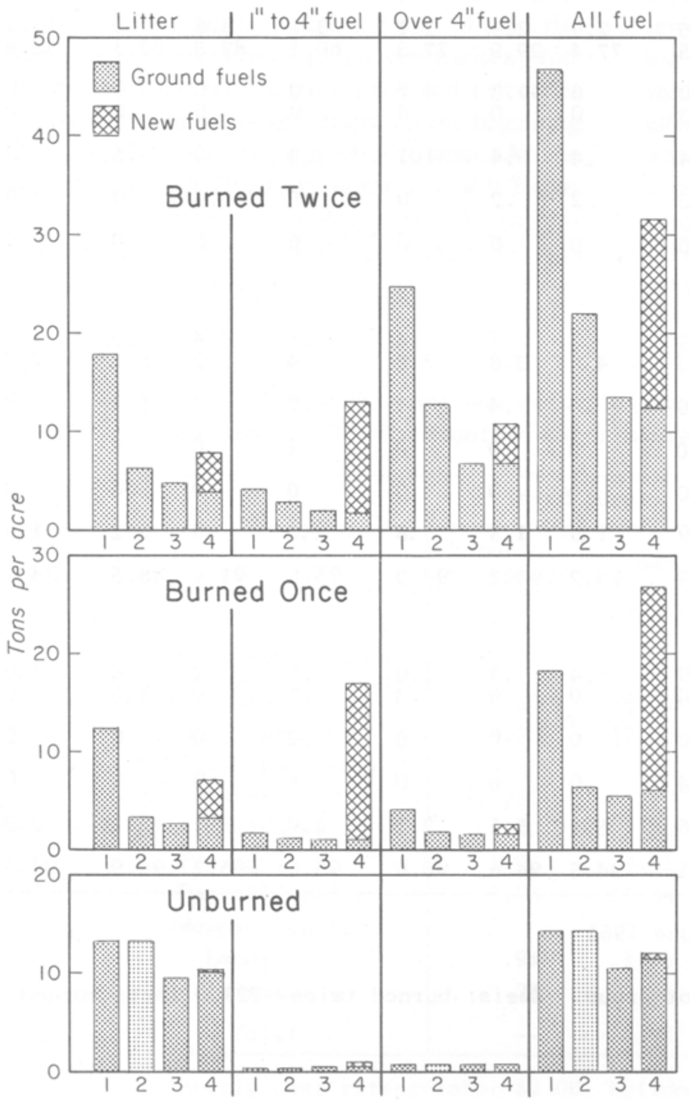


Figure 6. — *Third burn — fuel weights (oven-dry), by fuel size classes and plot groups. Numbers below bars refer to date when trees examined: 1 = May 1961 (before first burn); 2 = June 1961 (after first burn); 3 = May 1962 (after second burn); 4 = May 1964 (3 years after first burn). Bar 2 for unburned plots is assumed — no examination. The upper part of the fourth bar in each fuel class represents dead fuels which were cut, segregated by size, and weighed or measured at the last examination.*

Table 9.--*Line intercept class relationships, by plot groups at successive examinations, Blacks Mountain Experimental Forest*

| Intercept class and level | 11 plots burned twice, examined | | | | 9 plots burned once, examined | | | | 5 plots unburned, examined [1]... | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-burn May 1961 | After first burn June 1961 | After second burn May 1962 | Final May 1964 | Pre-burn May 1961 | After first burn June 1961 | After second burn May 1962 | Final May 1964 | Pre-burn May 1961 | After second burnt May 1962 | Final May 1964 |
| | *Percent*[3] | | | | | | | | | | |
| Ground level: | | | | | | | | | | | |
| Tree | 1.2 | 1.2 | 0.9 | 1.0 | 0.4 | 0.4 | 0.3 | 0.2 | 1.9 | 1.2 | 1.3 |
| Forbs | 5.7 | 3.8 | 1.4 | 1.0 | 2.4 | 1.9 | 1.2 | .2 | 1.9 | .1 | .1 |
| Grass | .8 | .2 | .6 | 1.1 | 1.3 | 1.0 | .3 | 1.2 | 1.0 | 2.4 | 1.7 |
| Sedge | .3 | .2 | .1 | .2 | .1 | .1 | .8 | .5 | 0 | 0 | .4 |
| Sage | 3.4 | 3.2 | .4 | .2 | 3.8 | 2.8 | .8 | 0 | 4.8 | 2.6 | .4 |
| Other brush | 0 | 0 | 0 | 0 | 0 | 0 | .1 | 0 | 0 | 4.7 | 1.9 |
| Rock | 3.3 | 3.3 | 3.6 | 5.4 | 11.1 | 11.1 | 11.3 | 14.0 | 3 .6 | 5.6 | 4.1 |
| Mineral soil | 1.9 | 1.9 | 5.4 | 3.6 | 2.9 | 2.9 | 2.1 | 3.1 | 3.6 | .8 | .9 |
| Litter | 76.4 | 34.6 | 59.2 | 82.5 | 77.4 | 29.9 | 77.3 | 80.5 | 82.8 | 82.1 | 88.4 |
| Charred litter | 0 | 44.8 | 24.0 | 0 | 0 | 49.3 | 4.7 | 0 | 0 | 0 | 0 |
| Bark | .4 | .2 | 0 | .3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1"- 4" dry fuel | 2.9 | 2.9 | 1.9 | 2.4 | .4 | .4 | 1.1 | .3 | 0 | .5 | .8 |
| 1" -4" wet fuel | .1 | .1 | 0 | .3 | .2 | .2 | 0 | 0 | .4 | 0 | 0 |
| Over 4" dry fuel | 3.6 | 3.6 | 2.5 | 2.0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18-inch level: | | | | | | | | | | | |
| Tree | .2 | .2 | 1.2 | .9 | .1 | .1 | .4 | .5 | 5.4 | 1.3 | 1.3 |
| Sage | .4 | 0 | 2.9 | 1.3 | 4.8 | 3.8 | 3.6 | .4 | 3.2 | 6.3 | 2.3 |
| Other brush | 0 | 0 | 0 | 0 | .4 | .4 | .3 | .7 | 0 | 1.1 | 0 |
| 1"- 4" dry fuel | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .4 | 0 | 0 | .4 |
| Over 4" dry fuel | 0 | 0 | 1.1 | 0 | 0 | 0 | 0 | 0 | 0 | .6 | 0 |
| "Overhead" fuel, fine, live or dead | 6 | .2 | 0 | .9 | 1.5 | 1.5 | .8 | 2.2 | 0 | 2.2 | 1.6 |
| Air | 98.8 | 99.6 | 94.8 | 96.9 | 93.2 | 94.2 | 94.9 | 95.8 | 91.4 | 88.5 | 94.4 |
| 48-inch level: | | | | | | | | | | | |
| Tree | 0 | 0 | .8 | .9 | .4 | .3 | 1.0 | .7 | .2 | .6 | 1.0 |
| Sage | 0. | 0 | 0 | 0 | 0 | 0 | .3 | .1 | 0 | 1.3 | .6 |
| Other brush | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .2 | 0 | 0 | 0 |
| 1"- 4" dry fuel | 0 | 0 | .1 | .4 | 0 | 0 | 0 | .4 | 0 | 0 | 0 |
| "Overhead" fuel, fine, live or dead | 1.8 | 1.8 | .8 | .6 | 5.1 | 5.1 | 2.1 | 2.0 | 3.1 | 3.2 | 3.9 |
| Air | 98.2 | 98.2 | 98.3 | 98.1 | 94.5 | 94.6 | 96.6 | 96.6 | 96.7 | 94.9 | 94.5 |

[1]No examination made after first burn, June 1961.

[2]Four plots only.

[3]Percent of total line sample in each plot group. Basis: .burned twice--229.9 feet; burned once--188.1 feet; unburned--104.5 feet.

The greatest increase in post-burn dead fuel, however, was in the 1- to 4-inch class. The potential future effect of this fuel is unknown and open to conjecture. Previous mention was made of the early bending of dead saplings and poles so that fine twigs in the crown become close to the ground. Within a few years, these small trees will fall into a jackstraw mass on, and slightly elevated above, the ground. When this occurs, enough annual needle cast from the live stand may accumulate to bring about a condition in which fire—intentional or accidental—would again encounter conditions favorable to high rate of spread and high intensity. And the resistance of the jackstraw mass to fire line construction would be considerable.

Almost as much dead fuel was found on the area at the end of the study as before the burns *(fig. 6).* Tonnage represented by new fuels is, of course, additive to the remaining part of the original ground fuel. For a rough comparison, fuel weight for areas burned both once and twice was simply averaged on an acre basis. At the beginning of the study, fuels aggregated 32.6 tons. At the end, they totaled 29.2 tons, consisting of 9.2 tons of ground fuel and 20 tons of new fuel. We accomplished, then, a net fuel reduction of about 3.4 tons per acre — 10 percent.

In the 1961 burn, only 42 percent of the ground surface area actually burned. A comparable figure for the second burn was 14 percent. These results illustrate that, under the prescribed conditions used, (a) fire was not a very efficient clean-up tool on an area basis, but (b) the heaviest concentrations of litter must have been reduced significantly.

Estimates of portion of area burned based on milacres and on line transects *(table 9),* were reasonably comparable. The milacre-based estimate for the first burn was 42 percent, compared to 47 percent estimated from line transects. The intercept class named "charred litter" was used for the latter estimate, this being the only fuel class which reflected a reduction.

Probably only a few general trends can be inferred from the data in table 9 which relate to low vegetation. Where low plants are scarce and scattered, I question the accuracy with which our technique could measure and remeasure them in a study of this size. For example, plant growth, the effects of animal browsing or trampling, and the action of the snow pack in bending small brush in a possible different direction each year, all could contribute significantly to sampling errors. Sampling in May 1961, 1962, and 1964 is believed to have been accomplished at about the same pheno-

Table 10.--*Work input and costs*[1] *associated with prescribed burns, acre basis, Blacks Mountain Experimental Forest, 1962*

| Activity | Third burn | | Reburn of third burn | |
|---|---|---|---|---|
| | Labor or equipment | Cost | Labor or equipment | Cost |
| | *Hours* | *Dollars* | *Hours* | *Dollars* |
| Crop tree selection and litter-removal | 7.11 | 14.22 | -- | -- |
| Rough pruning | 8.78 | 17.56 | -- | -- |
| Slash bunching: | | | | |
| Labor | .30 | .60 | -- | -- |
| Bulldozer | .30 | 1.35 | -- | -- |
| Firing | 1.06 | 2.12 | .85 | 1.70 |
| Patrolling fire | 5.76 | 11.34 | 5.08 | 10.16 |
| Mopping up fire: | | | | |
| Labor | .91 | 1.96 | 13.69 | 27.38 |
| Pumper | .23 | 2.76 | 2.54 | 30.48 |
| Total | -- | 51.91 | -- | 69.72 |

[1]Hourly cost rates: labor $2.00, bulldozer $4.50, pumper $12.00.

logical stages for low vegetation. Sampling in June 1961 followed that of May by only 10 days. But slight changes would probably have occurred in broad-leaved vegetation. These changes would further be confounded by effects of the first burn. In the third burn, there was a scarcity of low vegetation beneath this pole stand: only 8 to 9 percent of the ground surface was covered by living plants before the burn. On the other hand, about 80 percent of the surface was covered with dry fuel of all classes.

The general lack of fuel in the space from ground level to the 48-inch sampling level testifies to the effectiveness of the preburn "pruning" treatment.

Time-cost data require some comment *(table 10).* First, nothing is shown for planning, supervision, or fire trail construction. Nor is there a charge for standby of fire crew and pumper during the main burning period. Time-cost data for those items would be entirely out of proportion to other costs in such a small burn. Second, work time shown is productive time recorded to the nearest five minutes; no rest time is included.

Costs of similar work might vary considerably from one stand condition to another. The high mopup cost after the re-burn was unavoidable. Necessity for this work has been explained—changes from predicted weather conditions can occur in the eastside pine type at almost any time. When we consider the time-cost table and the qualifications above, we conclude that broadcast prescribed burning for hazard reduction cannot be done for "the cost of a box of matches."

# Experimental Replication

Except for a fall burn trial, we considered replications of these three burns under exactly similar or slightly modified prescriptions and conditions to be unnecessary. In each case we learned at least one important lesson which implied the fruitlessness of repetition: first burn—do not burn during warm dry conditions because of the danger of losing control; second burn—do not burn in unpruned or otherwise untreated pole stands because of the danger of damaging crown fires and creation of new fuel; third burn and re-burn—it is questionable whether the apparently fleeting reduction in fuel hazard obtained justifies the cost incurred during pre-burn preparation and burning.

# Factors Affecting Feasibility of Burning

## Weather

An area quite similar in appearance and treatment to the third burn area was prepared but never burned. Our goal was a fall burn for fuel hazard reduction in a pole stand. Plans were cancelled in 3 successive years because of unfavorable weather.

Inspection of Blacks Mountain weather records for a 19-year period, and records kept for the reported burns, shows that weather and fuel moisture conditions appropriate for prescribed broadcast burns exist for only a few hours on a few days each year—almost never would they exist all day for a few successive days. Rapid and wide daily fluctuations of air temperature and relative humidity are characteristic of the area in spring and fall. Weather conditions, then, would severely limit the period when areas could be broadcast burned safely in the eastside pine type. Weather forecasts needed for planning have been shown to lead into unexpected or sudden difficulties with fire control.

## Stand Structure

For each burn, we tried to select an area of reasonable uniformity in stand structure. The object was to reduce the potential variables in fire behavior and the after-effects. The general stand structure of the eastside pine type, however, is a mosaic of patches of trees of rather uniform size or age classes. Most of these patches are small—from less than one-tenth of an acre to a few acres. Stand densities range from as many as 17,000 stems per acre in stagnated sapling stands to scattered small groups of trees and isolated stems near the sagebrush flats.

Eastside pine stands consisting of pole-size or smaller stems, with the possible exception of stagnated sapling stands, usually have at least some differentiation of crown classes. This structural characteristic provides in many places a ladder of relatively fine aerial fuel from the ground upward. This ladder can be broken by pruning or thinning,

Figure 7. — *A young immature stand of ponderosa pine. White stick is 6 feet long.*

or both, so that some elements of a stand would survive one or more broadcast burns hot enough to accomplish some fuel hazard reduction. However, labor to accomplish this result is bound to be relatively costly. Alternatively, this ladder of aerial fuel could be broken in untreated areas by low-intensity burns, but only at the expense of killing large numbers and entire groups of seedling- and sapling-size trees. Additional burns required to clean up the newly created fuels would undoubtedly cause increasing problems of stem distribution. We must protect cost-free growing stock because regeneration is expensive. In summary, the stated conditions of stand structure are now seen as formidable obstacles confronting anyone attempting to use broadcast burning in the eastside pine type.

Immature ponderosa pine (75-150 years old)—the next age class larger than poles—is probably the most youthful stand condition in which broadcast burning could be used efficiently for any management purpose *(fig. 7)*. In such stands, litter and other fuels could probably be reduced by fire without causing much mortality. Repeated burns, however, might create an unacceptable number of fire scars. The desirability of removing all litter from a stand, considering what is known about erosion and the effect of litter on soil moisture relationships, might in itself be debatable—particularly if the trees covered a slope.

## Fuel Hazard Reduction

Data from the third burn area illustrate the difficulty of getting for more than a very brief period a significant net reduction of hazardous fuels in young stands. It might be argued that an additional burn, or burns, after all standing dead fuels had fallen would solve the problem. But the size, quantity, and jackstraw arrangement of these fallen fuels would probably require that any such subsequent burn be of very low intensity if the creation of even more dead fuels were to be avoided.

We have shown that low intensity fires actually burn less than half the area intended for treatment, and are inefficient in that sense. One can speculate on differences which might occur under the same burning conditions on a larger area where drip torch lines would be spaced farther apart than 5 to 10 feet, as was our practice. In the quantitative sense, however, such fires can reduce some fuels significantly, even if temporarily. Potential total benefits of scheduled periodic burns conducted primarily for the purpose of fuel hazard reduction are, of course, still open to question.

## Thinning

These studies indicate that dense seedling and sapling groups—those most in need of thinning—essentially would be completely killed by broadcast burns, thus adding to a fuel hazard problem (and a regeneration cost). And about the same amount of fuel would be created by any mechanical thinning method. A mechanical method would, however, have the advantage that superior trees would be left at desired spacing. We cannot credit fire with the intelligence to do that for us.

We have shown indirectly that fire could be used to thin pole stands, but only by spending about $34 per acre to protect the stands from excessive mortality. In 1964, a thinning contract awarded on the east side of Lassen National Forest cost about the same—"leave" trees in pole and sapling stands were marked and thinning work accomplished (including special work on 50-foot wide fire lanes) for about $33 an acre.

## General Implications

No significant amount of living timber stands in California has been intentionally broadcast-burned during recent times. Judicious use of fire in other parts of the United States has been an inexpensive means of reducing hazards and accomplishing certain degrees of thinning, but foresters in California have been reluctant to prescribe fire use for such purposes. Their reluctance might be a reaction to long-term observation of prevailing weather patterns, and of the behavior and results of fire in patchy stands. Such stands are not confined to the eastside pine type, but exist on much of California's commercial timber land.

In commercial timber stands, certain applications of prescribed burning to reduce ground or standing fuels, or both, seem entirely feasible: clearing organic material from clearcut areas, creating relatively wide fuel-breaks, or even hazard reduction in relatively large areas of certain "open" stand types. But our experience indicates that broadcast prescribed burning is not feasible in the eastside pine areas designated for high-level wood production, whether for fuel hazard reduction or thinning young stands.



GPO 975-151

Gordon, Donald T.

1967. **Prescribed burning in the interior ponderosa pine type of northeastern California . . . a preliminary study.** Berkeley. Calif., Pacific SW. Forest & Range Exp. Sta. 20 pp., illus. (U. S. Forest Serv. Res. Paper PSW-45 )

Three prescribed burns, made in 1959-62, in the interior ponderosa pine type of northeastern California are described in terms of meteorological factors, fire behavior, and effects of burning. Results were generally unsatisfactory. Factors that limit the usefulness of prescribed burning for reducing fuel hazard or for thinning in young-growth stands include stand structure, weather patterns, and costs.

*Oxford:* 187x626( 794) [--436 + 432.16 + 231.22 + 436]

*Retrieval Terms:* California; interior ponderosa pine; Blacks Mountain Experimental Forest; prescribed burning; burning weather; fuel hazard reduction; understory removal. Line Project: 1201.

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