# FOREST FIRE PREVENTION AND CONTROL IN THE UNITED STATES

BY

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CONTENTS

**Part III**
**FOREST FIRE ECONOMICS**

## PREFACE

[illegible] of the fundamental [illegible] [illegible] the forest from uncontrolled fires so that students of [illegible] acquainted with forest fire prevention and control technique that [illegible] in the United States.

The writer believes that there is a niche in our forestry education which can be [illegible] by devoting more time to the subject of forest fire prevention and control. [illegible] that each graduated forester have some special knowledge of forest pathology and forest entomology, two of the three phases of forest protection, but as a separate subject, protection from forest fires has been omitted. Because of its importance in forestry practice, and especially with the technical development in recent years, the theory and the practice of protecting the forest from fire is worthy of special treatment.

Although protection from forest fires may be largely an administrative matter, it nevertheless is based on certain theories and premises. The orderly execution of action based on sound theory makes protection from uncontrolled forest fires successful.

The numerous ramifications of the field of forest fire protection cannot be adequately covered in a publication of this type. This is merely an attempt to bring together between two covers a preliminary digest of the fundamental principles of forest fire prevention and control and, in a limited way, their application. With this phase of forest protection in a period of rapid evolution, some of the material contained herein will shortly be obsolete. To prevent the publication from becoming obsolete too quickly, the loose-leaf binding has presented a means of keeping the contents reasonably up-to-date without too great an expenditure. Individual chapters will be revised periodically so that the contents will include information on new developments and also enable the author to improve the treatment given to the several subjects. Chapters I, II, and XII have been revised to include additional information.

Acknowledgment is made for the suggestions for improvement extended by those who reviewed the whole or a part of the original manuscript. The author is particularly grateful to D. B. Demeritt, Paul W. Stickel, Evan W. Kelley, Clyde Leavitt, Harry Lee Baker, I. [illegible]. Young, and Taintor Parkinson for valuable suggestions. Acknowledgment is also made for the criticisms offered by those faculty members whose use of the text made a second printing possible. The cooperation given by numerous individuals in the several branches of the United States Forest Service and a few state forestry departments in submission of data, photographs, and drawings contributed materially to the contents of the publication.

A. D. FOLWEILER

University, Louisiana
July, 1938

## Chapter I

## INTRODUCTION

[illegible] advent of [illegible] forest fire control was the [illegible] forest fires are picturesque; they commence quickly; [illegible] of human life; they are full of [illegible] making them good copy. The control of forest fires, moreover, [illegible] forestry. Because of this, much of the public has [illegible] forest fire control as the whole of forestry.

[illegible] p.1208)* states that the prevention and control of fires is a basic require[illegible] practice of forestry, regardless of whether the property is managed for commercial timber pro[illegible] wild life, or recreational purposes. This statement indicates that any [illegible] deals with the management of forest land will, sooner or later, be confronted with the prob[illegible] forest fire control. The intelligence with which he approaches the problem will determine the de[illegible] success of the forester on whom direct responsibility rests with regard to forest fire prevention [illegible]trol.

[illegible] new in the idea of controlling forest fires as being good forestry practice. [illegible] have long recognized the damage it does and their administrative practice includes [illegible] fires.

In the United States, forest fire prevention and control has been practiced in some of the eastern [illegible] of the western states more or less effectively for 25 years. Until the western national [illegible] more [illegible]sible, effective forest fire control was almost impossible. Protection [illegible] is relatively new in the South. Although the South has no recorded conflagrations [illegible] in the Lake States, fires have influenced the composition of the forest.

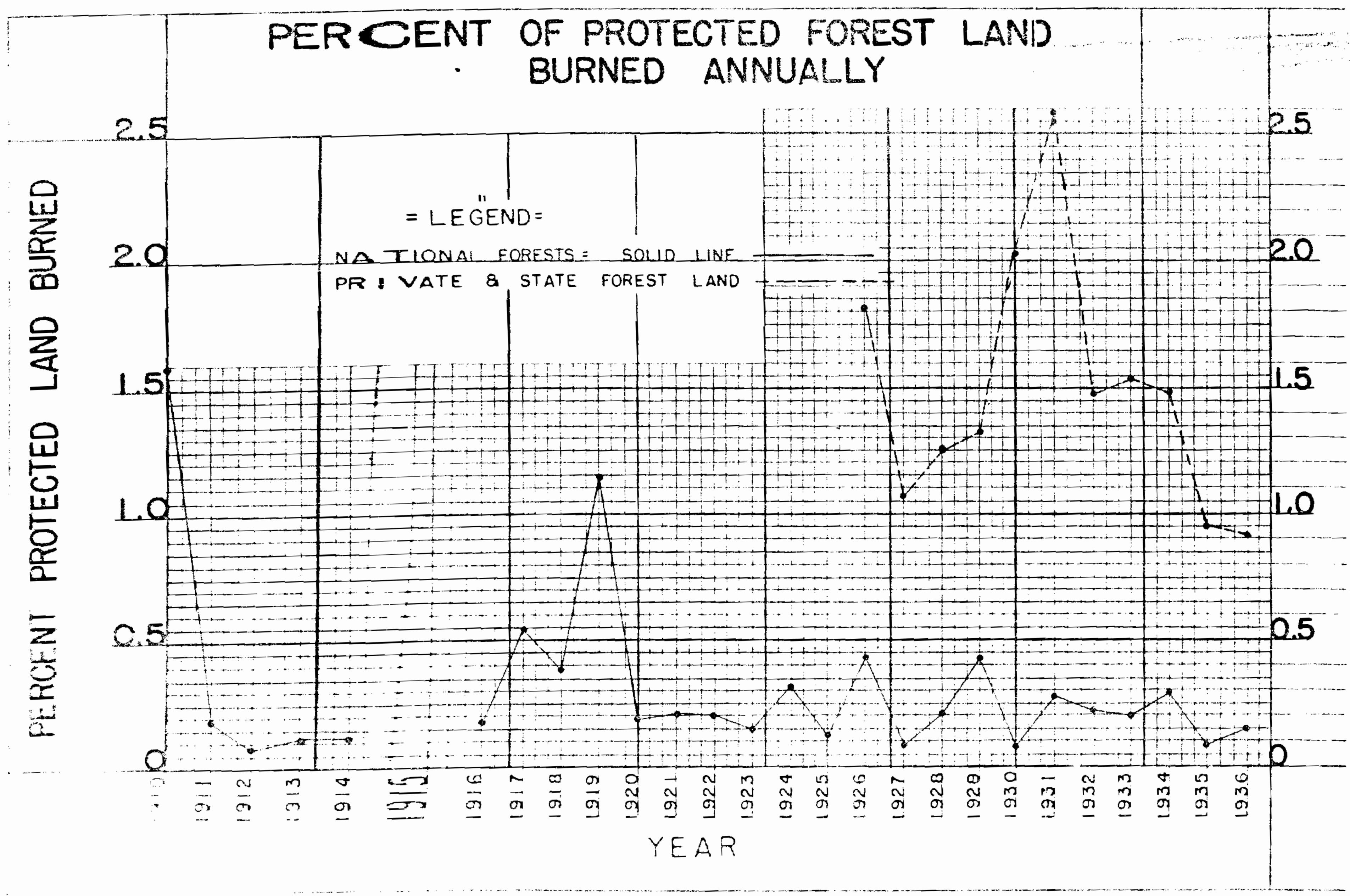
[illegible] of differences in climate, population density, and social pattern, the task of protecting the [illegible] fire varies in each forest region. Throughout the United States, however, in each forest re[illegible] there is a similarity of broad objectives and certain principles can be applied in achieving these [illegible], regardless of the location of the forest region.

[illegible] element in the prevention of forest fires is an understanding of the causes. In the [illegible] forest regions, where man is responsible for more than 98 percent of the forest fires, obviously [illegible] of prevention is one of public relations. In the western forest regions, lightning becomes a [illegible] important cause, but the job of human relations still exists. If there were no fires, the need for [illegible] would be unnecessary, but total absence of fire from the forest cannot be achieved, [illegible] there is human activity, fire is employed, and where there is fire, human carelessness, and [illegible], there surely will be occasional forest fires.

### The Merits of Forest Fire Prevention and Control in the Practice of Forestry

If forest land is to be managed for forestry purposes, and this implies maintaining the land in[illegible]finitely in productive condition whereby the fullest use may be derived from the tree growth on the area, protection against fire must be given to the area. If one regards tree growth on land as a secondary con[illegible]sideration, with some item such as the production of beef cattle as primary (205) (176), then one is util[illegible] land for some purpose other than the sustained production of timber. If, on the other hand, land is [illegible] for forestry purposes, then it is necessary to determine what effect fires have on forest land. "Forest fires," as used generally, convey the idea of the fuels of the forest in state of more or less violent, uncontrolled combustion with the fire permitted to take whatever direction it chooses and burn without consideration of effect. If forest fires cause damage, that is, if the net result of a forest fire is the lowering of the utility of land and the forest growth on it, then efforts are justifiable for the prevention and control of forest fires.

* Numbers in parentheses refer to tabulation of literature cited pp. 159-164.


PERCENT OF PROTECTED FOREST LAND
BURNED ANNUALLY
= LEGEND =
NATIONAL FORESTS = SOLID LINE
PRIVATE & STATE FOREST LAND
PERCENT PROTECTED LAND BURNED
YEAR
0
0.5
1.0
1.5
2.0
2.5
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
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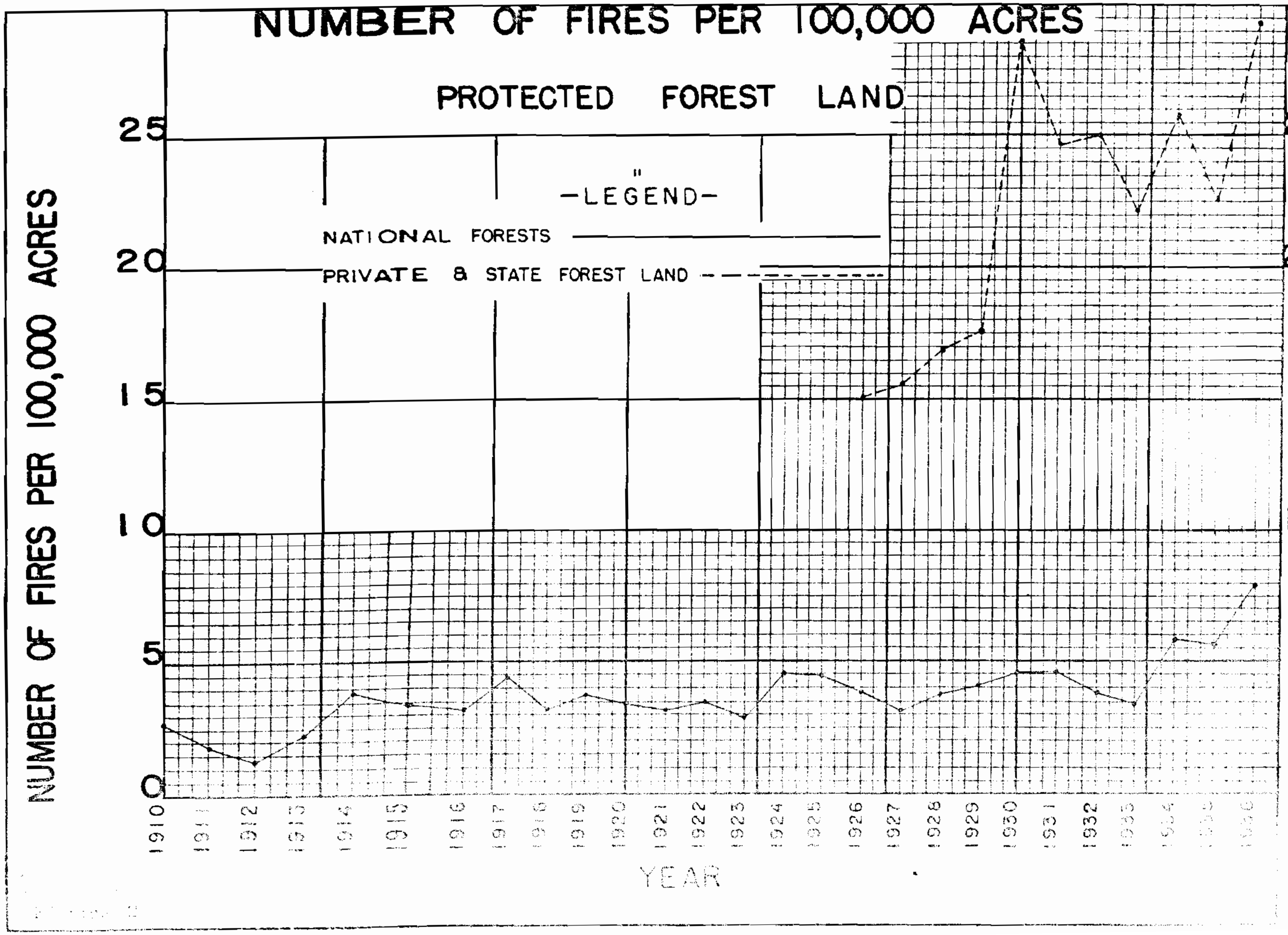
1932
1933
1934
1935
1936


NUMBER OF FIRES PER 100,000 ACRES
PROTECTED FOREST LAND
-LEGEND-
NATIONAL FORESTS
PRIVATE & STATE FOREST LAND
NUMBER OF FIRES PER 100,000 ACRES
0
5
10
15
20
25
YEAR
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936

## Table 1

[illegible]

[illegible] AND [illegible]

NATIONAL FORESTS, [illegible]

[illegible] AND PRIVATE LANDS PROTECTED FROM FIRE, [illegible]

| [illegible] | [illegible] | Area Burned: Nat'l Forests | Area Burned: State and Private Lands | Percent of Protected Area Burned: Nat'l Forests | Percent of Protected Area Burned: State and Private Lands | Number of Fires: Nat'l Forests | Number of Fires: State and Private Lands | Number of Fires Per 100,000 Acres Protected: Nat'l Forests | Number of Fires Per 100,000 Acres Protected: State and Private Lands |
|---|---|---|---|---|---|---|---|---|---|
| [illegible] | | [illegible],?76,10? | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible] | | [illegible] | | [illegible] | | 1.[illegible] | |
| [illegible] | | 147,[illegible] | | [illegible] | | ,17 | | [illegible] | |
| [illegible] | | [illegible]29,043 | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | 130,[illegible] | | [illegible] | | [illegible] | | 3.63 | |
| [illegible] | | | | | | [illegible] | | 7.44 | |
| [illegible] | | 303,[illegible] | | .1[illegible] | | [illegible] | | 6.[illegible] | |
| [illegible] | | [illegible] | | [illegible] | | [illegible] | | 4.44 | |
| [illegible] | | [illegible] | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible]97,[illegible] | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible] | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible] | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible] | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible] | | .139 | | [illegible] | | [illegible].64 | |
| [illegible] | | [illegible],044 | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | | [illegible]1,102 | | [illegible] | | [illegible] | | [illegible] | |
| [illegible] | [illegible] | [illegible] | 3,[illegible] | .4[illegible] | [illegible] | [illegible] | [illegible] | [illegible] | 15.[illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | .[illegible]5 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible] | [illegible] | [illegible],640,[illegible] | .202 | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |
| [illegible] | [illegible],277,[illegible] | 585,309 | 3,514,570 | .295 | [illegible] | [illegible] | [illegible] | [illegible] | 25.[illegible] |
| [illegible] | [illegible] | 16[illegible],394 | [illegible],311,430 | .090 | [illegible] | [illegible] | [illegible] | [illegible] | 22.[illegible] |
| [illegible] | [illegible] | 280,584 | [illegible],050 | [illegible] | [illegible] | [illegible] | [illegible],70[illegible] | [illegible] | [illegible] |

[illegible] this material contains a detailed description of the manner in which uncontrolled forest fires [illegible] the [illegible]ility of forest sites. With few exceptions, the record is in favor of protecting the forest against fire where there is a desire to maintain the forest in productive condition. There are [illegible], admittedly, where tree species of high commercial value have persisted in spite of uncontrolled fire, [illegible] one is entitled to ask, even though the answer is open to question, "Would not the [illegible] have remained in a more productive condition had the fire been controlled?"

History of Forest Fire Consciousness

[illegible] was a development which accompanied recognition of the place of forestry on the [illegible] of the nation. For 150 years the United States considered the forest a liability instead of an [illegible] it screened the hostile Indians and was in possession of soil needed for crops. This view-[illegible] changed until Congress passed the Timber Culture Act of 1873; forests then became assets [illegible] in the Great Plains region of the United States.

[illegible] for action against forest fires has been recognized in the United States for a long time. [illegible] were considered harmful is illustrated by action taken in 178[illegible] by the State of New York. [illegible] officials such as justices of the peace, town supervisors, highway commissioners, and [illegible] were charged with the extinguishing of forest fires and with power to summon residents [illegible] the penalty of a fine for refusal. (1-p. 764-777)

[illegible] Forestry Division was created in the United States Department of Agriculture, but with no [illegible] administer Federal forest lands, its activities were chiefly in the nature of the extension [illegible]. With the passage of the Act of 1891 whereby the President was empowered to create [illegible] of the public domain, the United States [illegible] al-[illegible] the reserves was given little [illegible] [illegible]ed to provide for the administration [illegible] 1905 [illegible] administration of the Timber Reserves [illegible] the Depart[illegible] [illegible] the Reserve [illegible] through the [illegible] known as the Forest Service became [illegible] national forests, aggregating approximately [illegible] [illegible] One of the first steps taken in the administration of these lands was the protection from fire.

The [illegible] of [illegible] forest administration [illegible] the principles [illegible] "[illegible] of Forests from Fire" [illegible]. The publication [illegible] [illegible], [illegible] successful practice of forestry is protection from [illegible] fire." [illegible] the Chief of the United States Forest Service [illegible] [illegible] uncontrolled fire was not compatible with good forestry practice.

During the period that the Federal Government was commencing to administer the Timber Reserves, several [illegible] were establishing administrative agencies for forest conservation. [illegible] has [illegible] of the four state forest administrative agencies that came into existence in 1885, the New [illegible] organization was the only one that survived. With its acquisition of forest lands in [illegible], covering [illegible] of important rivers, Pennsylvania too was confronted with the problem of protecting its forest land from fire. In [illegible], Minnesota also acquired forest land which required administration. In 1885 Colorado and New York passed laws which introduced the principle of centralized supervision of a state-wide local warden force. Admittedly, not much was accomplished under these early laws, [illegible] serve to illustrate the point that there was in some places tangible public admission of the need [illegible] against forest fires. It was not until almost twenty years later that some states commenced to [illegible] that the job of public effort in forest fire prevention and control was a specialized one that called for special training and that centralized control was necessary.

Private land owners were forced to form protective associations against forest fires in the Pacific Northwest where fires frequently resulted in conflagrations. Although the public admitted that organized state protection against forest fires was desirable, it was the owners of timber land who really had something at stake, so were forced to act as individuals to protect their lands.

The first timberland owners' forest fire protective association was formed in Idaho in 1906. The idea spread quickly in the region so that similar associations were formed in Washington and Oregon because of the inability of the state to adequately meet the protection needs. In several cases, however, not all owners were willing to cooperate. Those owners who wished protection were compelled, in their own interests, to extend protection to areas whose owners contributed nothing to the prevention and control work. Eventually this difficulty was overcome by the several northwestern states enacting laws which compelled all owners within the boundary of a private protective association to contribute to the maintenance of prevention and control forces.

The Weeks Law of 1911 and the Clark-McNary Law of 1924 both assisted materially in extending forest fire protection on state and private lands through the several state forestry organizations charged with forest fire prevention and control. Both these laws strengthened the state's work in affording better protection to private forest lands. The Weeks Law in particular helped to crystallize sentiment in several states that theretofore had been unwilling to accept the principle that the state had a responsibility in protecting private forest land against depredations by fire.

With the exception of four states now having in excess of 700,000 acres of forest land in the form of state forests, the protection of forests from fire damage is the largest job of the several state forestry departments. Those state forestry organizations which are not administrators of state forest land have various ways of extending their protection services to private timber lands. In some cases, the state assumes direct responsibility for forest fire suppression on private lands. In other instances, the responsibility lies entirely with the private owner.

**Phases of Forest Fire Protection**

Activity in protecting the forest from fires falls logically into two groups, namely (a) prevention and (b) control.

PREVENTION work, as the word implies, is directed toward preventing fires from starting. As discussed in Chapter 3, more than 90 percent of the fires in the United States are caused by human activity. Fires are set by men either through willfulness or carelessness. Those fires chargeable to carelessness predominate. With this in mind, one can realize that with no fires, there can be no damage. With no fires occurring, moreover, the cost of suppression can also be eliminated.

As discussed in Chapter 4, prevention can be accomplished by educating the public as to the effects of forest fires and the way people feel, indirectly or indirectly, the damage. Efforts in this direction ... vision. Prevention is also accomplished by altering the character of the fuels in ... that fires cannot start, or arranging the fuels so that if they ignite, the damage done is negligible. An illustration of this is hazard reduction, or the removal of the fuels by annual controlled ... of land paralleling a railroad where records have shown that fires have started sev-...

As pointed out previously, the total elimination of uncontrolled fire from the forest is impossible, so adequate facilities must be maintained to control the fires in event they occur. Even though the number of fires is reduced through prevention efforts, an organization is still always necessary to detect ... that start and control them before they do much damage.

... activity breaks down into two phases, (a) pre-suppression and (b) suppression. Pre-suppression ... is that done in advance of the occurrence of a fire and contributes materially in the reduction of ... of damage that would otherwise occur in its absence. Common illustrations of pre-suppression ... construction of lookout points for speeding the detection of fires, the construction of telephone ... installation of radio for the quick transmission of news of detection to suppression screws, the ... of roads to facilitate the delivery of the man-power to the fireline, the training of ... in their various functions, and the gathering of data whereby the administrative ... the probability of the occurrence of fires and their behavior if they start.

... phase of control consists of the active suppression of fires when they start. It deals ... of manpower and equipment on the basis of a plan and perfected by the training of ... suppression phase of control work was that part of forest fire protection that was ... individual effort originally exerted by the private owner who wished to keep damage by ... Later state legislatures gave public approval and support to organized suppression ... after this first step of suppression was taken were efforts directed toward pre-suppression ... was realized that the pre-suppression could contribute so materially to the suppression ...

Today a well balanced program of protecting the forest from fire includes activity in prevention, pre-suppression, and suppression. Local conditions will determine the need in each instance as to just ... receive the greatest support. To be able to know when an organization becomes un-... of the requirements of a good forest fire protection administrator.

**Prevention Versus the Control of Forest Fires**

... effective fire control efforts are always visible. For example, a fire is burning in ... organized man-power can usually stop it in a few minutes if the fire is small. In the ... fires, the effect of the man-power expenditure is easily seen. In the prevention of fires, ... direct association of cause and effect is much less readily observed. It is difficult for an ... responsible for protecting a forest from fire to justify expenditures for preventing fires from ... in fire prevention there is frequently no direct relationship between effort and results ... in control. This situation is probably accountable for so much past effort directed toward ... little toward prevention. With expenditures for control now reaching the point of diminishing ... for each increased dosage of funds, prevention is beginning to receive more attention. ... prove it by data would be extremely difficult, currently the return in dollars expended is ... from the prevention than from control phase. Just where the balance lies between prevention ... effort is difficult to determine. It should be recognized, however, that there is a balance ... prevention and control; the more nearly the two are balanced to meet the local requirements, ... will be the results.

**Agencies Concerned with Forest Fire Prevention and Control**

... United States there are both public and private agencies which have an interest in preventing ... fires. Although the United States was developed on the "laissez faire" theory of ... protecting timber lands on this plan has never progressed far without assistance ... The outstanding reasons for this situation are: (1) the individuals believed that ... would be exploited without thought of renewal because of their abundance. The [illegible] of forestry, which meant continued productivity, was of no importance to these individuals [illegible] the need for protection of timber against [illegible] because of limited resources and [illegible] fire could be controlled before it had advanced [illegible] individuals was best illustrated by the protective associations [illegible] associations became much more effective when the public insisted [illegible] private [illegible] in the protective associations.

There exist today private organizations for the protection of forest lands against fire. These organizations, however, are merely units of the cooperative arrangement that exists between the individual, the State, and the Federal Government. The successful operation of these private units is dependent upon State cooperation from a legal standpoint, and usually upon State and Federal cooperation from a financial standpoint.

There are also several national private organizations which, although their primary concern is in all the conservation aspects of forestry, know that forestry practice is based upon forest fire prevention and control. Examples of these agencies are the American Forestry Association and the American Tree Association. Although these organizations have nothing directly at stake, they aid greatly in crystallizing public opinion in the need for protection against forest fires.

Because of the early admission on the part of private agencies that protection from forest fires is closely associated with public responsibility, the United States Forest Service has gradually come to occupy [illegible] position in the forestry picture. It is the manager of approximately 185,000,000 acres of forest land to which the federal government holds title. It is also the federal bureau through which subsidies for forest fire protection are granted to the various states for preventing and controlling fires on state and private lands. As a manager of timberland, the Forest Service has taken leadership in forest fire control because from the beginning of its stewardship, it has believed that forest fire prevention and control is necessary for successful forest management. The experience of the Forest Service in protecting its lands from fire has been available to the states.

As a land manager, the Forest Service is forced to participate in all three phases of forest fire protection. As a dispenser of a subsidy, however, the bureau is concerned with the three phases only indirectly, for it can merely establish minimum requirements under which a state may qualify for the cooperative federal funds.

Other Federal agencies which play a role in the administration of federal forest land are the National Park Service, the Indian Service, and the Biological Survey. The first two of the above-mentioned are administered by the Department of the Interior, while the last-mentioned, like the Forest Service, lies in the Department of Agriculture. None of these administrative agencies are as active or so highly organized in forest fire control as is the Forest Service, but they all recognize the value of protection from fire and have taken some precaution to prevent and suppress fires.

**Requirements for Obtaining Forest Fire Prevention and Control**

If it may be assumed that the practice of forestry must be based on the prevention and control of forest fires, there are several minimum requirements that must be complied with. These are as follows:

1. Put into action a program to demonstrate the effects of forest fires on public welfare and solicit support for forest fire protection from the public.
2. Enact state laws fixing the responsibility on the state, as a public agency, for the protection of forest lands against fire.
3. Enact Federal and State regulations so that the responsible public agencies can perform their duties adequately.
4. Appropriate sufficient public funds so that the public agencies charged with protection can perform the duties imposed upon them.
5. Employ personnel trained in forest land management, with especial emphasis on forest fire protection.
6. Separate politics from the personnel so that it may function in the interest of the public welfare primarily.

The points that have been listed above admit that organized forest fire prevention and control should

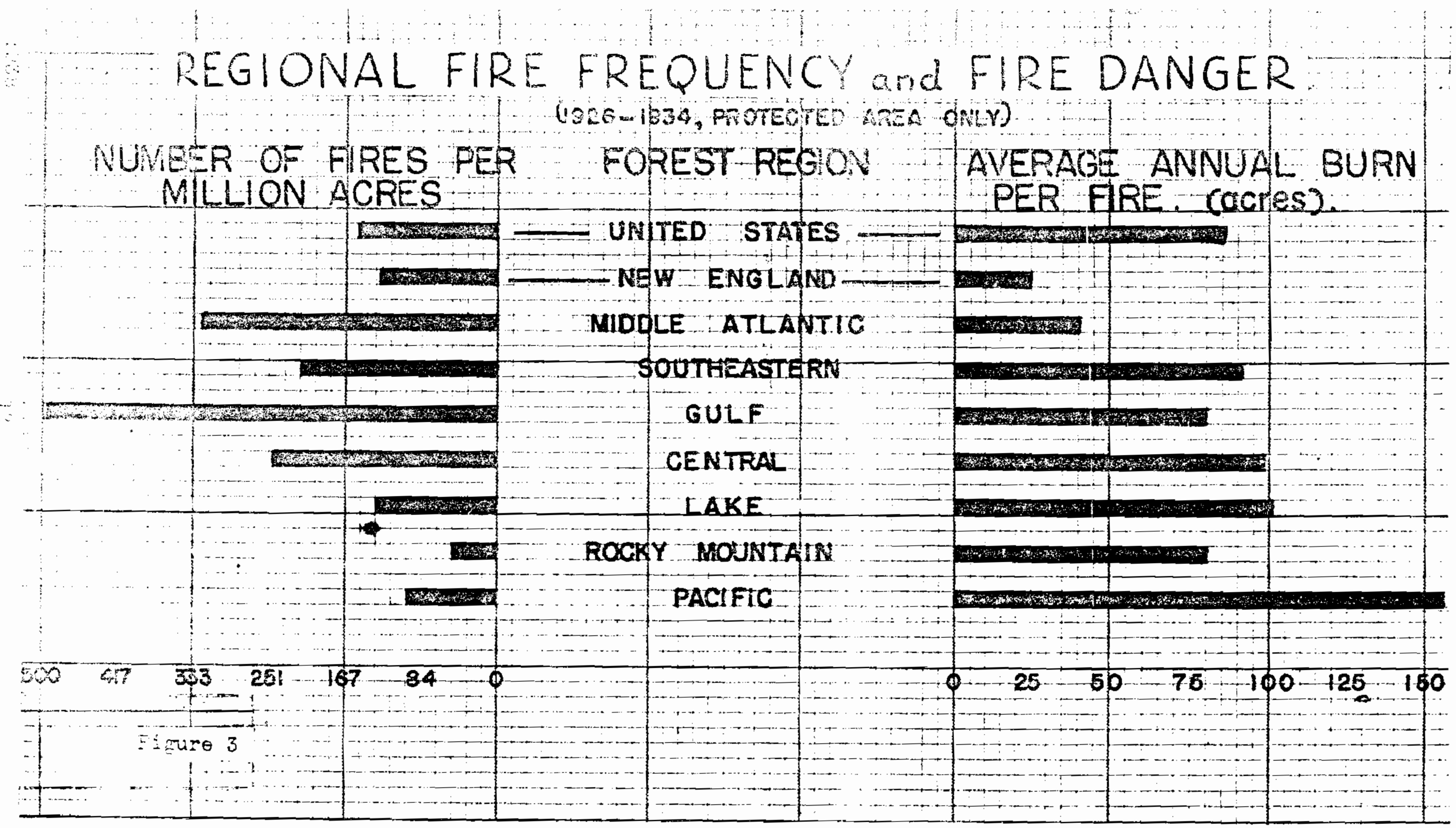

REGIONAL FIRE FREQUENCY and FIRE DANGER
(1926-1934, PROTECTED AREA ONLY)
NUMBER OF FIRES PER MILLION ACRES
FOREST REGION
AVERAGE ANNUAL BURN PER FIRE. (acres).
UNITED STATES
NEW ENGLAND
MIDDLE ATLANTIC
SOUTHEASTERN
GULF
CENTRAL
LAKE
ROCKY MOUNTAIN
PACIFIC
500 417 333 251 167 84 0
0 25 50 75 100 125 150

Figure 3

[illegible]. This does not mean, however, that [illegible] from fire. The suggestion that leadership [illegible] made so that the private owner's efforts [illegible] interested in protecting his forest land, he still [illegible] authority or must be willing to assume responsibility.

[illegible] are of relatively little importance in aiding in the [illegible] of these lands. As explained in a later chapter more fully, the Federal departmental regula- [illegible] have the full effect of law on Federal lands. As seen in Figure 1, it is the private lands that are in need of better protection from forest fires. When they are protected as well as the national forests, [illegible] have evidence that state forestry departments are redeeming their responsibility in protecting private lands against fires.

## Risk and Hazard

Two commonly used terms in forest fire prevention and control are "Risk" and "Hazard." Because of the frequency with which both these terms are used in many forest fire control discussions, it is desirable to explain the interpretation that may be given to each.

"Risk" has been defined (104) as the probability of a fire starting, based on the magnitude of the presence of causative agencies. Admittedly the same number of railroad fires may start on one day when the fuels have a very low moisture content and when few trains travel over a given forest area as on another day when the fuels have a higher moisture content but when many more trains contribute brands that convey heat to the fuels so they arrive at the point of combustion. In the second instance, the risk is to be considered greater than on the first.

"Hazard" has been defined (104) as the volume and character of the fuels that are combustible. It has no relationship to the inflammability of the fuels. It has been proposed by Martell (206) that the word "hazard" be eliminated from our forest fire prevention and control terminology so that the present confusion in its usage be avoided. It must be admitted that there are many instances where the use of these terms may have been erroneous. Some forest workers wish to have "risk" used as any subject of insurance. In this use, however, a stand of timber would be considered as a risk. The same group prefers to have "hazard" used to describe any situation or factors which menace the safety of the risk. Thus, the presence of campers in a forest containing fuels with high moisture content would be referred to as a hazard in the same manner as one would refer to the condition of the forest when the fuels have a low moisture content but there may be a total absence of causative agencies.

Until there is more common agreement in the use of these terms, it is advisable to have "risk" refer to the magnitude of the presence of the causative agencies, "hazard" as the volume and nature of the fuels, "inflammability" as the relative ease with which a fuel will arrive at combustibility when a given unit of heat is applied, and "fuels" as that combustible material in the forest that makes possible the start of a fire and the extension of its perimeter after starting. "Fire danger" is the combined product of risk, hazard, inflammability, and fuels as defined above.

To compare the acreage burned in any one region with that of another brings into consideration such items as efficiency of the control organizations and the expenditures which made possible the results achieved in addition to fire danger. Although the relative rating of the degree of difficulty encountered in controlling fires in the several regions, as shown in Table 2, is somewhat open to question, it is probably the best current index available. We must assume that for each region, the suppression forces are as efficient as the values at stake, the fuels, and the weather require.

Figure 3, which shows graphically the data in Table 2, indicates that the Gulf States Region has the highest risk, or 448 fires per million acres per year on protected land. The Rocky Mountain Region has the lowest, with 47 fires per million acres per year.

On the basis of hazard, the Pacific Region ranks highest with an average of 155 acres per fire for the period 1926-1934 inclusive. The New England States rank lowest with only 25.5 acres per fire per year.

**Table 2**

REGIONAL FIRE FREQUENCY AND EFFECT OF FIRE DANGER (137)
1926-1934
Protected Areas Only
FEDERAL, STATE, AND PRIVATE LANDS

| Region | Average Acreage Protected Annually | Average Number Annual Fires | Average Annual Number of Fires Per Million Acres | Average Annual Acreage Burned | Average Annual Burn Per Fire |
|---|---|---|---|---|---|
| United States | 336,927,405 | 52,071 | 155.5 | 4,476,947 | 85.9 |
| 1-New Eng. | 38,791,053 | 5,074 | 130.9 | 128,505 | 25.5 |
| 2-Middle Atlantic | 17,458,345 | 5,682 | 325.6 | 234,210 | 41.2 |
| 3-Southeastern | 29,651,105 | 6,433 | 219.1 | 604,240 | 93.9 |
| 4-Gulf | 31,829,935 | 14,271 | 448.8 | 1,155,505 | 80.9 |
| 5-Central | 10,314,063 | 2,566 | 248.8 | 253,094 | 98.7 |
| 6-Lake | 55,417,861 | 7,115 | 128.4 | 723,832 | 101.7 |
| 7-Rocky Mt. | 83,904,890 | 3,976 | 47.4 | 319,704 | 80.4 |
| 8-Pacific | 69,560,683 | 6,920 | 98.0 | 1,073,147 | 155.1 |

Groupings by regions--

(1) New England, Me., N.H., Vt., Mass., R.I., Conn., N.Y. (2) Middle Atlantic, N.J., Pa., Del., Md. (3) Southeastern, Va., N.C., S.C., Ga., Fla. (4) Gulf, Ala., Miss., La., Tex., Ark., Okla. (5) Central, Ohio, Ill., Ind., Ky., Tenn., Mo. (6) Lake States, Mich., Wisc., Minn. (7) Rocky Mountain, Mont., Ida., Wyo., N.D., S.D., Colo., Ariz., N.Mex., Nev., Utah. (8) Pacific Coast, Wash., Ore., Cal.

PART I

# EFFECTS OF FOREST FIRES AND THE CONDITIONS WHICH MAKE THEM POSSIBLE

[illegible] tations would report direc[illegible] head of research [illegible]ngton who, in turn, had imm[illegible] access to the chief [illegible]

[illegible] two lines of authority were [illegible]ized: one flowed [illegible] the chief through the regional [illegible] the ranger dis[illegible] and the other ran by way of the [illegible] of research from [illegible] forester to the experimen[illegible]. Research was [illegible] located sufficiently distan[illegible]rvice averred, to [illegible] a critical attitude and a de[illegible]tlook. Partly out [illegible] to allow full rein to in[illegible]nitiative and in[illegible] research itself was "high[illegible]ized" from the [illegible]ndpoint of Washington office [illegible]n.[20] "Resources [illegible]nagement begins and belongs on [illegible]und"[21]—this idea [illegible] long been a Service touchstone [illegible] would give it [illegible]ded [illegible]ality and strength.

[illegible] research's ability to fun[illegible] critical force— [illegible]ard to democratic princi[illegible]ministration and [illegible] effective offset to any trend [illegible]thoritarianism or [illegible] of science to politics"[22]— [illegible] on policies fos[illegible] the free exchange of scientific [illegible]on. Ever since its [illegible]ception, the department had end[illegible] *sine qua non* of [illegible] development. To be sure [illegible] legislation estab[illegible] the department had defined [illegible]ation "to acquire [illegible] diffuse among the people of the [illegible] States useful in[illegible] on subjects connected wi[illegible]ture in the most [illegible] and comprehensive sense [illegible]."[23] Reiterating [illegible] aim, Secretary of Agriculture J. [illegible] subsequently wrote [illegible] the department was obliged [illegible] research results [illegible] by a comprehensive schem[illegible]ication. . . . The [illegible]partment must in its informat[illegible] be exact, objec[illegible] critical and detached, even [illegible] to make it slow [illegible] ponderous as well. It must [illegible] much haste. It [illegible] afford to be in error. Its [illegible] authority entails



heavy responsibility."[24] Mindful of the furor provoked in 1913 by the Bureau of Public Roads' hiring of a "publicity agent," Milton Eisenhower, as director of information, later contended that his office had refrained from propagandizing the "Department's functions or activities. Our job is far different. Our function, as set out in the organic act of the Department, is to take the results of scientific research, put them into an understandable form and distribute them."[25]

Only recently, in 1955, the department reaffirmed its intention to pursue an "open-door" information policy encouraging correspondents to examine its operations "freely and without restriction."[26] As a constituent member of the Department, the Service is pledged to uphold this policy. It has likened its role to that of a corporation manager responsible through a board of directors (Congress) to the stockholders (citizens), with all this implies for communication to the public.[27]

Admittedly, information programs serve a dual purpose: to win consent for administrative decisions and to keep the electorate abreast of developments, however unpleasant, which might affect it. Foresters considered the stations to have potential value as demonstration centers embracing both objectives. C. A. Pearson (onetime Director, Fort Valley Station) has stressed the first: "An experiment station, if at all accessible, is visited by great numbers of people annually. Many are attracted by mere curiosity, but others show a genuine interest in the work. Not a few of these visitors are persons of scientific prominence. The experiment station is thus called upon to uphold the scientific prestige of the Forest Service."[28] But L. F. Kneipp (Assistant Chief) understood them to have a critical function as well: a "secondary but hardly less important purpose" of the stations was to "provide for the demonstration of results, favorable or otherwise."[29]

It is noteworthy, in this regard, that the Service had assured

## Chapter II

## THE EFFECTS OF FIRE

[illegible] large [illegible] fires had called to the attention of the public that uncontrolled fires [illegible] life [illegible] improved property. Such fires as the Miramichi of 18[illegible] which burned [illegible] acres in [illegible] New Brunswick, the Yaquina of 1846 which burned 450,000 acres in Oregon, the [illegible] which burned 1,000,000 acres, and more recently the Idaho fire of 1910 with [illegible] attracted attention because of their direct influence on the daily activity of people rather than because of the destruction of natural resources, disturbance to wild life, and [illegible] on streamflow. As the American frontier contracted and the Conservation Era was ushered in, at-[illegible] directed to the need for preventing and controlling forest fires. The desire to prevent and [illegible] forest fires rose out of the effects of uncontrolled forest fires. Some of the effects of forest [illegible] the loss of human life and destruction of improved property. There are numerous other effects, however, of equal importance but less apparent.

[illegible] the effects of forest fires are understood, then there will be a need for prevention and control. [illegible] understand just why and how fires should and can be prevented and controlled is based on a need for [illegible] things. That there is a need for forest fire prevention and control is demonstrated when one examines their effect.

The public has become conscious of the damage that forest fires do to such an extent that "forest fires" and "damage" have become synonyms. This state of mind has developed for good reasons. The great [illegible] of fires have caused losses because these fires have occurred when circumstances, such as weather, fuel, and topography, were favorable for the rapid spread and attendant heavy damage. But damage has not always been apparent immediately after the fire. In many instances, the damage was not apparent for several years after the fire occurred and then was seldom associated with the fire. To produce damage, a fire does not necessarily have to be large in size, travel fast, get into the crowns of conifers, and create enormous pillars of smoke. The slow-moving surface fire, hardly discernible at a distance of more than a mile, can do great damage just as does the large conflagration.

If forestry is that part of land management that is concerned with maintaining a stand of timber which may be used primarily for commercial purposes, or for controlling streamflow, or for recreational purposes, or for grazing, or a combination of these, then it is necessary to prevent fires from getting out of control. If fires are not controlled, then the forest land management for the above-mentioned purposes will be inadequate. There is ample evidence that uncontrolled fires can interfere most seriously with forest land management.

Because fires have been so destructive, it has been very natural for those agencies responsible for maintaining forest growth on land to do everything to discourage the use of fire in the forest at all times. Gradually a slightly altered point of view has developed among foresters toward fire to the point that, when used judiciously, controlled fire can be useful. In other words, fire can be used in the forest for constructive purposes. Just as a sharp knife in the hands of the clumsy, the unskilled, the malicious or ignorant can do tremendous damage, in the fingers of a skilled surgeon, it can be of great value, so with fire in the woods. There may be a use for controlled fire, but its use demands great skill so that the benefits will outweigh its destructiveness. By no means, however, is the uncontrolled, wild fire set through carelessness or maliciousness to be confused with a controlled fire set for gainful purpose.

### THE HARMFUL EFFECTS OF FIRE

Wild forest fires are so damaging because they lack the selective capacity. Shapely, vigorous trees are burned as severely as the spindly,misshapen ones. Songbirds as well as destructive hawks become blinded by the smoke of fire. Weed tree species are burned just as readily as those of high commercial value.

[illegible] that is done annually by the fires that burn in the United States may be grouped under the [illegible] below.

1. Tree growth
   a. [illegible] germination
   b. [illegible] of seedlings, saplings, poles, and standards
   c. [illegible] rate of growth
   d. [illegible] succession
2. [illegible] water relationships
3. [illegible] aeration and productivity
4. [illegible] and insect attacks
5. [illegible] activity and mortality
6. [illegible]

## 1. TREE GROWTH

### a. Seed Germination

[illegible] have a harmful effect on seed germination and survival of seedlings when they occur on sites with [illegible] deposition of organic matter resulting in the formation of wood ash to a depth of sev- [illegible] (31) found that the wood ash lowers the germination percent of the seeds and re- [illegible] mortality of the seedlings shortly after they germinate.

### b. Mortality of Seedlings, Saplings, Poles, and Standards

[illegible] are particularly injurious to seedlings which are un- [illegible]. It has been observed that even the seedlings of fire- [illegible] less than a year old succumb to the relatively [illegible] generated by a side fire in only a one-year rough. [illegible] have been cited in which the seedlings less than a [illegible] not killed, but these are probably exceptions rather [illegible] (10).

[illegible] pine reproduction has been severely damaged by a [illegible] fire which occurred late in November (11). The [illegible] in excess of 93 percent for all reproduction. An [illegible] of the report was that the degree of damage was [illegible] immediately after the fire. Seven weeks after the [illegible] occurred, a mortality of 58 percent had become apparent [illegible] percent 26 weeks after the fire. In other words, [illegible] six months were necessary to determine the final [illegible] due to the fire.

It has long been recognized that the period of highest mor- tality in the development of a tree is in its early stages when it [illegible] a seedling. A factor that contributes to the mortality is [illegible] at the base of the seedling when it is very sus- [illegible] injury during the first growing season after germina- [illegible] found that lethal temperatures for seedlings [illegible] F. for some species. All those coniferous [illegible] he worked were killed at 130° F. when exposed [illegible] for only a short time. When fire burns over [illegible] of the forest floor is changed from a green or light [illegible] gray or black, usually [illegible] of the black color, so receptive to all the colors of [illegible] and consequently [illegible] temperature. As seen in Table 2a, on the following page, [illegible] surface produced [illegible] temperatures that are fatal to seedlings.

[illegible] (169) the blackened surface caused an excessive heating of the tender seedling

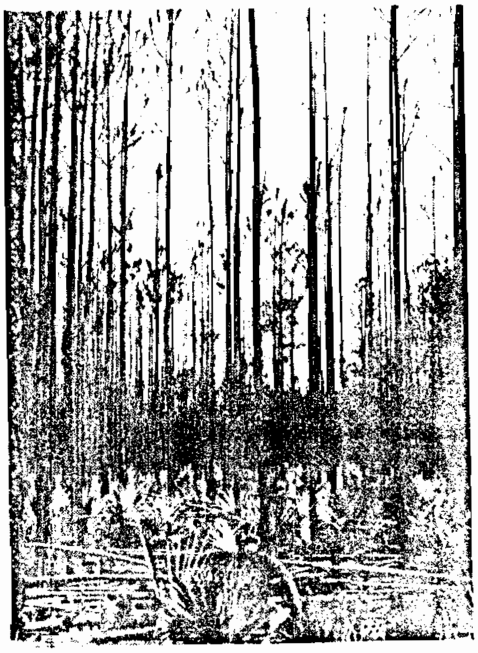


Photo by U. S. Forest Service-[illegible]

Figure 4

Complete Mortality Due To Fire In An Eleven-Year-Old Slash Pine Sapling Stand Which Had Been Thinned And The Slashing Left On The Ground As Ideal Fuel For Producing A Hot Fire

**Table 2a**

| At[illegible] | [illegible] SURFACE | | YELLOW MINERAL SOIL SURFACE | |
|---|---|---|---|---|
| | [illegible] Temp., ° F. | Cumulative Seedling Loss | Surface Temp., ° F. | Cumulative Seedling Loss |
| [illegible] | [illegible] | 47 | [illegible] | 0 |
| [illegible] | [illegible] | [illegible] | 135 | 16 |
| [illegible] | 144 | 100 | 137 | 16 |
| [illegible] | 134 | ... | 122 | 32 |
| 31 | 133 | ... | 121 | 32 |

[illegible] at the soil surface. Admittedly the seedlings were only 10 days old, but the color of the soil surface had a considerable effect on the percent of survival of the seedlings.

As discussed under the heading of "Light Burning" elsewhere in this chapter, there are some people who advocate that all forest types should be burned periodically to reduce the probability of conflagrations. The Jack Pine Plains of the Lake States are not immune to this belief. In order to get some specific information on the effect of burning the Jack Pine Plains during the period when the trees are still dormant, a "light fire" was set to learn whether damage would occur. The tally of the results (170) was as follows: reproduction 1"-24" tall, 99% mortality; seedlings 2'-7' tall, 96% mortality; saplings 2"-4" d.b.h., 84% mortality; poles and standards, 0% mortality. Admittedly the fire was set under conditions that would not have been chosen for a minimum of damage, for the fire was allowed to burn between [illegible] and 2 p.m. with an air temperature of 70° F., a relative humidity of 24%, with the moisture content of the fuels [illegible], and a wind velocity of 3 m.p.h. 6' above the ground level. It must be pointed out, however, that the "light burning" that is done usually takes place under similar conditions--those favorable for good combustion.

SAPLINGS, POLES, AND STANDARDS

Based on some of his sample plot work Stickel (13) found that the extent of fire damage in hardwoods is not immediately discernible after the fire; the extent of the damage, expressed in terms of tree mortality rather than acres, cannot be fully ascertained in the current growing period; the full extent of the injury is recorded by the trees the following growing season when they are no longer able to function as living organisms. In the effects of a hot fire in a mixed hardwood stand there was a 47% mortality, with the greatest amount in the lower diameter classes one year after the burn occurred. (See Table 3).

Longleaf pine stands, relatively fire resistant, are sometimes wiped out completely or in part when the fire occurs during a period of the year when the tree is actively functioning as a living organism. A longleaf area which had remained rough (unburned) for approximately 20 years caught fire in September and resulted in a high mortality from each group of trees on the area (12).

It is possible that what can and did happen on 60 acres might sometime occur on more extensive areas under favorable

**Table 3**

TREE MORTALITY IN A MIXED HARDWOOD STAND ONE YEAR AFTER THE FIRE

| Diameter Classes | Total Number | Number Dead | Percent Dead |
|---|---|---|---|
| 2" dbh. . . . | 17 | 11 | 65 |
| 3" dbh. . . . | 109 | 80 | 73 |
| 4" dbh. . . . | 294 | 156 | 53 |
| 5" dbh. . . . | 155 | 57 | 37 |
| 6" dbh. . . . | 80 | 17 | 21 |
| 7" dbh. . . . | 23 | 6 | 26 |
| 8" dbh. . . . | 28 | 17 | 61 |
| 9" dbh. . . . | 28 | 11 | 39 |
| 10" dbh. . . . | 23 | 6 | 26 |
| 11" dbh. . . . | 11 | 0 | 0 |
| 12" dbh. . . . | 6 | 0 | 0 |
| All diameters. | 774 | 361 | 47 |

**Table 4**

MORTALITY IN A LONGLEAF POLE STAND DUE TO A SUMMER FIRE
STAND PER ACRE BEFORE BURNING

| Species | 6" - 22" dbh | Saplings | Conifer and Hardwood Overtopped Seedlings |
|---|---|---|---|
| a. Longleaf and Loblolly | 11 | 900 | Several Hundred |
| b. Overtopped Hardwoods | Several Hundred | | ... |
| MORTALITY PER ACRE TWO YEARS AFTER BURNING | | | |
| a. Pine | 95% | 100% | 100% |
| b. Hardwood | ... | 100% | ... |

this condition. The natives of the South have seen what damage fire can do. The United States Forest Service, however, was confronted by the same situation when it commenced to administer the national forests [illegible] the natives were favorably disposed toward light burning and believed complete protection im- [illegible]. The record now stands at 0.19% burn for the period 1931-1934 inclusive for California which [illegible] the time which subscribed to the light-burning theory. Education coupled with ade- [illegible] technique was the means whereby the foresters substantiated their belief in the ade- [illegible] protection. By persistent educational effort and advancement in suppression technique, the [illegible] hazard can both be lowered considerably in the southern pine region.

Large forest fires are not uncommon in the West; even the relatively open stands of the ponderosa pine type are occasionally subjected to fires. In 1931 a 45,000 acre fire occurred in the ponderosa pine district of Central Idaho. Damage appraisals which are made immediately after fire are generally under the [illegible] which are made in the following growing season. On a 10% cruise of 20% of the burn, or an area [illegible],308 of the 45,000 acres, Connoughton (14) found extremely heavy losses.

As was observed by Miller and Patterson (15) in other instances, the beetle attack which followed this fire in the ponderosa pine stand was of relatively short duration; it had practically terminated at the end of three years.

Delayed mortality in Douglas fir is much more positive than in ponderosa pine stands. This condition is due to the root damage sustained by Douglas fir even in light ground and surface fires. Douglas fir [illegible] are located much closer to the soil surface than in the case of ponderosa pine; consequently [illegible] the ground fire affects them more seriously. The damage, however, does not become immediately [illegible] manifests itself several months after the fire has occurred.

Including the delayed mortality, the losses were as follows:

**Table 5**

DAMAGE TO TIMBER IN THE INTERMOUNTAIN REGION

| Age Class | Percent of Merchantable Volume Losses of Original Stand | |
|---|---|---|
| | Douglas Fir | Ponderosa Pine |
| Virgin Stands | 82 | 71 |
| Cutover Stands | 88 | 66 |
| Young Growth | 68 | 52 |

The loss in reproduction was tremendous. Reproduction was defined as being all trees with stems less than [illegible]" d.b.h. No reproduction survived on 58% of the plots established in the 9300 acre area; most of the surviving reproduction was found only on 7% of the plots. The loss in merchantable volume and reproduction was reflected in the density of the stand. Before the fire, there was a 60% stocking in the virgin stand; after the fire, it had been reduced to 9%. This had important implications in that artificial reforestation might have to be used to get an adequate amount of growing stock on the area within a reasonable period of time.

Large fires have occurred in the past in which the outright death to trees on millions of acres is still apparent today, twenty years after the burns. Although there are no records available concerning the number of trees killed in the large, historic fires reported by Plummer (62) for the period 1825-1910, there is no doubt but that fires of such magnitude, in burning areas ranging from 200,000 to 2,000,000 acres, must have killed outright not only single trees but wiped out whole stands. The Magee Ranger Dis- [illegible] of the Coeur D'Alene National Forest is representative of the effect of the Great Idaho Fire in 1910. [illegible] in 1936 is just beginning to be readily apparent. It has been on the ground for several [illegible] mountain slopes still look bare. Reproduction is not readily visible today, twenty-six years [illegible] fire which burned most of the slopes clean.

As was mentioned under the discussion on seedling mortality and elsewhere, the damage that occurs to [illegible] is not always readily apparent immediately after a fire. There is no very definite period [illegible] determine fully whether trees have succumbed because of the effect of the fire. In the

Lake States Region, the recommended policy for obtaining a reasonably accurate tally on jack pine mortality is to wait for at least four months after the fire (171). Trees 2' tall die almost at once when [illegible] severely. There is no delayed mortality. Trees in the sapling and larger class will probably survive, even if badly scorched, if they have not died within the four months' period. Reproduction between 2' tall and 4" d.b.h. usually dies if 90% or more of the crown is killed.

Those who have practiced "light" burning usually fired the woods when the trees were dormant. Presumably their practice was based on observations that the burns that occur in the dormant season do the least damage. The Lake States Forest Experiment Station (202) conducted tests in an open stand of all-aged jack pine to determine the season when burning is most damaging. Their observations can be summed up as follows: (a) in early spring, 95%-99% of all the reproduction is killed, a few saplings are killed, but no mortality occurs in saplings or larger size classes; (b) in late spring, the same condition prevails except that fewer saplings are killed; (c) in summer, many seedlings are killed, almost half the saplings, and a few poles are killed; (d) in the fall, only approximately half the seedlings are killed, few saplings, and no poles. Briefly, the lowest mortality in all size classes results from fall burning. One reason that fall burning is least destructive is due to its spottiness caused by some fuels having a high moisture content.

### C. Lessened Rate of Tree Growth

The Roberts Plots at Urania, Louisiana, are probably the oldest of their type in the South. These were established in 1915, each 1/4 acre in size, by Dr. S. T. Dana, then with the U.S. Forest Service, in cooperation with the Hardtners' Urania Lumber Company in Louisiana, to determine the effect of (A) burning and grazing by hogs and cattle, (B) burning and no grazing, (C) no burning and grazing, and (D) no burning and no grazing,on pine reproduction establishment and development. On the burned and grazed plot ("A" above), there was no reproduction of any sort by 1917. On the unburned and grazed plots, there was only loblolly and shortleaf remaining in 1917, ("C" above). The results cited in Table 6 have been obtained from plots "B" and "D" described above where grazing had been excluded entirely. Plot "B" has been burned annually since its establishment and fire has been kept out of plot "D" successfully since the inception of the experiment.

**Table 6**

CONTRASTING RATE OF GROWTH
BURNED AND UNBURNED ROBERTS PLOTS**

| | 1915 | | | 1920* | | | 1935 | | |
|---|---|---|---|---|---|---|---|---|---|
| | No. | Ave. d.b.h. | Ave. Ht. | No. | Ave. d.b.h. | Ave. Ht. | No. | Ave. d.b.h. | Ave. Ht. |
| UNBURNED Longleaf | 3708 | ... | ... | 6836 | ... | 1.1' | 1668 | 3.4" | 24.6' |
| Loblolly and Shortleaf | 12 | ... | ... | 136 | ... | 4.2' | 152 | 6.1" | 30.2' |
| BURNED (Annually) Longleaf | 3240 | ... | ... | 6052 | ... | 0.4' | 1656 | 2.3" | 14.0' |
| Loblolly and Shortleaf | 8 | ... | ... | 0 | ... | ... | ... | ... | ... |

* Heavy Seed Crop in 1919.
** Data Supplied by Southern Forest Experiment Station. U. S. Forest Service.

The difference in growth is shown distinctly in the figures in Table 6 for average diameter at breast height and average height. The data are admittedly few and limited to a small area, but they are the oldest available.

Growth rate is retarded due to fire, according to the data gathered by MacKinney (17) on longleaf plots in the Coastal Plain area of the Carolinas. The lessened growth rate was based on data for basal area and height on burned and unburned plots. The loss in growth of the smaller diameter trees was greater than for those trees of the larger diameter classes. This condition of poorer growth on the small trees might be explained in part by greater loss of percentage of leaf surface due to fire, although MacKinney makes no mention of this condition.

With fire so widely used in the longleaf stands of the South, there was the possibility that the fires might cause bark thickness to depart from normal, be atrophied or hypertrophied so that volumes computed by calipering trees that had been burned frequently might produce inaccurate results. Two investigators working independently of each other in young, burned and unburned longleaf stands, found that the difference between the burned and unburned trees was so slight as to have no effect on computed volumes. (172) found that fires reduced bark thickness approximately 0.05 inches, or, when calipered, trees under 9 inches diameter breast high. Wahlenberg (173) working on almost the same of longleaf, found the difference to be smaller, or 0.066 when calipered and 0.033 when for one thickness only. The trees that Wahlenberg measured for his burned data were obtained that had been burned annually for ten years.

Although longleaf pine is relatively immune to damage by fire, the needles of the trees that are being worked for the production of oleoresin are often removed by fires set in the winter. These fires are to lower the probability of damage during the season when the trees are being "worked." When the fires are set so that burning conditions are poor, the flames remain close to the ground. When the are allowed to burn under conditions suitable for rapid spread, defoliation takes place. The degree to which defoliation occurs is reflected by the gum yields (174). It is poor practice to work the trees which have been defoliated in excess of 2/3 of their needles. Defoliation reduces tree vigor. Because high gum yields require high tree vigor, a minimum of defoliation by fire is therefore necessary. It has been repeatedly observed, however, that in trees large enough to be worked for gum production, that defoliation leaves no permanent injury. Cary (175), who travelled extensively in the naval stores region, repeatedly noticed that gum production was influenced by needle loss caused by fire.

## c. Plant Succession

The natural development of vegetation on a site which has been seriously disturbed is upward in the scale of complexity of plant life, i.e., higher forms replace lower forms until the climax is reached. Repeated fires retarded the normal succession development to a point where plant life does not reach its climax or if it does attain its climax form, its development is abnormal. In an investigation of the ecological relations of the pitch pine plains of New Jersey, Lutz (18) concluded fire was the chief and outstanding cause of the curious plant association known as the "Plains". The Plains bear pitch pine and scrub oak as the principal tree species, but these trees are permanently dwarfed because periodically, on an average of eight years, the area is gutted by fire. The Plains are particularly susceptible to fire because of the topography and soil series which are excessively drained with little or no natural barriers in the form of streams and swamps which might impede the movement of the fire.

Some general conclusions in regard to the relationship between fire and normal plant succession which is essentially an ecological matter have been made by Brouse (30). For the Pennsylvania hardwood sites, the following conditions prevail:

a. Forest types change naturally from temporary to climax; the movement, unless some artificial agency invades, is always progressive rather than regressive.

b. The progression or regression is determined by the soil, frequency, and degree of invading agency, in this case fire, and the forest type on the site when the fire occurs.

c. Frequent fires prevent any progressive development of the type.

d. The vigor of the temporary type reaches its climax in the fifth year subsequent to the occurrence of the fire.

e. One fire in a climax type does not seriously lower the type in the scale of plant succession; several fires are required.

f. After devastation by fire, and the subsequent exclusion of fire, temporary types are generally crowded out in 20-25 years.

Leopold (176) believes that fire has played an important role in plant succession in the Southwest. He that one so frequently hears in the cow camps that the "brush" is taking over the southern foothills that once supported many head of cattle. The "brush" is forcing out the grass so necessary for livestock grazing. In Leopold's opinion, the brush is taking over what had been grass country are today less extensive. It was the periodic occurrence of extensive fires that made possible so coveted by the cattlemen. The fires presumably occurred because of lightning or may by the Indians. With the coming of the white man, extensive grazing commenced. As a matter [illegible] record, there was over-grazing, resulting in range depletion and subsequent erosion. [illegible] prevented extensive fires. With the absence of fires, the brush reclaimed for itself the [illegible] that it originally occupied before the fires drove it out. As Leopold so well expresses it, "The [illegible] and thin brush of pre-settlement days represented a temporary type. The substitution of [illegible] fire brought on a transition of thin grass and thick brush. This transition type is now reverting to the climax type [illegible]."

Fires have contributed to maintaining some sub-climax species which are highly valuable commercially, as well as preventing less desirable forest types from advancing in the scale of plant succession. When fire is kept out of aspen stands in the Lake States, there occurs an invasion of the better hardwoods (177). With its peculiar cone characteristics, jack pine has been àble to extend itself, aided by fire, in the Lake States (178). It is probably fire that has contributed to the establishment of white pine stands in the Lake States and the Northeast on some sites where it is not climax (6), (7). Larsen (179) and Huberman ([illegible]) among others believe that western white pine established itself through fire. Larsen points out that there are three stages readily distinguishable in the forest type succession made possible by fire. Lodgepole pine and larch first appear. These species are later crowded out by Douglas fir and white pine which frequently come in on single burns where the site has not been degraded to the point where only lodgepole pine and larch are able to reproduce. It is generally the double burns that produce the larch and lodgepole stands. With fire excluded entirely, white pine and Douglas fir are succeeded by western hemlock, western red cedar, and grand fir.

With jack pine as sub-climax on some sites, and with its increasing importance commercially, the question has now been raised whether it can be reproduced without the use of fire. This is a very logical question because jack pine has been able to extend itself so well because of fire. Eyre ([illegible]) has collected data that establish without much doubt that the habit of jack pine retaining its cones in unopened condition until high temperatures release the seed has made it possible for jack pine to take possession of burned areas; this fact, coupled with the establishment of a mineral seedbed. Previously Larsen (182) had enumerated the several ways in which some species might take possession of a site after a fire. Although he laoked proof for it at the time, Larsen was of the opinion that the source of seed for the establishment of a stand of timber on a recently burned site came from seed already there, contained in the cones on the trees or, on unburned slash on ground rather than from adjoining areas or having been stored in the duff.

## 2. Soil-Water Relationships

It is now a generally accepted fact that forests, runoff, erosion, and percolation are interrelated. The relationship has greater significance in regions of rough topography and impervious soils than in those regions of level topography and pervious soils. Toumey and Korstian (19), Zon (183), and [illegible] (184) have summarized most of the hydrographic effects of the forest. When the protective mantle of green leaves or needles and the forest debris commonly referred to as litter and humus are removed by fire, the result is reflected in the soil and water relationships. Especially in rough topography, forests decrease surface runoff, increase seepage, and thus build up underground reservoirs of water available in the drier p riods of the year. It is the flash runoff, made possible by removal of forest litter by fire, that contri tes to floods.

With its peculiar climatic conditions, California has its problems of floods and water deficiency. Lowdermilk (185) conducted an investigation to measure the relative effects on the absorption of rain by a mountain soil with chaparral cover type and one from which the chaparral had been recently removed by fire. He found that regardless of the physical characteristics of the soil beneath the litter, the surface runoff was greater from the burned surface than from the unburned. The ratio of runoff between the unburned and burned varied from 3:1 to 16:1. In general, the finer the texture of the soil, the greater was its effeotiveness in controlling runoff. An important reason why litter-covered soil is more effective than similar soil from which the litter has been removed is because the litter provides a source of food and a place of abode for both macro and micro-organisms. The activity of these organisms makes the soil more permeable. Litter-covered soil, moreover, Lowdermilk (185) found more effective than burned surfaces for controlling erosion. He found that the rate of erosion, as measured by the number of soil particles in suspension after rainfall, is a better index of a change in soil surface conditions than [illegible] Watermilk found also that the [illegible] than the canopy which creates [illegible] more important in affecting the [illegible]

[illegible] coniferous forest cover, there [illegible] mantles, the canopy and the [illegible] both, particularly the latter, [illegible], the soil freezes at a much [illegible] where the soil is protected by [illegible]) found that not only did the [illegible] rate of soil freezing considerably, [illegible] nature of the freezing. The litter- [illegible] openings making it possible [illegible] or percolation to occur, but a [illegible] freezing of the soil from which [illegible] removed resulted. The signifi- [illegible] of freezing is that frozen ground [illegible] because of its impervious na- [illegible] from freezing remains permeable [illegible] for a longer time, thereby [illegible] ground reservoirs.

Photo by U. S. Forest Service-[illegible]
Figure [illegible]
Because Of A Hard Burn, Erosion Is [illegible] So Rapidly That Normal Plant [illegible] Establish Itself To Control The [illegible] The Soil

[illegible] region in which precipitation [illegible] and relatively abundant in [illegible] is found in the areas of [illegible] which are undesirable for agri- [illegible]. By means of piping and irriga- [illegible] can be practiced on the fertile [illegible] precipitation is deficient for crop pro- [illegible] such as Los Angeles, moreover, pipe [illegible] water from the mountains. Any destructive agency such as fire which denudes the mountain- [illegible] immediate serious implications. On a watershed which was burned and then closely followed by [illegible], as much as 25,000 cubic yards of debris from the denuded site occurred; this was in [illegible] minimizing the water storage value of the soil on the area (20).

[illegible] California Forest Experiment Station found in the season of 1927-1928 that the ratio of run-off [illegible] burned plot compared with an unburned plot was 1 to 3.7 The flashy run-off, made pos- [illegible] denudation of the site, results in erosion, silting of reservoirs, and inadequate ground [illegible].

[illegible] loessial soils of Mississippi, a mature oak forest which had been undisturbed by fire for [illegible] had a much greater absorptive capacity than a site covered by scrub oak vegetation which had [illegible] from logging followed by frequent fires. The scrub oak type, resulting from over-cutting and [illegible] fires, caused run-off to occur when the precipitation exceeded .25 inches; the unburned oak forest, on the other hand, produced no run-off until precipitation amounted to .77 inches or approximately three times the amount found on the burned site (21).

**Table 7**

RATE OF WATER ABSORPTION IN CUBIC CENTIMETERS PER SECOND PER SQUARE [illegible], BURNED AND UNBURNED OAK FOREST

| Site Conditions | First Liter | Second Liter | Third Liter | Fourth Liter |
|---|---|---|---|---|
| [illegible] Oak Woods | 21.83 | 23.36 | 22.78 | 21.23 |
| [illegible] Oak Woods | 7.60 | 4.63 | 3.40 | 2.64 |
| [illegible] Oak Woods | 55.87 | 44.87 | 38.76 | 32.05 |
| [illegible] Oak Woods | 14.25 | 9.78 | 6.12 | 5.10 |

Cutover and virgin stands should both be protected from fire if only from the standpoint of watershed management (22). As might be expected, the severity of the burn plays an important part in that the greater the intensity of the burn the greater the subsequent erosion. Crown fires and severe surface fires cause almost identical amounts of erosion in cutover sites, while in the virgin stands the effect of the crown fires on erosion is much greater than for severe surface fires. A surface fire is one which consumes the litter and debris at the soil surface, the foliage of the lesser vegetation, and the reproduction.

Forest burning in the Ozarks has seriously decreased the capacity of the soil to absorb water [illegible]. With the protective mantle of leaves removed from the soil surface by fire, it has a greater tendency to [illegible]. Because dry soil particles resist the cohesive action of water, they are prone to settle and thereby prevent the downward movement of water. Unburned forest soils, on the other hand, by having a mantle of leaves to protect the surface soil, preserve it in a moist condition which is receptive rather than resistant to additional wetting; the result is a high rate of absorption by the unburned forest soil with its covering of leaves.

3. Soil Composition and Productivity

In a study of the effect of fires on longleaf pine soils, Heyward (67a) found that fires produce a fire climax profile which resembles grassland profiles rather than forest. Where frequent fires occur, the $A_0$ horizon is absent because the forest litter is burned before it can be decomposed by the slow-acting micro-organisms. The absence of the $A_0$ horizon prevents micro and macro-organisms from living and thus causes the surface soil to be relatively impervious, thereby reducing percolation, and increasing run-off and attendant erosion. When fire is excluded from an area previously burned frequently, an $A_0$ horizon develops, but approximately ten years are required for this change. Heyward found that there was very little difference in the profiles for those soils that had been protected from fire for an extended period of time and those where fires had been excluded for a lesser period of approximately ten years.

As has been mentioned previously in the discussion of Plant Succession, the aspen forest type can be maintained if fire is permitted to go through the stand before it becomes decadent. Shirley (187), (188) found that the number of root suckers and their height were greater on burned areas than on areas that had been only partly cut and not burned. There were two possible ways to account for this condition: (a) release of mineral salts by fire or (b) the soil temperatures on the burned quadrats were higher. After the first year of burning, there was no significant difference between the rate of growth of the suckers on the burned and the unburned areas, nor was there any significant difference in the soil temperature. In the first year after the burn, however, the soil temperatures on the burned plots averaged 10 °F. higher than for those on the unburned plots. With hardly any difference in soil temperature the second year, therefore, Shirley concluded that the increased soil temperatures made possible by burning accounted for the high rate of development and growth of the aspen suckers on the burned soil.

The site has been so altered by fire in the redwood region that the perpetuation of the species is [illegible]. Fritz (189) concedes that fire is necessary to dispose of redwood brush after logging, but all too frequently it is used so carelessly that the $A_0$ horizon is removed entirely. This condition permits bracken fern, shrubs, perennial herbs, and many annuals to obtain a foothold to the disadvantage of redwood reproduction. The soil conditions have become so badly damaged that even planted redwood seedlings have difficulty in surviving. It is impossible for natural redwood reproduction to become established on sites that have been burned repeatedly.

There are several investigations of record that, when studied as monographs, imply that uncontrolled fire does no harm. Alway and Rust (190) approached the problem of the effect of fire essentially from the standpoint of the possible impairment of the soil for agricultural purposes. Their viewpoint, therefore, must be taken into consideration when the results of their findings are examined. They found that fires caused little or no nitrogen loss in the 1"-3" horizon and in the 4"-6" horizon. There was only 0.00[illegible]% less nitrogen on the burned site than there was on the unburned. The moisture equivalent of the mineral burned soil varied hardly at all from the unburned, and the pH of the upper three-inch layer was raised slightly. They concluded, moreover, that the fire caused no significant change in the chemical composition or the physical properties below the surface layer. As a matter of fact, the lime, phosphoric acid, and potassium of the leafmold would suffer no actual chemical loss by burning but would be in more available form. They did find, however, that when oats were grown in soil mixed with unburned leafmold, presumably the $A_0$ horizon, they got better results than from oats grown in soil that had been burned and partly burned.

Alway (191) found that when recently cleared jack pine land was burned and planted to crops, the

... burning had no harmful effect on subsequent agricultural work. The productivity of the soil for ... recently cleared jack pine lands was approximately equal regardless of whether the ... the land or dragged off before plowing.

... a series of monographs on the effect of frequent fires on the soils of the longleaf region ... found that the heating of the upper soil layers by forest fires is not excessive from ... doing permanent soil damage to chemical composition or physical properties. In his publication, Heyward points out that soils literature contains evidence that some heating of the soil is ... from the standpoint of increasing the soil fertility, especially soils of fine texture. Heyward ... maximum soils temperatures produced by the surface fires were 274° F. at 1/4" depth and ... depth. The majority of the temperatures ranged from 150° F. to 175° F. The high temperatures ... were produced by artificially applying more fuels. The high temperatures lasted for a ... approximately four minutes, and then gradually fell to their previous temperature within ap... minutes. One reason why fires in the longleaf region do little damage to the chemical ... soil is because dry organic matter is charred only at temperatures above 350° F. Soil ... in the usual surface fire in the longleaf region, therefore, is never charred. Heyward ... conductive properties of the soil vary with moisture content and soil texture. Conduc... is increased with the moisture content up to between 15% and 25% moisture content. ... of the feeding roots close to the surface of the soil, and in the zone in which Heyward ... temperatures, it is possible that longleaf roots are well insulated against damage by fire. ... has developed due to an absence of fire, with the probability of roots getting into the ... decomposed organic matter which is inflammable, the temperatures may not be any higher, ... the roots and subsequent tree growth may be more damaging than in the instances re... It must be kept in mind that Heyward's results were obtained from stands where the ... heavy, but the $A_1$ horizon poorly developed.

... Disease and Insect Attacks

... a tree is injured in some way so ... is broken, spores of wood-rotting ... gain entrance. When the pro... tissue is removed by fire, spores ... gain entrance and commence their ...

... ) has pointed out that the ... of butt-scaring by fire are: ... weakening because of cessation ... over scarred area, (b) interrup... functions of transloca... nutrients, and water, and (c) ... entrance of wood-destroying fungi ...

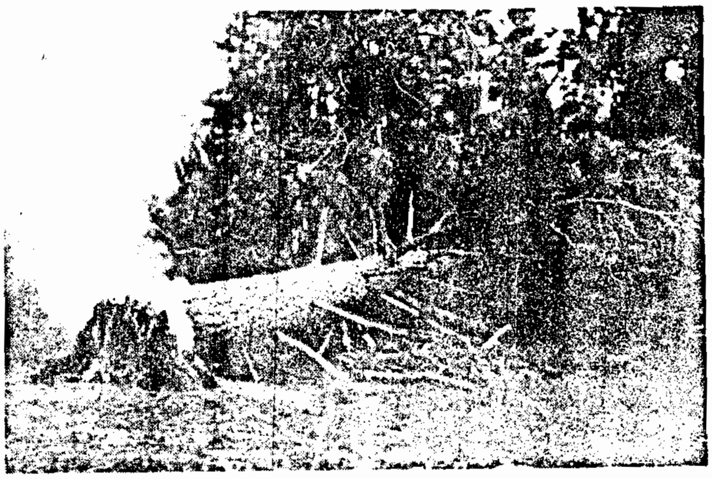


Photo by U. S. Forest Service-215583

Figure 6

Repeated "Light" Fires Take Their Toll Even Among The Veteran Ponderosa Pines

... develop because there has been ... at the base of the tree so ... the resultant temperatures kill the live tissues under the bark. After the tissue ... growth again commences from the edges of the wound and, given sufficient time, the exposed ... be covered by bark. Lachmund (193), who did considerable work on the formation and development ... has stated that it is in this interval between the time of the killing of the live tissue ... over of the wound that the tree goes through a critical period. If the bark over the dead ... off, the danger of infection is much greater than if it is allowed to stay on until the ex... has been healed by live tissue. Bark may stay over dead tissue for as many as five to ten ...

... factors that influence the susceptibility of a tree to damage by fire are: (a) resin content ... structure of the bark, and (c) thickness of bark. Tree species that have a thick "corky" [illegible] well insulated against the [illegible] generated by adjacent burning [illegible].

[illegible]mund (194) has classified [illegible] wounds to trees made by surface [illegible]. [illegible] (a) old scars, (b) the [illegible] of recent superficial wounds, [illegible], and (d) the hollowing [illegible] old wounds. The illustration on [illegible], Figure 6, is an example of [illegible] described under item (d) above. [illegible] illustration on page 26, Figure 8 is an example of item (a) above.

The importance of repeated fires [illegible] be emphasized too much. Each [illegible] wound is enlarged, there is a [illegible] in the number of vessels [illegible] needed by the tree in carrying [illegible] physiological functions such as [illegible] raw materials from the soil [illegible] the leaves. The mechanical proper[illegible] of the tree are also affected. The [illegible] reduction of fibres at the base [illegible] the tree, those fibres that hold it [illegible], was responsible for the damage shown in Figure 6, page 24.

Photo by U. S. Forest Service-21709[illegible]

Figure 7

Thrifty Young Oaks Damaged By Surface Fires. Although The Wound May Later Heal, The Damage Is Never Overcome

Fire damage is insidious because so often the new lesions are concealed by dead bark. Under charred [illegible], the cambium may or may not be dead. Time alone will be an important factor in determining damage. [illegible]toms of dead cambium may not be apparent for several years after the fire. Of numerous trees examined [illegible] the California region, Lachmund (194) found that only 20% of the extended and new lesions showed re[illegible]able symptoms of their presence. The remaining 80% were completely concealed so that they could be de[illegible]ted only by cutting through the bark. For the several important commercial hardwoods of the Southern [illegible]alachian region, Nelson, Sims, and Abell (195) found that there is a degree of correlation between the [illegible]coloration of the bark caused by charring and the actual killing of tissues. Information of this na[illegible]ture has value in appraising damage. In their investigation, they found that for a fairly large number of samples, the actual dead tissue area conformed closely with charred bark. For some species, diameter is an important variable influencing the relationship between bark char and dead tissue. In other species, however, diameter had no affect on the degree of wounding.

Trees within each forest region display individual characteristics in their response to charring. Some species are very susceptible to bole damage by fire; others are quite resistent. Starker (196) has proposed that a scale of resistence to fire be prepared for the commercial species in the several forest regions. Toward this end he prepared a tabulation of that fragmentary information that is available on the subject for the several regions.

There is ample evidence on hand today to show that fires are responsible for a great deal of loss to commercial timber. Meinicke (197) has stated that in over 40% of the white fir culls, decay commenced due to fire wounding. Similarly Boyce (198) found that for incense cedar, 84% of the severe cull cases were attributable to fire scars. Fritz (189) has said that fires are responsible for more than 80% of the [illegible]al decay in redwoods. The decay starts with cambium injury and then develops "goosepens," the type of wound being the enlargement of earlier wounds. This fire wounding of redwood, and subsequent "goosepen" cause windthrow, one of the very few factors responsible for the natural death of the trees of the species.

A forest region where fire damage is so insidious is the hardwood area of the Mississippi Delta. Although the fires are confined to the surface and are inconspicuous, tree stumps show the record of definite

... his examination of ... region, Hepting ... there was ample evi- ... dence of definite ... (200), (201) ... one stand in ... volume had to be ... decay for which butt ... In another ... volume had to be ... reason. The mana- ... of virgin hard- ... that, subsequent to a ... decay was responsible for ... volume loss. In these sur- ... reproduction ... the principle sufferers. ... killed outright and the ... severely scarred. Red gum ... characteristic after wound- ... A gum is exuded to ... This is effective in ... from getting to the sap- ... protective value is lost ... fires are not excluded. ... "light" surface fires de- ... scars amounting to 49% of the tree circumference and averaged 2' in height. Hepting found ... extension of the diseased area ranged from an average of 1.2" per year to 2.3" per year, ... the tree species. Kauffert (16), who made a similar study in the same region, expressed the ... that between 90 and 95 percent of the decay in hardwoods is caused by fire.

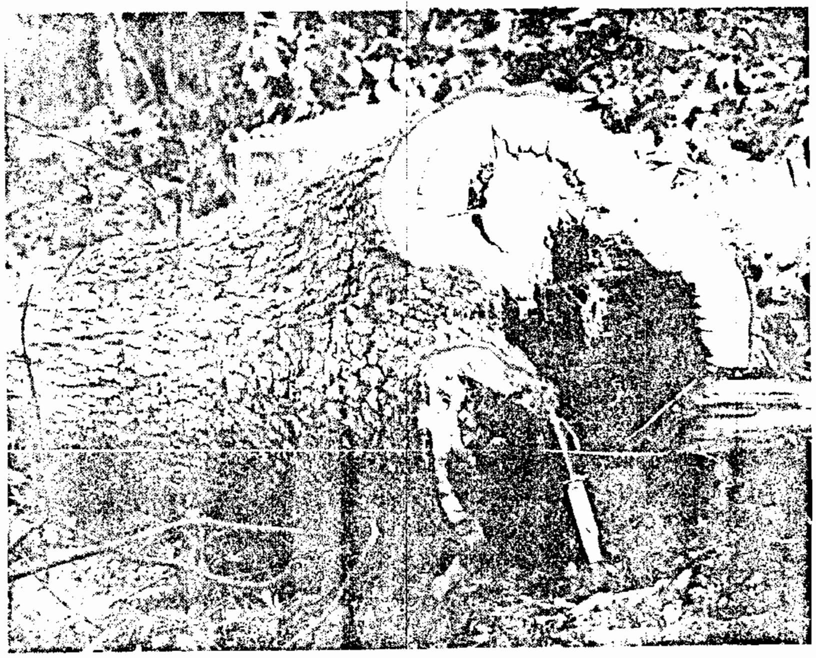


Photo by U. S. Forest Service- 40413

Figure

When The Butt Log Is Decayed, The Most Valuable Part Of The Tree Must Be Left In The Woods. This Is A 21" d.b.h. White Oak Of Which 10' Of The Butt Is Valueless

... scars require butt-jumping. With fewer logs per tree in hardwoods than in conifers, it is ... important in hardwoods that the necessity for butt-jumping be eliminated. On the basis of his ... Kauffert found that 8-year-old scars resulted in disease travelling upward 19 inches; ... scars, 58 inches; and 22-year-old scars 104 inches, or almost 9 feet.

... hardwood region extending from New Jersey to Tennessee, Hepting and Hedgecock (25) (208) ... approximately 2900 seedling hardwood trees of merchantable size. Among this number, 94% of all ... was caused by scars. Examination of trees on the logging areas lead the investigators to be- ... approximately 97% of the basal wounds were caused by fire. In their opinion, if fire were ex- ... the hardwood stands, the cull volume caused by butt damage would be two-thirds less than it ... time of examination.

Ambrosia beetles have been found attacking hardwoods after a fire in the mixed oak type in the Rampo Mountains of New York. The beetle attack was most severe on those living trees the bark of which had ... scorched by fire. Slightly charred bark on the trees which had not had their cambium severely ... infested. The ambrosia bettle is especially undesirable because its galleries are not ... i.e., within the bark only, confined to the cambium, but invade the tree woody area thus ... in manufacture (23).

... trees which were alive one year after a fire and showed on fruiting bodies on the charred ... years after the fire, Stickel and Marco (24) found 45% were actively infected by disease as ... fruiting bodies on the charred base of the tree. This situation should revise the belief ... trees can be counted upon to constitute a part of the final stand. Whenever the scorched ... merchantable size, it is desirable from an economic standpoint as well as a sanitary measure ... aspect to remove them.

## 5. Human Activity and Mortality

[illegible] travellers, interested primarily in recreation, are affected by forest fires has been [illegible] [illegible]. Tourists are seeking beautiful or unusually attractive landscapes. This type of [illegible] is [illegible] to the residents of California, for example, because tourist dollars represent [illegible], a [illegible]. When fires occur, tourists are driven to other parts of the region or country [illegible]. [illegible] in the Trinity Alps, Trinity County, California, a forest fire 35 miles removed from [illegible] from 50% to 60%.

[illegible] dedication for the Lassen Volcanic National Park had been extensively advertised for the summer of [illegible], but a few days before the occasion a fire started in the vicinity of the Park with the result that the attendance was distinctly under what had been anticipated.

Not unlike California, Florida is also dependent for a good share of her annual income upon tourists. [illegible] travel to Florida by car, so when forest fires in the winter of '31-'32 were so prevalent, tourists complained bitterly of the smoke which impeded travel on the highways, especially after sundown. Under [illegible] circumstances, fires do not seriously impede automobile traffic, but in the winter of '31-'32, the natural barriers such as ponds, swamps, and streams had dried up. The accumulated vegetational debris [illegible] seasons contributed sufficient fuel to produce conflagrations. Not only did natural resources [illegible], but future tourist dollars were driven away until memory became dimmed and water again filled the ponds and streams.

Periodically there appear in the newspapers headlines such as "Twenty-nine die in California Fire", "[illegible] Men Perish in South Jersey Fires", and similar captions. Annually the fires take their toll of [illegible] lives, boards of inquiry are appointed to investigate, but in the meanwhile the fire has been [illegible], and the public forgets until the newspapers again prod its consciousness by similar headlines. The subject matter is always the same, except that the number who die varies. As long as the wind will have the capacity to change quickly and the velocity double or quadruple suddenly men will probably continue to be trapped by fires.

Innocent victims as well as fire fighters succumb. In the Peshtigo fire in Wisconsin in October, [illegible], 1500 people perished, and in the Minnesota Hinckley conflagrations of 1894 whole towns were wiped out and 418 lives lost (30a).

It is the conflagrations which suddenly break out in hazardous times which become so destructive to human life and property; when the numerous factors which lead to the conflagrations are better understood, [illegible] precautions can be taken to minimize damage.

## 6. Wild Life

Photo by U. S. Forest Service-260971

Figure 9

Fire Not Only Consumes Game Cover But Also Destroys Game Directly. The Buck In The Above Picture Was Killed By Fire

Fires destroy timber and all the wild life which uses the timber for shelter. In large fires particularly, game losses are tremendous. Head-fires travel at speeds sometimes in excess of 20 miles per hour when fanned by high velocity winds which throw sparks before the head and kindle new fires. Kipp (28) cites the results to game [illegible] a 120,000 acre fire in Wisconsin. The fire occurred in 1930, the worst fire-year experienced since organized protection was begun in that state.

After the fire, the carcasses of 18 deer were found in close proximity; undoubtedly many more died because a 100% survey was not conducted. It was estimated that after the fire 60% of the live deer in the region had badly burned feet. A deer was encountered walking on its knees; its hooves and feet [illegible] broken off due to the excessive heat. The deer herds were weakened so badly that they became [illegible] their natural predators, thus providing another source for diminishing their number.

The [illegible] important game bird in the region was the sharp-tailed grouse, but these apparently fared [illegible] the deer because the estimated mortality was only 25%.

[illegible] the rabbits suffered a very low direct loss, they too, became ready prey to the predators [illegible] natural cover, in which they were accustomed to hide, was removed.

[illegible] oxygen and excessive alkalinity of the water in the streams killed thousands of water-[illegible] wild life such as fish and frogs.

[illegible] the direct loss is frequently severe, the indirect losses due to exposure to predators and [illegible] are generally greater after large fires than the direct losses. Few beaver are actually [illegible] fire, but their food supply is entirely eliminated. Fires also influence reproduction of [illegible] the individuals are rendered inefficient or impotent because of their weakened condition. The [illegible] after a fire, moreover, prevent the animals from pairing.

[illegible] of wild life in a fire is frequently pathetic. Female birds remain on their nest as the [illegible] of the oncoming fire was becoming more acute; apparently their only objective being in [illegible] their nest and protecting them (27). Partridges in particular are either fascinated or [illegible] smoke because they fly directly into a thick of it. A fawn was found remaining determinedly in [illegible] the path of a fire; its instinct and training compelled the animal to remain where its mother [illegible].

[illegible] climatic excesses, fires are able to do extreme damage where normally they are infrequent. [illegible] reports that in a fire in western Pennsylvania dead trout were carried by the bucketsful [illegible] stream located in a watershed that burned during a very dry season. Because of the de-[illegible] rain, the fish were so hungry they jumped from the water to snatch at flying ashes produced [illegible]. A large number of fish succumbed because of the alkalinity of the water even prior to the [illegible] into the stream by the rain.

## BENEFICIAL EFFECTS OF FOREST FIRE

At the beginning of this discussion, it is desirable to explain the use of the terms "controlled burning," "light burning," and "wild fire."

"CONTROLLED BURNING" means that fire is to be employed for some gainful purpose. It implies that, after the fire is started, it is confined to the area to be burned, the rate of spread and intensity of [illegible] controlled, and that this is to be accomplished by a plan. Those factors which affect the rate of spread and intensity of burn are at a minimum. On a day when the wind velocity is 30 m.p.h., for example, the chances of a fire breaking beyond the predetermined confines are good; controlled burning should, therefore, not be attempted.

"LIGHT BURNING". Show and Kotok (60) have defined "light burning" as "--the intentional burning of the [illegible] at intervals with the object of consuming much of the inflammable material and of so reducing [illegible] fire hazard that accidental fires will be controlled with ease and will cause but minimum [illegible] merchantable timber."

"Light burning" aroused a controversy between lumbermen and foresters in California; it was climaxed in [illegible] is summarized below by Bruce (3).

Light burning as practiced by California lumbermen, is based on the assumption that (1) even though fire [illegible] the forest, little or no damage is done; (2) the damage, if any, is largely correlated with [illegible] debris on the ground which, if burned periodically, will not accumlate and consequently [illegible] heat of combustion with little resultant damage to the timber; (3) that it is impracticable [illegible] fires. All of these points lead in the unmistakable direction that, since fires are [illegible] the forest should be burned periodically and at a time when the fires will do a minimum of [illegible]

[illegible] of the complete protection idea promulgated by the representatives of the United [illegible] Service based their argument on the facts that (1) light fires always do some damage, but [illegible] particularly to reproduction; (2) although admittedly a fire hazard, the accumulation of [illegible] litter is desirable; it will, moreover, diminish after five years - that is, not continue to [illegible] decay will offset surface accretion; and (3) complete protection has proved to be practicable in the United States.

The Forestry Committee investigating the problem undertook to ascertain a practical means of "light burning" in the California pine region - that is, whereby a minimum of damage would occur and reduce the hazard appreciably - all at a reasonable cost.

The Forestry committee which investigated the matter finally came to the following conclusions:

A - A light burning in spring is unsatisfactory because by the time the duff is dry enough to burn, it is possible for fire to be retained for a considerable period and thereby constitute a hazard.

B - Burning in summertime is satisfactory from the forester's viewpoint, but is economically unsound.

C - Fall burning is extremely spotty because vegetation dries out slowly and may become saturated again in a short time. The period of high hazard is generally ended by conditions which precede satisfactory burning.

D - The costs of light burning, irrespective of the season, are hardly commensurate with the gain derived.

E - All burns damage reproduction.

F - Most burns injure mature trees.

G - Light burning on large areas is impracticable because of varying degrees of slope and vegetative dryness.

The investigation was discontinued in 1923 without devising a fire control system, based on the light burning theory, which was more practicable or economical than that in use on the national forests at that time which consisted of complete protection.

"Light burning" and its proponents have existed for a long time. "Light burning", as understood today, implies no effort for confinement within a given area; the burner does not recognize the rights of adjoining land owners, nor does he take steps to protect adjoining lands from receiving the same treatment his own are given. It remains to be proved, however, that light burning has a place in the practice of forestry, even though Show and Kotok state (60) that light burning seems to have some merit from a silvicultural standpoint in that it readily kills reproduction of undesirable species, thins reproduction which is too dense, and is an aid in preparing planting sites. Show and Kotok, however, probably had in mind "controlled" rather than "light" burning insofar as the statements are concerned.

"WILD FIRE" is the same as "forest fire" as the word is commonly used. As was mentioned in the beginning of the chapter, forest fires are today synonyms for damage to the public. There is need for some new phraseology whereby there is the implication that not all fire in the woods produces a harmful effect. As will be shown later, there is evidence that there may be a distinct use for fire in the practice of silviculture, provided the fire is used intelligently. When handled carefully, fire may be of great aid to the forester in some timber types. Uncontrolled or wild fires are a distinct menace. Our immediate problem is to educate the public to the fact that when used by experts, fire in the forest can be useful. The public need be impressed with the fact that the use of controlled fire implies that the one using it is well aware of its potentialities for harm, so is cautious in its use. It is also necessary to impress the public that "controlled" burning and "light" burning are two different uses of fire in the forest. "Light" burning has been practiced for generations. "Controlled" burning, however, is something quite new and is based on technique.

It must be emphasized that the effect of fire will result in more good than harm to the forest cover and site only when controlled and in a forest type which has silvicultural characteristics that lend themselves to the use of fire. The instances of more good than harm produced to the forest by uncontrolled fires are so rare and isolated that they can be ignored entirely in this discussion. The so-called "light burning" has no evidence to support it as a desirable forestry practice. The two terms "controlled burning" and "light burning" imply totally different meanings.

As a Federal agency charged with maintaining in productive condition the National Forests, as well as cooperating with state and private agencies in forest fire control, the United States Forest Service has been placed in an awkward position by the findings of the Southern Forest Experiment Station in connection

...th fire in the longleaf forest type. For several years prior to 1935, several foresters familiar with (the ... ...ition) and some articulate representatives of the cattle industry had claimed that fire aids the ... of longleaf pine stands. In 1935, E. L. Demmon (132) of the Southern Forest Experiment ... a public statement that fire in the longleaf region was not always accompanied by damage and ... fires are actually beneficial to longleaf areas. When fire is controlled, the beneficial effects ... This statement of Demmon's marked a new departure in the policy of the United States ... It recognized that not all "forest fires" are detrimental in their effect on forest ...

... EMPLOYMENT OF CONTROLLED FIRE in forestry practice, so that there will be a net gain, may be summarized ... follows:

1. As a silvicultural tool
2. For protection against excessive damage
3. For game management
4. For modifying some soil characteristics

### 1. As a Silvicultural Tool

The chief uses of fire for silvicultural purposes are (a) for the perpetuation of temporary and subclimax ... types, (b) for the preparation of mineral seedbeds required by some species, (c) for control ... some tree diseases, and (d) for reducing competition which may be in the form of grass, low woody ..., or other trees.

(a) There are several forest types in the United States which are of high commercial value but classed as temporary or sub-climax vegetative types in the scale of plant succession. Outstanding among ... are northern white pine (Pinus strobus); western white pine (Pinus monticola), and Douglas fir (Pseudotsuga taxifolia). Where old-growth Douglas fir stands have been logged with the cutting followed by fire, Douglas fir has definitely taken over possession of the site. It is quite probable that, ... the second-growth stands of the above-mentioned species created by fire, the use of controlled burning may in the future be a part of the procedure for obtaining natural reproduction.

Western white pine, as well as northern white pine, both owe their existence today in some degree to fire. Because the climax forests of the western white pine region contain comparatively little white pine, being composed of more tolerant species, principally cedar, hemlock, and white fir, Davis (4a) recommends clear cutting followed by controlled broadcast burning. In cutover western white pine stands, hemlock generally constitutes such a large percentage of the residual trees that, if it is permitted to remain on the site, it will exclude white pine in the subsequent stand; if it is merely girdled, the fire hazard will be excessive. The solution to these twin difficulties, therefore, is to use controlled burning.

... (6) and Maissurov (7) have also emphasized the important part played by fire in creating extensive stands of northern white pine in the Northeast and Lake States Regions. The claim that without fire the species would disappear is considered, however, to be extreme.

As mentioned previously, it is probable that jack pine in the Lake States was able to extend itself because of fire. The relationship between jack pine reproduction and fire is so intimate that the question ... raised, "Can jack pine be regenerated without fire?" (181) Some source of heat is necessary to release the seed stored so tightly beneath the cone scales of jack pine. Fire in the past has been the ... agency to accomplish this. Although Eyre (181) has stated that technique has not yet been ... satisfactorily reproduce jack pine with fire, there may be, and probably is, a means whereby ... fire can be used to secure jack pine reproduction at a reasonable cost.

The longleaf type (Pinus palustris) of the South is sometimes referred to as a "fire climax", ... that with the exclusion of fire, longleaf pine would be forced out of the dominant position it ... a large part of the southern pine region. For several years, H. H. Chapman (8) has been a ... of the use of the controlled burning in the longleaf type for reproducing the area to ... the absence of an agency, such as fire, to remove the mechanical interference provided by dead ... grass, coniferous leaf litter, or any other vegetation which produces "...rough", will [illegible] longleaf seed from getting in contact with mineral earth so that germination may [illegible] [illegible].

In [illegible] investigations relative to seedbed requirements of longleaf, Harper and Osborne ([illegible]) [illegible] [illegible] seedbed, regardless of how it was produced, was more favorable for germination of [illegible] [illegible] "rough" [illegible]. The mineral seedbeds were created by discing, spading, and burning, but there [illegible] significant result which would show that discing or spading were superior to burning for the creation of a favorable seedbed. Inasmuch as burning is considerably cheaper than the other two methods used for [illegible] the mineral seedbed, the burning procedure is the preferred technique. With the same number of available seeds, the exposed or mineral seedbeds yielded approximately four times the quantity of seedlings [illegible] the four-year-old rough produced in the work conducted by Osborne and Harper.

Although the study on the same subject made by Roberts (5) was less comprehensive than that con- [illegible] by Osborne and Harper, his findings were very similar. On those burned beds which were protected from rodents, the germination of seeds was 49.7% and survival of these 84.1% in contrast to the unburned [illegible] in which the germination was 35.3% and survival 75.5%. The unburned beds were located on a rough [illegible] one year old; on an older rough, it may be presumed from the work by Osborne and Harper, that the discrepancy would be still greater in favor of the burned seedbed.

Watson (207) has pointed out that another difficulty encountered in reproducing jack pine is the preparation of a suitable seedbed. It was found that jack pine requires a mineral seedbed. To secure the seedbed, the undecomposed organic matter on the forest floor must somehow be removed so that the seed can get in contact with the soil. Harrowing the soil has produced the required seedbed, but it is possible that the same results can be achieved with the use of controlled fire, for fires in the past have enabled jack pine to reproduce itself so well in the past (207).

(c) One of the most outstanding examples of the use of fire for the control of a pathological agency is in the longleaf region where fire reduces the sporulation of brown spot needle blight. Periodic controlled burning in areas severely affected by the disease has a beneficial influence in controlling its virulence. When the disease is not controlled, there is considerable reduction of green leaf surface for the manufacture of food materials with consequent reduction in vitality to the point where height growth of longleaf is impossible (8) (9). The use of controlled burning at three-year intervals reduces the needle blight activity to a point where the seedlings are able to make more growth than would otherwise be possible.

The burning method is effective for reducing Ribes population in stream bottoms. The fire destroys the plants and also burns the seeds stored in the duff (134).

Some Californians have advocated "light burning" as a means of controling the dendroctonus beetle. It was White's belief that "light burning" definitely lessened the attacks, but entomologists are of the opinion that severe attacks have occurred prior to the periodic light burning of the California forests and that fire actually is of no value for controlling the insect attacks.

**2. For Protection Against Excessive Damage**

It has long been the custom in various regions to burn strips annually around improved property such as buildings, cranberry bogs, and other improvements surrounded by forest growth. These burnings can be definitely considered as controlled burning inasmuch as they are confined to a limited area.

The old system of light burning the southern pine woods for reducing fuels as a protective measure in naval stores operations has in some instances graduated to controlled burning where the burner selects humid, still weather and confines the fire to the property being worked for naval stores.

Controlled burning has also been employed to a limited extent in young stands of slash pine in the sapling stage to lower the risk of crown fires. The surface fires reduce the ground fuels and also reduce the stand density. Slash pine reproduction frequently occurs in great density; this situation exposes the stand to a very high hazard. In order to overcome the probability of destructive crown fires in the dense stands of young slash pine second growth, thinnings, followed by controlled fires have been used. Examination of the growth of the trees left on an area given this treatment showed that the fire affected the height growth to some extent the stand of low density, but hardly at all where the density was high. (See Table 7a for data and Figure 12 for illustration).

Photo by U. S. Forest Service-3[illegible]

Figure 10

[illegible]

## Slash Disposal

One of the first steps taken by the United States Forest Service in the management of the western national forests was to control fire. One of the chief sources of destructive fires was in the slashings produced by logging operations. To make it possible to control fire on cut-over areas, as well as to reduce the hazard, a policy was originated somewhere around 1905 that, on the national forests in California, slash should be removed after logging in order to lower the fire hazard. The policy has been standardized for the western regions. The general procedure is to pile the slash and burn it.

There has been some question as to the advisability of removing the slash completely. It is a recognized fact that, to permit the slash to remain in place after it falls, there may be value from the standpoint of aiding reproduction to establish itself or have favorable effect in reducing flash runoff, erosion, and maintaining satisfactory rate of water flow in the stream. Munger and Westveld (135) approached the subject of slash disposal with the idea of developing a method of disposal which would strike a balance whereby the fire hazard could be reduced by disposing the brush but at the same time leave a sufficient amount

[illegible]

to obtain attendant benefits [illegible] tural and erosion control [illegible], [illegible]ly reducing the cost of [illegible] to the point where there [illegible] omy and resultant benefit [illegible] the residual stand of timber [illegible] hazard conditions created by [illegible].

Possibly the value of leaving [illegible] cover of branches and needle litter [illegible] favoring reproduction in the Southwest has been over-emphasized. There is no single superior method of disposing slash [illegible] taining combined values in hazard [illegible], seedling development, and erosion [illegible]; the method to be used will depend [illegible] local conditions encountered. Pearson [illegible] makes the statement that the primary [illegible] of slash disposal is to reduce fire [illegible] to a point where fire control is possible. The use of fire, in the form of piling [illegible] ing the slash, was justifiable (a) [illegible] areas of high fire danger or high value [illegible] form of abundant advance reproduction; [illegible] areas of low danger and where potential soil erosion demands that a cover be left, fire is unnecessary for eliminating slash except along firebreaks (137).

Photo by U. S. Forest Service-301112

Figure [illegible]

Dense Stands Of Slash Pine Saplings Typical Of Those That Have Been Burned Under Control To Reduce The Likelihood Of A Destructive Fire.

Where fire is used to dispose of the debris left from logging, it is presumed that a plan is followed so that the fire is confined to definite areas and the burning produces a minimum of damage to the seed supply on the area or the residual trees. The burning methods of disposing slash left from logging are: (a) broadcast in strips or blocks, (b) piling in windows and then firing, (c) piling in small piles of approximately 10' in diameter and then firing. Just which of the methods is most satisfactory depends on the forest type, the time of year, and the objectives sought.

The method recommended (201) for the disposal of slash in the Douglas fir region is broadcast burning under certain limitations. The objective is to reduce the probability of a conflagration and secondarily create conditions favorable for the reproduction of Douglas fir. As recommended, (a) the area should have definite boundaries, (b) the burning should be done just before a rain falls, (c) fire should be started downhill rather than uphill, and the burn should progress from the boundary inward rather than the reverse, (d) the slash should be fired late in the afternoon, and (e) the burning should be done speedily and safely.

### 3. For Forest Game Management

Comparatively little work has been done in the use of controlled fire in forest game management. Because Stoddard was able to observe the effects of light fires which sometimes resembled controlled fires in their effect, he commenced to use fire as an aid in his management of forest land for quail and turkey production in the Southeast. The use of controlled fire is quite legitimate on certain game ranges and he has applied it

**Table 7[illegible]**

HEIGHT GROWTH OF YOUNG SLASH PINE TREES
ON
UNBURNED AND CONTROLLED BURN AREAS

| Stand Type | Height Growth in Feet | | | | | |
|---|---|---|---|---|---|---|
| | 1 Year Before Burning | | 1 Year After Burning | | 2 Years After Burning | |
| | Burned | Unburned | Burned | Unburned | Burned | Unburned |
| Open | 2.81 | 3.26 | 2.86 | 3.14 | [illegible] | [illegible] |
| Dense | 2.85 | 2.75 | 2.46 | 2.20 | 4.74 | [illegible] |
| Very dense | 1.82 | 1.67 | 1.36 | 1.30 | 2.55 | [illegible] |

...ly in his region. Controlled fire is of value for several reasons. (a) Without periodic burn- ... gradually develops into a tangle of broom sedge, wire grass, and pine straw, all of which ... birds, which are comparatively weak scratchers, from obtaining their food which lodges under ... mat. (b) The mat of organic material also has a smothering effect on native perennial ... require a mineral seedbed and are of great importance as feed for quail. (c) Controlled ... debris close to the ground but do not open the canopy of the forest and the secondary ... by the herbaceous plants; this is an ideal abode for birds which need overhead protection ... open ground beneath their low roosts to keep away such natural predators as skunks, cats, ... Stoddard (65) (66) is as much opposed to wild or uncontrolled fires as he is in favor of con- ... fires for game bird management.

4. For Modifying Some Soil Characteristics

One of the early arguments used by the United States Forest Service in its campaigns for the control of ... fires was that fires impoverish the soil. That there is a considerable element of truth in this ... is recognized, but there has been increasing doubt among some foresters as to the general appli- ... this belief. The South, with its frequent fires, particularly in the longleaf type, has managed ... new stands of timber on soils which have been burned periodically.

Because fires have been so common in the South, in the longleaf type, the results of the investiga- ... on the effect of burning on the chemical composition of longleaf soils is of timely interest. ... were obtained from representative longleaf areas in the Southeast on paired plots, i.e., from ... which had been burned frequently paired with another nearby area having the same soil series, on ... fire had been excluded for several years. On the basis of these investigations, Barnette and ... came to the conclusion that soils which had been burned frequently (a) were less acid, (b) had ... percentage of replaceable calcium, and (c) had more total nitrogen than those soils which had re- ... rough.

Soils from burned areas had pH values ranging from 0.15 - 0.48 units higher than for unburned areas. Replaceable calcium content of burned soils was much as 101 percent greater than for unburned soils, and total nitrogen 14 percent higher on the burned soils.

The investigation of Heyward and Barnette indicates that annual burning has a desirable rather than undesirable effect on the chemical composition of soils common to longleaf pine, so from this standpoint, frequent fires can hardly be condemned.

The more recent work of Heyward (192) in connection with soil temperatures substantiates some of his earlier findings obtained in investigating the effect of frequent fires on the chemical composition of longleaf soils (67). As has been pointed out previously in this chapter under the heading "Soil Composition and Productivity" although it would appear that the surface soil temperatures generated by the burning of a four-year rough are low enough to avoid charring the soil organic matter and yet probably high enough to make available more soil nutrients and possibly promote greater activity among the micro-organisms, there is no evidence that the heat of a controlled surface fire in a stand of longleaf pine that has produced an $A_0$ horizon may not be more harmful than beneficial by actually killing the tree roots in the $A_0$ horizon and removing the abode and the food materials of the macro- and micro-organisms. Further investigation in the field of controlled burning may produce technique that will show how controlled burning can be conducted to do a minimum of damage.

# Chapter III

## CAUSES

Because the United States Forest Service in cooperation with the several forested states has acted as the forest fire actuary, it has had the opportunity to standardize the causes into definite groups so that there are now comparative statistics available, based on state boundaries, concerning causes, losses, and costs of forest fires. These data are of value in understanding that the problem of forest fire control is not uniform throughout the United States but is dependent upon numerous variables, one of which is causes.

### Cause Classification and Definition

The United States Forest Service has set up a classification of causes which is now used as a standard for reporting by all state agencies as well as by the Federal Government on its national forests; this is listed below.

1. LIGHTNING - Caused directly or indirectly by lightning.
2. RAILROAD - Fires from sparks or cinders of all classes of locomotives, clearing of right-of-way, and all other fires incidental to operations on or to the occupancy of the right-of-way of an established common carrier railroad and to common carrier railroads under construction.
3. CAMP FIRES - Fires resulting in any manner, smoking excepted, from carelessness of campers and travellers through the forest such as stockmen, prospectors, picnickers, surveyors, berry pickers, hunters, fishermen; this also includes warming fires.
4. SMOKERS - Fires caused by smokers' matches and burning tobacco in all its forms.
5. BRUSH BURNING - Fires caused by clearing lands for any purpose, other than rights-of-way for common carrier railroad or brush burning on logging operations, or by rubbish, garbage, range stubble, or meadow burning.
6. INCENDIARY - Fires which, within a reasonable degree of certainty, are willfully set to burn forest lands.
7. LUMBERING - Fires incidental to all lumbering operations; caused by sawmill engines, donkey engines, logging locomotives and woods camps; smokers and warming fires set by loggers, however, are excepted and should be listed under "smokers".
8. MISCELLANEOUS - Fires which cannot be properly classified under any of the other standard headings.
9. UNKNOWN - Used by many state agencies, but not recognized by the administrative branch of the United States Forest Service; this classification, however, is used in the annual forest fire statistical reports.

### Discussion of Causes

A simple grouping of the causes of forest fires consists of (1) those caused by natural agencies beyond human control, and (2) those caused by agencies over which man has a direct influence regarding their existence.

In the first group, the forest fire statistics cover the agencies under "lightning". There may be a very few instances of an unusual nature, other than lightning, which are caused by natural forces not controllable by man, but these are so few that for practical purposes, lightning may be considered as the sole cause found under this major group.

In the second major group, causes over which man has control, are found all those agencies other than lightning such as railroad, campfires, smokers, brush burning, incendiarism, and lumbering.

Obviously there can be no prevention work done in the first major group to remove the causative agency; man is unable to control those meteorological conditions which are responsible for lightning. On the other hand, however, all the causes other than lightning can be controlled inasmuch as their source is human activity.

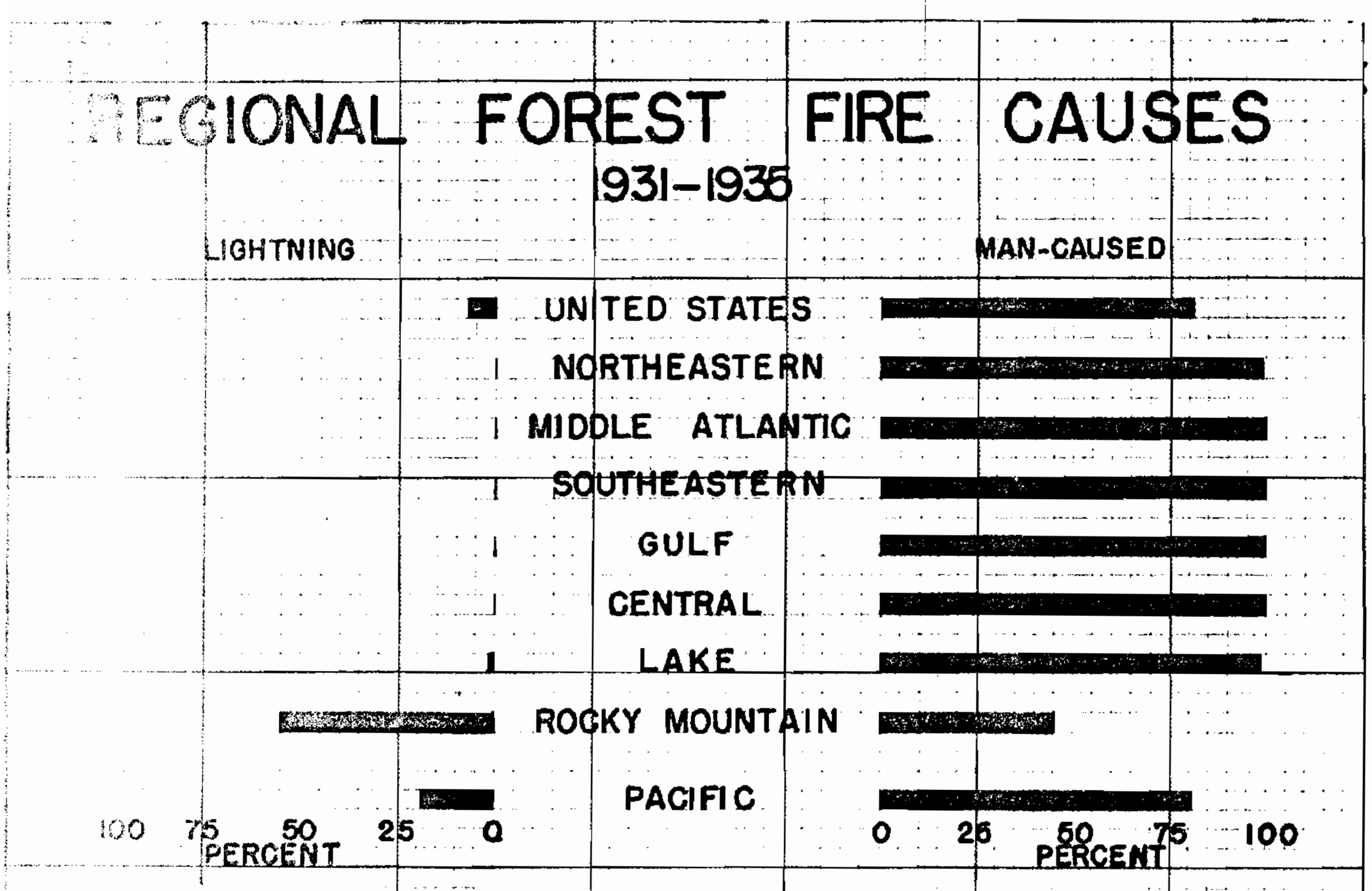



Figure 13

... simple tabulation below illustrates that from a nation-wide standpoint, human-caused fires pre... ...; lightning-caused fires are responsible for less than 1/10 of the total annual ... fires. These data serve to indicate that the chief problem in the protection of forests from ... ...ically the removal or control of the cause. Inasmuch as most fires are the result of human ... which incidentally, rather than willfully, sets fire to the forest, the problem is essentially ... must, for success, attack the cause at its source in the form of education. This means to prevent ... before they commence rather than to wait for them to start and then attack.

## LIGHTNING FIRES

...s indicated in Table 9, lightning fires are essentially localized in the two western regions, notab... the Pacific and Rocky Mountain, where the topography, being as rough as it is, generates lightning wh... coupled with peculiar fuel conditions, described ...where, produces a situation which is extremely dif-... to control.

**Table 8**

...MBER OF LIGHTNING FIRES AND HUMAN-CAUSED
FIRES IN THE UNITED STATES
PROTECTED AREAS ONLY, 1926-1935, INC.
FEDERAL, STATE, PRIVATE LANDS

| [illegible] | Lightning | Human-Caused | Total |
|---|---|---|---|
| [illegible] | 43,390 | 487,815 | 531,205 |
| [illegible] | 4,339 ([illegible].2%) | 48,781 (91.8%) | 53,120 (100%) |

**Table 9**

PERCENT OF FOREST FIRES BY CAUSE
IN THE UNITED STATES
PROTECTED AREAS ONLY
1931-1935

| Region | Lightning-Caused | Human-Caused |
|---|---|---|
| Northeastern . . . . | 1.3 | 98.7 |
| Middle Atlantic. . . | 0.5 | 99.5 |
| Southeastern . . . . | 1.3 | 98.7 |
| Gulf . . . . . . . . | 1.2 | 98.8 |
| Central. . . . . . . | 0.2 | 99.8 |
| Lake . . . . . . . . | 2.0 | 98.0 |
| Rocky Mountain . . . | 55.0 | 45.0 |
| Pacific. . . . . . . | 19.0 | 81.0 |
| Average for U. S. A. | 7.2 | 92.8 |

As the greatest single cause of forest fires in the western regions, constituting [illegible] of the fires in Idaho and Montana and 50[illegible] in Washington and Oregon, lightning storms have received considerable attention as to their behavior in order that administrative action might be taken [illegible] damage resulting therefrom. Lightning storm characteristics have been studied by Gisborne [illegible] of the Northern Rocky Mountain Forest Experiment Station and Morris (5[illegible]) of the Pacific Northwest [illegible] Station. The findings of these investigations, together with observations by other [illegible], are briefly summarized below.

**Lightning Storm Characteristics**

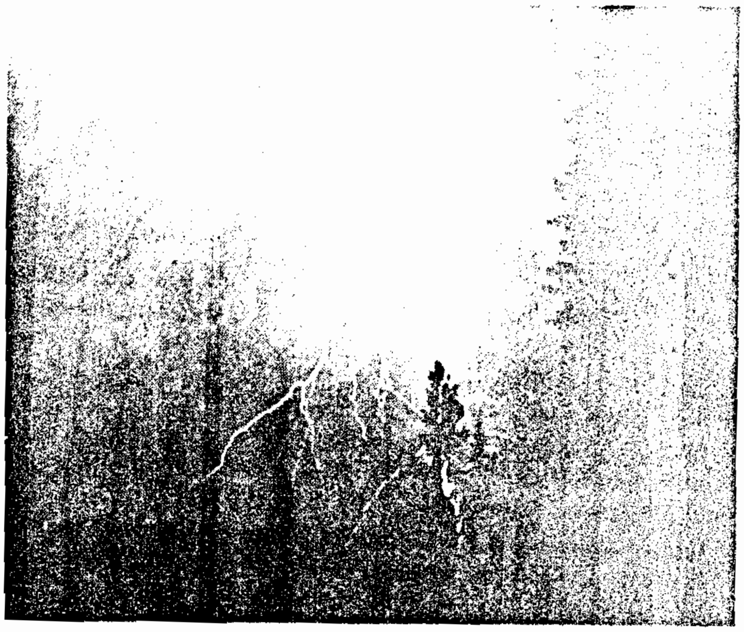


Photo by U. S. Forest Service-1[illegible]74

Figure 13a

A Lightning Strike

1. Bunching of strikes--One of the continual menaces of lightning storms is the occasional extreme bunching of strikes which cause terrific loads on the part of the control organization. It is economically inadvisable to man the forests to combat with these occasional extreme loads; when they do occur, therefore, there exist high probabilities for the creation of a conflagration with which no average control agency can combat successfully. In 1917 a single storm was responsible for more than 100 strikes on one forest; also, in 19[illegible] on the Kaniksu National Forest of Idaho, one storm was responsible for 15[illegible] recorded strikes on a gross area of approximately 600,000 acres (53).
2. Wet and dry storms--There is a term used among fire control men which presumes to indicate a storm characteristic which may show whether there will be an unusual amount of difficulty in control. A "dry" storm is supposed to have little or no precipitation accompanying it, while a "wet" storm brings with it considerable rainfall. For the Northern Rockies, only approximately 10% of the storms could be called dry; of these dry storms, 68% were harmless, i.e., did not cause fires. Of the wet storms, those accompanied by some precipitation, 66% were harmless. This exploded a common belief among fire control men that dry storms were responsible for so many fires.
3. Safe and dangerous storms--Whether a lightning storm is "safe" or "dangerous" is largely determined by two factors, (1) the accompanying precipitation and (2) the cloud-to-ground strikes. In lightning storms, Gisborne found that the average duration of the "scud" rain--that preceding the actual lightning flashes--was twelve minutes and the secondary rain--that following the period of intense lightning flashes--was thirty-seven minutes. As would seem logical, the more precipitation which accompanied the lightning, before and after the flashes, the less-likelihood was there of a fire starting. A "safe" type of storm is one in which three-fourths or more of the flashes are cloud-to-cloud, but if more than one-half of the flashes are cloud to ground strikes, the storm is "dangerous".
4. Sleepers--Another characteristic indicated by Gisborne's analysis was that lightning fires are frequently not actually picked up until sometimes as long as two weeks after the storm; these are known as "sleepers". About half the fires caused by lightning are discovered within three hours after the storm has occurred.
5. Time and place of occurrence--Lightning storms may be of a general or a local nature, that is, cover a relatively high proportion of the region or a small proportion. A surprisingly high percentage occur in the Pacific Northwest at night, 10:00 P.M. to 4:00 A.M.; here 28% occur as compared to 6% for the Northern Rockies. Midnight, however, was used as an indicator of the night storm frequency, so it may or may not have an important bearing.

the Pacific Northwest, the storms usually travel under eighty miles before they are ... there are instances where a distance of 280 miles was covered before disappearance. ... travel rather slowly, about 6 to 20 m.p.h., but seldom over 40. The direction taken is ... north and northeast. In the Northern Rockies, 67% travel northeastward and eastward. ...graphy--There is a close correlation between rough topography, lightning storm frequency, ... There is no altitudinal correlation with inception; approximately as many lightning ... low altitudes as in high altitudes, per given land area.

...--The fuels in which lightning strikes are most likely to kindle fires are duff, live ... dead trees. These fuels are arranged in descending order of importance. Because lightning ... occur at any time on any part of the protected area, the same degree of control must be ex... parts of the forest area, except where there is a wide difference in fuel types. In ... a contrast is afforded to forests where man-caused fires predominate inasmuch as these are ... areas where the risk is bunched; consequently the control organization can be planned so as ... with the risk rather than spread out uniformly as in the case of forests where lightning ... any place, any time during the fire season.

... fires possess the disadvantage, moreover, of sometimes occurring in highly inaccessible ... travel time slow and the control job tedious and even hazardous. Lightning-caused fires ... by the morning of the day after the storm, can usually be readily controlled with small ... (38). A higher percentage of California lightning fires break loose again after having ... than any other cause of fire. This can probably be explained, however, by storms fre... such intensive bunching of cloud-to-ground strikes that the normal organization can... them; co-operators are pressed into service with the result that, either because of ... experience or pressure for speedy action on each fire, fires are not actually corralled or ... reported.

### MAN-CAUSED FIRES

... fires are due either to carelessness or maliciousness. All the malicious fires are of ... nature, but all the incendiary fires are not set with malicious intent. An example of the ... incendiary fire may be shown by a group of inhabitants within or adjacent to a protected forest ... to set numerous fires to embarrass the administrative officer; or, because of actual or ... to them by the landowner, wishing to harass his representative.

... of the non-malicious cause is found in a case where a local resident wishes to burn off a ... own in order to obtain early grass for his cattle; this is incendiary, but not malicious. ... he believes to be a desirable type of day to meet his requirements, but neglects to inform ... administrative officers of his intentions with the result that the fire leaps the fire-... on land receiving protection. The net result of his short-sightedness is suppression ... due to his fire which was not confined to the area to be burned.

... FIRES vary in importance, dependent upon the type of trains travelling the area, the ter... fuels.

... Atlantic States, with their high railroad mileages and heavy traffic loads, all report a ... of railroad fires, with New Jersey outstanding in this respect. New Jersey has many miles ... the locomotives travel at high speed and use forced draft frequently; much of the railroad ... in a region where the pyrosity of the fuels is high.

... action can be taken in order to minimize the number of railroad fires. In some instances, ... in the smoke stacks of the locomotives has lowered the number of fires due to this ...

... indicates the trend which railroad fires in New Jersey are taking. With a genuine effort ... of railroad fires, a more positive showing could probably be made to lower them.

... 1926-1934, railroads were responsible for only 4.4% of the total number of fires in ... Even for the more recent five-year period cited for New Jersey, with 21.6% of the ... is still quite a discrepancy between the average for the country and the railroad ... New Jersey. The economics of the matter seems to be that the railroads in the state are probably of the opinion that it is cheaper to continue to settle with the State for suppression costs and with private land owners for damages than to widen their firebreaks.

CAMPERS' fires vary in frequency by locality. The fire [illegible] is a [illegible] of fire which can be eliminated [illegible], but never [illegible] because it is intimately associated with the human element of carelessness. The only manner in which thoughtlessness in the woods can be eliminated is to attack each separate source as an individual problem.

The people who cause fires classed as campers are (1) fishermen, (2) hunters, (3) picnickers, (4) woods workers, (5) transients, (6) prospectors, (7) berry pickers, etc Many of the fires are distinctly warming fires and can be eliminated only with persistent education.

Table 10

RAILROAD FIRES IN NEW JERSEY

| Five-Year Period 1931-1935 | | Five-Year Period 1926-1930 | |
|---|---|---|---|
| Year | Percent | Year | Percent |
| 1935 . . . . . | 29.6 | 1930 . . . . . | 17.5 |
| 1934 . . . . . | 27.1 | 1929 . . . . . | 31.8 |
| 1933 . . . . . | 23.2 | 1928 . . . . . | 24.4 |
| 1932 . . . . . | 20.8 | 1927 . . . . . | 30.5 |
| 1931 . . . . . | 16.1 | 1926 . . . . . | 30.1 |
| Average for Period. . . . | 21.6 | Average for Period. . . | 26.9 |

Sportsmen can be appealed to by some device at the time the license is given to them, or propaganda against woods burning can be incorporated in the hunting license itself.

Woodsworkers can be cautioned through their employers and by appealing directly to them in a manner so that they realize the relation between their employment and the forest.

Picnickers generally congregate in public rather than private grounds; they are not a serious menace.

The class of people who have no regard for the property of others since they have little or no responsibility, are the transients. They kindle warming or cooking fires just off the edge of the highways; toward morning the fire dies down until it cannot be distinguished from the road. The rising winds of the latter part of the morning fan the ashes into a blaze. The transient leaves his fire to the mercies of the wind; since he gains nothing by extinguishing the fire, he seldom bothers. The movement of transients can be controlled, however, with the cooperation of highway patrol agencies.

As a group class, however, campers' fires are an important single cause in a very few states. In only three western states, namely Utah, Colorado, and Wyoming, are they important. In the first-named state, they sometimes account for as much as 30% of the total number of fires.

SMOKERS fires is a classification which is probably much abused. Upon examination of the available data on causes, the question immediately rises: Why, in a five-year average, were 44% of the known fires classed as "smokers" in Pennsylvania when across the Delaware River, under very similar conditions of topography, climate, soil, vegetation, social pattern, and industrial activity, New Jersey reported only 2% attributable to smokers?

There is considerable room for research in this direction, that is, to determine the risk which is so frequently attributed to smokers. It is not unlikely that the figure cited by the New Jersey organization is more nearly correct than in the case of Pennsylvania.

In a study of effective fire brands correlated with the moisture content of the duff, Stickel (78) found that the smouldering cigarette butt is important as a firebrand only when the surface duff has a moisture content of less than six percent. The match, on the other hand, is an effective firebrand even with a low fire hazard when the moisture content of the duff is 17 to 22 percent. With these facts in mind, the discrepancy between the percentage of smoker fires in New Jersey and Pennsylvania appears to be most unusual.

BRUSH BURNING fires are peculiar to no one region. Massachusetts for instance, reported 13.7% caused by brush burning as against Idaho's 3.4%; Massachusetts is one of the oldest states in the union, while Idaho is a state much newer and less developed than Massachusetts, so one would expect a larger percent of fires in the western state. One is led to believe that either the citizens of Idaho are more careful with their brush burning or have much less brush to burn. North Carolina, another old state, reports 12.4% for the same period. Brush burning, it would seem, is hardly identified with pioneering.

This class of fire, however, is one of the easiest to eliminate or control. Brush burning, in most cases, causes a sufficient amount of smoke to be picked up by a lookout who can dispatch a patrolman to warn the burner and place the suppression agency on guard. Because the burner knows that if his fire gets [illegible] he will be prosecuted and convicted, he will be doubly cautious.

The number of debris fires in several states is undoubtedly lowered by the permit law which requires [illegible] to obtain a permit before burning in some states.

Incendiarism is normally low with the exception of a few of the southern states. Except for these states there is little incentive for burning the woods; in other regions, incendiarism is largely of a [illegible]. In the South, however, burning is frequently practiced to "green up the woods" so that [illegible] forage at an earlier date than would otherwise be the case. This type of burning is [illegible] with fires set with malicious intent. The motive is purely a selfish one whereby some [illegible] to the woods burner, admittedly at the expense of forest growth.

In 1931, when the Southeast was suffering from a rainfall deficiency, Florida reported for state and private lands under protection, 1577 fires as being of incendiary origin; this amounted to 71% of the total number for the year as against 45.2% for the period 1926-1934. It is difficult to understand just why there should be a marked departure in one year from the average for eight years. It would appear that the [illegible] were excessively high for those fires attributed to incendiarism. It would seem more logical for the number of causes other than incendiarism to mount because the incendiarist seldom [illegible] in setting his fire, regardless of the hazard. The more combustible the fuels, the more liable fires are to start. The cigarette butt may normally be harmless, but do to excessive dryness, the hazard is increased and makes it possible for the normally non-dangerous cigarette to kindle the dry fuels. It is doubtful whether an increase in hazard raises the risk due to any one cause as could be inferred from the 1931 Florida data referred to above.

The situation in the Southeast in 1931 and 1932 was so acute that considerable attention was focused there due to a loss of 8.93% of protected land in Florida in 1931 and 12.10% in Georgia in 1932. The conflagrations of 1931-32 in the Southeast caused Evans (32) to write a brief analysis of the background for the events which caused Florida tourists to comment so unfavorably. Florida was not peculiar among the states in the Southeast so far as a large burn was concerned, but it had a higher percent of its forest land burned than its neighboring states in 1931. Two major reasons were given for the situation: (1) instability of forest land ownership,and (2) lack of respect for property rights.

Under the first item, there is a relationship between the fire control problem and the "New Public Domain", an expression frequently used in recent years to describe the status of the tax delinquent lands. The action of the Florida state legislature in 1931 accentuated the difficulty when it prohibited the expenditure of any cooperative state and federal fire control funds on tax delinquent land. This legislation caused the abandonment of approximately half of the area previously protected by the state forestry department. This "rough" area was soon gutted by subsequent fires, so that the expenditures invested for fire control prior to 1931 were voided on tax delinquent land. The action of the legislature was most unfortunate because it was negative throughout--it neither deprived a landowner of his right to manage his tax delinquent land nor did it propose to assist the delinquent in restoring real values to the land by aiding him in protecting it from fire.

Under the second group of reasons, i.e., lack of respect for property rights, woods burning for early spring forage for cattle and the annual burning by turpentine operators to safeguard their investment in stumpage and cups and aprons from total destruction by fire are good examples. These fires, set to burn a definite area, are seldom confined to the unit to be burned, but burn unmolested to the property of adjoining owners. The average naval stores operator has no intention of protecting reproduction from destruction by his fires because he leases his chipping timber and seldom owns the land outright. The absentee owner situation does little or nothing to improve matters; frequently there is no overseer and if there is one, he may see no value in forest fire control.

#### RELIABILITY OF REPORTED CAUSES

Too much significance should not be attached to the data on causes of fires because the Federal compilations for fires on state and private lands are based on statistics submitted by separate state agencies which are individually administered, so each organization consequently reflects more clearly the [illegible] of its administrative head than is the case among the various national forests which have a [illegible] administrative procedure.

Much of Louisiana's protected area is located on soils which have timber types quite comparable to those found in eastern Texas; the social pattern on these areas is also quite similar, yet for the period 1926-1934 Louisiana reported 56.8% of its fires as being of incendiary cause, while for the same period Texas reported 27.1%. The data also indicated that the Texans are also three times as careless in their smoking habits as are the Louisianans because for the period mentioned above, they reported 34.4% and 9.7% respectively.

**Table 11**

COMPARATIVE CAUSES OF FOREST FIRES (68)
FOR NEARBY OR ADJOINING STATES
PROTECTED LAND, 1926-1934

| Cause | Region | | | | | |
|---|---|---|---|---|---|---|
| | Middle Atlantic | | Southeast | | Rocky Mountain | |
| | Md. | N.J. | Ga. | Ala. | Colo. | Wyo. |
| | Percent | | Percent | | Percent | |
| Lightning | 0.2 | 0.1 | 0.9 | 0.2 | 51.0 | 43.2 |
| Railroads | 13.0 | 27.1 | 4.2 | 5.4 | 6.5 | 0.0 |
| Campers | 1.9 | 0.2 | 2.6 | 6.0 | 11.3 | 27.1 |
| Smokers | 39.2 | 1.5 | 3.1 | 15.1 | 23.7 | 23.2 |
| Debris Burning | 23.7 | 5.9 | 12.0 | 26.1 | 2.3 | 3.9 |
| Incendiary | 17.5 | 0.1 | 44.9 | 32.2 | 2.3 | 0.4 |
| Lumbering | 0.4 | 0.0 | 1.0 | 2.0 | 0.3 | 0.0 |
| Miscellaneous | 4.0 | 3.0 | 20.0 | 13.0 | 2.6 | 0.4 |
| Unknown | 0.1 | 62.1 | 11.3 | 0.0 | 0.0 | 1.8 |

Table 11 lists the causes by states which are reasonably comparable to each other from the standpoint of geographic location, area protected, and general human activity. It can be readily noted that the comparative figures present discrepancies which are especially acute in the case of New Jersey and Maryland, both small states with concentrations of population and varied forest types ranging from coastal plain pine land to mountain hardwoods. For the period covered by the table, there were no national forests in Maryland and New Jersey, few in Alabama and Georgia, and several in Wyoming and Colorado. There was considerable uniformity of causes among the Western states, several discrepancies in the Southern, and many in the Middle Atlantic. The variation between the unknown fires in New Jersey and Maryland illustrates the need for better actuarial procedure.

One of the basic reasons for discrepancies in reports on causes is because, when a fire breaks out, the chief duty of the person in charge of the fire is to suppress it in the shortest possible time; if he had the opportunity to conduct an investigation for cause, he frequently would be able to determine it fairly definitely on the basis of circumstantial evidence which, although it might not be sufficient to secure a court conviction, would nevertheless reduce the degree of guesswork considerably. There is not much difficulty entailed in determining whether a fire is man-caused or lightning-caused; if the fire quite obviously has not been caused by lightning, it must be man-caused; just what the nature of the man-caused fire is can be determined only by prompt investigation upon the arrival at the fire. Those agencies sincerely interested in reducing the number of fires will attempt to determine the cause accurately in order to take steps to eliminate or reduce their number; where this desire is dormant, there is little incentive to fix responsibility.

## Chapter IV

## FOREST FUELS

[illegible] which are the principal components of fire danger are (a) constant or permanent with [illegible] variation; these are topography, fuels, aspect, and forest cover. There are also (b) the [illegible] or temporary factors which vary considerably; these include risks and the several meterologi- [illegible]

[illegible] are the most important of the constant factors. The fuels make forest fires possible; without [illegible] would be no need for forest fire control. The other constant factors such as topography, [illegible] and forest cover merely influence the combustible condition of the fuels or their rate of spread [illegible] fire gets started.

[illegible] as all forest fires are concerned with the peculiar behavior of the fuels upon combustion, [illegible] and basic to determine those factors which may set fire to the fuels and the reaction of [illegible] when ignited. The causes have been discussed in Chapter III. This immediate discussion is con- [illegible] with fuels.

[illegible] are reasonably constant factors in fire control. The word "constant" has been qualified be- [illegible] the obvious physical characteristics, such as fineness, depth, and state of decomposition [illegible] same from July 1 of one year to June 30 of the following year, the moisture content will [illegible]. The behavior of a given fuel when burning will depend upon the presence or absence of [illegible] factors which cause fires to burn fiercely at one time and slowly at another.

### Cover Type, Fuels, and Control Planning

[illegible] earliest work in [illegible] planning was [illegible] in estab- [illegible] between [illegible] of spread of [illegible] of specific [illegible] fuels pro- [illegible] that crown [illegible] in the chapar- [illegible], surface fires [illegible], ponderosa [illegible], and the [illegible], and ground [illegible] pine-fir and [illegible] fuels produced by [illegible] also gave indi- [illegible] of spread which [illegible] bearing on the [illegible] to meet the [illegible] control which have [illegible] for a given forest [illegible] indicates that [illegible] varies with the [illegible] other factors be- [illegible] equal.

[illegible] planning work in fire [illegible] for the California

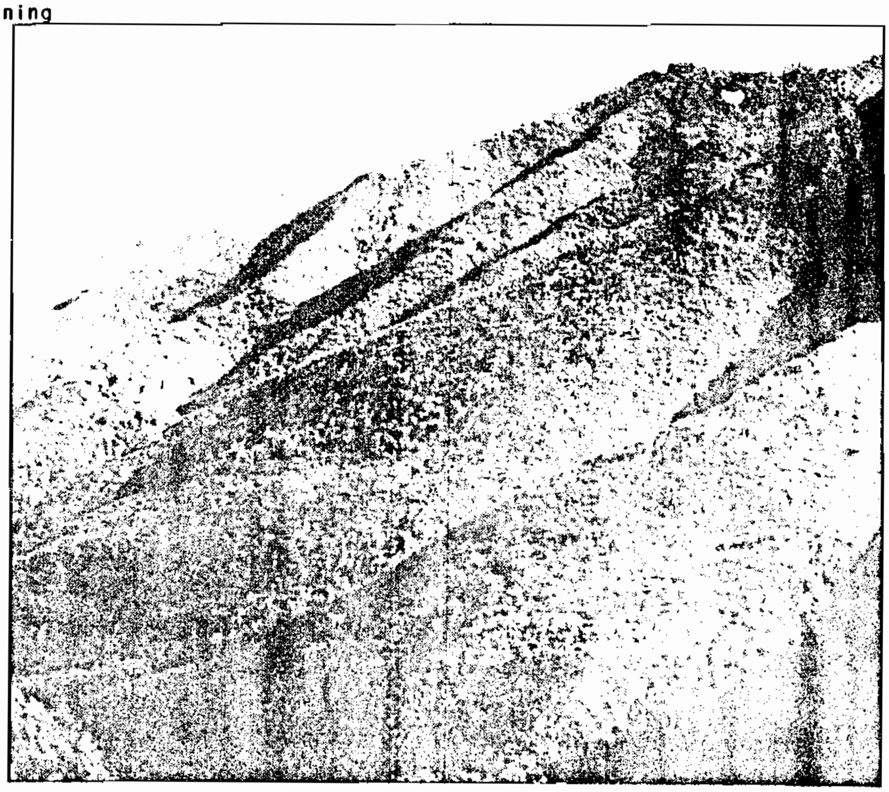


Photo [illegible] U. S. Forest Service [illegible]

Figure 11b

Chaparral Slopes Typical of A Very Rapid Rate of Spread [illegible]tion in the application of rate of spread to the man-power and improvement requirements necessary to meet the protection objective (40). A phrase, "Hour control", was evolved in reference to the speed of attack factor; it includes the total elapsed time from the inception of fire to the commencement of suppression work. It includes detection, communication, get-away, and travel time. For each timber type, hour control was calculated and the organization geared to attain the control objectives. The term, "Hour control", however, has been succeeded by "speed of attack".

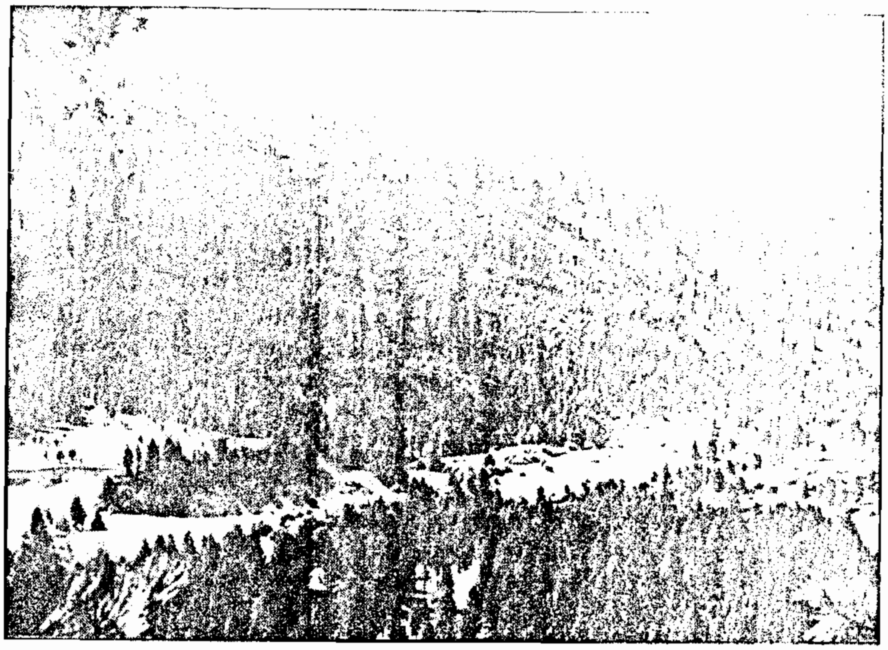


Photo by U. S. Forest Service-199332

Figure 13c

Ponderosa Pine Slopes Which Grow In More Open Stands Than Chaparral And Consequently Have A Lower Rate Of Spread Than In The Case Of The Chaparral

### Moisture Content of Forest Fuels

That there is a relationship between the condition of the fuels and the character and severity of the fire has long been recognized. In one of the earliest publications on the subject of forest fires in the United States, Graves (33) mentioned that the moisture content of forest fuels has a marked influence on the occurrence of and behavior of fires.

**Table 15**

RATE OF SPREAD IN TIMBER TYPES, CALIFORNIA REGION (39)

| Timber Type | Acres Burned per Hour Elapsed Time 1911--1920 Northern California Forests |
|---|---|
| Chaparral, grass, woodland | 33 |
| Brush | 14 |
| Yellow Pine-Mixed Conifer | 6 |
| Sugar Pine-fir Douglas Fir, fir | 3 |

That the moisture content of the fuels, the "humus" in particular, affected forest fire behavior was also noted by Williams (45), Forecaster for the Weather Bureau. It was his opinion that the fire hazard is proportional to the rate of evaporation at the fuel surface. The rate of evaporation naturally influences the moisture content of the fuels themselves.

Two pioneers in the field of forest fire investigation were Show and Gisborne who commenced intensive work on determining the relationship between fire behavior and fuel dryness. Gisborne stated that the dryness of the fuels, of which duff was one, was the best indicator of the current degree of forest fire hazard. Although precipitation was the meteorological element most frequently used by foresters to indicate the degree of fire danger, this element failed to record the varying drying effect the atmosphere may have on the fuels between periods of precipitation. Those fuels used by Gisborne (46) as fuel dryness indicators to reflect the degree of fire danger were (1) light moss and dead herbaceous leaves, (2) twigs, duff, and branchwood, (3) top 1/4" layer of duff, (4) heavy slash and windfalls.

The dryness of the several fuels establishes the fire danger. When the heavy slash and windfall become extremely dry, there is not only the possibility of a conflagration, but also extreme difficulty of suppression because of the terrific heat generated.

### Reaction of Fuels to Drying Influences

There are several classes of fuels; the basis for the grouping is their sensitivity to the drying influences. The lighter the fuel, the more sensitive it is to drying influences; the heavier the fuel, the better the indicator it is of the cumulative effect of the several drying factors, but is a poor indicator of current conditions because of the lag between the moisture of the fuel and the drying causes.

Progressing from the light to the heavy fuels, Gisborne found that they dried out in order of their weight, i.e., the light fuels responded readily to short-term drying or moistening influences, while with the heavier fuels there was much more lag in their drying rate.

The situation presented statistically in Table 16 is readily understandable when it is realized that with the lighter fuels, such as twigs, a higher percent of the total volume of the fuels is directly exposed to drying influences than is the case where a much smaller percentage of the fuel surfaces is exposed, as in windfalls.

**Table 16**

MOISTURE CONTENT VARIATIONS OF FOREST FUELS

| Fuel | Percent Moisture Content | | |
|---|---|---|---|
| | Minimum | Maximum | Average |
| a) Twigs. . . . . . . . . | 6 | 140 | 19 |
| b) Top ¼" duff. . . . . . | 7 | 120 | 24 |
| c) Heavy dead branchwood. | 9 | 127 | 28 |
| d) Outside ½" of windfalls | 12 | 216 | 60 |
| e) Full layer of duff . . | 9 | 320 | 63 |

### INFLUENCE OF FUELS ON FIRE BEHAVIOR

Extensive application of fire danger as indicated by fuel conditions is practiced in Region 1 of the United States Forest Service--the Northern Rocky Mountains. Hornby (41,42) developed a system of classifying and mapping fuels. Two aspects of fuels contribute directly to fire control work; rate of spread and resistance to control. By knowing how rapidly a fire will travel through a given type of fuel and the degree of difficulty encountered in constructing a fireline, a dispatcher can estimate with reasonable accuracy the man power required to corral the fire. Another use of fuel classification is in determining the location of roads and transportation systems.

The rate of spread and resistance to control were each broken down into four classes: low, medium, high, and extreme. Thus fuel referred to as HL would mean one having a high rate of spread but low resistance of control.

#### Rate of Spread

An interesting phase of Hornby's study was the use of the perimeter of a fire rather than the acreage involved as the factor which determined the corral time.

**Table 17**

RATE OF SPREAD FOR TIMBER TYPES

1. Brush-grass . . . . . . . . . .rapid
2. Ponderosa
3. Larch-fir
4. Douglas fir and lodgepole pine
5. White pine and cedar hemlock
6. Subalpine
7. White fir and spruce. . . . . slow

The perimeter is used because it is the part of the fire on which the work is done. The perimeter is the active part of the fire. It is the point between the burning and the unburned or combustible fuels, as represented by the going fire, which are of concern from a suppression standpoint.

On the basis of timber type, Hornby was able to prepare a table on rate of spread in which the types are arranged at left in descending order; these contribute only a part of the fuel picture because such factors as presence of few or many snags, relative amount of moss, blow-downs per acre, whether previously burned once, several times, or not at all, whether cut-over recently, have all been omitted from consideration, but all of these factors contribute materially to the rate of spread and resistance to control.

Instead of associating timber types with their relative rates of spread, the phraseology of "low", "medium", "high", and "extreme" rate of spread was coined, with a specific rate of perimeter increase assigned to each for average burning conditions. The data in Table 18 on following page show the specific values assigned to each rate of spread class.

#### Resistance to Control

Resistance to control was also broken down into four parts; this factor indicates the quantitative rate of perimeter of held line produced by one man in an hour.

Hornby lists those factors which contribute toward resistance to control as follows:

A. Fuel Conditions
- a. amount
- b. arrangement
- c. size
- d. species
- e. decay

B. Existing In
- a. standing green timber
- b. snags
- c. windfall and slash
- d. brush, reproduction and grass
- e. duff and roots

**Table 18**

RATE OF SPREAD OF CLASSES OF FUELS

| Relative Rate of Spread | Increase in Perimeter per hour |
|---|---|
| Low | 4-6 chains |
| Medium | 6-8 chains |
| High | 8-10 chains |
| Extreme | 10-14 chains |

**Table 19**

RESISTANCE TO CONTROL AS DETERMINED BY FUELS

| Relative Resistance to Control | Amount of Held Line Constructed per man-hour |
|---|---|
| Low | 6.7 chains |
| Medium | 4.1 chains |
| High | 1.5 chains |
| Extreme | 0.2 chains |

In the planning work for the Northern Rockies, the several factors affecting the rate of spread and resistance to control of the several forest types were classified. Table 20 is an excerpt from the tables of fuel hazard ratings compiled for the larch-fir, white pine, and lodgepole pines forest types. Seven separate conditions of spread and resistance to control have been established for these types. These forest types, if they occur on northeast slopes in dense mature stands, with very few snags present and small amounts of tree moss produce fires which increase their perimeter slowly and are easily controlled. If, on the other hand, in these same forest types with stands of mature timber which have been burned over once by a light fire, resulting in dense reproduction occurring, with many windfalls on the ground and highly inflammable snags present 50'-75' apart, a fire were to start, it would spread very rapidly and be most difficult to control.

**Devices for Determining Fuel Moisture Content**

The best indicator of forest fire danger is the relative degree of resistance offered by the fuels to ignition. That factor which has the greatest influence on the inflammability of the fuels is moisture content, because the more moisture present, the more energy is needed to drive off the moisture before the fuel is kindled.

The first satisfactory instrumental device produced for measuring the moisture content of duff, as representative of the lighter fuels, was the "duff hygrometer" originated by Dunlapp of the Forest Products Laboratory, in cooperation with Gisborne of the Northern Rocky Mountain Experiment Station.

Although the duff hygrometer is well adapted to the measurement of the moisture content of the lighter fuels, it is of little value in determining directly the moisture content of the heavier fuels, such as dead branches, brush, limbs, and snags. The dryness of the heavier fuels contributes largely to the intensity of the heat produced by the fire. "Hazard sticks" of several sizes and combinations have been produced by the Northern Rocky Mountain Forest Experiment Station and the Pacific Northwest Forest Experiment Station. There is a marked similarity in the type of sticks, one difference being that the Pacific Northwest uses square sticks and the Northern Rockies use round sticks which are similar to branchwood in cross-section.

Neither the duff hygrometer nor the hazard sticks as generally used record graphically moisture content fluctuations. There is in

**Table 20**

FIRE HAZARD RATINGS FOR FUELS

(Excerpt from "Instructions for Fuel Type Mapping", by L. G. Hornby, R-1, USFS)

| No. | Forest Conditions | Rate of Spread | Resistance to Control |
|---|---|---|---|
| 1 | Mature larch-fir, white pine, or lodgepole on protected flats or northeast slopes, where windfall is light and not continuous; stand dense enough to shelter fuels on ground. Ground vegetation conspicuously low shrubs throughout. Trees clean and snags few. Tree moss may be moderate. | L | L |
| 2 | If above stand is exposed to almost full sun and wind has moderate access to ground. | M | L |
| 3 | If windfall and snags are moderate but conspicuous and mixed with continuous grass carpet and stand is exposed to wind and sun. | M | M |
| 4 | If windfall and snags are moderate to heavy, continuous and intermixed with only scattered trees of the old stand, and reproduction does not fully shade windfalls on protected N E slopes. | M | H |
| 5 | On exposed S W slopes. | H | H |
| 6 | If these same mature stands were burned over by light fire, or were heavily bug killed, resulting in dense reproduction 20-30 years old, not completely shading windfalls and continuous rotten, broom-topped or otherwise inflammable snags 50-75 feet apart on protected N E slopes. | H | E |
| 7 | On exposed S W slopes. | E | E |

operation at the Priest River Experimental Forest, however, an instrument which records the moisture content of the duff and the hazard sticks, as well as wind velocity and duff temperature.

THE DUFF HYGROMETER consists of a piece of rattan about 12 inches long incased in a perforated metal cylinder approximately 1/2 inch in diameter. The one end of the cylinder has attached to it the fixed end of the rattan; the other end is attached to levers which control a dial which is calibrated from 0% to 30%. The dial has been marked to show the expansion and contraction of the rattan based on the moisture content of the atmosphere surrounding the duff. Rattan is fairly responsive to the moisture content of the surrounding medium. When the rattan contracts, due to the drying out of the surrounding medium, which is the duff on the forest floor, the pointer on the dial drops toward the zero end of the dial; when the rattan elongates due to increased moisture, the pointer moves toward the 30% end of the dial. As Gisborne (50) points out in his description of the device, fires do not occur when the fuel moisture content of the duff is in excess of 30%; this determined the magnitude of the range of the dial.

THE HAZARD STICKS are indicators of the moisture content, and indirectly the inflammability of the heavier fuels, such as branches. They consist of wood cylinders 1/2 inch and 2 inches in diameter and 18 inches long when round; when square, 1/2" x 24" and 2" x 24". The half-inch sticks are referred to as "triplets", inasmuch as three are used jointly for the purpose of producing average results which will be more accurate than if single sticks were used. Because no two pieces of wood have identical structure; the use of three diminishes departures from normal for any one cylinder. Considerable care is exercised in the preparation of the cylinders so that those evidencing wide departures from the behavior of others are discarded and not put into use. Ponderosa pine sapwood is the material from which the round sticks are made. Gisborne (50) has written in detail the manner of preparation and method of field set-up. Matthews experimented considerably with the various species most generally available for the region in which he was investigating; his final choice was ponderosa sapwood for tho 1/2 inch sticks and fine-grained Douglas fir for the two inch sticks.

The Pacific Northwest Region has devised a means for determining the moisture content of the hazard sticks without any computations, thus lowering the possibility of the human element making an error in the moisture content determination. The sticks are placed on a beam arm scale which has been calibrated to read directly in terms of moisture content rather than grams for the sticks being weighed.

As might be supposed, the smaller sticks are the more responsive to changes of factors which influence their moisture content. Both of the standard sizes, however, are indicators of cumulative weather conditions which are not shown by any other single measurement. The two-inch sticks in particular are indicators of cumulative conditions which are not so well shown by either the duff hygrometer or the 1/2 inch sticks because both respond fairly quickly to those factors which influence their moisture content.

The investigators who have devised and worked continuously with the hazard sticks have found that their responsiveness to influencing factors diminishes with age; after four years of use, they are no longer reliable.

In the correlation of the factors of weather, fuels, and forest fires, Gisborne's (56) study of the subject was the most complete at the time of its publication. Although Show and Kotok had done some preliminary work with the moisture content of fuels as determining fire danger, Gisborne carried the work to a much more advanced point where he was able to produce a table of relative hazard, based on the moisture content of the upper layer of duff.

**Table 21**

GISBORNE'S HAZARD TABLE

| Relative Fire Danger | Duff Moisture (% of Dry Weight) |
|---|---|
| Non-inflammable . . . . | 25 - plus |
| Very low inflammability | 25 - 19 |
| Low inflammability. . . | 18 - 14 |
| Medium inflammability . | 13 - 11 |
| High inflammability . . | 10 - 8 |
| Extreme inflammability. | 7 - 0 |

Table 22

STICKEL'S DANGER RATING TABLE

| Degree of Hazard | Moisture Content Surface Duff | Effective Fire Brands |
|---|---|---|
| Extreme | Below 6% | Cigarettes, locomotive sparks, pipe heels, matches, and camp fires. |
| High | 6% - 10% | Locomotive sparks, pipe heels, matches, and camp fires. |
| Medium | 11% - 16% | Pipe heels, matches, and camp fires. |
| Low | 17% - 22% | Matches and camp fires. |
| Very low | 23% - 29% | Camp fires; duff at edges will smolder but not spread much. |
| Generally safe | 30% or more | None: Generally safe from all. |

Stickel (78) went a step farther than Gisborne and not only specified the degree of hazard which exists with a given moisture content of the duff, but even identified the type of firebrand with a given degree of hazard. The percent of moisture content of the duff and the resultant hazard as arrived at by both Stickel and Gisborne is very similar when Stickel's danger rating table above is compared with Gisborne's Hazard Table 21.

Stickel used firebrands which are always associated with man-caused fires and his results are particularly applicable to Northeastern forest conditions where man-caused fires constitute such a high percentage of causes. It is interesting to note that only under the most extreme fuel conditions is the cigarette butt a serious factor as a firebrand. It is the burning or smouldering match which is responsiblo for fires rather than the cigarette.

## Chapter V

### FACTORS AFFECTING INFLAMMABILITY OF FUELS

[illegible] ability of any given fuel is dependent upon the amount of moisture contained in it. To [illegible] point of being ridiculous, it can be said that fires do not burn when rain is falling, [illegible] weather, or immediately after rain has occurred. At the other extremity of fuel moisture [illegible] one who has participated in fire suppression knows that conflagrations occur during [illegible] lated precipitation deficiencies which are generally accompanied by low atmospheric [illegible] have long wanted some sort of index, however, which would enable them to know just [illegible] fire danger actually exists at a given time and what the probable trend will be.

[illegible] which contribute toward the relative dryness or wetness of the fuels are listed below.

A - [illegible]

1) [illegible] itation
2) [illegible] ic moisture
3) wind movement
4) rate of evaporation
5) temperature
6) [illegible] ic pressure

B - Other factors

1) slope, altitude, and aspect
2) forest cover
3) height of the ground water table

### METEROLOGICAL FACTORS

[illegible] and meteorologists have been analyzing the relation between fire inception and spread with [illegible] factors enumerated above. That the several meteorological elements constituting weather had [illegible] forest fire conditions was recognized as early as 1912 by Beals (43), Forecaster for the [illegible], Weather Bureau District. For forest areas of relatively level topography, a reasonably [illegible] could be made for wind and temperature, the two elements which are considered of great- [illegible] as far as an influence on forest fire inception and control was concerned. Regional fore- [illegible] very limited application in regions where the topography is rough, as represented by the [illegible].

[illegible] reproduced weather maps for the periods when the Michigan, Hinckley, Great Idaho, and Minnesota [illegible]; the maps had plotted on them only the isobars. There was an indication that the con- [illegible] more or less coincident with stagnant air which, when heated by a relatively small [illegible] terrific convection currents which aided by extremely dry fuels, rapidly enlarged the [illegible] of the fire so that the rate of spread was almost beyond human control.

[illegible] by Beals (44) that the Great Idaho Fire was due to a combination of factors such as (a) [illegible] deficiency, winter of '09 - '10, (b) premature spring causing snow to disappear two months [illegible], and (c) only light rains during the warm months.

[illegible] emphasis was given by the Weather Bureau to wind movement in connection with velocities, but [illegible] to humidity was only casual. No attempt was made to predict humidity, but it was understood by [illegible] on the Pacific Slope that when hot weather prevailed, the humidity was low, and a prediction of [illegible] during a drought practically covers both elements.

[illegible] investigators used weather elements such as rate of evaporation and relative humidity as in- [illegible] fuel dryness. Munns (47) found a close correlation between rate of evaporation and area [illegible] several California forests. Munns found that wind direction had an important correlation with [illegible] several California forests during the period 1913-1916. For each of 67 fires which burned [illegible] acres, 50 occurred when the wind direction was from the northerly quadrant; for 42 fires [illegible] burned 1000 acres or more, 29 burned when the wind blew from the north. A question could be [illegible] northerly north winds may not have greater velocity and be drier than winds from any of the [illegible] quadrants. Other investigators in the same region came to the conclusion that wind velocity had a direct effect on spread of fire; when the velocity is doubled, the rate of spread is quadrupled.

Show (43) credits [illegible] as the first investigator to recognize the importance of low relative humidity [illegible].

Osborne and [illegible] the use of relative humidity in determining periods of high hazard. In their work [illegible], they proposed to establish a scale of fire danger based on relative humidity; [illegible] relative humidity fires will not spread, while at 25%, fires will crown.

[illegible] also correlated relative humidity with forest fires, but used frequency of inception [illegible] size of fires inasmuch as when size is used, the variable of control efficiency cannot be [illegible].

The results of fire danger investigations to date indicate that (a) the dryness of the fuels determines the readiness with which they can be ignited, and to some extent the rate of spread and ease or difficulty of control; (b) the moisture content of the fuels is determined in part by soil moisture, but largely by those atmospheric factors such as precipitation, air moisture, wind movement, air temperature, and [illegible] radiation all of which have the ability to remove moisture from the fuels.

Since fire danger must indicate not only the readiness with which fuels will ignite, but also the rate of spread, the situation becomes a complex one and can be best understood by a discussion of the individual contributing factors; each factor, moreover, is the result of atmospheric conditions created by the cyclonic or anti-cyclonic condition prevailing over a given area at a given time.

### Precipitation

Precipitation, or rainfall is a crude indicator of the degree of fire danger; it is a contributing factor, like relative humidity, wind, and temperature, and although it must receive recognition, it is possible for it to receive too much emphasis.

The cumulative records of rainfall have been used by Loveridge (51) as a basis for determining the forest fire hazard for forest regions and for the entire forest area of the United States. Precipitation records have been maintained throughout the country by the Weather Bureau for a long period of time; these records serve as a basis for comparison of current precipitation. A deficiency departure receives a negative sign and an excess departure receives a positive sign; the difference between the positive and negative figures multiplied by the acreage involved produces the cumulative hazard index figure. By this method, Loveridge shows that for the forested area of the country a tremendous cumulative precipitation deficiency has been built up.

The magnitude of the precipitation is an important factor in affecting hazard. Rains which deposit large quantities of water over a considerable period of time are of much more influence in increasing the moisture content of the heavy fuels than are light rains of short duration. To know that there has been precipitation is important, but to know the volume is of much greater value because, although light rains decrease the hazard, heavy rains have the same effect but for a much longer period of time. In his study of precipitation in connection with forest fires in the Southwest, Pearson (138) stated that the amount of rain which is required to eliminate fire danger depends on a number of circumstances, such as distribution of showers, character of succeeding weather, topography, and the amount and character of the inflammable material. For the Southwest, ordinarily one-half inch of precipitation will minimize the fire danger for approximately two weeks.

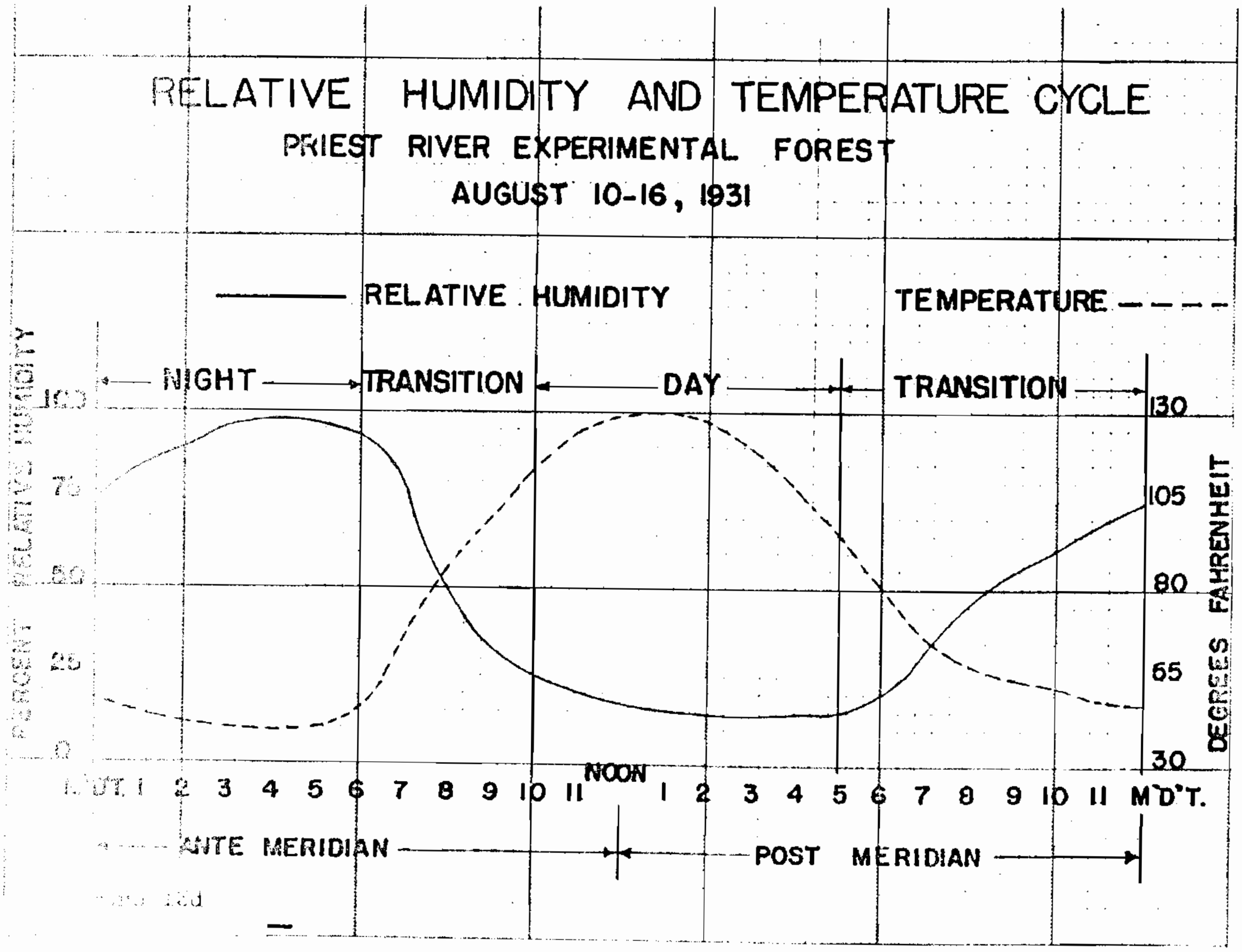
For Minnesota, Mitchell (139) has stated that the effectiveness of a given quantity of precipitation in preventing fire is determined by the season of the year; one-half inch of rainfall in a ten day period during the summer part of the fire season is less effective than in spring and considerably less than in fall. This situation can be attributed to the fact that in the summer there is considerable interception by foliage so that much less precipitation actually wets the fuels, while in the fall, with the foliage gone, the rainfall has a much better opportunity to get to the fuels on the soil. In a more recent publication, Mitchell and Richman (140) have plotted rainfall probability for the same region for 10-day periods during the fire season. The resulting maps show that the probability of a high hazard is high for certain periods of the fire season, while for other parts of the same region, for the identical period, the probability is very low. The charts show that there is greater probability of less [illegible] of precipitation in northern Wisconsin for several 10-day periods than for any other [illegible] of the region; this would indicate a greater probability of high hazard.

Atmospheric Moisture

[illegible] moisture is of importance in fire control because it influences the moisture content of [illegible]. The moisture in the atmosphere is seldom in a state of equilibrium with moisture on surfaces exposed to it. The atmosphere is frequently drier than surfaces, such as forest fuels, with the result that a pull is exerted on the moisture found on the surface of the fuels. With increasing temperature, resulting in greater molecular activity, the moisture on the surface of the fuels passes from the fuels to the air at an increased rate. On the other hand, the forest fuels are frequently drier than the air and the lighter fuels in particular absorb moisture from the atmosphere when this condition exists. When there is no pull from the surface moisture to the atmosphere, or vice versa, from the atmosphere to the fuels, the moisture conditions of the atmosphere are in a state of equilibrium; this condition, however, rarely exists except for short intervals.

There are three means of measuring atmospheric moisture, or the "psychrometric factors" as Stickel (7a) chooses to call them; these are (a) relative humidity (b) absolute humidity, and (c) depression of the dew point.

RELATIVE HUMIDITY is an expression of the degree of saturation of the atmosphere at a given temperature. As the temperature of the air increases, its capacity to contain water vapor rises. With air at a temperature of 80 degrees Fahrenheit and a humidity of 100%, a lowering of the temperature to 60 degrees Fahrenheit would squeeze out, or precipitate the excess water vapor which the air is not capable of containing.



The range of relative humidity extends from 0% to 100% of saturation. Whenever the relative humidity is less than the moisture content of [illegible] such as humus, twigs, and branches, the atmosphere acts like a huge sponge, pulling vapor [illegible] into the air from all moist surfaces; those surfaces of particular interest in fire control [illegible] forest fuels, or combustible material found in the forest.

Relative humidity [illegible] influence on the size which fires attain and particularly the frequency of occurrence; [illegible] influence of the atmosphere when it contains small amounts of moisture. [illegible] was prepared by Show and Kotok to show the relation between rate of spread and relative humidity.

Table 23

INFLUENCE OF RELATIVE HUMIDITY UPON RATE OF SPREAD OF FIRES, CALIFORNIA REGION

| Percent Relative Humidity | Average Fire Areas in Three Wind Velocity Periods | | | Average of all Fires |
|---|---|---|---|---|
| | Less than One Mile | 1-20 M.P.H. | 20 plus M.P.H. | |
| [illegible]-25 | 57 acres | 214 acres | 478 acres | 292 acres |
| 26-30 | 80 " | 244 " | ... | 218 " |
| 31-35 | 57 " | 31 " | 663 " | 47 " |
| 36-40 | 16 " | 81 " | 420 " | 76 " |
| 41-45 | 19 " | 22 " | 80 " | 21 " |
| 46-50 | 12 " | 40 " | ... | 36 " |
| 51-55 | 11 " | 82 " | 80 " | 78 " |

Table 24

INFLUENCE OF RELATIVE HUMIDITY UPON FOREST FIRE INCEPTION
CENTRAL NEW JERSEY, 1926

| Percent Relative Humidity (day period) | Number of Fires | Percent Relative Humidity (day period) | Number of Fires |
|---|---|---|---|
| 24 | 18 | 38 | 4 |
| 26 | 15 | 40 | 3 |
| 28 | 13 | 42 | 2 |
| 30 | 11 | 44 | 2 |
| 32 | 8 | 46 | 1 |
| 34 | 7 | 48 | 1 |
| 36 | 5 | 50 plus | 0 |

A table of relation between relative humidity and forest fire inception has been prepared from Central New Jersey's 1926 fires. Inasmuch as wind is such a factor in rate of spread, inception is believed to be influenced more by relative humidity than rate of spread.

It is interesting to note from the above data for western as well as eastern conditions that around [illegible] 55% relative humidity presents the point at which little or no inception occurs and relatively little spread when the wind velocities are low.

Under cloudless sky conditions and little movement in the large air masses, there is a 24-hour cycle through which relative humidity passes. The 24-hour daily cycle can be divided into four periods; two are transitional, one the day or low period, and another night or high period.

| period | segment of 24-hour day |
|---|---|
| 1. day (low) | noon - 4 p.m. |
| 2. night transition | 4 p.m. - midnight |
| 3. night (high) | midnight - 6 a.m. |
| 4. day transition | 6 a.m. - noon |

A similar situation is displayed on hygrograph charts located at the Priest River Experimental Forest in Northern Idaho. Although the periods shown on Figure 13d for the Idaho station do not coincide precisely with those for the New Jersey station, with the day period being longer and the night period shorter, this might be accounted for in part by the readings for the Idaho station being taken in August while those for the New Jersey station were taken in March and April when the days were shorter.

Relative humidity frequently does not follow its normal trend; its departures from the normal contribute toward "blow-ups". Unexpected changes in atmospheric conditions may be the cause, as was the case on April 19, 1928, the approximate peak of the fire season in the coastal plain area of New Jersey. On the above date the hourly average humidity for the day period was 43%, but at 5:30 p.m. it was 16% and did not rise above 30% until after 9:00 p.m. The low humidity, attended by 26 m.p.h. velocities resulted in an 11,000 acre fire created by abnormal weather conditions due to a small high pressure area suddenly forming over New Jersey.

Such low values as 5% relative humidity have been reported by Gisborne (50) for the Priest River Experimental Forest; this is an exceptionally low value. In general, fire weather in the West is accompanied by lower relative humidities than in the East; the duration of the low humidity periods are also more prolonged in the West. A relative humidity of 16% in the East seldom occurs and is considered to be especially low; these humidities, however, are frequent in western forests.

A rise in relative humidity is not indicative, by any means, of lessened hazard. It is the cumulative effect of atmospheric moisture conditions which actually determine the degree of fire danger. The ... fire of 1934 in Idaho made one of its most rapid runs when the relative humidity was 43%. This condition was attributed to the cumulative effect of a preceding extended period of low humidity which dried out the heavy fuels to the point of being highly inflammable; these heavy fuels both dry out and absorb atmospheric moisture very slowly.

CUMULATIVE RELATIVE HUMIDITY is a term which has been coined by the Intermountain Region of the United States Forest Service. It is a means whereby the deficiencies of atmospheric saturation, expressed in terms of relative humidity, are measured and recorded for an entire fire season as a means of gauging the degree of fire danger which currently exists. As explained later in the discussion under the heading "Fire Danger Rating", it is a term which has been coined to show the application of relative humidity in anticipating and gauging current forest fire hazard.

ABSOLUTE HUMIDITY, or the weight of aqueous vapor, is influenced by the air temperature and the degree of saturation of a given unit of air; the unit commonly used is a cubic foot. The absolute humidity is expressed in terms of the weight in grains of aqueous vapor in a cubic foot. At an air temperature of 70 degrees Fahrenheit and a relative humidity of 30%, the weight of the aqueous vapor is 3.990 grains; with the same temperature and a relative humidity of 70%, the weight is 5.586 grains.

Aqueous vapor's presence is also expressed in the inches of pressure which its expansive force exerts on a column of mercury. For example, in the Psychometric Tables (78a) prepared by the Weather Bureau, at 100% relative humidity and 80 degrees Fahrenheit, the vapor pressure is 1.022 inches.

DEPRESSION OF THE DEW POINT is an indication of the moisture saturation deficit of the atmosphere and is probably a more reliable index of atmospheric dryness than relative humidity because it includes a consideration of temperature's influence upon the atmosphere's capacity to contain aqueous vapor. It has been recognized that with an air temperature of 80 degrees Fahrenheit and a relative humidity of 20%, the fire danger is greater than when the air temperature is 50 degrees Fahrenheit with the same relative humidity of 20%.

Dew point is defined by Moore (79, p.19) as ". . .the temperature of saturation." It is the temperature at which water vapor condenses. Although the dew point probably produces results of greater precision, its practical application is limited because of the care necessary to obtain the dew point depression as compared with obtaining relative humidity readings.

Wind Movement

Wind movement has two aspects--direction and velocity. It is dominated by the mass movements of air which are shown on the daily weather maps by the arrangement of the isobars. The movement of air masses across the country produces wind direction and velocity.

Wind velocity is important in forest fire control from the standpoint of rate of spread; the more rapidly the wind blows, the greater will be the rate of spread because more quantities of oxygen, necessary for combustion, are supplied to the fuels in a given period of time.

Table XX shows the relation of wind velocity to size of fires; it shows that, with a given relative humidity, the greater the wind velocity the greater the acreage burned.

An analysis of fire inception and wind velocities for New Jersey indicated that there was a correlation with inception. It is quite probable that for a specific area with given conditions of fuels, type of detection system, and atmospheric conditions other than wind, and man-caused fires only, approximately the ... risk exists each day; with the fuels in hazardous condition, many fires may start. On windy days ... fuels may not be in a very dry condition, but may be ... and ignite ... heavier fuels, which fanned by high wind, may create ... a "head". Under ... conditions but with less wind movement, the heavier fuels ... ignited and the lighter ... probably be so moist that fire could not continue to burn ... that they would never ... sufficient size to be detected by a lookout.

[illegible] direction is important as an [illegible] of probability of fire weather occurrence. [illegible] [illegible], [illegible] (3[illegible]) found [illegible] when winds blow from the northerly [illegible] [illegible] is considerable [illegible].

[illegible] in Table [illegible] New Jersey fires, fire weather was most [illegible] the westerly quadrant.

[illegible] for [illegible] Adirondacks, there [illegible] a correlation [illegible] fuel dryness as represented by surface duff. [illegible] the greatest drying influence while wind [illegible] and [illegible] least; this coincides with the correlation [illegible] for wind direction and fires in New Jersey.

[illegible] constitutes dangerous forest conditions [illegible] regions. The Adirondacks and New Jersey are generally [illegible] by the same air masses. The air masses which have an in[illegible] on fire danger in California and Florida, however, are not [illegible] because the movement of the masses dominating Florida are [illegible] from those which at any time were over California.

**Table 24a**

[illegible]
IN NEW JERSEY, [illegible]

| Prevailing Wind Direction 2:00 P.M. | [illegible] Fire Days | [illegible] |
|---|---|---|
| North. . . . . | 13 | 7 |
| Northeast. . . | 11 | 6 |
| East . . . . . | 1 | 0.5 |
| Southeast. . . | 1[illegible] | 9 |
| South. . . . . | 1[illegible] | [illegible] |
| Southwest. . . | 30 | 15 |
| West . . . . . | 42 | 22 |
| Northwest. . . | 63 | 32 |

### Evaporation

Evaporation is not an element of weather; it is the result of the combined effect of wind movement, air temperature, atmospheric moisture and solar radiation. Munns (47) has advanced the idea that rate of evaporation is the best index of anticipating the trend in fuel dryness. There may be distinct limitations in the use of evaporation as a measure of fire weather due to the use of several of the elements which constitute evaporation; also the rate of evaporation does not always give sufficient significant indications of wind movement insofar as it affects rate of spread.

One reason that several investigators have been inclined to discount the real value of rate of evaporation is because of the nature of the instruments used to determine it. In his work for the Adirondacks, Stickel (72) found the rate of evaporation to be a very satisfactory gauge for getting the trend of the atmospheric drying influences. There was a very close correlation between evaporation rate [illegible] moisture content of the duff. Stickel paired evaporation rate per hour, duff temperature, hours since last measurable rainfall, air temperature, depression of the dew point, and relative humidity with duff moisture content to ascertain which of these items gave the highest correlation. It was found that the degree of correlation occurred in the above order, with evaporation per hour highest and relative humidity lowest.

It is quite possible that the atmometer has not yet been fully exploited as an indicator of trend in the drying capacity of the forest fuels. The manner of obtaining accurate results from a porous cup atmometer, however, requires careful handling, so it is distinctly limited for general field use.

### Temperature

Air temperature is reflected by relative humidity in that the higher the air temperature, the greater capacity it has for moisture content or deficiency. High temperatures, moreover, are conducive to increased molecular activity which hastens the passage of moisture from the fuels to surrounding dry air and is therefore an extremely important influence on the rate of evaporation.

High temperatures occur with dangerous fire weather. This condition is particularly applicable in areas where the atmosphere becomes heated to high temperatures due to stagnant atmospheric conditions. In calm, hot weather, strong convection currents are readily set up by a fire. In the Northwest, the hot, dry winds striking the Idaho and Montana forests from the desert and plains areas to the east and west often create enormous hazard. Similarly the hot, dry winds from the Great Plains cause "blow-ups" in the Lake States.

High temperatures alone are contributory to hazard increase, but they are also generally accompanied by very dry atmosphere in some forest regions. Because of this complex situation, high temperatures must be viewed with alarm locally. Gray (62) has established a correlation of losses, expressed in terms of dollar damage plus suppression costs, with mean annual temperatures. It is somewhat questionable, how-

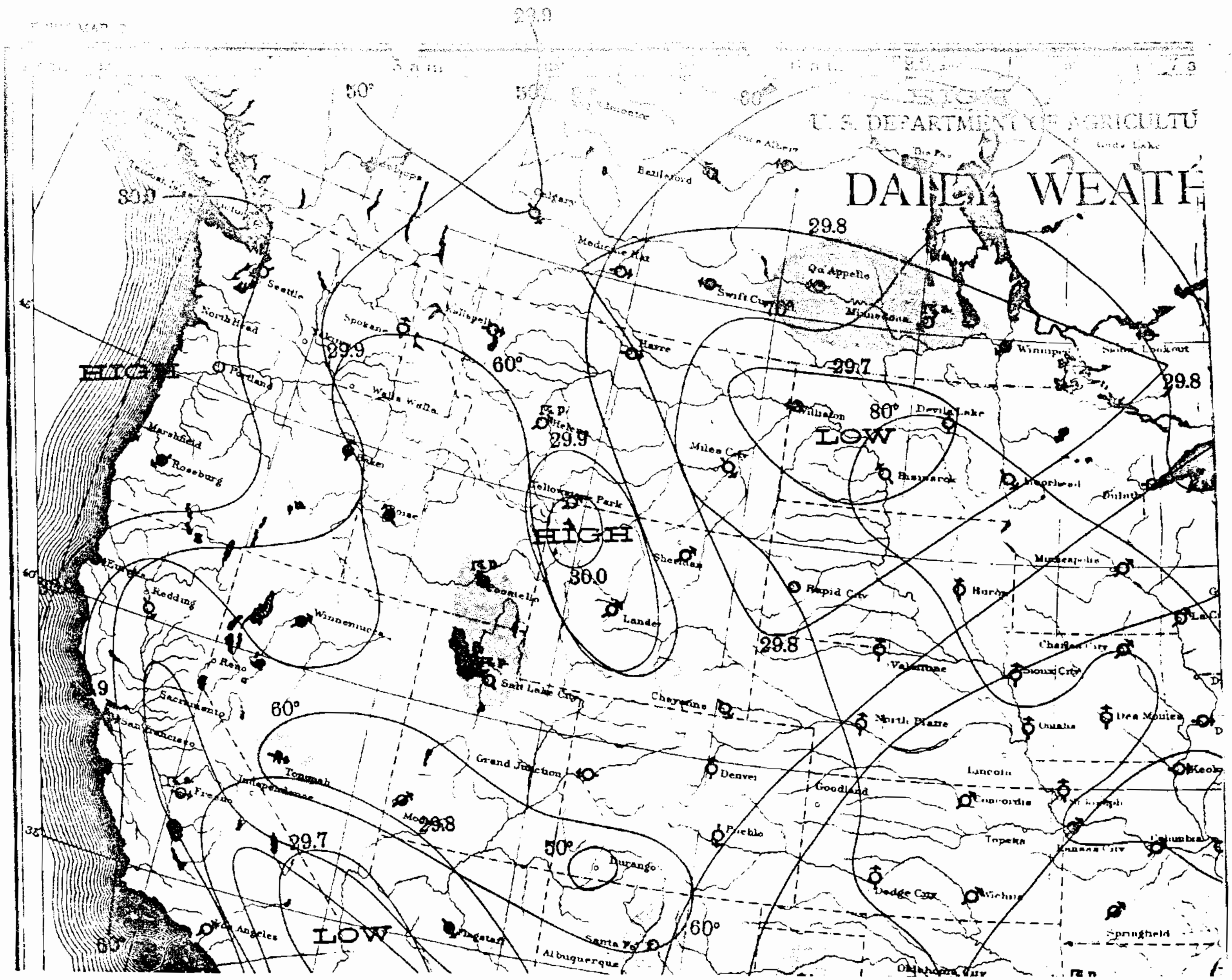



Figure 13e

SECTION OF WEATHER MAP OF JULY 7, 1936

Weather Conditions Which Produced Numerous Lightning Storms in the Northern Rockies [illegible] whether this correlation has value from a practicable fire control standpoint in which the [illegible] is interested in current and cumulative changes from the standpoint of anticipation rather than for the purpose of weighting the [illegible] severity of the season.

A discussion of temperature is hardly complete without some reference to solar radiation. "Temperature", [illegible], refers to air temperature in the shade at a point 4½ feet above the [illegible]. It is commonly assumed that air temperature only as just described is applicable to fire [illegible], but such is not the case because forest fire control is concerned with fuels [illegible], especially in "[illegible]" areas, are exposed to the influences of solar radiation [illegible] rays of the sun strike the fuels directly and have a much greater influence in drying them [illegible] if the heat activating the molecular activity was obtained indirectly from the air which is heated by [illegible] solar radiation as well as by direct sun rays. Gast and Stickel (58) have shown that solar radiation is an important factor in fire danger. The greater the amount of solar radiation, as measured [illegible] thermopile, coming in direct contact with the duff, the lower the moisture content of the fuel.

### Barometric Pressure

To use barometric pressure singly as a meteorological factor for determining fire danger is meaningless because it is merely an index of the atmospheric pressure of the air mass which effects a given locality.

Barometric pressure, in terms of sea-level pressure, is the basis for the construction of the isobars which show the location of the air masses over the United States, indicated by high pressure and low pressure areas on the weather map. A "high" is an air mass rotating in clockwise direction, generally accompanied by fair weather and low humidities. A "low" rotates in a counter-clockwise direction; it is generally accompanied by cloudy weather and frequently by precipitation. The range in pressure extends from approximately 29.70 to 30.30 inches for normal weather.

The frequency of the isobars determines wind velocities; when there are numerous isobars per unit area of region covered, (steep pressure gradient), there are high winds; when the gradient is relatively flat, the velocity of the winds is low.

A weather map as drawn daily, and sometimes twice each day, in the Weather Bureau offices, is based on barometric pressure which indicates the locations of the pressure areas which are dominating the United States and adjacent regions at a given time. These maps, together with temperatures of the upper air mass and wind direction, form the basis for the probable movement of the air mass and the effect it will have on all these meteorological elements which constitute weather. These maps make it possible to prognosticate the various elements which constitute weather.

Investigative work in weather and forest fires by foresters and meteorologists has been almost entirely confined to the effect of the several factors on forest fires; little has been done to forecast these factors. The meteorologists which have been stationed at San Francisco, California and Missoula, Montana for forecasting fire weather confine their forecasts to very short periods. They are handicapped moreover, because of occasional lack of signals from the Pacific Ocean and Canada whereby their maps are deficient in desirable data; also the rough topography of the West sets up so many local influences that regional forecasts are of relatively little value. One of their outstanding contributions, however, has been the forecasting of lightning storms which so frequently cause forest fires.

## OTHER FACTORS

### Altitude, Aspect, and Slope

The elevation and the direction the site faces (aspect) have an important bearing on degree of fire danger inasmuch as both factors influence the atmospheric conditions which determine moisture content of the lighter fuels.

Hayes, of the Priest River Experimental Forest found that the minimum temperature varied considerably on the basis of the altitude, with as much of a difference of 20 degrees Fahrenheit between 2300 and 5100 feet elevation. The same investigation showed that the midpoint on the slope, around 3800 feet, was drier than the 2700 foot and the 5500 foot stations. The half-inch wood cylinders for a week showed that at [illegible]00 feet the range was 8-14%; at 3800 feet, 6-9%; and at 5500 feet, 9-11%. Duff moisture also went lower during the day at the mid-point station, and did not rise as much at night as was the case for the lower and upper stations.

Vegetational conditions have long indicated that south slopes are chronically drier than north slopes because they are more exposed to the effects of solar radiation. Fuels dry out at a more rapid rate on slopes with southern aspects than on any other. There is also the factor to be considered, however, that the dry slopes support relatively little vegetation which eventually form the fuels, so dense fuels which produce a high hazard are seldom found on the southern aspects.

## Forest Cover

As an ecologist, Toumey (19) realized the effect that the forest cover has on weather factors under the canopy; it produces lower temperatures, higher humidities, and lessened wind movement. Jameson (57) investigated the various effects which (a) an open site (the result of clear-cutting or burning), (b) a half-cut area, and (c) a full-timbered area had on several weather factors.

**Table 25**

EFFECT OF FOREST COVER IN THE WESTERN PINE REGION

| Factor | Mean Readings | | |
|---|---|---|---|
| | Full Timbered | Half Cut Area | Clear Cut Area |
| Maximum air temperature. . . . | 79.3°F. | 81.7°F. | 84.1°F. |
| Maximum air surface duff temp. | 77.0°F. | 91.0°F. | 126.[illegible]°F. |
| Relative humidity, 4:30 P.M. . | 35.8°F. | 29.0°F. | 27.3°F. |
| Wind movement, 24 hours. . . . | 3.8 mi. | 18.8 mi. | 32.[illegible] mi. |
| Evaporation rate . . . . . . . . | 40.0 gms. | 77.0 gms. | 163.0 gms. |
| Duff moisture. . . . . . . . . . | 18.8% | 9.[illegible]% | 6.4% |

As indicated in the data in Table 25, the effect of the forest cover on weather factors, which in turn influence the moisture content of the fuels, is determined to a large extent by the density of the forest cover.

It is highly desirable to have some sort of ground cover, even though it may not be forest growth, in order to reduce the fire danger. Gast and Stickel (58) have shown that the amount of solar radiation influences the moisture content of the duff; the greater the radiation, the less the moisture content, provided the radiation is able to hit the duff directly. The more interception there is given to solar radiation by tree, shrub, or grassy growth, the less exposed will fuels be to dessicating influences.

## Height of Ground Water Table

The net effect of precipitation on the degree of forest fire danger is shown by the height of the ground water table. A considerable amount of investigative work has been conducted by foresters and meteorologists concerning the effect of atmospheric factors, particularly moisture, on the dryness of fuels, but relatively little has been done to establish a useable significant correlation between soil moisture and fuel moisture content.

In a rather general way, Thompson (52) points out that there is a correlation between the height of the ground water table and forest fire inception. The height of the ground water table is roughly the net effect of the balance between precipitation and the rate of evaporation. The height of the ground water table, as an indicator of the dryness of the fuels, combined with close observance of relative humidity as the indicator of danger between periods of precipitation, has possibilities which might be exploited to good advantage.

The indications of fire danger, as produced by the height of the ground water table, and stream-flow as shown by Gisborne (50) have little difference. Whether stream-flow or height of ground water table are used is determined largely on whether the region is located in rugged mountain or hill country or whether in a coastal plain area.

## Relative Importance of the Individual Factors

In the elaborate studies conducted by Stickel (78), he concluded that the evaporation rate per hour is the best single index of current atmospheric factors having an influence on fire danger. His statistical analyses of the correlation between the moisture content of the duff and the several meteorological factors such as evaporation rate, duff temperature, hours since last measurable rainfall, air temperature, depression of the dew point, and relative humidity showed that the first-mentioned had the highest correlation index and the last-mentioned had the least.

## Instrumental Devices for Measuring Some Meteorological Factors

a) RELATIVE HUMIDITY is measured by psychrometers and hygrographs.

The psychrometric readings are obtained by the difference in readings of a dry bulb and wet bulb mercury thermometer simultaneously exposed to air movement in the shade. The application of the readings to the prepared psychrometric table indicates the relative degree of atmospheric saturation with water vapor. The commonly used instrument is the sling psychrometer; stationary psychrometers are also effective.

The hygrographs are employed where precise readings are not required and precision can be sacrificed to continuity of record. Foresters have been handicapped by not having hygrograph records available for forested areas and the Weather Bureau operates very few recording instruments. The hygrographs require continuous checking with a psychrometer. For readings between 20% and 80%, the hygrographs are reasonably accurate.

b) WIND MOVEMENT is made up of direction and velocity.

Direction is indicated by vanes which point toward the azimuth from which the wind is blowing. A south wind, for example, means that the wind is blowing <u>from</u> the south <u>to</u> the north. Various electric devices have been constructed for continuously recording wind direction.

Wind velocity is measured by various types of anemometers ranging from simple to multiple blade types and three and four cup Robinson types which are considered standard by the Weather Bureau. Anemometers may record current or cumulative wind velocities. Average wind velocity for a 24-hour period means the total wind movement, which might have been 72 miles, divided by 24 hours, which would result in 3 miles per hour average. Most of the 72 miles of movement, however, might have been accumulated in a few hours when the velocities attained might have been as high as 15 m.p.h. for short periods of time.

c) TEMPERATURE is obtained by means of mercury thermometers; they may be the standard type which records current temperatures or they may be arranged with constrictions so that they will record the maximum or minimum temperatures.

Thermographs have been devised and are used for recording temperatures; they produce a permanent record continuous for daily or weekly periods.

d) PRECIPITATION is measured by collecting rainfall in a funnel-shaped container which in turn leads the water to an inner container which is used for measurement purposes. A stick, which has been calibrated, is inserted into the inner container to measure the volume of rainfall in terms of inches per time unit.

e) EVAPORATION is measured by several methods, one of the most common being the black and white porous clay spheres exposed to the atmosphere. The exposure of the spheres permits all the factors affecting evaporation to influence the loss of moisture from the containers.

# PART II

## PROCEDURE FOR THE REDUCTION OF THE NUMBER OF FIRES, ANTICIPATION OF THEIR OCCURRENCE, AND CONTROL AFTER INCEPTION

## Chapter VI

## FOREST FIRE EDUCATION AND PREVENTION

### The Problem

The whole field of prevention and education is one which is recognized by the forestry profession as being important; this is particularly true for those forest regions where man-caused fires constitute more than one-half of the fires. To date, a national plan for preventing forest fires is still in the making. At the Spokane Fire Control Meeting of 1936, several fire control executives recognized the need for a better approach to the prevention aspect of fire control work. It may be that foresters, by virtue of the undergraduate training to which they are subjected, are not competent to adequately administer prevention.

Fire prevention is a never-ending task. Periodically there is a new generation to educate. If each oncoming generation is left ignorant, during its formative period, concerning fire prevention, it must obtain its education on this subject from the preceding generation which frequently is not qualified to do a good job. In some forest regions, a representative one being the Ozarks, annual woods burning has been an established custom for generations. Some of the native local residents have always regarded the administrative officers on the national forests in the Ozarks as interlopers; although their resentment today may be more passive than what it was ten years ago, that resentment is still there and the feeling is generally transmitted to the younger generation. This state of mind can be changed only through patient, constructive educational work over a period of years. The fact that persistent and constructive efforts toward educating the local population of the Ozarks in the prevention of fires is producing good results is demonstrated below in Table 12. Even with an increase in gross area protected, the number of fires per unit area is steadily decreasing. In 1935, with a precipitation similar to that which occurred twelve years previously, there were only one-third the number of fires.

**Table 12**

DATA ON MAN-CAUSED FIRES
OZARK NATIONAL FOREST

| Year | Gross Acreage Protected | Precipitation Departure From Normal | Number of Fires Per 100,000 Acres |
|---|---|---|---|
| 1923 | 530,000 | +11.5 | 14 |
| 1926 | 530,000 | + 0.9 | 21 |
| 1929 | 634,000 | - 2.2 | 19 |
| 1932 | 634,000 | + 2.8 | 21 |
| 1935 | 886,000 | + 8.7 | 13 |

### Education, the Solution to the Problem

Educational activity can be broadly divided into two principal groups--adult and juvenile. This division is a natural one because the methods best applicable to adults are generally not adapted to juveniles, and the reverse is just as true.

In a state organization, where a large area must be covered and thousands of people contacted under varying conditions, it is essential that educational activity be conducted with groups rather than individuals. Intensive contact work is possible only on and around a national forest, a state forest, and a cooperative protective unit of private landowners.

### Juvenile Education

All juvenile educational work is founded on the idea that the youthful mind is plastic and can be molded to new forms better than mature minds. For this reason many foresters who have done forest fire prevention work are rather generally agreed that per dollar expended, the results are greater when used in connection with juveniles.

Educational work in forestry is very much like educational work of any nature--the idea needs persistent, never-ending promotion. It is just as important that juveniles be taught an appreciation of the importance of natural resources as of the business of government. It is highly desirable for each generation to know about the effect of uncontrolled forest fires. For this reason, materials should be

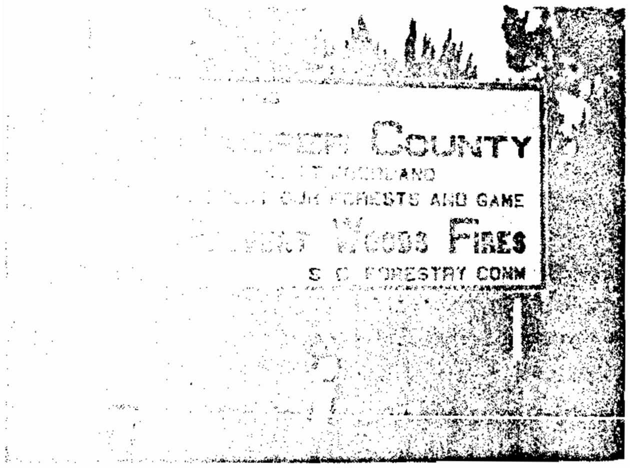



Figure 14

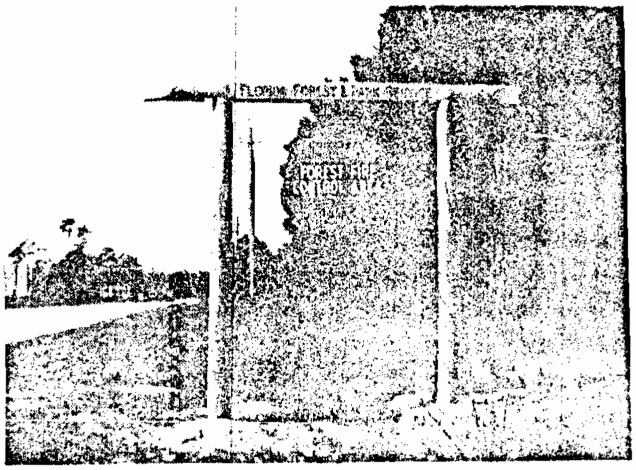


Photo by Florida Forest Service
Figure 15

Typical Roadside Signs Used By Forestry Organizations To Focus Public Attention To Forest Fire Prevention

[illegible] public school systems which will show the students that they, as part of the public, are [illegible] of the forest fires in the United States. When they become conscious of this fact, and [illegible] the rest of the public can stop forest fires, genuine progress will be made in prevent- [illegible] these same students will some day be the responsible leaders in their several communities. [illegible] of some forest fire prevention education, they can materially aid in the reduction of [illegible] especially where the practice of forestry is a part of the economic fabric of a region in the [illegible] utilization of wood products.

[illegible] relatively little energy expended by the forestry profession to educate the educators [illegible] necessity of the teaching of conservation during some period that the child is in school. A few state forestry organizations have made some progress in this direction, but their job is difficult [illegible] work is optional in the school curriculum and has taken hold in only a few localities. Too [illegible] educational phase has fallen back on the shoulders of the individual state forestry organi- [illegible] which are generally so poorly and inadequately financed that the educational projects are ex- [illegible] limited in scope. The basic difficulty is due to lack of agreement on the part of foresters as to [illegible] educational work is desirable. As a result, there is no national plan for educating the public in the prevention of forest fires.

There are two methods of approach to the educational work--the one is that fire prevention is the only [illegible] which should be included; the other is that in order to get interest in fire prevention, there must [illegible] of all be an incentive. The incentive can be provided by making the forest appealing, giving it a human interest. Once there is an interest aroused in the forest, there is antagonism developed toward agencies responsible for forest destruction, one of which is forest fires. The author subscribes to the latter theory and is of the opinion that by this procedure only will progress be made in forest fire prevention on an extensive scale.

## Extensive Juvenile Education

[illegible] in the United States is administered from the standpoint of state rather than national [illegible]. Consequently responsibility for extensive educational work becomes a state rather than a [illegible] problem. This fact probably accounts for the leadership which some state forestry organizations [illegible] in forestry educational work.

[illegible] States Forest Service (69) (70) (71) has cooperated with several states and private [illegible] publication of material for use in the public schools. Two of these publications were [illegible] fire prevention. A publication was also produced by the United States Forest Service [illegible] forestry educational work in which fire prevention played a minor role. Several states [illegible] specialized material which is broken up into subject-matter suitable for a limited age clubs. Sponsored by the Florida Forest Service for juvenile forestry education in Florida, Smith and MacGowan (73) prepared a bulletin for high school students, [illegible] (74) compiled a bulletin for [illegible] forestry in vocational [illegible], and Thomas (75) wrote a [illegible] for elementary school use, all of these publications stressed the need for forest fire prevention. The American Tree Association (76) has for several years made available to forestry agencies subject-matter fairly suitable for educational work.

Table 13

EDUCATIONAL AND PREVENTION CONTACTS

A - GROUP CONTACT CLASSIFICATION

| Subject | Group | Specific Organization |
|---|---|---|
| Juvenile | Clubs | Vocational Agriculture<br>4-H Clubs<br>Boy Scouts |
| | Schools | Elementary school nature study classes<br>High school science classes<br>Colleges-<br>Agricultural education<br>Science teachers |
| Adult | Women's Clubs | Garden Clubs<br>Federation of Women's Clubs<br>Service Clubs |
| | Men's Clubs | Service and Social Clubs |
| | Trade Associations | |
| | Sportsmen | |

B - CONTACT METHODS

| Classification | Methods |
|---|---|
| a) Visual | Printed matter; news items, newspaper supplements, magazine articles<br>Movies; semi-educational as well as entertaining<br>Window displays<br>Portable exhibits |
| b) Sound | Talks, with or without slides<br>Radio |
| c) Projects | School forests, Boy Scout forests, individual demonstrations, timber protective associations |

The public school is logical approach to the young generation concerning fire prevention; persistent action in this direction will ultimately rid a region of old prejudices. Admittedly there is an extended period of time involved, but the results should be extremely positive and lasting.

Mass contact with groups of either juveniles or adults by the visual or sound methods is extremely temporary in its results. The director of the Southern Forestry Educational Project expressed the belief that the work of his trucks equipped with motion picture outfits would soon be erased by time and that, unless a sustained follow-up of this initial work were done, the value of the impressions created by the truck would be zero. If these initial impressions are sustained by group projects, the effect will be positive for a period, or maybe even permanently, dependent upon the subject.

### Intensive or Project Method Education

The teaching of a subject is most effective when the theory is supplemented by practice. The high school as well as the university student learns to apply principles of biology, chemistry, and physics in a laboratory. Because of its effectiveness, juvenile educational work in the prevention of fires should be done by the project method rather than by the visual or sound systems. If a juvenile be a part of some project and goes through certain motions and observes the responses, the impression gained through participation will be much more lasting than if he has been told the same thing.

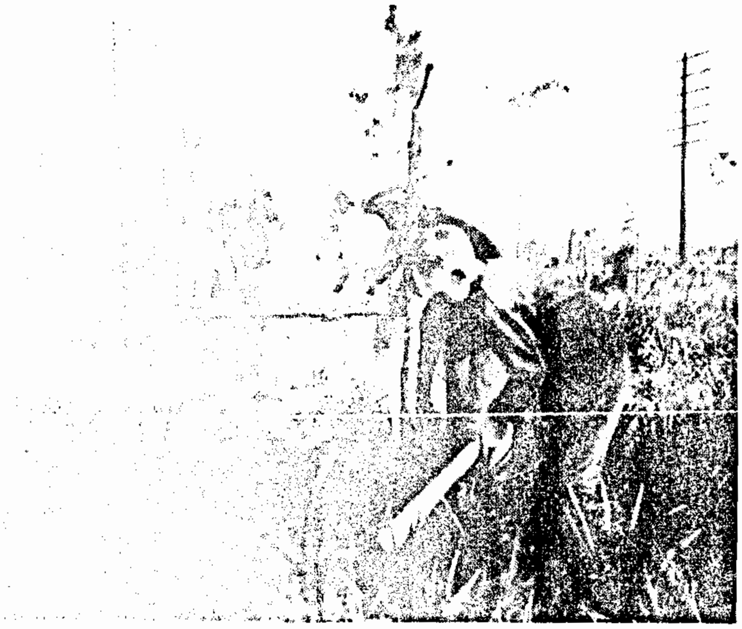
In contrast to the extensive juvenile method of education, the intensive educational job is concentrated among a few groups. This procedure can be carried on independently or supplemental to the extensive work. Actually it is the laboratory method of teaching the subject. The most fertile groups for work of this sort will vary with the individual regions. The projects discussed below, however, have national application inasmuch as both organizations are found throughout the United States.

### Vocational Agricultural Schools

One of the most successful contacts in juvenile forest fire prevention education is in vocational agricultural schools. The set-up is one which is conducive to good results for several reasons.

1. The teacher has a background of education and experience which makes him sympathetic to the purpose.

2. The students come from an agricultural community and can therefore understand some of the principles involved in the practice of forestry. The vocational work lags only when the project is used in



[illegible] Students Making A [illegible] Around a Demonstration Plot

a region where the crops are highly specialized or where the teacher, either through lack of background or inclination, neglects the work.

3. The students know that in the past the farm woodlot has been generally ignored or overlooked as a revenue-producer frequently because fire control has never been practiced.

4. They will have an opportunity to apply the information they receive.

### Boy Scouts

The work with this particular group generally supplements the activity discussed just above. Scouting thrives in urban areas, while vocation agricultural teaching is carried on in rural communities where scouting seldom takes root. It is just as essential that the town boy know something of the cause and effect of fire as the rural resident, possibly more so because he has less opportunity to rub up against actualities and see for himself such as the country boy.

[illegible] of a forestry project in a Scout Troop is usually welcomed by the Scoutmaster. [illegible] boys who are at an age when outdoors life is glamorous and when they are eager [illegible]

[illegible] of most educational activites, unless the enthusiasm and cooperation of the Scoutmaster [illegible], the forestry, or fire protection project amounts to little or nothing. The [illegible] essentially be built around some fire prevention idea. One state insists that a part of [illegible] maintenance of two adjoining plots, burning the one annually and keeping the other [illegible] cause and effect; also that a firebreak be constructed round the property to exclude fire.

### Adult Education

From the standpoint of forest fire prevention, extensive adult education has been of negligible value. [illegible] are usually an insult to the intelligent man and fail to register with the ignorant. [illegible] woods burners are ever converted by this method; they require individual attention.

[illegible] education is confined largely to individuals, it resolves itself into a job [illegible] areas on which it is desirable to control fires, such as national forests, state [illegible], private forest land on which forestry is practiced, national parks, and such state and municipal [illegible] woodland.

[illegible] responsible for the administration of these areas have a reasonably accurate conception of [illegible] their man-caused fires. On public, as well as private land, causes can be isolated and [illegible] there will gradually be a decrease in number. Prevention action can also be taken whereby [illegible]; this procedure is described in greater detail elsewhere.

## PUBLIC AGENCIES CONCERNED WITH EDUCATION AND PREVENTION

### A. The United States Forest Service

1. As a Land Manager

[illegible] of manager of approximately 180,000,000 acres of forest land, the United States [illegible] its Branch of National Forests, comes into direct contact with the prevention of [illegible] fires on the numerous Ranger Districts scattered throughout the United States.

[illegible] new property, the educational front has been extended [illegible] administration [illegible] forests is amply supported by regulations. It has never [illegible] activities of the natives without giving them [illegible] to administer the property. This all requires educational [illegible] personnel. In the great majority of instances, the native population, although frequently antagonistic or passive to the program, gradually has its antipathies reduced if dealt with sympathetically.

On a ranger district, which is the administrative unit on a national forest, personal contacts form the most desirable type of means of reducing risks. Since man-caused fires are a common type of risk, and since man-caused fires can be reduced in number, if not eliminated, the drive to reduce this type of risk can be made very intensive on a ranger district. The technique of the risk education program will have to be adapted to the nature of risk and personality of the ranger.

The usual "boiler-plate" material such as leaflets and folders, news releases, exhibits, lectures, signs and posters can all be pressed into service in educational work on a ranger district, but for reducing the risk caused by local inhabitants and frequent users of the forest, personal contacts can hardly be surpassed.

A prevention practice utilized by several of the western regions is the enforcement of a regulation which compels all users of the forest to carry with tham an axe, bucket, and a shovel of certain minimum specifications, when they enter the forest during the critical period of the fire season.

The frequent and conspicuous posting of signs relative to the prevention of fire is one of the oldest methods of the Service in its effort to educate the public.

"Showboats", or portable talking motion picture outfits mounted on light trucks rotate over several forests within a region or part of a region, on and just around national forests, showing movies of a semi-entertaining nature regarding forest fire prevention.

For intensive educational work, however, personal contact will retain first rank for effectiveness. A means of preventing fires which has been used effectively, although not frequently, is the court sentence. Although law enforcement is discussed under a separate heading, it nevertheless must be regarded as a part of the prevention activity.

### The Coeur D'Alene Prevention Project

On the Coeur D'Alene National Forest in the Northern Rocky Mountain Region, a prevention drive was commenced during the fire season of 1936. Six men were assigned to the job on the national forest which has a gross area of approximately 800,000 acres.

The duties assigned to the men consisted of contacting residents and general users of the forest relative to the extreme fire hazard which exists at certain periods and urge their cooperation in preventing fires; to assist residents to burn brush; to advise brush burners concerning good and poor technique for burning; to inform prospective brush burners relative to the state law covering the subject; to issue burning permits; to cooperate with forest gatemen in contacting forest users who are ignorant of or careless with fire; to instruct campers in good campfire building technique; to see that the regulation relative to smoking only in designated places is observed; and in general to take every means of reducing the number of man-caused fires even to chasing down of supicious smokes reported by lookouts.

The results of the first year's efforts on this project are shown in Table 14.

That the prevention activity produced the desired results is evidenced by the right-hand column in the table of data. The results produced by the project in the 1936 fire season were somewhat beclouded by the unusual extension of the fire season into November, a month in which fires seldom occur. For the period 1931-1935, no fires had been reported for November. In 1936, however, due to a prolonged, dry autumn, thirteen of the thirty man-caused fires were reported. The special prevention forces had been withdrawn September 1, so it would be unfair to include the thirteen November fires in weighing the results of the prevention work. The number of man-caused fires in 1936 was 59% less than the previous five-

TABLE 14 (Revised)

[illegible] NATIONAL FOREST

| [illegible] | [illegible] | Man-Caused: [illegible] of Total | Man-Caused |
|---|---|---|---|
| [illegible] | [illegible] | [illegible] | [illegible]% (five year average) |
| [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | |
| [illegible] | [illegible] | [illegible] | [illegible]% (two year average) |
| [illegible] | [illegible] | [illegible] | |

[illegible] for November fires.

year average, if the November fires are excluded. That the exclusion of the November fires is justifiable for arriving at a true estimate of the worth of the project is shown by the record for the 1937 fire season when the special prevention forces operated on a basis similar to that used in 1936. Man-caused fires were responsible for only 24% of the total number in 1937. This percentage compares favorably with the 23% man-caused fires of the year previous, but making allowance for the unusual November fires.

[illegible] fires are due to a combination of lightning and man, reduction in number of fires is applicable [illegible] latter type inasmuch as the occurrence of lightning fires is uncontrollable. Through the re[illegible] number of man-caused fires, the organization is better prepared to handle lightning fires, [illegible] years 1934, 1935, 1936 average higher than the previous three years of 1931, 1932, 1933. In [illegible] more lightning fires than for any single year of the six-year period. Without a reduc[illegible] fires, it is possible that the suppression organization would have to be enlarged to [illegible] increasing load due to lightning-caused fires

2. As an Aid to Private and State Forestry Organizations

[illegible] Federal Forest Service there is a division known as the Branch of State and Private Coopera[illegible] known as the Branch of Public Relations. Its activities include the administration of the [illegible] Act, the Conservation Code, or remnants of it as included in the National Recovery Act, and [illegible]. This last activity was set up as belonging to this Branch in anticipation of the passage [illegible] Bill.

[illegible] outstanding performances of this Branch has been the fostering of state forestry depart[illegible] the country; several state organizations were able to come into existence only because [illegible] were available for cooperation between the private owner and the federal government for forest fire protection purposes.

Clarke-McNary Law

[illegible] active cooperation of the United States Forest Service with the states is possible because of the Clarke-McNary Law. This law was enacted June, 1924. It specifically authorized the Forest Service to cooperate with private individuals through the proper state official, in the dissemination of the sub[illegible] for forest fire protection.

The Clarke-McNary Act set up the cornerstone for a triumviate whose objective was forest fire pro[illegible] on private lands; the triumviate consisted of the United States Forest Service, the several state forest services, and the forest land owning individuals who wished to protect their forest lands against fire.

[illegible] viewed from one aspect, the whole expenditure was in the nature of an educational program. It assumed that if one private owner successfully demonstrated that forest fire protection is practicable, his neighbor would ultimately pursue the same course. It also presumed that private owners could afford to practice forestry.

The manner in which Section 2 of the Clarke-McNary fund operates is designed to make it desirable for private landowners, who are interested in maintaining their lands in productive condition, to practice fire control. The Federal Government deals with the private forest landowners through a state agency, rather than directly. It means, moreover, that the states which wish to be eligible for the subsidy, make [illegible] funds also.

[illegible] Clarke-McNary Law specifies that the amount of Federal funds made available for forest protection [illegible] state should not be in excess of that expended for like purposes by the state and private [illegible]. The United States Forest Service has, moreover, adopted the ruling that funds expended [illegible] and presuppression purposes only be recognized as being eligible for reimbursement by the [illegible]. Suppression costs are to receive little or no weight inasmuch as expenditures of this [illegible] toward lowering the risk.

### 3. Stimulation of State Organizations

The Federal Forest Service has unquestionably stimulated forest fire protection on private lands in the South, one of the regions where control has been badly needed. As indicated in Table [illegible] this region has the greatest number of fires per million acres of protected forest land. With Federal [illegible] the southern states received considerable impetus in their attempt to control fires on private land.

The United States Forest Service recognized that one of the best ways to aid in the control of forest fires on private land in the South would be through capable state forestry organizations. With this point in mind, the Branch of Public Relations of the Service must be credited for several of the progressive state forestry departments which today exist in the South. To cite a case in point, in 1925 the Branch of Public Relations sent an assistant district inspector into one of the southern states to crystallize forest fire protection sentiment. The inspector persuaded the state to set up a forestry department. In 1927 this inspector was appointed state forester for the state to which he sold the program. This is one instance where, through the leadership of the Federal government, a state adopted a forestry program and commenced its execution.

## B. THE STATE ORGANIZATIONS

In those state forestry organizations which administer little or no forest land owned by the state, the agency functions chiefly in an educational, preventive, and punitive or law-enforcement capacity. There are a few instances where the state forestry department has been charged with the responsibility of directly controlling fires throughout the state. In 1936 those states in which statewide control occurred were Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Pennsylvania, Delaware, Maryland, Michigan, Wisconsin, Minnesota, Washington, Oregon, and California. In these states, the educational and prevention activity have been dwarfed due to the large administrative job involved in the direct control of fires. The administrative job is sometimes so large that the true perspective is distorted whereby educational and preventive efforts are minimized. There are several states which do excellent sustained educational and prevention work, in spite of their large administrative control responsibilities.

In those states where statewide control does not take place, educational work receives considerable attention, and although leadership is shown in enabling private landowners to control their fires, these organizations recognize that lasting progress in the job of fire control can be accomplished only in good educational and prevention work.

## C. PRIVATE EDUCATIONAL EFFORTS

### The Southern Forestry Educational Project

An educational project which attracted considerable attention because of its geographic magnitude and attendant publicity was generally known as "The Southern Forestry Educational Project" sponsored by the American Forestry Association.

The project was proposed to the Board of Directors of the Association early in 1925 by Ovid Butler, the executive secretary of the Association. The final report (35) of the project stated that the purpose was to demonstrate the value of localized education as a means of permanently safeguarding natural resources of great economic and social importance. The sum proposed for expenditure was $150,000 over a three-year period, a part of which was to be contributed by the several states in the Deep South in which the project was to be conducted.

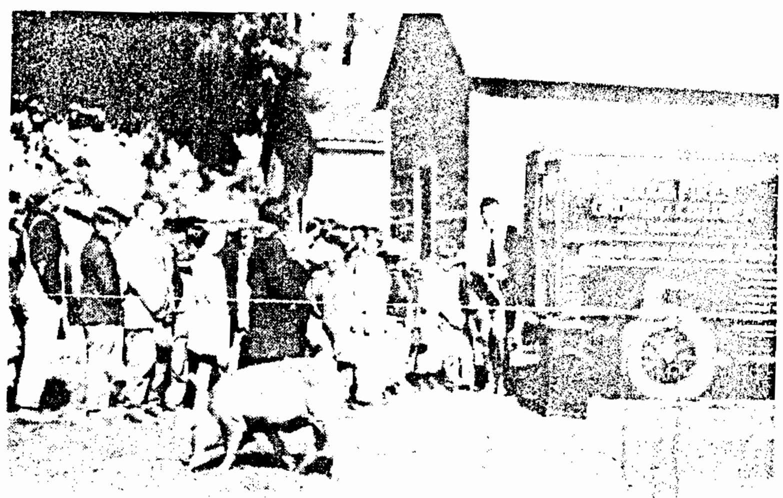


Photo by American Forestry Association

Figure 17

Southern Forestry Educational Project Motion Picture Truck Getting Ready For A Set-up At A Rural School

It was proposed to concentrate efforts in the states of Georgia, Florida and Mississippi. Visual [illegible] and personal contact methods were to be followed because it was well known that the inhabitants of [illegible] woods are not readers. It was also assumed that forest fire control would be followed by [illegible] to renew a rapidly dwindling natural resource, and thus finally contribute toward [illegible] economic stability in local political units and raising the standard of living conditions.

[illegible] the work actually got underway through the field direction of W. C. McCormick. The [illegible] contact used were: (1) traveling motor trucks as mobile propaganda units, (2) educational [illegible] at fairs and other public gatherings, (3) enlistment of local cooperation thru rural [illegible]

Incidental to the technique outlined above, newspapers were provided with items whenever a truck was [illegible] in that particular locality; essay contests on the effect of forest fires were put on in many [illegible] and prizes awarded to the winner; a special Pullman car was made available by the Georgia and [illegible] Railroad for operation in Georgia during one summer, and cooperative pledges for fire prevention [illegible] from adult attendants in the audiences.

[illegible] leaflet "Woods Fires, Everyman's Enemy," prepared especially for the project, was dis[illegible] wherever the trucks operated. Rulers bearing slogans on fire prevention were given to the pupils [illegible] where the pictures were shown, and posters were scattered broadside.

[illegible] motion pictures, however, were the big drawing card because many of the mountain and coastal [illegible] had never had an opportunity to see a movie. At first, United States Department of [illegible] educational pictures only were used; these portrayed plenty of moralizing, little action, and [illegible] humor. This type of purely educational film had little positive value from a fire preven[illegible]

[illegible] felt that the pictures shown lacked sufficient local color and plot to appeal as they should, so '[illegible]' was produced. To provide more comedy, "Danny Boone" was filmed; it stressed the game con[illegible] phase of forest fires. Toward the end of the project, "Burnin' Bill" was produced; this [illegible] and was never as well received as "Pardners." From the standpoint of having local color, [illegible], some humor, and educational features, "Pardners" was excellent. All three of the above [illegible] pictures were produced by the Project in the South, and doubtless contributed much to the success [illegible]

[illegible]

[illegible] much doubt, the Southern Forestry Educational Project stimulated a considerable interest in [illegible] fire protection in the states contacted; this resulted in a strengthening of the state forestry [illegible] so that they became more effective.

It is difficult to judge the value of educational effort because it can seldom be measured in direct [illegible]. The expenditure of funds in a region, however, where there is no local organization to follow up the [illegible] educational work, is of little value. With an organization to follow up the original work, there is seldom any question as to its importance in arousing public cooperation.

**Cape Cod Forest Fire Prevention Experiment**

[illegible] the same time that the American Forestry Association was preparing for its Southern Forestry [illegible] Project, the Massachusetts Forestry Association proposed an experiment in forest fire educa[illegible] prevention which was concentrated in an area of approximately 100,000 acres.

[illegible] purpose of the experiment was to determine the value of public education and forest patrol in the [illegible] of forest fires.

[illegible] stated, the experiment proved that for 1/5 less money spent in total for prevention, pre[illegible], and suppression, with emphasis on prevention, the losses were reduced by 4/5. These figures [illegible] three-year period, the duration of the experiment.

[illegible] experiment was designed to determine the value of greater emphasis on the prevention and [illegible] aspects of fire control instead of weighing the suppression factor so heavily as had been done formerly. The principle involved was the application of the old adage of locking the stable before the horse was stolen.

The agencies cooperating were the Massachusetts Forestry Association, Massachusetts Division of Forestry, and the Federal Forest Service.

An area of 1[illegible],000 acres was selected on Cape Cod where some of the worst fire conditions in the East are encountered. Winds veer quickly, oak leaves carry fire in advance of the headfire, and the scrubby sprout growth of pitch pine crowns easily. Approximately 9 percent of the area burned over annually for the three years prior to the experiment.

The permanent population in the area was about 15,000, but during the summer months this increased to about 100,000 due to the influx of summer residents and tourists. Fortunately, however, the hazard is low, under normal weather, when this heavy increase of population occurs.

EXECUTION OF THE EXPERIMENT

The report of the project, issued by the Massachusetts Forestry Association (36) presented the highlights as listed below:

A forester with considerable experience in fires was employed to give talks locally on forestry and fire prevention, and to show movies to schools, clubs, fraternal, and other local organizations.

The agricultural extension service assisted by distributing pamphlets and leaflets.

The chief lecturer of the United States Forest Service spent a week in the area.

Old public and private roads were brushed out, dividing the area into blocks of approximately 160 acres each.

Two local residents were employed as Rangers. In the three-year period, they worked on 205 fires. They were on duty seven months of the year, had no regular route, but "interviewed the occupants of all cars parked by the roadside" and acted in a preventive as well as suppression capacity.

Each year of the experiment there was one large incendiary fire; these three fires constituted 73 percent of the total three-year burn. Naturally they burned on windy, dry days.

NUMBER OF FIRES

In one significant respect; the experiment did not produce the results expected because the number of fires rose from 219 for the preceding three-year period to 249 or an increase of 14 percent. It was felt, however, that the increase in number of fires was due to three factors: (a) a real estate boom which caused a heavy influx of people ignorant of forest fire hazards, (b) increased alertness of the wardens caused small fires to be picked up and worked on which probably would otherwise have died out naturally, and (c) delay in the first year in employment of wardens.

By applying funds and effort toward education and pre-suppression, 64 percent less money was spent and the fire losses were reduced by 92 percent.

CONCLUSIONS

1. Forest fire losses can be reduced when prevention and pre-suppression are recognized as being as important as suppression.
2. Patrolmen's services should be utilized only when the hazard demands it.
3. During periods of severe hazard, the number of patrolmen should be increased.
4. If prevention efforts are consistently followed, a reduction in number, size, cost and loss will result.

**Application**

The United States Forest Service has always realized the value of educational and pre-suppression activity; in Clarke-McNary subsidies for forest fire control, little recognition is given to suppression expenditures. The Forest Service has not been able to point to any outstanding specific case to demonstrate the application of its theory, but the Cape Cod Experiment proved that the theory is correct. Without consideration of the phase of prevention, where man-caused fires dominate, fire control activity should be judged from the standpoint of damage reduction; if the risk is not lowered, the periodic blow-ups will result in much greater losses than if the risks had been reduced in number.

## Chapter VII

## FOREST FIRE LAWS AND LAW ENFORCEMENT

When all the educational and prevention procedures described previously fail to adequately reduce the number of forest fires in a locality, the enforcement of laws relative to forest fires generally has the desired effect. There are some residents in almost every forest community who have respect for individuals or property only when they or their kind have felt the impact of legal procedure.

When legal procedure is used, care and good judgment must be used by the forest officer concerned to see that he has ample evidence to obtain a conviction beyond a reasonable doubt. Weak attempts to convict offenders are worse than no attempt at all. To bring an offender before a magistrate or court of justice without reasonably good evidence whereby the court is able to find the culprit guilty, even though the court may be fully in sympathy with the prosecution, will lower the esteem of the local population for the forestry organization which is pressing the case. Prosecution of a case demands as much effort in planning and executing the plan as a large "C size" fire.

Successful law enforcement demands an intelligent understanding of the local legal procedure. The United States Forest Service generally carries enough prestige, as a branch of the Federal Government, to avoid many of the lesser, although devious, devices frequently used to avoid convictions in the lesser courts found in each state. It is desirable for state forestry organizations to instruct local forest wardens in the job of good law enforcement and make available the assistance of a special forest officer to a forest warden whenever the latter has a case on hand which may not be as definite or desirable for [illegible]. Too often state organizations neglect to instruct their personnel sufficiently in [illegible]. The prestige of any law enforcement agency is enhanced whenever it obtains a conviction. Several well-handled law enforcement cases each year will frequently help more to build up prestige for the state forestry agency than any other single educational effort.

To obtain the respect of the public, however, there must be an absence of personal feeling on the part of the forest officer who initiates the case; it must be a prosecution and not a "persecution" to build up public good-will.

### Civil and Criminal Action

[illegible] states that civil action involves such matters as one person sustaining damage for which another person, or his employee is responsible. In civil process, only two parties, or sets of parties are affected; the public has nothing at stake.

Criminal action is the activity of an individual or a group of persons participating in some deed whereby some governmental branch is forced to recognize and attempt to subdue it inasmuch as it is injurious to the public at large. Any action which reacts to the serious disadvantage of the public becomes a [illegible].

An example of justification of civil action is illustrated below. A land owner is conducting a logging operation. The equipment includes a logging locomotive which sets fire to the woods where it is operating. Before the fire can be controlled, it burns several hundred acres of a stand of young second growth timber on an adjacent tract. There is no law which specifies that the locomotive has to be equipped in such a manner that sparks are not thrown out. The landowner who is doing the logging can be prosecuted under civil court procedure for damages sustained by the adjoining landowner because of the destruction of several hundred acres of his second growth timber. The logger, however, can not be arrested and jailed for the offense since there is no statute which brands him as a public enemy because his locomotive set fire to the woods.

This case would have been one for criminal action if there had been a statute in existence whereby the logger was supposed to equip his locomotive with a spark arrester. The law would have been enacted stating that locomotives without spark arresters are a public menace in that they frequently set fire to the woods and cause conflagrations, especially in periods when the fuels are unusually dry. In the case cited above the logger had not equipped his locomotive with a spark-arrester; the result was that the woods caught fire from sparks from the locomotive and burned several hundred acres in the vicinity. The fire might have burned the dwellings in a nearby village and rendered several families homeless had the fire not been controlled. Inasmuch as there was a statute on the books which made punishable such negligence as the lack of use of a spark-arrester, it becomes the duty of some public official to institute proceedings whereby the offender is prosecuted and subjected to a fine or jail sentence, or possibly both, dependent upon the penalty attached to the violation of the statute. In this instance, the state forester is the logical state officer to commence prosecution.

The fining and jailing of the offender, the result of criminal action, would not immunize him from prosecution by civil procedure in which the several landowners would attempt to collect damages for the loss sustained on their properties due to the fire. If the criminal action instituted resulted in a conviction, then there would be little difficulty in obtaining a favorable decision from the civil court because the conviction under the criminal court established guilt; by the civil procedure, guilt having already been established, the only requirement would be to determine the extent of the damage and the capacity of the defendant to meet the demands of the plaintiff, provided they were sustained by the court.

### Law Enforcement on Private and Public Lands

There are some individuals who are of the opinion that the sole, or at least the most important, function of state forestry organizations should be that of law enforcement; it is argued that with real enforcement of the laws pertaining to forest fires, there would be very few fires caused by man. Essentially such action would be of a negative nature. It is believed by a majority of those concerned with forest fire protection, that a state forestry department should include educational and pre-suppression work, and possibly suppression in its list of jobs. More will be accomplished in reducing the man-caused risk if a definite attempt is made to educate the public relative to the damaging effects of forest fires than to use law enforcement measures only. Law enforcement on a large scale, as a means of preventing fires, should be used when other measures have failed, or supplemental to them.

There is little doubt but that one of the important duties of a state forestry organization is the enforcement of laws pertaining to forest fires. In the current social pattern, law enforcement is conducted by specially constituted bodies or persons. A highway patrol, for instance, is concerned chiefly with the enforcement of laws applicable to highway traffic. The individual citizen has no authority to enforce laws. Owners of forest land have no more authority to enforce laws applicable to forest fires than they have to enforce laws pertaining to highway traffic. For this reason, state forestry organizations can be of invaluable assistance to owners of forest land in the prosecution of offenses which violate statutes relative to forest fires. The owner of 10,000 acres of forest land might be seriously troubled with incendiary fires, but he has no authority to make arrests. He can, however, solicit the help of the state forestry agency in prosecuting the offender. It is generally the obligation of the state forester to prosecute the case.

In most states, the state forester is specifically charged with the enforcement of statutes pertinent to forest fires. In Texas (157), the state forester "--shall enforce all laws pertaining to the protection of forest and woodlands, and prosecute any violation of such laws--." In North Carolina (158), "The state forester, as the state forest warden shall --- cause violations of the laws regarding forest fires to be prosecuted." There can be little doubt, from the above quotations which are characteristic of state laws which define the duties of a state forester, that the state forester and his organization are charged with the prosecutions of violations of laws affecting forest land. The private owner interested in protection from fire, can demand that the state forester prosecute violations of forest laws. Because of the responsibility with which state foresters are specifically charged, and because of the importance of successfully prosecuting glaring violations of forest laws, it would be advantageous to all state forestry organizations to have their personnel, or at least a part of their personnel, well instructed in law enforcement.

In the performance of the job of law enforcement, considerable judgment must be exercised in making decisions as to whether a case shall be prosecuted and whether, if a conviction is obtained, it may be advisable to recommend the suspension of the sentence. It must be recognized that there are instances where fires occur in which the person responsible for the fire is liable for criminal prosecution accord-

[illegible] the law, but there may be nothing about the case which indicates that the responsible party might [illegible] the fire deliberately and maliciously. An instance is shown in the case where a farmer burned [illegible] a field broadcast; he had taken reasonable precautions to prevent the fire from getting into the ad- [illegible], but, due to a sudden gust of wind, the flames jumped the fire-break at a narrow point. [illegible] finally controlled by the state forestry department. To prosecute the man for causing a [illegible] naturally irritate him inasmuch as he had taken reasonable precautions to confine the [illegible] field. Admittedly the precautions had not been ample, but his efforts had been sincere. In [illegible], a compromise is frequently affected whereby the responsible party agrees to pay the state [illegible] suppression. He generally is glad to have this compromise because the states' suppression [illegible] materially reduced the acreage burned on the adjoining tract of woodland, which lessened the [illegible] of an expensive civil suit for damages due to the destruction of the timber on the adjacent property.

Circumstances will determine whether it is advisable to compromise or to take vigorous action for a conviction. In regions or localities where there has never been fire control practiced, some of the [illegible] population are vigorously opposed to such procedure because they may have deliberately set fire to [illegible] which they had no control merely for the purpose of having better hunting or grazing for their [illegible]. For selfish reasons, they wish to prevent successful fire control, so organized incendiarism [illegible]. When incendiarism is conducted on an organized basis, it is extremely difficult to apprehend [illegible]. A landowner, as an individual, is powerless to cope adequately with the situation. It is [illegible] responsibility of the state fire control organization, in such an instance, to lend as much assistance [illegible] will permit toward the apprehension of the guilty party and when he or they are appre- [illegible] prosecute vigorously.

The enforcement of forest fire laws on private land is particularly difficult when the public is [illegible]. Criminal action frequently requires jury trial; if the public is not sympathetic with the [illegible], the jury, regardless of the evidence, will report "not guilty," making it necessary for the judge [illegible] the defendant.

[illegible] the policy of the United States Forest Service (130, 5-T) to settle civil cases amicably, but to prosecute the criminal cases. "Law enforcement in the sense of swift prosecution, must be the chief [illegible] overcoming criminal negligence as well as dealing with incendiarism."

## Misdemeanors and Felonies

[illegible] there should be some confusion in the minds of fire wardens charged with the prosecution of forest fire law violations as to what is a misdemeanor and a felony is not unusual, inasmuch as the legal profession in general does not make a clear distinction. It is important in enforcement work however, that a warden be able to identify each in order that his preparation of the case be guided accordingly.

[illegible] (159 -p. 1202) states, "--in the United States Criminal Code, paragraph 335, all offenses punishable by death or imprisonment for over one year are felonies; all other offenses are misdemeanors. [illegible] by statutes in many states, usually in affect that all offenses punishable either by death or [illegible] in the state prison shall be felonies." The term misdemeanors is used to express offenses [illegible] in punishment to felonies.

In North Carolina, for example, "A felony is a crime which is or may be punishable by either death or imprisonment in the State's prison. Any other crime is a misdemeanor. (Rev., s. 3291; 1891, c. 205, s.1) [illegible], C. 82, s. 4171.

"Every person who shall be convicted of any felony for which no specific punishment is prescribed by statute shall be imprisoned in the county jail or state prison not exceeding two years, or be fined, in the [illegible] of the court, or if the offense be infamous, the person offending shall be imprisoned in [illegible] or state prison not less than four months nor more than ten years, or be fined. [illegible]; Code, s. 1906; R. C., C. 34, s. 27) Code 1931, C. 82, s. 4172."

[illegible], since it is punishable by imprisonment with or without hard labor and therefore subject to [illegible]; 'felony' being high crime, for which imprisonment at hard labor or death may be [illegible] by jury, and appealable of right in view of Const. 1921, art.-7, para. 10, 4." (State vs. [illegible] La. 146, 147-8, 111 So. 6566, 1927)

Felonies are always tried in the higher courts of general jurisdiction, such as a state district court. Misdemeanors are tried in the lesser courts of limited jurisdiction, such as those presided over by a magistrate. Felonies generally involve trial by jury; misdemeanors have as the sole judge of the merits of the case, as well as power to mete out punishment, the presiding magistrate. In the prosecution of a person or persons accused of a felony, the local warden should be assisted in the preparation as well as prosecution of the case by someone qualified and experienced so that a strong case may be built against the offender and in event there is insufficient evidence for a probably conviction, drop the case so that the prestige of the organization will not be lowered.

With adequate instruction, there is no reason why the local wardens should not personally prosecute all violations which fall within the misdemeanor class. As a matter of fact, it is desirable for them to handle the case since they are personally acquainted, or should be, with themagistrate as well as very familiar with the circumstances under which the violation took place.

In his discussion of forest fires laws and the prosecution of their violation, Talbott (160) groups the wardens' enforcement activities under two headings, namely, (a) investigation and (b) prosecution. He believes that prosecution should never be attempted without making an adequate investigation to determine responsibility.

Admittedly the local warden is generally more than occupied with his job of controlling the fire. Too often, however, generally because of personal dislike for the law enforcement phase of his job, he avoids it entirely. The state forester, however, should insist on adequate investigation of the cause of fires; if the local warden wishes to avoid personal participation in the prosecution of the case, where the offender may be an acquaintance of his, another forest officer can always be imported to conduct the prosecution. When forest officers charged with forest fire protection insist on investigative work on a par with the standards they demand in suppression, there will be more prosecutions, fewer man-caused fires, and better data on causes of fires. It is here admitted that the job of controlling a fire is so all-absorbing that there is little time for investigative work, but innumerable instances might be cited where wardens with a natural bent for investigative work have collected excellent evidence on the cause of the fire, incidental to their job as crew leader of the party taking initial action on the fire.

Talbott (160) pointed out the need for procuring clues in building up a case; these clues might be in the form of horse tracks, foot prints, or auto tires with peculiar markings. Notes on time of arrival at the fire and probable time of inception are always valuable evidence in a case. When all the evidence has been collected, a study must be made of it to fix responsibility. If the nature of the offense is minor, a misdeameanor, it is desirable to discuss the matter with the offender, obtain an admission of guilt, and then either collect fire fighting costs from him, if he is cooperative, or bring him before a magistrate, if belligerent. If the case is presented to the offender in any impersonal manner and the seriousness of his offense explained, generally he becomes a better citizen from the standpoint of cooperativeness in forest fire prevention. A parade of authority and a show of firearms should always be discouraged on the part of wardens; such action antagonizes local citizenry and weakens rather than strengthens the case of forest fire protection.

In almost all states, forest wardens are authorized to make arrests with or without a warrant, when the violation has been committed in their presence. In absence of direct evidence on the part of the warden, a warrant will have to be served on the offender and the case tried before a magistrate at once if it is classed as a misdemeanor. If it is a felony, the magistrate should read the charge to the offender and then, because he has no authority to conduct trials for felonies, forward the case to the court having jurisdiction over the offense. Desirable procedure in felonies, however, where the forest officer has not personally witnessed the violation, is to conduct his investigation secretly. When he is satisfied that he has sufficient evidence for a conviction, he should have a representative of the court having jurisdiction over felonies make the arrest, since in most localities a forest officer is looked upon not as an arm of the law, but rather as a state representative charged with controlling fires. This situation is desirable in most cases, since it encourages public participation in fire prevention. Most wood dwellers are antagonistic, rather than cooperative, with law enforcement officers.

**Distinction between Enforcement on Federal and other Lands**

The authority for punishment of a person or persons who are responsible for a forest fire on national forest land is derived from departmental regulations which, when enforced, have the same standing in a Federal court as state laws have in any court recognized by the State.

The violation of a Federal regulation pertaining to forest fires is referred to as a fire trespass. Specific Department of Agriculture regulations have been drawn up for fire, property, and timber trespass, applicable to national forests; this discussion, however, pertains only to fire.

The prosecution of a misdemeanor or a felony in any state court is dependent upon the existence of a statute which outlaws a specific action. A state forester, for instance, requires the aid of the state legislature to make brush-burning without a permit a misdemeanor; the legislature enacts a statute which limits brush-burning activities. On the National Forest, however, a regulation, issued by the Chief Forester and approved by the Secretary of Agriculture, has all the force of a law in the Federal courts. An act of Congress is not necessary to stop woods burners on national forests.

Whether prosecution for an offense on national forest land is conducted under state laws or before a Federal judge is determined on the merits of the individual case. When state laws are adequate, the courts and public sympathetic, and the state officials willing to cooperate fully, it may be preferable to prosecute before a state court, even though the offense was committed on federal land. On the other hand, the state laws may not be adequate or cooperation on the part of the state officials may be meagre; in such cases it is advisable for the matter to be handled by a federal court.

## State Forest Fire Laws

No legislature has given to its chief forest officer the authority which the federal government has vested in the Secretary of Agriculture who is able to impose regulations relative to activity on national forests and which have the same authority as an act of any state legislature. It is highly questionable whether a state officer should have such sweeping authority, in that so much of his activity is concerned with the control of fires on private land. The degree to which any public control should be exercised over private land is a matter which should be specifically designated by the state legislature which is supposed to be representative of the will of the majority of the citizens of the state.

There are several legislative acts which have been enacted specifically to strengthen fire control in most of the forested states. These acts, although varying somewhat in detailed wording, cover approximately the same subjects. The items covered by most of the commonly enacted laws consist of (1) regulating brush-burning, (2) installation of special mechanical devices for preventing forest fires caused by donkey engines and locomotives, (3) prohibition of promiscuous backfiring, (4) elimination of hazards, (5) penalties for setting fires maliciously and for accidental fires, and (6) enabling acts which permit the cooperation of a political unit of the state, such as a county, with state authorities in fire control for the specific purpose of controlling all fires within the boundaries of a political unit such as a county.

To enact a law without including a penalty for violation thereof is of little value. One state, for instance, has legislated that all who cut brush must dispose of such brush for a space within forty feet of the land where it borders railroads, roads, or other woodlands, but no penalty is provided for the non-compliance of this statute.

## Some Typical Forest Fire Laws

FELONIES

"If any person shall maliciously set fire to, or cause to be set on fire, directly or indirectly, in person or by agent, any woodlot, forest, or wild land, or property, material, or vegetation being or growing thereon, such person shall be guilty of a felony, and upon conviction shall be sentenced to pay a fine not exceeding five thousand dollars and be imprisoned in a penitentiary for a period not exceeding ten years." (51-p. 68)

MISDEMEANORS

"The forest warden or his deputies may summon any male resident between the ages of eighteen and fifty years to assist in extinguishing fires, and may require the use of horses and other property for such purpose; any person so summoned, and who is physically able, who refuses or neglects to assist or to allow the use of horses, wagons, or other material required, shall be guilty of a misdemeanor and upon conviction shall be subject to a fine of not less than five dollars nor more than fifty dollars. --(1915, C. 243, s. 6, 19[illegible], C. 106, ss. 1, 2; 1925, C. 240; 1927, C. 150, s. 4) Code 19[illegible], [illegible], section 6137." (16[illegible])

"Permission to burn brush - when and by whom given. In any township or any part thereof for which fire wardens have been appointed under the provisions of this act, no person shall set fire to or cause to be burned waste, fallows, stumps, logs, brush, dry grass, fallen timber or anything that may cause a forest fire unless the written permission of the State Fire Warden, or a division fire warden, or of a township or district fire warden of the township or district in which such fire is set has been first obtained. Such permission shall not be granted by any fire warden, if, in his opinion, any forest or woodland will be endangered thereby,--" (163-p. 6)

"OWNERS TO PROTECT AGAINST FIRES--Every owner of forest land in the state of Washington shall furnish, or provide therefor, during the season of the year when there is danger of forest fires, adequate protection against the spread of fire thereon or therefrom which shall meet with the approval of the state board of forest commissioners: Provided, however, that for the purposes of this section forest lands shall be deemed to be adequately protected if within one mile of the owner's permanent residence or if the owner shall furnish patrol and protection therefor equal in standard, efficiency and seasonal duration to that of those who are in good faith maintaining organized patrol and protection of their lands against fire with the approval of the state board of forest commissioners: Provided further, that for the purposes of this section forest lands, lying in counties east of the summit of the Cascade Mountains, shall be deemed to be adequately protected where patrol is furnished by the United States forest service of a standard and efficiency and seasonal duration, deemed by the state board of forest commissioners to be sufficient for the proper protection of the forest land of such counties. Remington's Compiled Statutes '22, s. 5804.

"PROTECTION PROVIDED BY STATE FORESTER. If any owner or owners of forest land neglect or fail to provide adequate fire protection therefore as required by section 5804, then the state supervisor of forestry under direction from the director of the department of conservation and development shall provide such protection therefor at a cost not to exceed five (5) cents an acre per annum, and for that purpose may divide the forest lands of the state, or any part of the same, into districts, for patrol and assessment purposes, may classify lands according to the character of timber prevailing, and the fire hazard existing and place unprotected lands under the administration of the proper district.

"Any fire on any forest land in the state of Washington burning uncontrolled and without proper precaution being taken to prevent its spread is hereby declared a public nuisance by reason of its menace to life or property. Any person, firm or corporation responsible for either the starting or the existence of such fire is hereby required to control or extinguish it immediately, without awaiting instructions from a forest officer, and if said responsible person, firm or corporation shall refuse, neglect or fail to do so, the state forester, or any fire warden or forest ranger acting with his authority, may summarily abate the nuisance thus constituted by controlling or extinguishing the fire and the cost thereof may be recovered from said responsible person, firm or corporation by action for debt and, if the work is performed on the property of the offender, shall also constitute a lien upon said property. Rem. C. S. '22, s. 5806." (162)

"Every person that wilfully or maliciously sets on fire any wood, brush, or grass lands, or causes to be set on fire any wood, brush, or grass lands, whereby the property of another is injured or destroyed, shall upon conviction be punished by a fine of not less than twenty-five dollars ($25.00) nor more than two hundred dollars ($200.00) or by imprisonment for a term of not less than ten (10) days nor more than three (3) months, or by both such fine and imprisonment.--Acts of 1922, No. 90, s.4 - General Statutes 1932, s. 3323." (163, p. 24)

"Preventing the escape of sparks. All logging and railroad locomotives, dinkey engines and other engines and boiler operated or used within two hundred feet of any forest, cut-over, brush, or grass land, which do not use oil as fuel, shall be equipped with efficient appliances or devices to prevent the escape of fire and sparks from the smoke stacks, ash pans, and fire boxes thereof.--Any person operating any logging or railroad locomotive, dinkey engine, or other engine or boiler in violation of any provision of this article shall be fined not less than ten nor more than one hundred dollars for each offense. Acts 1923, p. 270, Penal Code 1928, Title 17. Chap. 2, Article 1329," (164. p. 32)

## Chapter VIII

## FIRE DANGER RATING

As has been pointed out previously, there is some degree of correlation between most of the meteoro- [illegible] discussed and forest fire inception and rate of spread. Factors other than meteorologi- [illegible] influence the degree of danger which exists because of forest fires. Various devices have [illegible] measure the degree of danger which prevails at any time. Several devices for determining [illegible] explained in some detail below.

"[illegible] METER"--This is a device which was designed by Gisborne (59) of the Northern Rocky Mountain [illegible] Experiment Station for measuring the degree of fire danger which exists for individual [illegible] units in the Northern Rocky Mountain Region (R-1) of the United States Forest Service. The [illegible] the meter are (1) period of the fire season, (2) lookout visibility, (3) fuel moisture [illegible] wind velocity, and (5) causes, with emphasis on lightning. The various combinations have the [illegible] rule in producing varied results; these are known as "Fire Danger Class" days.

[illegible], usually identified with the several classes of fire danger, is explained in Table 26.

**Table 26**

FIRE BEHAVIOR ASSOCIATED WITH DANGER CLASS
(From Fire Danger Meter, Northern Rocky Mt. Forest and Range Experiment Station)

| Danger Class | Behavior |
|---|---|
| 1 | Brush burning and other fires do not spread enough to require any trenching. |
| 2 | No spread under dense timber or on north slopes. On open areas and on south slopes fires spread during the heat of day. |
| 3 | Fires spread slowly and hold over night on north slopes and under dense timber and make short runs in open and through slash. Running crown fires are very rare however, except with fresh and strong winds. |
| 4 | Fires crown in single trees and groups but do not make long runs in full timber on north slopes. Occasional crown runs on south slopes and flats with moderate fresh winds. |
| 5 | Occasional runs in full timber on north slopes but seldom crossing pronounced topographic divides. Fast spread certain on south slopes, cut over areas, and heavily fueled old burns. |
| 6 | Big runs common on all exposures within a single drainage but only occasionally crossing pronounced topographic barriers. |
| 7 | Explosive conditions with fire spreading at rates up to 1500 or 2000 acres per hour including densely timbered north slopes during afternoon and evening. Topographic and other usual barriers such as rivers and large cultivated fields ineffectual during peak of day. |

[illegible] (60) (63) has been largely [illegible] for the system for rating [illegible] and has explained the [illegible] involved in some detail in [illegible].

[illegible] of a highly organized [illegible] system involving the use of [illegible], telegraph, and radio, [illegible] the meteorologist at [illegible] receives from approx- [illegible] stations located in the sev- eral forests in the Region, reports on [illegible] of the following conditions: [illegible] and minimum temperature for the [illegible] 24 hours, (b) relative humidity, (c) wind direction, (d) velo- city [illegible] of the current day and [illegible] the preceding day, (e) 9 a.m. [illegible], and (f) reports on [illegible] precipitation occurrence. [illegible] are utilized in making up the [illegible] forecast which may be broken up into parts applicable to specific sections of the region. [illegible] forecast covers (a) sky conditions, (b) absence or probability of thundershowers or general [illegible], (c) temperature changes, and (d) wind direction and velocity. These forecasts are issued at [illegible] and generally arrive in the woods by 11 a.m. or noon.

[illegible] factors which contribute toward hazardous conditions are maintained on a Fire Danger Chart in [illegible] Supervisor's office as well as in the Regional Office. A brief, five-minute study of the [illegible] specific forest will give an immediate picture of the fire danger. The chart covers the [illegible] period May 1 to October 10 and includes lightning storm occurrence, visibility distance, fuel [illegible], average daily wind velocity for the period noon to 6 p.m., minimum or 5 p.m. relative [illegible], the index aggregate of these factors known as the "class of fire danger;" and the percent of [illegible] force on duty. With all this information at his disposal, the supervisor or fire chief is [illegible] of the acuteness of the local fire situation and can control activity and man-power [illegible]. Figure 18a is a copy of the Fire Danger Chart compiled for the Kootenai National [illegible] Northern Rocky Mountain Region.


A-Front of Meter

Meter set for period July 11-Aug. 31 with no lightning within past two days but with extremely low visibility. The seasonal factors and presence of absence of lightning storms, in combination with other factors, produces a fire danger index number on reverse side of meter.

B-Reverse side of Meter

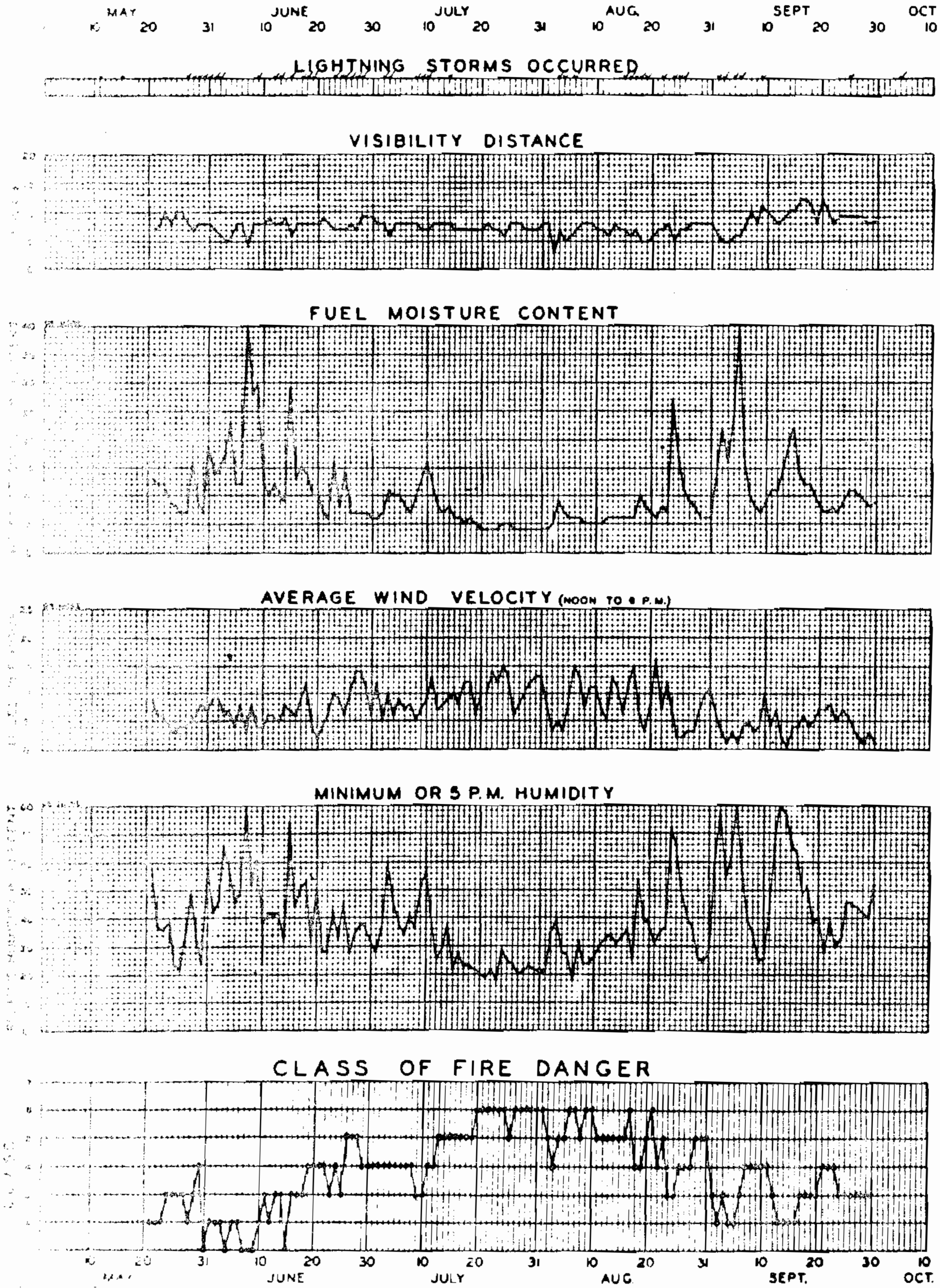
The settings of the movable disks on the front of the meter, considered along with wind velocity and moisture content of duff and branchwood fuels, produces a Fire Danger Class, with Class 1 as the lowest and Class 7 as the highest.

FIRE DANGER METER

Figure 18

# FIRE DANGER 1936

## *Kootenai* NATIONAL FOREST



## Fire Danger Board

The principles involved in the construction of this board are very similar to those [illegible] Fire Danger Meter. Altho it has been designed and is used in the Pacific Northwest [illegible] State Forest Service, it is merely a variation of the fundamental principles on which [illegible] Meter" was based. The [illegible], relative humidity, and degree of curing of the herbaceous [illegible] given more weight than in the case of the meter used in the Northern Rocky Mountain Region. [illegible] Danger Board is actually a composite of the Forest Danger Meter and the Fire Danger Chart of [illegible].

## Fire Danger Rating by New Jersey Forest Fire Service

A similar, but not so elaborate method of forecasting fire weather and dissemination [illegible] force has been in use in New Jersey since 1928. The system for forecasting is based on [illegible] the absolute humidity of a high pressure area remains approximately constant in its [illegible] the continent. In the eastward movement of an air mass its probable drying power over [illegible] of the Mississippi River can be forecast with a fair degree of accuracy, assuming that the forecaster has a fair knowledge of the probable path of air masses and all the factors resulting from the movement of the particular mass in question. The theory was tried out somewhat experimentally and gave fairly good results which would undoubtedly have been of a higher quality had the forecaster had more experience in the behavior of air masses. The absolute humidity calculations were based on daily signals obtained from key stations which were located in the most frequented paths of air masses. These were located at Columbia, South Carolina, Nashville, Tennessee, and Fort Wayne, Indiana. The signals provided data whereby it was possible to calculate the absolute humidity for the air mass which dominated each key station. If it was determined that the air mass which was dominant over Fort Wayne, for instance, had an absolute humidity of 1.321, and probable that 24 or 36 hours later the same air mass would dominate New Jersey, then with a temperature prognostication for the period that the Fort Wayne air mass would dominate New Jersey, applied to the known absolute humidity of the air mass, the probable relative humidity for the day period 24 to 36 hours in advance of its arrival at New Jersey could be computed. The procedure made it possible to advise key men in the field regarding relative humidity, wind velocity, wind direction, and fire danger measured in terms of inception frequency for the night period following the morning the forecast was prepared, and the day period for the following day.

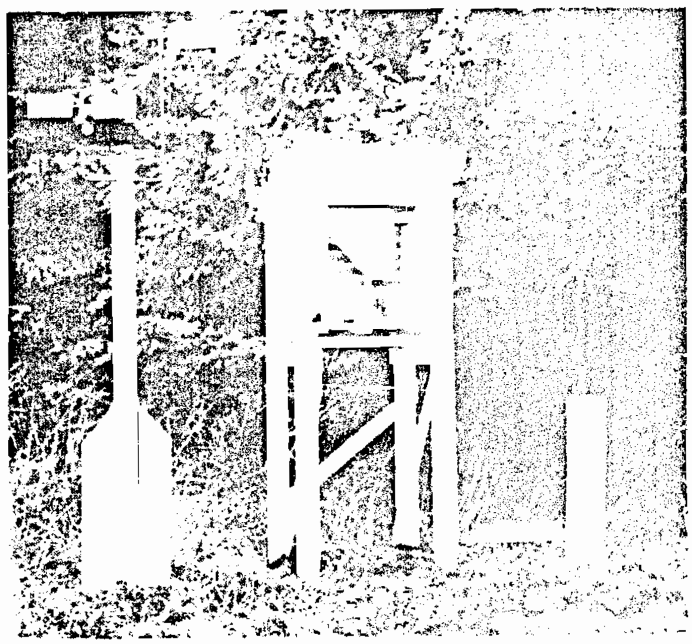


Photo by U. S. Forest Service-[illegible]

Figure 19

FIRE DANGER STATION USED BY THE PACIFIC NORTHWEST REGION (WASHINGTON AND OREGON) OF THE UNITED STATES FOREST SERVICE

(a) The instruments mounted on the post are an anemometer to the left to measure current velocity and a vane on the right to determine direction.
(b) In the background of the shelter is a scale for making direct moisture content determinations of the hazard sticks.
In the foreground of the shelter is a [illegible] psychrometer to determine relative humidity.
(c) In the foreground to the right of the shelter are a set of "triplets" and 2-inch wood cylinders for measuring fuel moisture content.
(d) At the extreme right is a rain gauge for measuring the volume of precipitation.

A fire warden who received the telegram which read "None gentle southwest safe many moderate west dangerous" would understand it to mean that (a) for the period from midnight of the day the telegram was received to 6 a.m. of the following morning the relative humidity would average between 80% to 100% which meant no fires would start; (b) the wind velocity would average between 13 to 18 miles per hour; (c) the prevailing wind direction would be southwest, and (d) there would probably be no need for his services. (e) For the period noon to 4 p.m. of the following day, the humidity would average between 30% to 40%, (f) the wind velocity average 18 to 23 miles per hour, (g) the wind would be from the west, (h) fires [illegible] would spread rapidly but would be controlled without great difficulty.

### The Cumulative Relative Humidity or Shank System

[illegible] was developed for the Inter-Mountain Region (R-4) of the United States Forest Service by [illegible]. The [illegible] value of the system is the recognition of the fact that the accumulation of a de- [illegible] for a meteorological element has a marked influence in the degree of fire danger which [illegible] is based on the principle that ten consecutive days of minimum relative humidity [illegible] fire danger than two or three consecutive days of identical readings. The drying [illegible] several days of very low relative humidities has cumulative effect - hence the term - [illegible] humidity." Ten days of low relative humidity will leave the fuels drier than two [illegible] humidity.

[illegible] fire danger system is based entirely on relative humidity readings; no additional [illegible] other factors are considered.

[illegible] national forests having similar climatic, vegetational, risk, and other factors which [illegible] group, a "humidity base" is determined. Just what base humidity percentage is [illegible] by a study of past humidity records correlated with fire data. The base for one [illegible] was chosen as 21% at Boise, Idaho. A 6 p.m. reading of 15%, for instance, would indicate [illegible] was worse than normal. If a number of consecutive days would pass in which the [illegible] humidity were lower than 21%, the fire danger would increase with each day on which the [illegible] than 21%. A humidity of 15% would represent a departure of 6, and would receive a nega- [illegible] chart which is maintained; a reading of 30% would receive a positive value of 9%. The [illegible] humidity on any day is the algebraic sum of daily differences from the established [illegible] the beginning of the season to any given date. Table 27 is taken from the discussion [illegible] appears in the Region 4 Fire Manual (143).

[illegible] humidity periods have been developed for ad- [illegible]. These periods are as follows:- Period [illegible] 2, 0 to -60; Period 3, -60 to -120; [illegible] -180; Period 5, -180 to more than this [illegible].

[illegible] humidity period will determine the adminis- [illegible] by the Forest Supervisors for the [illegible]. For a humidity period of 4, the number of [illegible] be approximately five hundred percent [illegible] in Period 1; in Period 2, an increase of [illegible] is required in the number of guards. [illegible] Guard Placement Plan for the Region is [illegible] humidity period, it also takes into [illegible], (b) occurrence of fires, (c) values [illegible] type, (e) resistance to control, and [illegible] of reserve man-power. The dispatching [illegible] on the humidity periods prevalent for [illegible] in which the fire occurs. In a Humidity [illegible], the man-power which would be dispatched to a fire would be much greater than for [illegible].

**Table 27**

CUMULATIVE HUMIDITY PERIOD - BOISE, IDAHO, 1935
BASE HUMIDITY 21%
(From R-4 Fire Manual, p. 15)

| Date | 6:00 p.m. humidity % | Difference from 21% | Cumulative* Humidity (algebraic sum) |
|---|---|---|---|
| June 21 | 16 | - 5 | - 5 |
| 22 | 18 | - 3 | - 8 |
| 23 | 19 | - 2 | -10 |
| 24 | 20 | - 1 | -11 |
| 25 | 20 | - 1 | -12 |
| 26 | 23 | + 2 | -10 |
| 27 | 17 | + 4 | -14 |
| 28 | 43 | +22 | + 8 |
| 29 | 31 | +10 | +18 |
| 30 | 23 | + 2 | +20 |
| July 1 | 15 | - 6 | +14 |
| 2 | 14 | - 7 | + 7 |
| 3 | 16 | - 5 | + 2 |
| 4 | 12 | - 9 | - 7 |

*The cumulative humidity is the factor which determines what the Humidity Period is; it is this Humidity Period which governs administrative actions.

## Chapter IX

## FOREST IMPROVEMENTS FOR PRESUPPRESSION

### Detection

Methods

There are two basic methods of detection, each of which has certain advantages and modifications. The methods are: (a) the patrol system and (b) the lookout system.

The patrol system is of special value from a public relations standpoint, because the public, when it sees a patrol, associates it with forest fires and becomes conscious of the fact that someone is doing something about the occurrence and suppression of fires.

There are two forms of patrol - aerial and ground.

The aerial patrol has the advantage of covering an enormous amount of terrain in a relatively short time. It is, moreover, able to adjust its activity to the variable visibility factor. On days with low visibility, the range of the individual plane can be contracted; on days of good visibility, it can be expanded.

It is of particular advantage in spotting lightning fires in the "hinterland" or back country where there is no habitation and the communication system is poor, or where the establishment of a lookout system would be extremely expensive.

A disadvantage of the aerial patrol is that the atmosphere is generally turbulent after a lightning storm; it is in these periods, immediately after a lightning storm, that it should be particularly useful, but its value is directly related to the air-worthiness of the ship. Moreover, it cannot detect lightning strikes as can a lookout who is securely housed when the storm passes over or nearby. For a region where lightning storms are important, lookouts appear to have advantages over the aerial patrol.

The grounded motorized patrol is excellent in that presuppression and suppression duties can be combined in one unit. It is ideally adapted to coastal plain country, especially when used to supplement the primary lookout system. It reaches its peak of usefulness when equipped with a receiving set for radio messages.

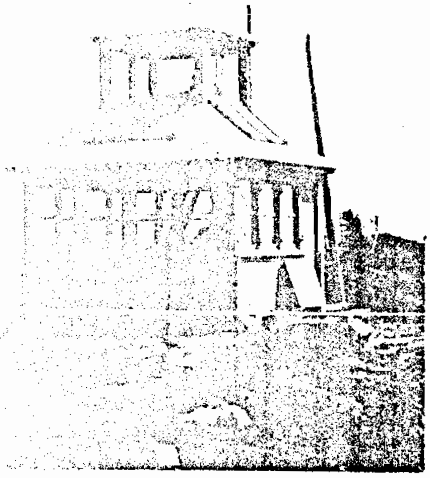
There are a few instances in which grounded patrols are conducted on horseback. The chief value of this type of patrol is from a public relations standpoint. The patrolmen can gain the goodwill of the residents, thereby lowering the risk. Its value is correlated, moreover, with the rate at which a fire can spread. Where the fire can spread rapidly and do considerable damage in a short time, it has little value because the fire would be beyond quick control by the time suppression crews could arrive on the job.

Grounded patrols mounted on motor vehicles are generally a combination of detection and suppression crews. These units are really roving suppression crews. They are of immeasurable value when the visibility has been reduced to a negligible amount when the usefulness of lookout points has been seriously reduced.

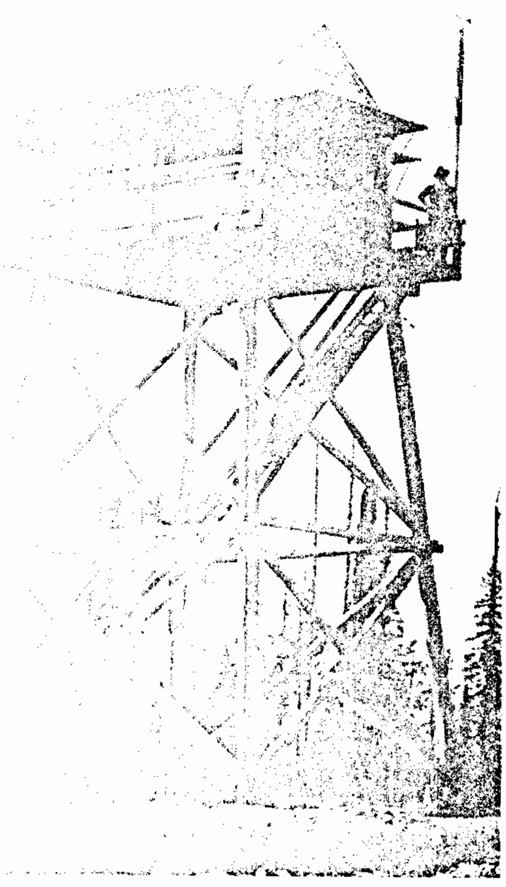
The lookout or observer system is the one most generally employed in the United States. By this system, a base point is selected at which a lookout is permanently stationed during the fire season. He may, or may not, reside at the base point, but he is supposed to be on duty during fire weather.

The outstanding advantage of the system is from the viewpoint of liaison. The lookout is also able to give at all times a report on hazard conditions for that territory over which he watches and, because of his residence there, should be better informed on the behavior of weather than any other person. In periods of high fire danger the administrative officer should be able to communicate with him at all times. When fires occur in the immediate vicinity, the lookout is able to give an accurate report on the condition of the fire, i. e., its rate of spread, location of hot spots and quiet sectors. His quarters may also serve as a temporary base for fire suppression operations.

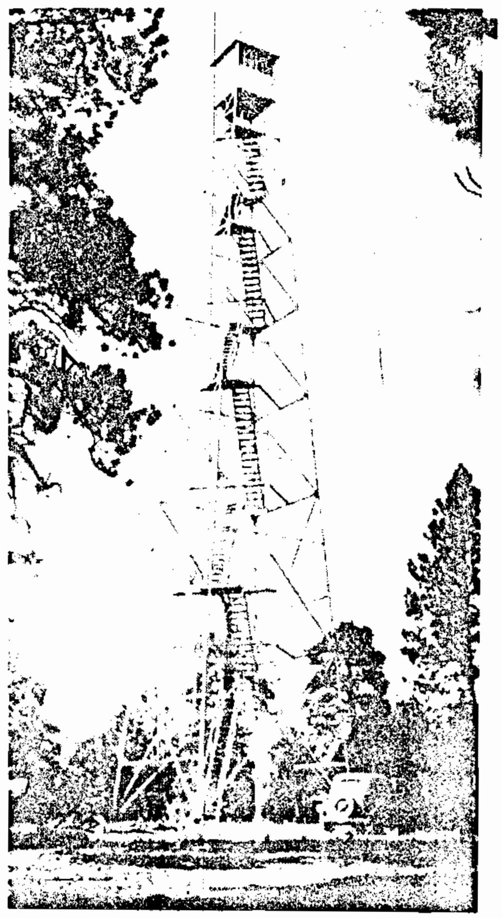
The lookout points have various types of improvements dependent upon local conditions. (a) A small cabin, 10' x 10' may be built directly on the point of vantage, provided it affords adequate visibility to the observer. (b) If the observer needs to be elevated for obtaining the maximum benefit of the site, the cabin may be raised on legs which place the lookout anywhere from 20' to 120' above the surface. The cabin may be relatively small, 6' x 6', which requires the lookout to be quartered in a separate building nearby and is the system most generally used in Eastern Regions. There has been an increasing tendency in the Western Regions to enlarge the legged cabin in order that the observer may use it as quarters as well as a point of vantage. (c) Auxiliary or secondary lookout points very frequently consist merely of a raised platform without cabin shelter, or may be only a crowsnest mounted on a pole. This type of lookout, however, is highly unsatisfactory for primary points because it affords the observer no shelter from the elements.



[illegible] 1[illegible]40[illegible]



[illegible] Figure [illegible] [illegible]81



(c) Figure 22 [illegible]

[illegible] OF LOOKOUT [illegible]
([illegible] U. S. Forest Service)

[illegible] Observer on duty [illegible]. Used chiefly in very rug[illegible] topography.
[illegible] used also in rugged topography but where geological formation [illegible] quarters from [illegible] on ground. Quarters [illegible] 14' x 14'.
[illegible] used in coastal plain [illegible] where mountains have relatively little [illegible]

The materials out of which the towers are constructed are generally wood or pre-fabricated steel. A few of the lookout towers over the country have been constructed of treated as well as untreated wood. Because of the lower cost of steel towers, however, they have been placed in general use. If methods of treated wooden towers could be perfected, it is possible that the cost might be lowered to a price which would be more competitive for the steel material.

The relative importance of the lookout points in the detection scheme determines whether it is classed as (a) primary or (b) secondary. Primary lookouts are all manned, or most of them, during the entire fire season. Secondary points are manned when the visibility impedes the effectiveness of the primary points or when there may be a temporary increase in the risk due to a logging operation, or an influx of transients, or unusually high hazard which may demand higher detection standards.

The person who mans a point of vantage is referred to as the "lookout." The duties of the observer or "lookout" vary with the several forest regions. When his only duty consists of locating and reporting fires, and such other miscellaneous duties as will not take him from his observation point during fire weather, he is only an observer. When, however, his duty of detection is paired with the job of suppression, he becomes a "fireman." Western regions generally man their lookout points with firemen. Eastern regions depend for their initial action on man-power other than the observer.

## Some Principles of Visibility Which Affect Detection

As was pointed out in the discussion of fuels and fire danger, one of the factors used by Gisborne in preparing his Danger Meter was visibility distance; in other words, it is one of the variables which determines the degree of fire danger. When small smokes are visible for long distances, the intensity of the detection system can be reduced. On the other hand, when the visibility is low, detection facilities may be increased for the reason that the more quickly fires are detected after inception, the lower is the "hour control time" which is a most important factor affecting the size of the fire. A study of some of the aspects of the detection system as generally employed, i. e., lookouts located at elevated points, showed that visibility is a variable factor which influences lookout effectiveness very definitely.

Visibility is one of the factors which influences the placement of man-power. If first-line defense is composed of firemen, i. e., forest officers in whom are combined the two duties of detector and controller, it is especially important that any limitations which may influence their range of activity be known. McArdle (84) of the Northwest Forest Experiment Station investigated visibility factors at some length and thereby eliminated some erroneous conceptions as well as contributed several advanced ideas fundamental to effective operation of the detection system. As outlined by McArdle, some of the factors which influence the ease or difficulty encountered in detecting smokes, are (a) the condition of the atmosphere, determined by its transparency or haziness; (b) type of background supplied to the smoke, whether relatively light or dark; (c) the time of day as influencing the angle produced between a line drawn to the smoke and a line drawn to the sun; (d) size of the smoke column, whether large or small in diameter and spread; (e) character of sky conditions, whether overcast or partly cloudy, or clear; and (f) location of smoke relative to its being so low that, for the time of day to be observed, it is in the shadow cast by a mountain or the steep walls of a canyon.

There are periods in which the atmosphere has extreme transparency, but the fire days coincident with this condition are limited. On these days small smokes are readily seen at relatively long distances. Most frequently, however, there is some haziness in the atmosphore which lowers the natural colors of the landscape from their peak of brillance at extreme atmospheric transparency to nearly drab shades in conditions of considerable haze. Since smoke as caused by forest fires is a neutral color, it is difficult on hazy days to differentiate readily between the neutral color of the smoke and the nearly neutral color of the background.

The study of McArdle's showed the rather unusual feature that visibility is greater on days when the sky is overcast with light clouds, producing indirect light, than on days when the sunlight is not intercepted by clouds.

Byram, who worked with McArdle on the project, has estimated that the visibility of a small smoke increases in relation to the increase in size, but not directly. If a column of smoke is visible fourteen miles from the lookout, an increase of four times the original diameter will increase its visibility only [illegible]; if the column of smoke is enlarged eight times, its visibility will be increased only [illegible] miles.

[illegible] general opinion among fire control men, all other things being equal, smokes are generally [illegible] visible when the observer looks into the sun than away from it. McArdle's figures on [illegible] away from the sun at time of detection were 9.4 miles average distance when the fire [illegible] the quadrant in which the sun lay and 8.5 miles distance when the observer was not facing [illegible] time of detection.

[illegible] of his investigations, McArdle came to the conclusion that, for all practical purposes [illegible], the visibility in all directions is equal, regardless of the position of the sun.

[illegible] of the visibility studies for Washington and Oregon, the primary lookout system is based [illegible] mile radius with a secondary or supplemental system for use when visibility is low; this [illegible] mile radius for each observer.

[illegible] of Hornby's (85) investigations relative to visibility in the Northern Rockies, he found [illegible] of small smokes at 4:00 p.m. on days when the atmosphere were particularly clear, [illegible] differences in whether the sun was located between the observer and the smoke or [illegible]. When the lookout is compelled to look into the sun, on an especially clear day, he will [illegible] small smoke only ten miles off; with his back to the sun, however, a smoke can be seen [illegible] miles away. On days when visibility is low, the same principle holds except that the dis[illegible] detection toward the sun is as low as 3.5 miles and away 6.0 miles. These findings of [illegible] to be contrary to what McArdle published, but it must be borne in mind that Hornby's [illegible] based upon 4:00 p.m. results when the sun is low; at this time, shadows commence to in[illegible] and the conclusion is in agreement with McArdle's who stated that shadows cast by [illegible] canyons seriously lower the visibility of smokes which develop in them.

[illegible] of lookout placement should be determined by burning severities of the forest types [illegible] as well as visibility because visibility is only one of the factors contributing to fire danger. [illegible] average, and minimum burning severities, the lookouts should be placed so that the radii of [illegible] approximately less than five, eight, and fifteen miles, respectively.

## Seen-Area or Visibility Maps

[illegible] that smokes must be seen quickly after inception has lead fire control planners to [illegible] observation points in such a manner that the lookouts can see directly the area which the point of vantage [illegible] serve. That is, within a ten mile radius, even on a day of high visibility, there is some [illegible] which is not directly visible; this is particularly true in regions of rugged topography. One of the factors which affects the efficiency of any lookout point is the percent of the area within a ten mile radius which can be seen directly. It should not be necessary for a lookout to be compelled to wait until [illegible] rises over a ridge top to be able to detect it; as much as several hours might thus be required [illegible] the smoke. By the time it becomes visible, the fire might easily be Class C in size. [illegible] which can be seen directly is mapped as the "seen-area" and the map on which this area is [illegible] referred to as the "visibility map." This type of map is important because it is one of the [illegible] will determine whether a point of vantage is desirable from a fire control standpoint. All [illegible] being equal, the factor which determines the location of a lookout point is the percent of [illegible] directly from it.

[illegible] the application of analysis to fire control improvement placement, visibility maps were not [illegible] of expenditure on lookout improvement or transportation facilities servicing the point. [illegible] practice demands the construction of visibility maps before lookout points are improved.

[illegible] by Shank (92) there are three methods of constructing the seen-area maps. (a) By the use [illegible] on a profile map, which gives the elevation of the proposed lookout point and the relative [illegible] visible from it, the area can be determined which is directly visible to the lookout. [illegible] of a relief model, based on a topographic map; after the model has been con[illegible] light and shadows produced by an electric light bulb at the observation point makes [illegible] the area seen directly from the proposed point. (c) [illegible] from the [illegible] requires the use of a telescopic alidade and considerable field work.

Under systems "a" and "b", no field work is necessary; it is essential, however, that [illegible] maps be available otherwise the systems cannot be employed. With system "c", however, the only [illegible] ment is a base map of some sort, one preferably with such culture as streams, roads, and prominent [illegible] topographic elevations.

Shank kept cost records of two methods, "b" and "c", and found that the latter was the less expensive; approximately 40¢ per square mile, while the "b" method was approximately 55¢ per square mile mapped. On the basis of resultant efficiency, the two systems are approximately equal inasmuch as by the one system it was found that the total area included was quite nearly equal to that obtained by the other, and that the field sketching system showed 45.0% of the area visible while the light and shadow on a relief map showed 45.7% visible for the same area. For areas where contour maps are not available, it is nevertheless possible to construct visibility maps.

Lookout Equipment

A requisite for primary lookouts is adequate shelter for the observer so that he will not be exposed to the elements. It is unreasonable to expect an observer to remain on duty at an exposed point and function efficiently when the wind is blowing 20 m. p. h. and the temperature is 45 degrees Fahrenheit or lower. On windy days it is especially desirable for lookouts to be at their post of duty. They will hardly remain on duty constantly when working conditions produce extreme discomfort.

Another requisite is living quarters at the towers so that the observer is available at all times in event of a sudden flareup in fire danger.

The minimum equipment available to each primary lookout should be:

(a) Oriented map on board; (b) alidade; (c) wall map with adjacent lookout points located and equipped with vernier and strings at each point; (d) communication instrument such as radio or telephone.

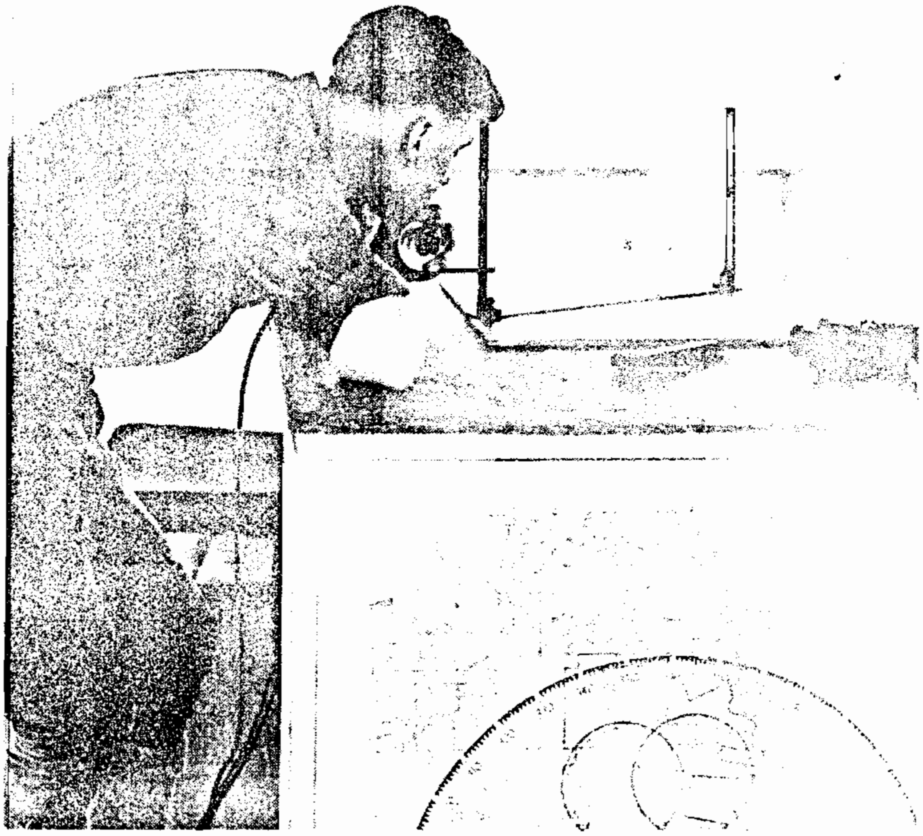


Photo by U. S. Forest Service-225037

Figure 23

OBSERVER IN ACTION. The Alidade Has Been Placed On The Map Board. By Sighting Smoke Thru The Alidade, Obtaining The Azimuth Reading, and Contacting The Dispatcher by Phone, The Fire Can Be Located With Precision For Dispatch of Man-Power.

Equipment to supplement the above for detection purposes is as follows: (a) range finder, (b) binoculars, (c) haze meter, (d) goggles.

Because lookouts are continuously on duty, they are frequently required to attend to fire danger measuring devices such as duff hygrometers, hazard sticks, anemometers, psychrometers, and evaporimeters.

RANGE FINDER

The range finder is of particular value when cross-readings are not obtainable either because of poor

... because of the non-existence of other lookout points. The Osborne Range Finder was at one ... use in the West, but is no longer so important because of the greater frequency of lookout ... cross-readings possible.

... supplied to lookouts in some regions in order to minimize eyestrain. At one time it was ... that fewer smokes were detected when looking into the sun than when looking away from ... pointed out, however, this conception is erroneous. Because approximately two-thirds of ... detected by lookouts when the observer is looking into the sun, efforts have been made to ... eyestrain caused by the sunlight exposure. Various types of glasses and lenses have been ... eyestrain. Blue and amber glasses filter out some of the spectrum so that they distort ... reaches the eyes. A neutral lense, such as the "smoked," is most desirable because it permits ... to reach the eye, but lowers it quantitatively so that the eye strain is considerably ... very greatly in quality. The cheap types are merely pressed glass which has irregulari- ... require unequal muscular effort by the eye and so induce, rather than relieve, strain. Goggles ... lenses are recommended for increasing lookout efficiency. (80)

BINOCULARS AND TELESCOPES

... in fire control work are not in agreement concerning the value of binoculars or tele- ... forest regions have supplied this type of magnifying equipment to some of their lookouts for ... purposes, but there is little definitely known as to their real value. Curry (86), has ... which are afforded lookouts equipped with binoculars. These are as follows: ... examination of area of known high risk, (2) for distinguishing between true and false ... detection of lightning fires which may produce only faint wisps of smoke, (4) for accurate ... readings, (5) for estimating size of fires and rate of spread.

... indicated elsewhere in the discussion of visibility in its association with fire danger, it is one of ... items which, until recently, has been expressed in loose, indefinite terms. Lookouts ... atmospheric transparency as "good," "fair," or "poor" without any very definite measuring ...; or if they have progressed beyond this method of measurement, they may state it in terms of ... miles visibility without having a definite idea as to the size of the smoke they believe ... the atmospheric conditions existent at time of reporting. In his discussion of the prin- ... visibility, McArdle (84) has fixed the size of the smoke as that volume produced in ... ponderosa pine duff fuels, covering an area of 10' x 20', burning on a midsummer day; no ... made, however, of the diameter of the smoke column, but it might be presumed to be approxi- ... feet. With this size column of smoke as standard, under average conditions the safe range of ... for lookouts with normal eyesight was limited to the brightness of the background. There is a ... between background brightness and the brightness of the horizon just above the background ... the smoke. If the background is 60 percent as bright as the horizon at that point, the ... is approximately the maximum limit of safe range.

... order to eliminate the guesswork in determining safe visibility, the Byram haze meter was designed ... the percentage of brightness of the horizon was correlated with the brightness of the background ... the smoke of standard size just described. In days when the visibility is low, the farther ... the horizon is from the point of observation, the less is the contrast between the background ... to the smoke; this automatically lowers the visibility distance.

... use of the original Byram haze meter employed in mountain country, however, has its limitations ... computations are required which all lookouts are not qualified to execute. The fact remains, ... with visibility constituting so important an element of fire danger, it is desirable to ... in terms of definite mileages based on instrumental measurement rather than to permit it to be ... guesswork on the part of lookouts. The haze meter is now usable in flat or coastal plain ... instrument has been constructed which does not demand the presence of mountain ranges for ... visibility distances.

## COMMUNICATION

Because the time element is so extremely important in fire control, it is highly desirable to have available communications systems which are speedy and dependable, such as the telegraph, telephone, and radio. Fire control, moreover, is conducted on an extensive basis which makes it necessary to employ the type of communication which is available for use at all times by men who require no special technical knowledge.

With so much of the forest area of the United States having a low population density, public utilities engaged in communications business have avoided it. The result of this situation has been the development, by forestry agencies, of thousands of miles of telephone systems in forested regions where communication is necessary but where there has not been sufficient traffic to warrant the attention of the public utilities. It has been the general policy of all forestry agencies to construct these communications systems only when public utility lines were not available.

These speedy communications systems commonly employed in the United States are (a) telephone, (b) telegraph, (c) radio, and (d) wireless. Foresters have relied almost exclusively, until recently, on the telephone for use in the forest. Radio is gradually becoming of increasing importance. The telegraph and wireless have never played important roles as forest communications systems because they operate on a code basis which requires special training for the user, in contrast to the telephone which has very simple operating principles.

### The Telephone Systems

There are two types of telephone systems employed in forest areas. These are the "slack line" or grounded circuit system whereby the circuit of electrical current utilizes the ground and one metallic line for completion; the other system, known as the metallic circuit, makes it possible to transmit sound via two wires instead of one.

#### THE GROUNDED LINE

The grounded or "slack line" system has been the one most commonly utilized in the forest to date, largely for very practical reasons which are (a) cheapness and (b) serviceability.

The grounded line is cheap to construct because only one strand of wire need be strung; this cuts materials expenditures almost in half when compared with the metallic system. The right-of-way clearance, moreover, need not be so elaborate as the metallic circuit and the routing is more elastic because the line is suspended from trees. With relatively little clearing to do, original construction work is at a minimum. The greatest amount of mileage for fire control purposes is through wooded areas where the line can be suspended from trees; this eliminates the investment in poles and resultant maintenance charges. From a serviceability standpoint, or "woods-worthiness," the metallic system is considerably inferior to the grounded circuit. With the latter, a slack line can be constructed which will remain serviceable in event a snag or tree falls on it; there is sufficient slack to permit an obstacle to bear the line to the ground and still not exert so much tension that the line will be severed. Except in damp or wet weather, a grounded circuit system is still serviceable even though the wire may be on or close to the ground; when such atmospheric conditions prevail, however, the fire hazard is at a minimum. It would be possible to construct a slack line metallic circuit, but the expenditure required would be approximately twice the cost of the construction of a grounded circuit with very little more utility. It would be almost impossible to construct a metallic circuit slack line with both wires on the same right-of-way in the woods. If the strands were near each other, gusts of wind would frequently cause the two strands of wire to form contact which would render the system unserviceable for the period of contact.

#### METALLIC CIRCUIT

At the present time there is a tendency to construct metallic circuits in preference to grounded circuits because of increasing traffic and higher utility standards. There is no doubt that the metallic circuit makes for greater audibility; this, however, is largely confined to the trunk lines rather than to the short stubs, especially when switchboard service is available.

When communications routes were first installed in most of the forest regions, the demands were fully met, but as the organization was enlarged and as fire control measures became more intense, the demands on [illegible] systems gradually expanded until many arrived at a point where they were not functioning efficiently because the load was too great for the available facilities.

## The Decibel

Brown and Funke (100) developed some technical details applicable to telephone line construction [illegible] States Forest Service Telephone Handbook (101) has to date excluded. A table of decibel [illegible] which is an index for determining what is a workable circuit. The basis for "workability" is the ability of the line to transmit the human voice; it is measured by a unit known as the [illegible] "DB." Wiley (103) has stated that an increase in one DB is the smallest unit in- [illegible] perceptible to the human ear. The DB is actually a logarithmic unit for expressing power [illegible] influences the audibility of a circuit. For the doubling of the power used in a transmission [illegible], the result is an increase equal to 3 DB.

There are numerous types of impedances which exert themselves in such a manner as to reduce the voice [illegible] of a circuit; they might be caused by the resistance of the wire itself, the use of a [illegible], an extra ringer, etc. Brown and Funke contributed material to forest communications [illegible] these losses or gains in terms of decibels. The ratings have been listed in Table 28.

For satisfactory talking service on any specific [illegible], the [illegible] decibel loss should be less than 31; the [illegible], the more satisfactory will be the talk- [illegible] audibility.

With [illegible] values at the disposal of a forest [illegible] a communication system, he is able [illegible] allowable number of stubs, ringers, [illegible] and plan the necessary boosting devices to [illegible] decibel losses so that high degree of [illegible] retained for a specific circuit.

**Table 28**

DECIBEL RATINGS ASSIGNED TO TELEPHONE LINES
(after Brown and Funke)

| | |
|---|---|
| 1 mile grounded line. . . . . . | 0.20 db. loss |
| 1 mile metallic line. . . . . . | 0.0417 db. loss |
| 1 ringer. . . . . . . . . . . . | 1.00 db. loss |
| 1 stub line . . . . . . . . . . | 1.00 db. loss |
| 1 repeating coil. . . . . . . . | 0.50 db. loss |
| 1 switch. . . . . . . . . . . . | 0.50 db. loss |
| 1 receiver off hook (rubbering). | 3.00 db. loss |
| transmitter in use. . . . . . . | 2.00 db. gain |
| passage through exchange. . . . | 3.00 db. gain |

The telephone has distinct limitations as a communication system in fire control, especially in suppression activity. [illegible] fires frequently render telephone systems [illegible], if the line is tied to timber, the trees burn off or the numerous falling snags sever the line; if the line is tied to poles, at least several poles burn off and in falling break the circuit. On large fires particularly, temporary line cannot be strung fast enough to keep the base camp constantly [illegible] of what is going on at the line of fire.

## Radio

The use of radio has aided fire control communications considerably. It is doubtful, however, whether it will ever replace the telephone, but when used to supplement the telephone, attains its highest level of utility.

Because commercial communication lines exist between the central headquarters of a forest and the headquarters of adjoining forests, radio has its principal value in one forest administrative unit such as a Ranger District.

For forest use, its outstanding values are as follows:

(a) For establishing communication with lookout points which are manned so infrequently that a telephone line has not been warranted, especially if the observation points are on an isolated, inaccessible point.

(b) For maintaining close contact with improvement crews during an extremely hazardous period, especially when there is no telephone communication at the point where the crew is working and a messenger would [illegible], thus increasing the elapsed time necessary to get the crew to the fire. A radio with the [illegible] satisfactory liaison with the fire desk or dispatching station and thus eliminates [illegible] by."

(c) [illegible], when time is so important an element, communication between the fire boss and crew [illegible] keeps the former constantly aware of the favorable or unfavorable developments on the line of fire. Before radio was available, runners were necessary; this frequently involved a loss of valuable time. When the fire boss was finally informed by the runner as to developments on the line, so much time had elapsed that he was unable to make intelligent decisions or made unwise decisions due entirely to his unavoidable ignorance.

[illegible]) Liaison between scouting planes used for fire control purposes, and the ground, has been possible until recently only on a one-way basis. The plane could receive messages but could not transmit them; communication with the ground was established only by dropping messages from the plane. Recent radio developments by Region 1 of the United States Forest Service have made conversation possible between plane and sector crews on the line of fire by which the crew boss is able to ascertain what is going on at the head of the fire. This will permit him to take whatever sort of action is required.

Photo by U. S. Forest Service-316100

Figure 24

Night Communications On The Fireline Via a Portable Radio Set

There are certain disadvantages which the radio offers as a means of communication; these are (1) the need of a technician to set up and operate under stress, (2) poor performance due to "blind" spots, local interference, and weather conditions, and (3) the limitations imposed by regulations of the Federal Communications Commission.

Except for emergencies, it is somewhat questionable whether any forestry agency is warranted in building up an extensive radio communications system which will duplicate a commercial concern. In one forest region of the United States, daily reports are received at the Regional Office concerning the hazard existing at twenty-nine points scattered over an area of approximately 10,000,000 acres. This results, however, in some duplication of private telephone or telegraph systems already in existence.

The use of radio for forest communications has its limitations because an essential necessity for a field set is light weight for portability and yet sufficient ruggedness to withstand rough usage. With low weight, the available power becomes limited, and the amount of power available determines the range of satisfactory transmission.

Various types of sets have been developed by the United States Forest Service, designed with forest usage particularly in mind. The information in Table 29 was obtained from the Radio Laboratory Bulletin (61).

In Table 29, those sets which are sufficiently light in weight for back-packing on a fire have a limited effective working range, but nevertheless have sufficient range for use on any going fire where they have their greatest utility.

Types T, S, U and A are ultra-high frequency (UHF) sets; this distinctly limits their use to two points which are inter-visible. They are of no value where there are obstacles in the path of the radio waves; obstructions such as tall timber and ridges prevent their general use. For conversation between two lookouts points which have no obstructions between them, or for conversation between a fire boss and a scouting plane overhead, they serve the purpose very well.

Some practical suggestions relative to transmission of radio messages on going fires are digested below: (37)

(a) Messages should be written before transmission is attempted; this will cut down on duplication and wordiness.

(b) Those messages which are received should be written down and filed to eliminate possibility of a

**Table 29**

TYPES OF RADIO SETS IN USE BY U. S. FOREST SERVICE

| Type | Transmits | | Receives | | Wt. in Pounds | Working Range in Miles | Approx. Cost in $ | Type of Usage (Adaptability) | Remarks |
|---|---|---|---|---|---|---|---|---|---|
| | Code | Voice | Code | Voice | | | | | |
| P | x | | x | x | 9 | 20 | 50 | Smokechasers | Extreme portability but has limited use |
| PF | x | x | x | x | 15 | 10-voice 20-code | 75 | Smokechasers improvement crews | Has wider utility than P type |
| PF [illegible] | | | | | 35 | | | Firemen | When used to supplement the PF type, gives it wider range of usage |
| [illegible] | x | x | x | x | 58 | 15-voice 25-code | 150 | Field use where portability is not important | Requires less skill to operate than the PF receiver; has higher battery drain than PF; preferable to P and PF |
| M | x | x | x | x | 125 | 50 | 375 | Central Stations | Uses commercial current; plug in on any light socket |
| [illegible] | | x | | x | 50-100 | 100 | 130 | Stand-by operation | Limited to use in optical parts |
| [illegible] | | x | | x | 8 | 50 | 30 | Smokechasers fire bosses scouts | Unusual portability and quickly set up |
| [illegible] | | x | | x | 40 | | | Airplane use and two-way auto communication | |
| [illegible] | | x | | x | 300 | | | Central fire dispatcher office | Simplicity of operation |

[illegible]standing.

(c) Men with experience as radio or telephone operators are preferred to those without experience.

(d) Green men with office experience are preferable to those who have a smattering of technical knowledge.

(e) A sharp, clear, voice, an even temper, and speed with a pencil are splendid assets for the operation of a radio on a fire.

(f) Someone should be placed in charge of all communications work on a large fire, preferable one who has a firefighting knowledge as well as technical radio and telephone ability.

Although the radio has had its widest use in the Northern Rockies and Pacific Northwest, it need not be limited to those regions. The forest areas east of the Great Plains have utilized radio to only a limited extent. Because of his previous experience in radio work, Oettmeir (102) was able to adapt it to his [illegible] in fire control work on a 200,000 acre tract of forest land in the coastal plain country of the Southeast. Other eastern forestry agencies have recently commenced to exploit the utility of radio in fire control.

## TRANSPORTATION

For some regions consideration of a means of transportation is inseparable from a study of firebreaks. The importance of correlating the two depends upon the topography and the fuels.

In those regions where the topography is very rugged, it is doubtful whether firebreaks are of real value; they are essentially adapted to terrain which has no marked relief.

Firebreaks can easily shade into foot-rails, way trails, or truck trails, or a way trail can be used as the initial point of development for firebreak construction. Foot-trails can be converted into firebreaks with little effort; firebreaks, on the other hand, can serve as foot or truck trails.

In as much as any planned opening through the woods can be used for transportation as well as for fire-[illegible], it is somewhat difficult to define very clearly just what a trail is and what a firebreak is. [illegible] is constructed primarily for transportation purposes; the mode of travel is immaterial inasmuch as it may be by foot, saddle, or wheeled vehicle. Incidentally, a trail might also serve as a [illegible]. A firebreak is constructed primarily to impede the spread of fire; it is located at those [illegible] natural or artificial barriers are non-existent or need to be augmented in order to be effective in checking the spread, if a fire occurred there. Dependent upon the nature of their construction, firebreaks may be used for transportation purposes on general administrative work on the forest. If it is no longer used primarily for suppression purposes, a firebreak, which is used for travel, should be considered a part of the transportation system, and considered as a trail rather than a firebreak.

Whether an improvement is classed as a firebreak or as a trail is important from a financial standpoint. If a truck trail is justifiable because it serves the dual purpose of transportation as well as a barrier, expenditures for its development are surely much more justifiable than if its utility would be for one purpose only.

## TRAILS

Because modern fire suppression is based on low elapsed time between discovery and commencement of actual fire fighting, this means that a rapid mode of travel should be used. Truck trails, therefore, are designed to carry vehicles at a fair rate of speed. In other words, low travel time requirements justify the construction of a good transportation system.

There are a few regions in which it is cheaper to construct landing fields for planes and depend on them for long hauls for transportation of man-power, equipment, and supplies, than to construct a system of trails for speedy transportation. A specific illustration of this is eastern Montana where, in normal years, the hazard is very low; the forest areas, moreover, are scattered and, to make man-power quickly available by trails for fire-fighting throughout the region would require a considerable expenditure of funds for construction and maintenance of improvements for a hazard which develops at a frequency of once in several years rather than annually. The fuel types, moreover, are not of a nature demanding much man-power. A few landing fields will make transportation by air possible and eliminate the need for a permanent investment in a truck trail system. Way trails, supplementing the landing fields, are sufficient to take care of normal fire season man-power requirements.

### Trail Classification

The broad classifications used by the United States Forest Service (93) are as follows: (a) way (b) secondary (c) primary, and (d) truck.

THE WAY TRAIL is one over which a loaded pack animal may be taken safely. It is built primarily for foot travel for fire control purposes.

THE SECONDARY TRAIL is built primarily for pack animal travel, and so far as construction standards are concerned, is mid-way between those for way trails and primary trails.

THE PRIMARY TRAILS are those over which on an average more than one pack or saddle animal will pass per day during the field season.

THE TRUCK TRAILS are those constructed for administrative purposes and are designated as "trails" instead of "roads" in order to differentiate this type of transportation system from "roads" which are supervised by the Bureau of Public Roads.

Way trails are constructed in regions of extremely rough topography which result in a high degree of inaccessibility. They are most extensively used in western regions where, until recently, there was much "back" country which could not be reached by any means other than way trails. The primary and secondary trails are of considerable importance in fire control work but their use is not limited to fire control activity.

Standards of trail construction for the saddle or pack animal trails are relatively simple. The United States Forest Service Trail Manual (94-p. 16) states, "The object of the trail is to make certain of a passable route in the time of need." Grades should be confined to 15% or less except for short distances. Because way trails are not frequently used, they should be distinctly marked to minimize time lost in locating them during a period of a going fire. Treads are sometimes provided, but only 24 inches or less in width.

TRUCK TRAILS are annually playing a more important role in fire control because their construction permits motorized transportation which is an important factor in reducing hour control. They have to be scrutinized carefully (1) from the standpoint of where they should be located, their construction stand-

..., and construction and maintenance costs, as well as (2) from the aspect of whether they may be a ... factor in the increase in risk after they have been constructed.

... trails have been subjected to considerable criticism recently from the standpoint of Item 2 ... A particular case in point is the value of their construction in the Adirondacks. Lithgow ... has defended their construction from the standpoint of their contribution to fire control ... they facilitate man-power movement which would otherwise be extremely tedious in the "back" country. Marshall (96) seriously questions the value of the truck trail construction even from their merit for the movement of man-power, in periods of high hazard, to going fires. Marshall is of the opinion that they increase the risk far beyond their value from a presuppression and suppression aspect. ... doubt of the value of the one-way, single-tread type of truck trail, and even points ... the hazard is increased by opening the forest canopy causing the fuels to dry out along the truck trail edges and thereby making it doubly undesirable to have any movement of the public over the trails. With truck trail construction, he points out, the number of forest users will be increased, and even though they may not be permitted to operate private cars over the trails, they nevertheless some day may ... privilege.

... the same viewpoint as that expressed by Marshall is voiced by Dahlberg (97) who was formerly Conservation Commissioner of Wisconsin. His viewpoint is not so much from the fire control aspect, but rather from the effect truck trails have on game slaughter since areas which before had not been accessible and therefore, had served as a game refuge are opened to the hunting public.

... national forests, particularly in the West, formerly had vast areas of "back" country, accessible only by saddle and pack trails; these areas today are open to the public due to truck trail construction. In several national forests the risk has very definitely increased since the construction of ... trails. A case in point is the blueberry industry in the Northwest. Several national forests have a much higher risk today than several years ago because the commercial gathering of blueberries, which has increased tremendously with truck trail development, is coincident with the period of high hazard.

TRUCK TRAIL STANDARD CLASSIFICATIONS are based on (a) degree of permanence, (b) type of service required of them.

The degree of permanence is expressed in terms of (1) temporary, (2) permanent, (3) progressive development.

A permanent trail implies that it is or was constructed on a location which will not have to be altered with a change in use from a fire control to multiple-use road.

A temporary road means that the location may or will later be changed; it does not necessarily mean that the roadbed itself, the material used or its width, will not sustain a reasonable amount of traffic--at least for the purpose for which it was constructed.

Stage construction refers to locations which can be used, if, as, and when the standards are raised; many fills or cuts can be utilized in whole or part, but may have to be changed or refined in places.

When truck trails are constructed, the standards employed are dictated largely by the type of traffic which will use the trail. It is natural that a stub trail up a canyon should not require the same standards as in arterial trail which is fed by the stubs.

## TRUCK TRAIL SERVICE CLASSIFICATION (97)

A low service truck trail (3rd class) is one where 15 m.p.h. or lower speed requirements are met; 11%-15% is the allowable maximum grade.

A medium service truck trail (2nd class) is one which will permit speeds of between 16 and 20 m.p.h.; 9%-12% is the allowable maximum grade.

A high service (1st class) truck trail is one which will permit speeds in excess of 20 m.p.h. These trails constitute the backbone of the road system and are classed as primary; 6%-10% is the allowable maximum grade.

The low service truck trails are all single track; the high service trails are frequently double width, but not necessarily so.

Single tread roads vary in crown width from 10'-12'; double width from 16'-18'.

Those factors which contribute to the type of service a trail is capable of withstanding are as follows: (a) width, (b) alignment, (c) gradient on tangents, on curves, on bridges, (d) radius of curves, (e) surface, (f) curve banking, and (g) fills and cuts.

### Bridges and Culverts

Whether a structure spanning a drainage ditch or a stream is a "bridge" or "culvert" is based purely on the length of the structure. The width is referred to as the distance parallel to the direction of the stream flow. A culvert is 10' or less in length while a bridge is more than 10' in length.

There are several types of bridges dependent on the construction principles employed. The most common types used on forests are: (1) mud sill, (2) piling, (3) low water, (4) king post truss, (5) multiple truss and (6) suspension.

The first three classes are utilized where the span need not be excessive, i.e., where bents can be constructed frequently. The types 4, 5, and 6 are used when topographic conditions do not permit short spans, 25' or less.

The parts of a timber bridge are (a) hand rails and wheel guards, (b) decking, (c) stringers, (d) caps, (e) piling, (f) mud sills, and (g) cribbing and abutments.

A "bent" is a unit made up of piling, mud sill, and cap on which the stringers rest.

## FIREBREAKS

Firebreaks are improvements which are generally constructed in anticipation of the occurrence of fires; they function (1) as a point from which to backfire, and (2) as a barrier which will automatically stop the spread of fires. Because they are in most cases constructed by heavy-duty equipment which is not very mobile, they are seldom built at the time a fire is raging.

The nature of the construction is rather varied. One type consists of exposing mineral soil which is non-inflammable. The other type is known as a shaded break. To date, by far the most commonly used break is the one which exposes mineral earth. Several agencies have recently begun to use, in a limited way, the shaded break, but its use is still in the experimental stage and results have been somewhat inconclusive. It is possible that a combination of the two may prove to be of greatest advantage.

Mineral firebreaks are constructed by removing the fuels down to mineral earth either by grubbing, burning, plowing, or scraping.

The width of the break varies from a single narrow strip not in excess of 1' to 150', dependent upon the hazard and fuel type.

In some regions, where the fuels vary with the vegetative type, and where the forest type lines are so distinct as to be almost abrupt, breaks have been constructed parallel to the type lines in order to prevent fire from passing from one fuel with low resistance to control, to another with high resistance to control. Fires are known to start more readily in some fuels than in others, but the rate of spread and the resulting damage may be entirely different, dependent on the fuels.

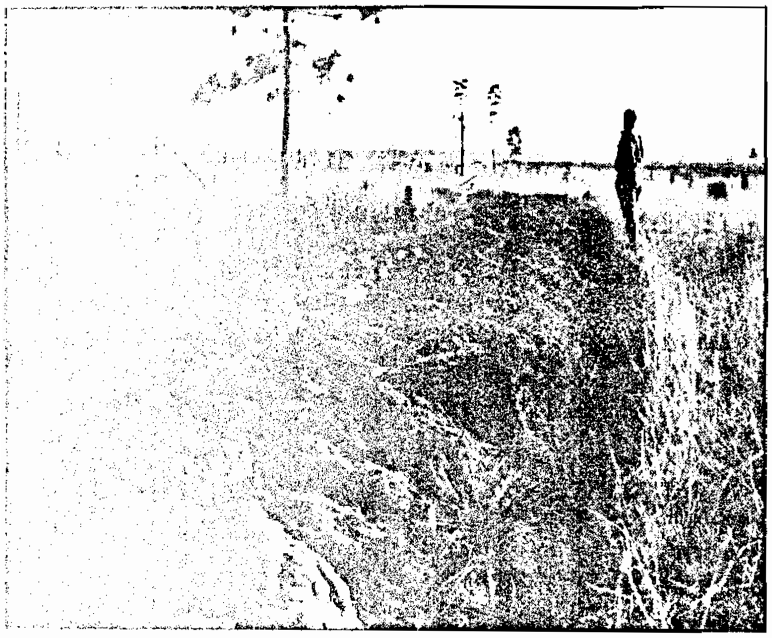
### The Ponderosa Way

Today California boasts of the "longest firebreak in the world," 650 miles long, known as the Ponderosa Way. Price (98) states that the firebreak was constructed to prevent fires from spreading from the grass land, woodland, and chaparral of the lower valleys where the rate of spread is high, control easy, and damage to timber values low, to the ponderosa pine type where the rate of spread is slower, control more difficult, and the timber values higher. The hazard of the grasslands and woodlands is extremely high during the fire season. Fires which start spread uphill toward the ponderosa forest type. The Ponderosa Way will stop some fires automatically, but its chief use is to enable firefighters to backfire against the rapidly spreading fires from the grasslands.

The break has been constructed under the forest canopy in order to utilize the principles advocated for the shaded firebreak. For a width of 50 feet to more than 200 feet in some places, the ground fuels [illegible] removed. By preserving the canopy, construction as well as maintenance costs are relatively low. The [illegible] of occurrence of crown fires developing, which would take the fires over the break [illegible], is low, since the break is on the edge of the forest type, and the ground fuels, which [illegible] fire into the crowns, have been removed. The width of the break is determined by the forest cover [illegible]

## Regional Application

[illegible] of firebreaks varies considerably by regions; its use in all regions is increasing, [illegible] acceleration varies. In the Southeast where, by virtue of soil and topography, fire[illegible] are [illegible] constructed, a forested area can be readily broken up by numerous breaks. Here thou[illegible] of [illegible] firebreaks have been constructed.



[illegible]

Figure [illegible]

[illegible] Coastal Plain 10-Foot Plowed Firebreak

In the more rugged, rocky regions, firebreaks are utilized with much less frequency because of the cost entailed for construction and maintenance.

Some forest fire executives are of the opinion that firebreaks should be "automatic" to be of any real value. By automatic is meant that a fire will be stopped when it butts up against a break because of lack of fuel to carry it on. For California, Price (37) is of the opinion that firebreaks are of value under two conditions: (1) in localities where the values are high, and (2) to prevent conflagrations by placing the breaks on lines which separate one watershed from another. For fuels which have an extreme rate of spread, such as in chaparral lands, breaks are of little automatic value and their value diminishes as the region becomes more inaccessible, unless they are automatic.

Because firebreaks are used more commonly in the Southeast than in any other region, agencies in this area have [illegible] experimented in their construction. When fire breaks were first employed, they were gener[illegible] by burning between two parallel furrows; the width of the break between them varied from [illegible] expense of burning these widebreaks, together with the hazard entailed, caused their [illegible] were replaced with plowed breaks which have found rather general favor, depending on [illegible] the results produced by the equipment utilized. The plowed breaks require reworking annual[illegible]

[illegible] width of the plowed breaks is 7' - 10', dependent on the plow. These breaks are generally referred [illegible] "random" in that they can be constructed without clearing a right-of-way. Wide breaks, [illegible] require clearing which entails considerable capital outlay and are therefore more expensive [illegible] than the narrower, random breaks.

[illegible] of a firebreak depends on the thoroughness of planning for location and the efficiency of [illegible]. Breaks are sometimes plowed parallel to roads to eliminate roadside fires; the [illegible] is open to question. A consideration of roads is sometimes ignored entirely and [illegible] are followed. When contour lines are followed in the Southeast, it frequently amounts [illegible] forest type boundaries. A break is most effective when it does not cross sloughs, streams, [illegible] systems. In other words, the more closely it conforms to or parallels contour lines, [illegible] it is.

The intensity of a firebreak system is generally a balance between risk, hazard, and value protected. The unit of smallest size with any general use is 10 acres. From this size, it diverges upwards into units of 40, 160 and 640 acre and larger units.

On some national forests in the Southeast, the plowing objective is 40 acre blocks. The ultimate objective on private lands will probably be 160 acre blocks, especially when Civilian Conservation Corps aid is abandoned and the owners are compelled to maintain their improvements out of their own resources.

Maintenance of firebreaks is a matter which requires consideration inasmuch as it is extremely costly — frequently being between 50% and 80% of the original cost of the break; it is considerably less, however, where right-of-way clearance is a part of the original cost. Random firebreaks cost approximately $2.50 per mile to construct. Adequate maintenance requires replowing or reburning the break each year or at the longest, every two years.

There is a modification of the plowed break known as the "carpet grass break." This is created by seeding the firebreak with carpet grass on the moister sites and centipede grass on the drier sites. The theory behind the seeding is that cattle grazing in the woods will keep the forage grazed closely. Although a fire may hit the break, it is slowed up to a point where it can be readily controlled inasmuch as the grass is always green except for the three winter months. The effectiveness of the seeded break depends on the amount of grazing; where well-cropped, it is effective; where not closely grazed, it is considerably less effective than when plowed annually. These breaks, moreover, are supposed to reduce maintenance costs considerably, although no information is at hand to support this premise. Another fallacy of the efficiency of the forage grass break is that the break is not green in February when it is most needed.

### Shaded Firebreaks

Gisborne (99) has pointed out that shaded firebreaks might be a desirable type in large areas which have been clear-cut. Forest cover has a definite effect upon atmospheric conditions under the canopy. This in turn affects the moisture content of the fuels. Strips of green timber would probably serve to raise the humidity, lower temperature, cut down wind movement, reduce solar radiation. All of these factors would increase the moisture content of the fuels; this would be of material assistance in using the evergreen strips as a point from which to backfire. An eastern state has for several years constructed shaded breaks, built alongside highways and truck trails. The hardwood canopy has not yet gotten sufficiently dense to crowd out all herbaceous growth. To eliminate the fuels, therefore, the breaks are either hand-mown or burned annually. As the hardwood canopy becomes denser, it is assumed that the maintenance costs will become less due to the presence of less herbaceous growth.

## Chapter X

## FIRE CONTROL PLANNING

## or

## THE INTEGRATION OF CAUSE, HAZARD, IMPROVEMENTS AND MAN-POWER

The purpose of the integration is to obtain minimum losses in forest values and a maximum return from investments in improvements which have been constructed for the purpose of providing protection to the forest values.

The fire control activity which falls under this heading is essentially concerned with the location, installation, and manning of improvements which will contribute toward the reduction of losses due to fires. Much effort is today being expended toward producing planning technique to make fire control expenditures more effective than they have been in the past. Lookout towers can be placed to better advantage, trails can be located where the risk is highest, and communications systems can conform to current needs which have outgrown the conditions for which the original communications were designed. In this manner, the planning of pre-suppression work makes possible better fire control.

Even though fire suppression technique were perfected to the point where, with the arrival of a crew, the fire would be controlled within thirty minutes, there still would be no assurance against excessive losses due to lack of provision for detecting a fire while in its incipient stage. The larger the fire, the greater the loss and the greater the cost of suppression. The objective of fire control is the reduction of loss, not essentially the corralling of fires; this procedure is merely incidental to the [illegible] of loss reduction.

In order to control fires so that the loss will be small, it is necessary to definitely limit the area burned. To keep the size of the average fire low, the fires must be detected within a short period after inception and man-power must arrive on the job within limits determined by the degree of fire danger [illegible].

### CAUSES

The classification and discussion of individual causes has been covered in Chapter III. In the formation of protection plans, however, it is important that consideration is given to individual causes. If [illegible] of the fires are caused by lightning, the detection, communication and transportation facilities must be scattered with a certain degree of uniformity throughout the area protected. If the causes are produced by man, and 60% are due to railroads, 30% to campers, and 10% miscellaneous, the lookout points should be arranged so that they will give intense coverage to those areas where the accumulated records show the hot-spots to be.

### Fire Seasons

The various forest regions of the United States have individual fire seasons determined entirely by climatic and fuel conditions. As shown in Table 30, which is the basis for the graph on Figure 26, peak loads are seasonal. For those areas east of the Mississippi River, the peak loads occur in spring.

The peak loads in the western regions occur during the summer months. In the Pacific Northwest, the Northern Rockies, and California, the fire season reaches its climax in July and August. In the Southwest, the fire season falls off abruptly after July. In the Northeast, the peak of the season at the lower altitudes is in April; in New York, in the more populous areas, a sharp peak is attained in April. In New Jersey, however, the peak is much flatter; this creates a longer fire season in the coastal plain and piedmont areas with an almost equal risk in March, April, and May. In the hardwood, mountain area of the state, however, the spring peak is much sharper, with 43% of the fires occurring in April in contrast to [illegible] for the balance of the state. There is, moreover, a fall season in the hardwood region. In the fall months, 17% of the fires start in the hardwood region as against 9% in the coastal plain pine area. In Florida, a flat peak is reached in March, but the fire season commences in December when 11% of the fires

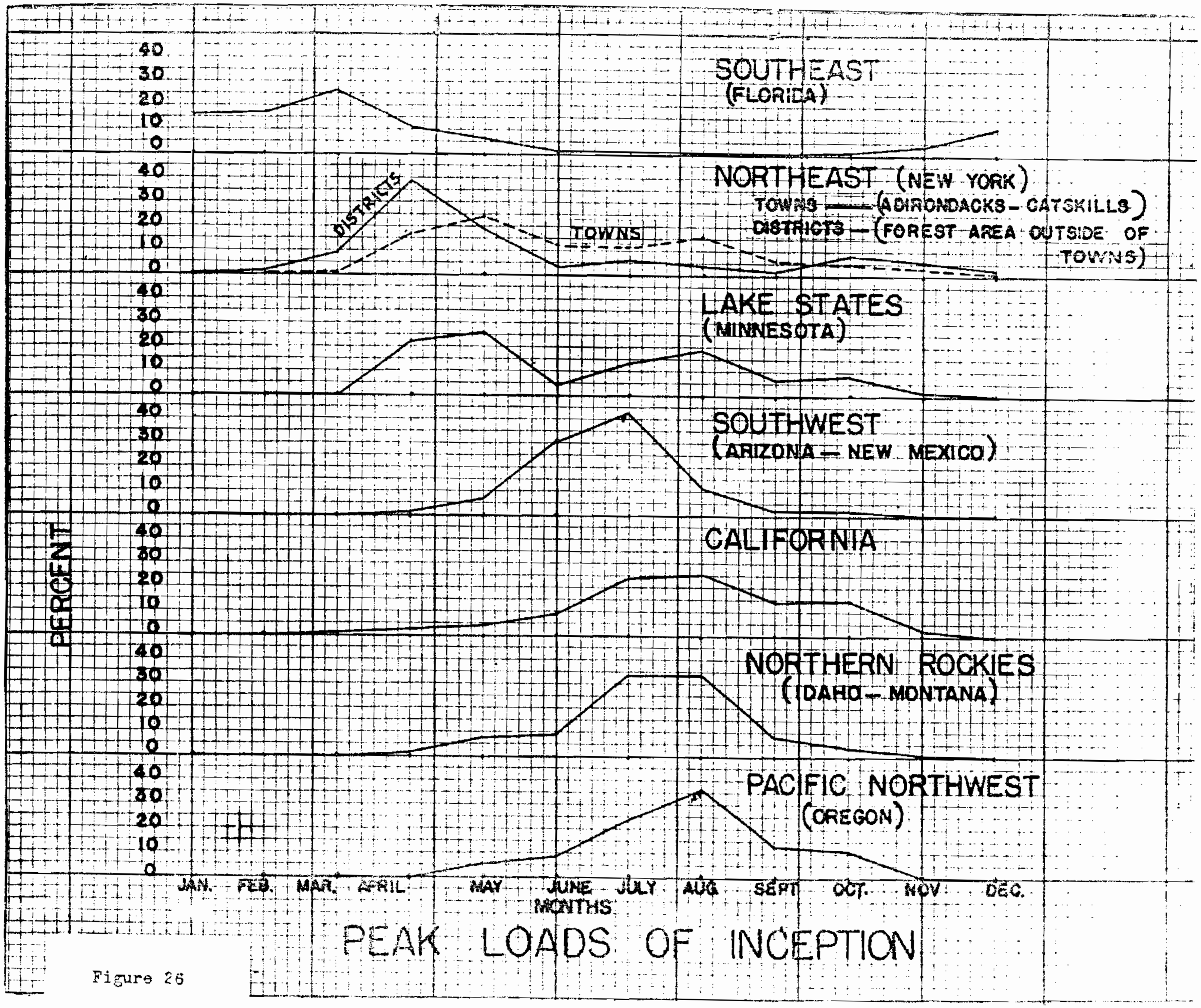

PERCENT
40
30
20
10
0
SOUTHEAST
(FLORIDA)
NORTHEAST (NEW YORK)
TOWNS —— (ADIRONDACKS - CATSKILLS)
DISTRICTS -- (FOREST AREA OUTSIDE OF TOWNS)
DISTRICTS
TOWNS
LAKE STATES
(MINNESOTA)
SOUTHWEST
(ARIZONA — NEW MEXICO)
CALIFORNIA
NORTHERN ROCKIES
(IDAHO — MONTANA)
PACIFIC NORTHWEST
(OREGON)
JAN.
FEB.
MAR.
APRIL
MAY
JUNE
JULY
AUG.
SEPT.
OCT.
NOV.
DEC.
MONTHS
PEAK LOADS OF INCEPTION

Figure 26

time. In contrast to the Northwest where the summer months are coincident with the greatest risk, forest fires are almost absent at that time in the Southeast.

### Location

The whole objective of forest fire control is to reduce or eliminate the damage done by uncontrolled forest fires. If there are accumulated data which show that fires are more liable to occur in several zones than in others, it naturally follows, other factors being equal, that a high investment in presuppression and suppression devices is justifiable where the risk is high; less investment is needed where the risk is low.

**Table 30**

FIRE SEASON OCCURRENCE BY REGIONS

| Month | Southeast | Middle Atlantic | | | | Lake States | Pacific Northwest | Southwest | California | Northern Rockies |
|---|---|---|---|---|---|---|---|---|---|---|
| | Fla. | Mts. of | | Level Topo | | Minn. | Oregon | Ariz.-N. Mex. | | Ida.-Mont. |
| | | N. J. | N. Y. | N. J. | N. Y. | | | | | |
| Jan. | 16.1% | 1.7% | 0.3% | 2.1% | 0.7% | ... | ... | ... | 0.1% | ... |
| Feb. | 16.8 | 0.6 | ... | 2.6 | 1.4 | ... | ... | ... | ... | ... |
| Mar. | 27.3 | 14.5 | 1.13 | 20.2 | 9.2 | ... | ... | ... | 1.4 | ... |
| Apr. | 11.8 | 43.5 | 18.7 | 28.3 | 37.8 | 22.4% | ... | 1.6% | 2.0 | 1.6% |
| May | 6.6 | 17.1 | 26.2 | 21.4 | 19.2 | 25.8 | 5.6% | 7.0 | 4.9 | 7.9 |
| June | 2.2 | 0.9 | 9.8 | 5.9 | 3.2 | 4.5 | 8.1 | 30.8 | 9.8 | 9.0 |
| July | 1.1 | 0.6 | 12.6 | 5.2 | 6.2 | 14.5 | 24.4 | 43.2 | 23.7 | 33.6 |
| Aug. | 0.7 | 0.6 | 14.6 | 2.5 | 3.5 | 18.9 | 37.6 | 12.1 | 25.5 | 34.4 |
| Sept. | 0.2 | 0.3 | 5.5 | 1.4 | 2.4 | 5.8 | 13.5 | 2.2 | 14.4 | 8.2 |
| Oct. | 1.5 | 4.9 | 7.3 | 2.6 | 7.9 | 7.8 | 10.8 | 3.1 | 15.1 | 4.5 |
| Nov. | 3.7 | 12.8 | 3.1 | 6.6 | 5.6 | 0.2 | ... | ... | 2.6 | 0.8 |
| Dec. | 10.3 | 3.6 | 0.7 | 1.4 | 2.6 | ... | ... | ... | 0.5 | ... |

REFERENCES

| Region | Number of Fires For Period | Years | Approximate Acreage Protected | Agency |
|---|---|---|---|---|
| Southeast | 4418 | '29-'30; '32-'33; '35-'36 | 1,100,000 | Florida Forest Service |
| Middle Atlantic | 1117 | 1923-1927 | 1,900,000 | New Jersey Forest Service |
| | 10,907 | 1931-1935 | 16,980,000 | N. Y. Division of Forestry |
| Lake States | 6,635 | 1933-1934 | 21,360,000 | Minnesota Forest Service |
| Pacific N.W. | 1137 | 1932-1936 | 3,759,000 | 3 Oregon National Forests (R-6) |
| Northern Rockies | 798 | 1932-1936 | 3,261,000 | 3 national forests, Idaho, Montana (R-1) |
| Southwest | 479 | 1932-1936 | 5,402,000 | 3 national forests, Ariz., N.M. (R-3) |
| California | 2573 | 1932-1936 | 5,115,000 | 3 national forests, Northern Cal. (R-5) |

**Table 31**

RELATIVE ORDER OF IMPORTANCE
TIME OF DAY AND FIRE INCEPTION

NEW JERSEY, 1924-1926

| Frequency Rating | Percent | A.M. | P.M. | Frequency Rating | Percent | A.M. | P.M. |
|---|---|---|---|---|---|---|---|
| 1. | 14.2 | ... | 1-2 | 7. | 7.4 | 9-10 | ... |
| 2. | 12.3 | ... | 2-3 | 8. | 7.4 | ... | 4-5 |
| 3. | 11.7 | ... | Noon-1 | 9. | 3.2 | ... | 5-6 |
| 4. | 11.1 | 11-Noon | ... | 10. | 2.4 | 8-9 | ... |
| 5. | 10.6 | ... | 3-4 | 11. | 5.9 | ... | 6-mid't. |
| 6. | 10.3 | 10-11 | ... | 12. | 2.3 | Mid't.-8 a. m. | ... |

Several methods are available for the determination of risk location. One means is to locate on a map the points where fires have started over a period of years, preferably of duration of seven or more; ten years is the figure frequently used. This will produce an ocular means of locating areas of high risk. The risk frequency can also be determined mathematically by zoning the area and determining the relative importance of the several zones. Either method will produce the same results, i.e., learning the location of those areas which demand considerable protection because of the probability of the occurrence of fires.

### Time of Day

If the pyrosity of the fuels were constant and human activity of equal intensity throughout the diurnal period, the curve of fire inception would be almost a horizontal flat line. With the fuel pyrosity and human activity both increasing from dawn to noon, the fire danger mounts because the hazard and risk both undergo acceleration. The period from 10:00 a.m. to 4:00 p.m. is the peak.

Figure 27 is a graph of the inception of fires for the fire season 1924-26 for New Jersey and for 1923 for Minnesota. There is considerable coordination of the curves of inception because the fires, with the exception of 10% of the total number in Minnesota, are due to human agencies.

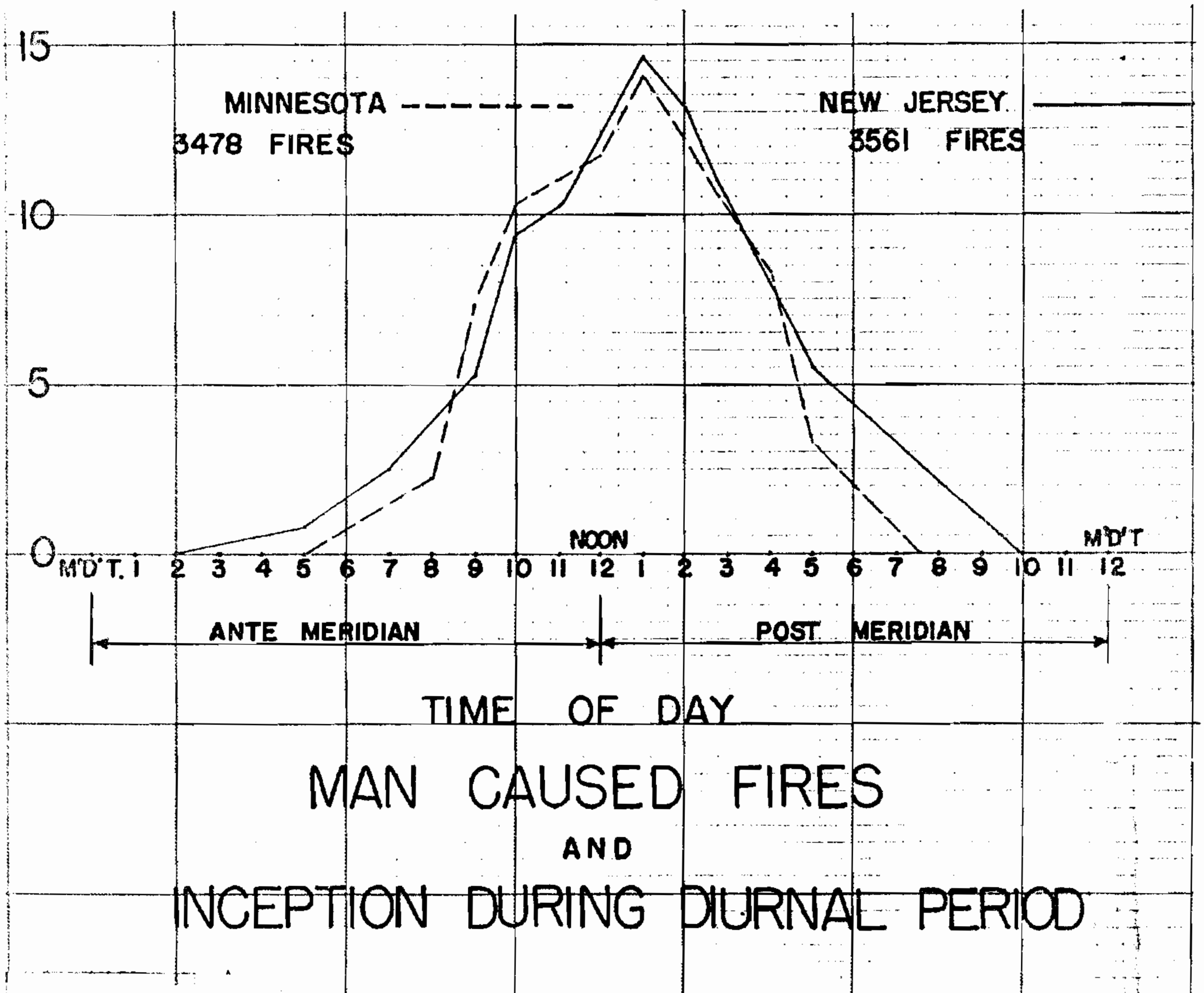



Figure 27

and [illegible] both undergo acceleration. The period from 10:00 a.m. to 4:00 p.m. is the peak.

## HAZARD

The rate of spread and resistance to control are determined by the fuels, wind velocity, and slope; these factors, in association with each other, constitute forest fire hazard. The percent of slope and some of the physical factors of the fuels, such as their size, thickness, arrangement and state of decomposition are constant. The combustibility of the fuels, as determined by the moisture content, and the wind velocity are variables; the more important of these is combustibility which fluctuates over a narrower range within short periods of time than wind velocity. Combustibility may increase steadily over a period of twenty-one or more days; with wind velocity, however, there may be a maximum of 15 m.p.h. on one day, 5 m.p.h. the following day, and 10 m.p.h. on the third day.

### Fuels

Of the factors enumerated above, fuels contribute such a large share of determining the hazard that much of the planning work which has been done to date has been in connection with them.

As indicated previously under the discussion of fuels in Chapter IV, they can be classified concerning their importance in suppression work, i.e., their rate of spread and resistance to control. Those fuels which have an LL rating certainly do not demand the investment in improvements that EE or HH fuels require.

### Slope

Inasmuch as slope is also a factor which contributes toward the rate of spread, it has to be accounted for. The rate of spread of a given fuel type may be only M with a 10% slope, but if the same fuel conditions exist on a 40% slope, the rate of spread will be higher; this will produce increased fire danger.

### Speed of Attack

Whether a fuel has an M, H, or E rating for rate of spread will influence the amount man-power which should arrive on the job within a given amount of time in order to control the fire before it is able to make a "run". Travel time is a variable element which can be adjusted to meet the control requirements of any fuel type. In order that travel time requirements for various fuels may be calculated, tables have been compiled by Hornby of the Northern Rocky Mountain Region for the allowable amount of time between discovery and actual control, rate of perimeter increase, and rate of construction of held line for initial action crews which generally consist of one man in that region. The calculations however, have been worked up for initial action crews of less than four men. The formula which Hornby has prepared for calculating travel time, with the above as the known elements, is discussed later under "Transportation."

**Table 32**
SMOKECHASER TRAVEL TIME* REQUIRED FOR INITIAL ATTACK WHEN BURNING CONDITIONS ARE AVERAGE

| Rate of Spread | Fuel resistance to control | | | |
|---|---|---|---|---|
| | Extreme | High | Medium | Low |
| Extreme | 0.75* | 0.75 | 1.50 | 1.50 |
| High | 0.75 | 1.50 | 1.50 | 2.50 |
| Medium | 0.75 | 1.50 | 2.50 | 3.75 |
| Low | ... | 2.50 | 4.50 | 5.25 |

*Travel time expressed in hours or fractions thereof.

The curves in Figure 28 indicate that for the general run of fires with a low rate of spread there will be probably a perimeter increase of two chains per hour; a few will increase their perimeter at the rate of 10 chains per hour; a very small number in the low-spread fuels will increase at 20 or more chains per hour. The rate of spread is influenced, in addition to physical characteristics of the fuels, by slope and fuel dryness. The curves were drawn from data obtained from approximately 8800 fires which occurred in the several forest types with cut-over lands representing the highest rate of spread and white fir and spruce the lowest.

In the determination of the fixed or constant hazards for a forest area, a reconnaissance must be made to map the fuels on the basis of their effect on the rate of spread and resistance to control.

## DETECTION

The work of planning the location of observation points covers two phases; (a) the one is concerned

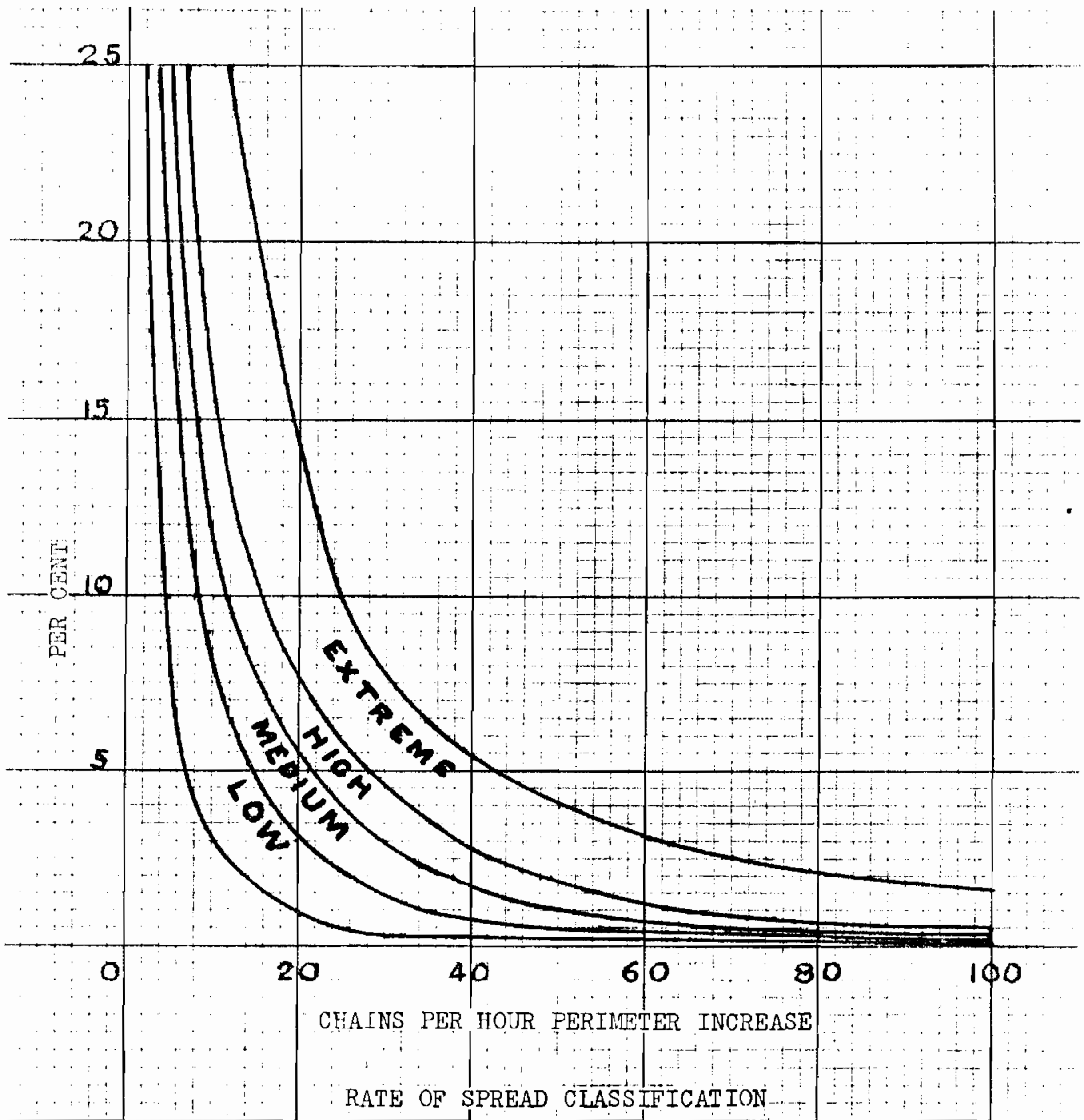



Figure 28 Northern Rocky Mountain Region, U.S.F.S.

with the location of lookout points for an area which has not been previously protected; the other, (b) is for the purpose of revising the system which exists currently but which has been out-moded because of an increase or decrease in risk, hazard, or funds available for protection.

Because considerable investment must be made in the installation of lookout points and trails which service them, the location planning demands conclusions arrived at on the basis of a thorough study of the problem. Trails are constructed as a service to the lookout points, i. e., to facilitate the movement of man-power for fire control purposes, consequently their location should be subordinate to the requirements of the lookout points. The quick detection of fires demands the location of lookouts at those places where this can be accomplished. There is seldom little doubt, after a study of the matter, whether Point A has better coverage than Point B. If Point A has superior advantages to Point B for quick detection and direct coverage, then A should be selected even though it may be easier or cheaper to construct a trail to B. On the other hand, if points A and B are equally effective as lookout points, that site should be selected which will give consideration to other items such as use for utilization or recrea-

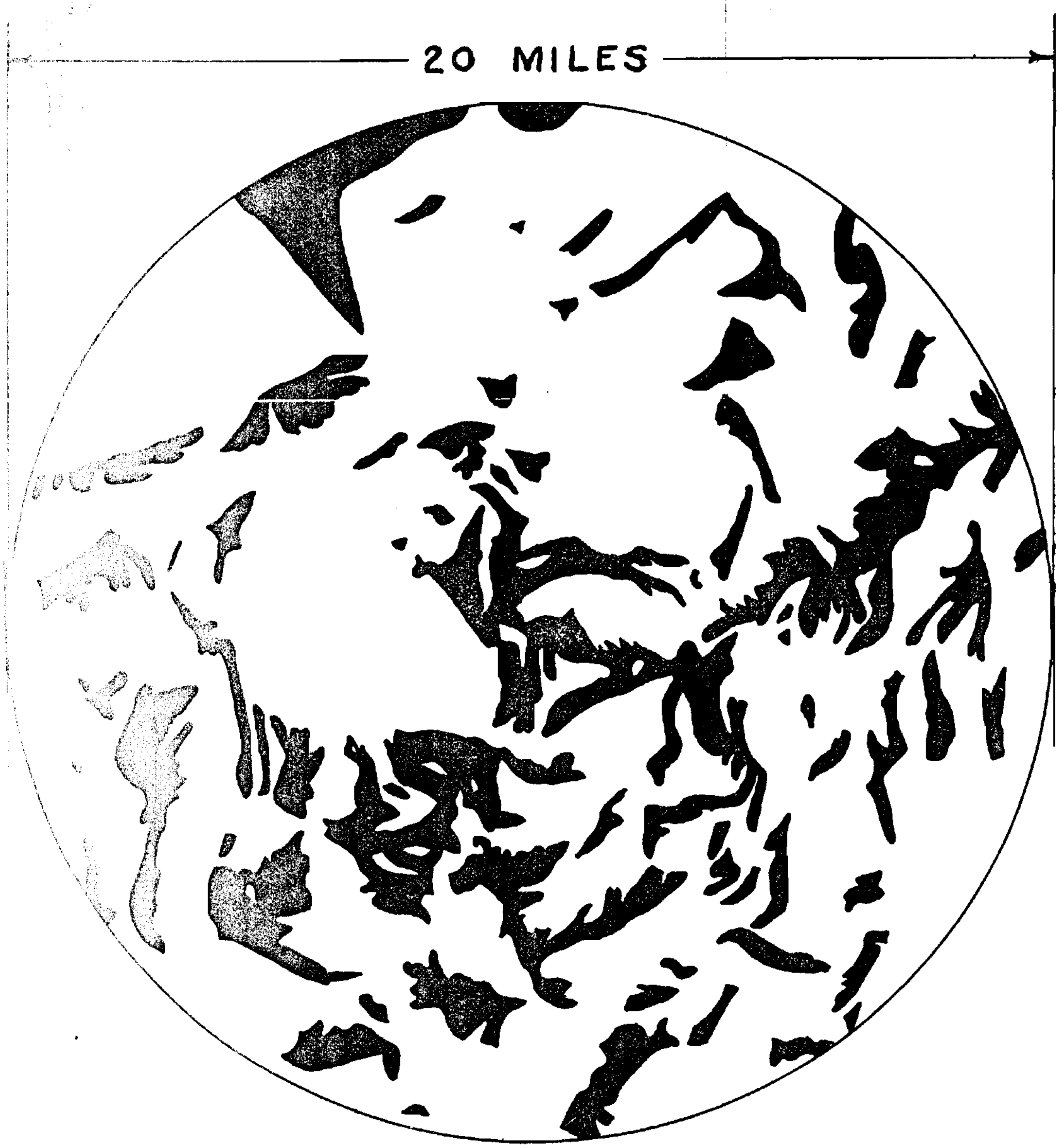



Photo by U.S. Forest Service

Figure 29

SEEN AREA MAP

The colored area is directly visible from the cabin of the 40' tower. Of the total area within the 10-mile radius circle, 20.9% is directly visible from this point, or almost twice the area visible from a near-by point illustrated in Figure 30.

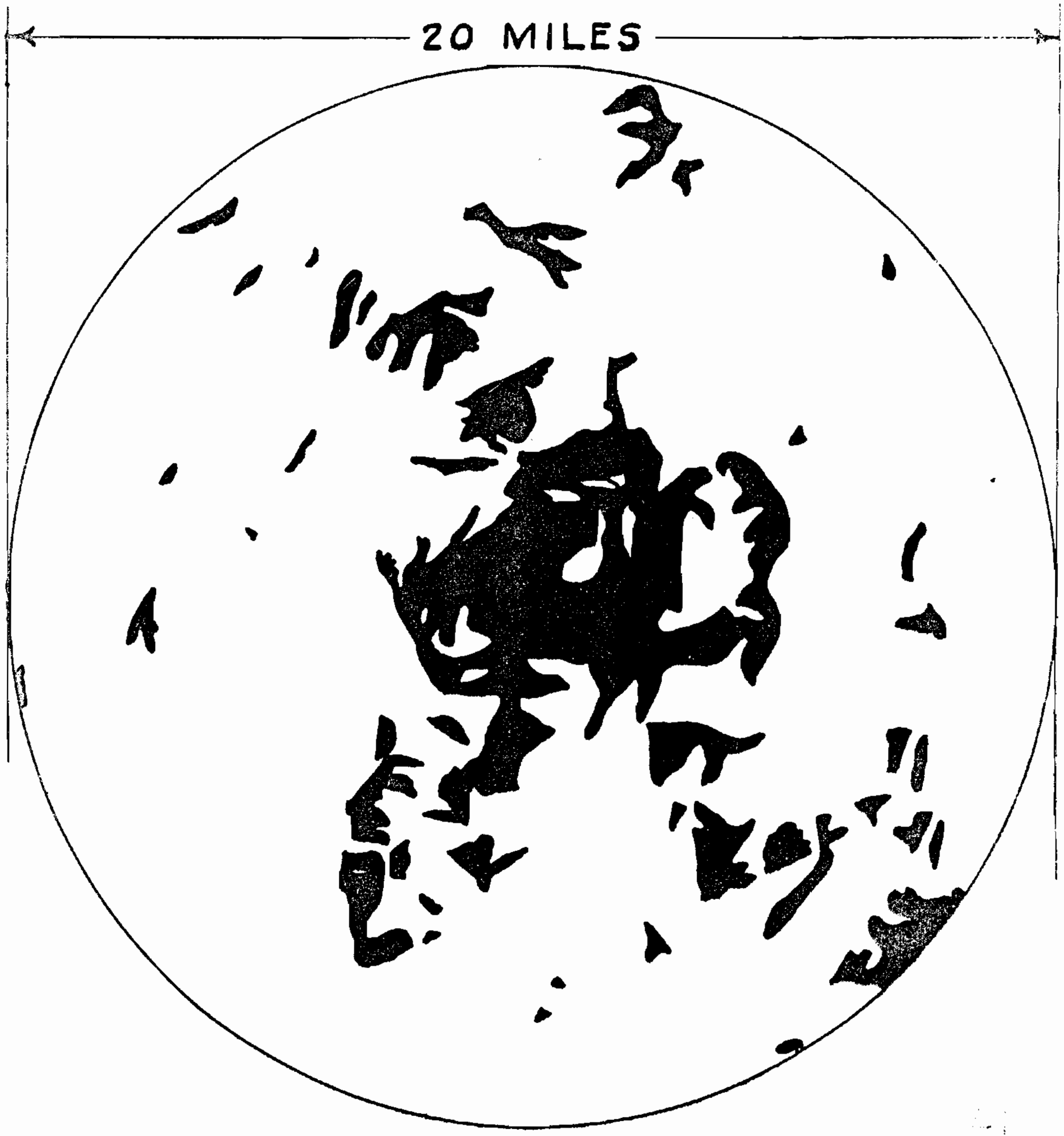



Photo by U.S. Forest Service

Figure 30

There is 12.8% of the area or 25,736 acres, directly visible of the 201,062 acres within the 10-mile radius. The seen-area from this point, or 25,736 acres, is considerably less than the 42,022 acres seen from another point, six miles SSE, illustrated in Figure 29.

signal purposes.

### Density per Unit Area

The lookout density per million acres is determined by the risk and hazard. Hornby (85) has shown that for the Northern Rocky Mountain Region, where lightning contributes a large percentage of causes and where the hazard is sometimes extreme, 30 stations per million acres provide the highest rate of efficiency; with densities greater than this, there will be rapidly diminishing returns. For regions where the fires are caused chiefly by man and concentrated in rather definite areas, the lookouts should be established at a density greater than 30 per million; where the risk is low, the density should be less than 30 per million. These data as compiled by Hornby are pertinent to the Northern Rockies; for other regions the density would probably vary.

For the rough topography of the Northern Rockies, when 75% of the coverage provided by the detection and cross-shading overlays was produced, 25% was scattered and assumed curious shapes. Coverage in excess of 75% gave rapidly diminishing returns. Also, when 50% of the seen-area is covered, overlapping with other lookouts results and when 80% is reached, the remaining 20% is scattered among small areas. Approximately 800 points per million acres would have to be manned to obtain 100% coverage in rough topography, while 50 points cover 75% to 89% of the 1,000,000 acres.

Technique for the planning of a lookout system has been prepared by the Eastern Region (R-7) of the United States Forest Service. In their discussion of the technique, Abell and Beeman (99a) state that the first step is to prepare visible area maps for 65 to 85 potential lookout points per million acres. This large number is recommended in order that secondary points as well as primary points may be established.

Figures 29 and 30 were prepared from visible area maps made in connection with the lookout system planning work conducted by Abell and Beeman in the Southern Applachians. It is desirable to point out that the percentage of area directly visible from the lookout point for the 10 mile radius is relatively low: [illegible] for the Rich Mountain point, and only 12.8% for the Slaty Knob point. Close examination of the maps, however, will show that when visibility is low, Slaty Mountain will be a more effective lookout point than Rich Mountain for the reason that within a five-mile radius there is a larger percentage of area directly visible to the lookout. Periods of high hazard are very frequently accompanied by low visibility, so in the selection of the more desirable point, visible area only considered, Slaty Knob is the better point. There are other factors to be considered, however, such as danger zones, based on inception frequency and fuels, effective visibility radius based on haze meter readings, as well as seen-area maps. A method of computing the relative value of the several lookout points based on the above factors, has been formulated by Abell and Beeman (99a).

### Smoke Chasers vs. Firemen

In the early period of forest fire protection in the western regions, it was considered good practice to locate observers on the tallest mountains. High altitude was assumed to give maximum detection service. The lookout points were scattered at a low density per million acres, and the suppression work was done by smokechasers who were quartered with the lookout or might have been located in a near-by valley. When it was found that altitude was not closely correlated with low detection time, the "fireman" system was introduced. With the use of firemen, the man-power would be spread out more thinly over the same area, and detection and travel time lowered so that hour control standards could be raised. The use of the fireman system however, is based on the premise that one man can successfully take initial action and corral the fire while it still is in the class "A" size.

## TRANSPARENT OVERLAYS FOR AFFECTING COORDINATION

For the coordination of the areas of high risk, high hazard, and good detection coverage, transparent overlays are used. The overlays are constructed of transparent material on which have been shown with solid tinting the part of the area which is seen direct from the lookout point; the clear part represents the "blind spots." If an area of high hazard or high risk can be seen through the transparent overlays, it [illegible] that an undesirable lookout point has been chosen.

In the systems discussed by Hornby (85) and Abell and Beeman (99a) there was available for each lookout or potential lookout point, a seen-area map. In a process of trial and error by fitting seen-area or visibility maps over the fuel and risk maps or by computation, those lookout points which afford the best coverage for areas of high risk and hazard can be selected. If by this procedure, improved points show up poorly in comparison to unimproved points which produce a much better coverage, abandonment of the old point may be justifiable.

### Disadvantage of Panoramic Views

As has been pointed out previously, the United States Forest Service conducted its original fire control work with considerably less money and experience than it has at its disposal today. As more funds gradually became available, more improvements were added. In the case of lookout points, the original selections were merely supplemented; this meant, however, that if the original point was actually poorly located, by using it as a focal point for additional locations, the error would be transmitted and magnified if the point was used as a base in the selection of additional lookout sites. The California Region has recognized the existence of poorly located lookout stations with the result that the whole matter of location of lookout points has been reviewed and analyzed. After the analysis of location was made, it was found that many lookout points which afforded excellent panoramic views were in reality inefficient from the standpoint of meeting the requirements of observation points, mainly based on seen-area within limits of effective visibility.

Brown (91) based his study of effectiveness of location of lookout points on some of the California National Forests on a definite plan. The high points of the analytical procedure are outlined below.

1. The area studied was first analyzed as to risk; zones were established on this basis.
2. Each risk zone was broken up into groups based on four classes of risk, or frequency of inception.
3. Seen-area maps were made for each lookout point.
4. The number of acres in each risk zone multiplied by the average annual risk for ten years produced the index of the importance of the specific lookout in question.

Under the system outlined above the nature of cause, area seen, and risk were the only factors considered; hazard was not included because, according to Brown, there was seldom an important variation in the fuels of two closely competing lookout points.

## Transportation

One of the earliest attempts at transportation planning has been discussed by Show and Kotok (39) for California in a publication on the subject. The idea of incorporating the transportation item as an element contributory toward reducing hour control time was refined by Norcross and Grefe. As stated by Norcross and Grefe (90), the objective of transportation planning is a transportation system which will deliver man-power for fire fighting to any of the area under protection within the limits of travel time allowed for the fuels in which the fire is burning and at the least annual cost per unit area.

### Determination of Travel Time

The study of fuels, as discussed under that heading, involved the determination of the rate of spread in terms of chains of perimeter increase of a fire in low, medium, high, and extreme rate of spread fuels. By knowing what the rate of spread of fire in a given fuel type is going to be under "average" burning conditions, and assuming that the detection, communication, and get-a-way elapsed time standards are complied with, an estimate can be made of the maximum amount of time which can be allowed to the suppression unit which is supposed to make the initial attack. For the purpose of this immediate discussion, it will be assumed that the initial attack will be made by a fireman inasmuch as this type of planning work has had greater use in the West than in any other regions. The fire-fighting capacity of the average firemen or initial attacker is known; in other words, his ability is measured in terms of chains of fire perimeter he can control in an hour under low, average, and high hazard burning conditions. It is the combination of these two factors, (a) the rate of spread of the fire in a specific fuel type, and (b) the control capacity of the fireman, which determines the speed with which he must arrive at the fire. If the fireman must travel over a way-trail on foot, the amount of time required to arrive at his destination point is going to be considerably greater than if he is able to reach the same point by means of an auto via a truck trail. A decision will have to be made, therefore, whether it would be more economical to add another fireman to the area or construct a truck trail whereby the hour control time could be reduced so that the initial attack could be made within the control time requirements.

### Transportation Facilities and the Time Factor

The question which continually confronts persons engaged in fire control pre-suppression planning is time. If a suppression unit which is mounted on a wheeled vehicle can travel four times as fast as a man who is compelled to travel by foot, the area of a specific fuel type which the mounted person can cover is somewhere between three and four times as great as that which the person who must walk can cover. It must be recognized that the wheeled vehicle will not always deliver to the line of fire the unit taking the initial attack; some walking is generally required. Figure 31 illustrates the point made above in that, with no trails available, travel time for a given distance in each direction is approximately equal; with a truck trail over which a car may be operated, running in one direction from the point of departure, the area which can be covered within the desirable time standard can be enlarged; with several foot and truck trails, the area which can be covered is greater than with only one.

With a base map of fuels, a tabulation of rates of spread for each of the fuels, and an overlay of lookout points which have been selected because of their high percentage of seen-area quality, the transportation plan can then be made which will make it possible for the fireman to arrive at the several fuel types which he is required to service. If the rate of spread is low, the fireman may be able to reach all the fuels within his direct visibility by means of foot trails; if the rate of spread is high, demanding rapid travel, a truck trail will have to be constructed or another lookout point may have to be established in order to meet the fire control standards of allowable loss.

### Transportation Revision

For those areas where fire control has been practiced for several years, resulting in the improvement of lookout points, and the construction of trails to service them, it may be necessary to abandon some of trails and construct new ones after the fuels have been mapped. To arrive at a decision for the change, silhouettes or "overlays" of the area which can be covered within given time limits from the existing trails are constructed; these are then placed over the fuel maps. If the transportation silhouettes do not fully accommodate the time requirements of the fuels, new trails have to be planned.

As mentioned before under "Hazard," Hornby prepared a formula whereby the travel time could be calculated when the following factors of initial smokechasing attack for mid-day fires are known: (a) allowable maximum elapsed time between discovery and actual control, expressed in hours, the symbol for this in the formula being "C"; (b) speed in constructing held fire line, in terms of chains per hour with crews of four men or less, formula symbol being "W"; (c) rate of perimeter increase between time of discovery and time the attack is begun, symbol "p"; (d) report and getaway time, symbol 0.25 in formula; (e) travel time, or the quantity desired by the application of the formula, symbol being "t".

$$t = \frac{CW}{W + 0.5\,p} - 0.25 \text{ hr.}$$

## COMMUNICATION

Silhouettes or overlays have been used in redesigning telephone communications systems. The general principles, as used by Brown and Funk (101) for redesigning telephone lines in California national forests can be applied to planning new systems. Briefly, the procedure is outlined below.

(1) Indicate on a map of the area under consideration the location of all existing and proposed truck trails, and all points on the forest which must be served with communication.

(2) Construct transparent overlays of commercial telephone lines and power lines.

(3) Prepare an overlay which will serve as a model communications system, keeping in mind the present and proposed transportation system and commercial telephone lines.

(4) With the model communications system overlay, commercial systems and power line overlay, the overlay of the present forest communications system, and the map showing the points requiring communication, as reference material, a new system can be planned on the base map by utilizing those parts of

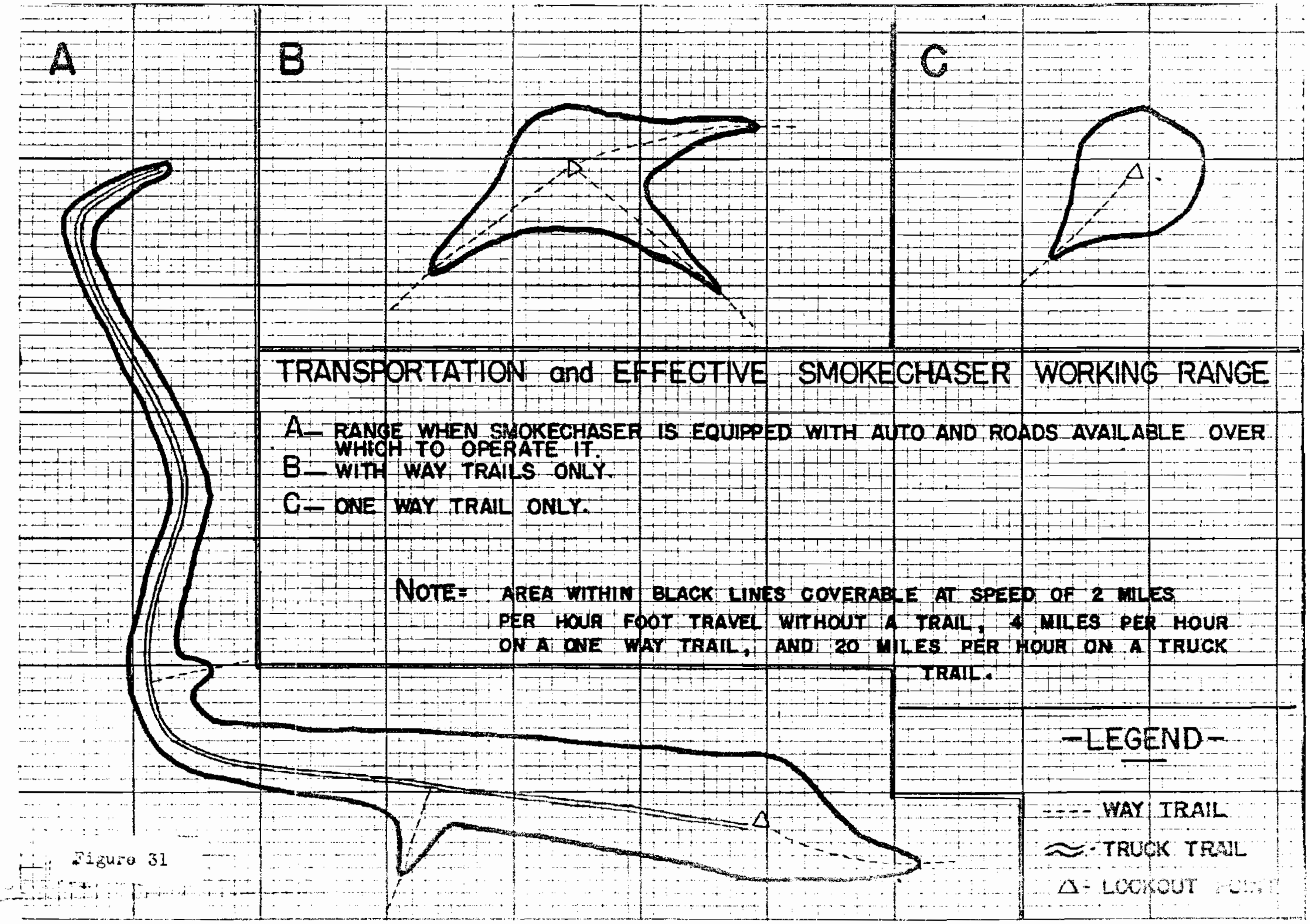

A
B
C
TRANSPORTATION and EFFECTIVE SMOKECHASER WORKING RANGE
A— RANGE WHEN SMOKECHASER IS EQUIPPED WITH AUTO AND ROADS AVAILABLE OVER WHICH TO OPERATE IT.
B— WITH WAY TRAILS ONLY.
C— ONE WAY TRAIL ONLY.
NOTE= AREA WITHIN BLACK LINES COVERABLE AT SPEED OF 2 MILES PER HOUR FOOT TRAVEL WITHOUT A TRAIL, 4 MILES PER HOUR ON A ONE WAY TRAIL, AND 20 MILES PER HOUR ON A TRUCK TRAIL.
—LEGEND—
---- WAY TRAIL
TRUCK TRAIL
△ - LOOKOUT

Figure 31

[illegible] which conform closely to the model system and discarding entirely those links in the old system which cannot be adopted to the present and probable future demands. These missing links will be [illegible] those on the model system map.

## THE FIRE PLAN

The fire plan is the action prescribed when a fire breaks out. The plan is prepared in advance of the necessary action; it contains the facts on which the proposed action is based.

Each fire plan should be made up of the following parts: (a) atlas, (b) copies of special fire instructions to personnel concerned with fire control, (c) emergency plan, and (d) cooperative agreements. There should be a fire plan prepared for each administrative unit.

The ATLAS contains all those facts and data on which the plan is built. It should contain the organization chart showing all the personnel engaged directly or indirectly in fire control, the visibility maps for each lookout point, communications maps, transportation maps, fuel maps, risk maps, maps showing the location of unburned, single-burned, and multiple burned areas, the plan of organization in the event of an outbreak of fires, i.e., who is responsible for initial action, where the reenforcement action will come from, and records regarding cause classes, costs, elapsed time, damage, and any cumulative fire data which may be of assistance in analyzing any situation before action is taken.

SPECIAL FIRE INSTRUCTIONS involve details applicable to specific administrative units. With several ranger districts each of which has some peculiar problems under one superior, procedure could easily vary between districts when the risk or the scheme of suppression may be totally different because of topography or timber type. There are generalized fire instructions in each Regional Fire Manual prepared by the United States Forest Service, but these cover policy rather than specific action for individual areas. The special fire instructions are supplemental to the fire manual.

The EMERGENCY PLAN is designed to meet an unusual situation with which the normal man-power or overhead on the forest cannot cope adequately. In order to minimize the time required to obtain the necessary additional men or materials needed in an emergency, these points are thought of in advance and plans made to meet an emergency in the shortest possible time.

COOPERATIVE AGREEMENTS are sometimes made between public administrative agencies and owners of private land whereby the private land is administered for fire control purposes by a federal or a state agency. Because cooperative agreements generally include increased responsibility on the part of the public agency, it is desirable to include them in the fire plan so that the responsibilities are clearly understood by all concerned. Although cooperative agreements involve additional responsibility, frequently there is some compensation in the form of increased authority in some area, or the availability of manpower which might not be otherwise available.

The fire plan will vary distinctly with local conditions; what may be acceptable procedure in one locality may not be applicable in another. The outline of items to be included in the fire plan, listed above, however, has general application, subject to additions and revisions, with few deductions. Briefly, the fire plan which is drawn for any administrative unit is the result of anticipating various combinations of situations. The purpose of fire planning is preparedness, coupled with imagination. Headley (100) has stated, however, that the imagination should be under full control, tempered by reason and experience. A good fire plan is the result of anticipating the requirements of a situation when it may develop under unusual conditions.

The fire plan includes the composite of all studies conducted for any administrative unit; it covers all phases of fire control so that, in any period of low or extreme hazard, all situations can be met and all action will be executed on a procedure calmly planned. The result of following a plan of this sort will be orderly action. Most large fires are the result of either poor planning or poor execution of a [illegible] Either will produce unfortunate results, but a deficiency in both will magnify poorly managed action.

### Fire Manuals

From a broad viewpoint, the fire control manuals issued by each regional office of the United States Forest Service represent the fire plans for the several regions. Certain standards of procedure and performance are prescribed in each manual. The orderly execution of the procedures generally result in lowered loss. The manual of the Inter-mountain Region (R-4) of the United States Forest Service is an excellent example of concise, orderly arrangement of material.

From a more narrow point of view, the fire plan is a set of specifications for individual administrative units. The essential difference between the Regional Fire Control Manual and the fire plan for a ranger district is that the former is the more comprehensive but the latter is more specific.

## PERSONNEL TRAINING

As covered in this discussion, the personnel referred to is essentially the part-time employee. Those employees who require instruction and training are (1) lookouts, (2) smokechasers, (3) dispatchers, (4) per diem guards, (5) scouts, (6) pump operators, and (7) fire bosses. Although many of the men who fill these positions are part-time employees, they serve as the backbone of the presuppression and suppression organization. The purpose of the training is to show clearly to each employee just what his particular duties are and where he fits into the fire control organization. The men in the positions listed above take the initial action on fires, so each person performs a vital function. If each employee is qualified to perform the duties imposed upon him, the likelihood of having large fires occur is much less than if there is some question as to duties and responsibility. Without a clear understanding of duties, confusion can easily occur. With a high turn-over in part-time personnel, it is necessary to have annual training periods. For instance, a lookout without previous instruction knows nothing about the use of a haze meter; he requires special instruction in its use. A fireman must know how to arrange his pack so that everything is in readiness in event he must control a fire. A scout must be told just what is expected of him on a going fire so that no time is wasted; he may have general knowledge which qualifies him for the job, but he needs to be informed specifically what information is needed when he makes a reconnaisance. In the western regions of the United States Forest Service where part-time employees are used to a considerable extent, the importance of training has been recognized. Several national forest regions have produced manuals on the subject to serve as a guide to administrative officers concerned with instruction of part-time men in fire control. In order to train these men adequately, two western regions of the Forest Service prepared special manuals of procedure on the subject (107) (108).

The Pacific Northwest Guard Training Manual (108) breaks up the group training jobs into several sections--(a) fire prevention, (b) tools, equipment, and quarters, (c) detection, (d) smoke chasing, (e) small fire suppression, (f) the use of standard forms for submitting reports, and (g) advanced training for specialty jobs such as camp boss, pump operators, fire chiefs, and scouts. This procedure utilizes time effectively; it eliminates addressing smokechasers, for example, with information on scouting for which they will have no use.

**Table 33**

EFFECT OF FIRE CONTROL OVERHEAD AND TRAINING OF TEMPORARY HELP ON AREA BURNED IN THE NATIONAL FORESTS OF THE NORTHERN ROCKY MOUNTAIN REGION

| Year | Yearlong Man-Power Available for Fire Control Duty (Number of Men) | Training given to Temporary Employees (Man-Days) | Area burned (Acres, National Forest Land) |
|---|---|---|---|
| 1922 | 188 | 1100 | |
| 1923 | 194 | 1350 | |
| 1924 | 191 | 1700 | |
| 1925 | 181 | 1850 | |
| 1926 | 190 | 2250 | 400,000 |
| 1927 | 196 | 2600 | |
| 1928 | 200 | 2750 | |
| 1929 | 190 | 2800 | 300,000 |
| 1930 | 188 | 3350 | |
| 1931 | 152 | 2900 | 130,000 |
| 1932 | 154 | 2500 | |
| 1933 | 149 | 1450 | |
| 1934 | 142 | 2300 | 350,000 |

Hornby (65) has shown statistically for the Northern Rocky Mountain Region in Table 33, that there may be a direct relation between seasons in which bad fires occur, reduced year-round fire control over-head, and man-days of fire control training given to part-time employees. In 1934 there were fewer available year-round fire control men in Region 1 than for any year subsequent to 1932; there were also relatively few hours given to the training of the part-time personnel. There were high losses in 1934. There was found some correlation between personnel training and decrease in burned area. The increase in area in 1934, after several years of short training periods may, or may not, have been a coincidence, but there is an element of probability which cannot be ignored.

A plan which works well in the training of temporary men is to subject prospective employees to a short training period well in advance of the fire season to determine the ability of the prospect to absorb the sort of information required of them. Those prospects who do not function satisfactorily in the training camp should be eliminated from further consideration. The men who are likely to prove satisfactory should be subjected to group training at a later period, but prior to going into the field; their contact in these group training periods with the more experienced full-time and former part-time personnel provides background for their job. After the inexperienced employee gets on the job, he should be given further individual training so that questions which may have occurred in his brief period of service can be answered. This contact also affords an opportunity to make corrections if the wrong pro-cedure is being followed.

## Chapter XI

## EQUIPMENT AND SUPPLIES

### Adaptability

The type of equipment used on any going fire is determined by certain regional standards which are based on fuel conditions, topography, availability of water, and method of attack. In other words, adaptability of the equipment to the particular job at hand determines the standards. Within a given region, or a particular fuel within a region, there are forest conditions which make it possible to standardize equipment.

In the Southeast, characterized by relatively level and rolling topography, motorized fire units, water using equipment, and direct attack form the basis of the control of most fires. In the Rocky Mountain regions with their rugged topography, water-using equipment is adapted to a limited number of fires; a few special hand-tools are the principal means of securing control lines with the parallel method and trenching as the general system for control. In the eastern mountain hardwood area, hand tools, principally a special rake, are generally the accepted items of equipment.

### Hand tools

Each forest region has its "pet" equipment, the product of experience on the fireline. In the West,

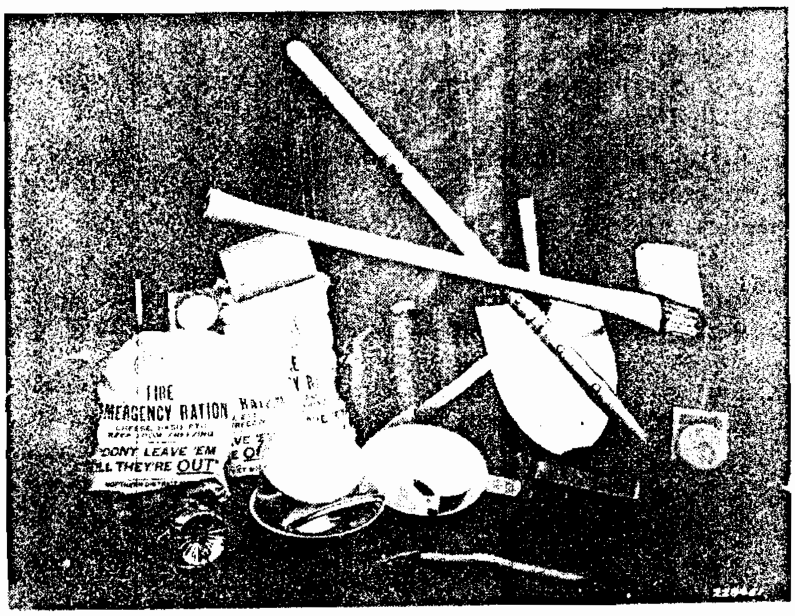



Photo by U. S. Forest Service-228451
Figure 32
A--Smoke Chaser's Pack, Open, Western Regions.

Equipment Includes--

(a) Compass (b) map folder
(c) Detachable-Handle Shovel
(d) Pulaski Fire Tool
(e) First Aid Pack (f) one day rations (g) canteen
(h) Flashlight (i) carborundum stone; The above all wrapped in a
(j) shelter-half.

... the accepted method, ... several hand tools such as ... McCloud, and Kortick ... combination hoe and ... supplemented by a few ...

... coniferous forests ... Plain and Piedmont ... accepted tools are the ... rake, a five-gallon ... pump, and a swatter, ... axes and shovels.

... attack, or backfiring, ... devised and is very fre... regions. It is ... the principal of produc... such as is found ... blow-torch; the fuel and ... pressure tank are packed on ... The fire-bearing ... by a 3-foot length of ...

Photo by U. S. Forest Service-...
Figure 33
B--The Fire Pack Assembled For Action.

... and Power Equipment

... (101) reviewed the ... needs in fire sup... in 1931, relatively ... published concerning ... equipment which ... or even regional, use. ... equipment such as de... determining moisture content ... radio for pre-suppres... as suppression work has ... and considerable has ... on the subject. Altho ... been done on firefighting ... not much has been written ... the results.

... for the construction of fire... are required for firefighting as well as for pre-suppression. Where the topography is not severe, ... deep, and rocks generally absent, plows are used in western regions. The plows are of the middle... type to speed up trenching. A relatively light plow, drawn with a horse, has considerable advan... over tractor drawn, heavy plows where steep grades exist. The rate of trench construction with a ... two to ten times more rapid than with hand tools.

Where the topography has grades of less than ten per cent, the Killifer plow drawn by a tractor, is ... for machine trenching in the West.

... has for several years used two types of break-making equipment. (See Figures 34 and 35) ... is a heavy, five-disc plow mounted on a heavy frame; the other is a six-disc harrow which is con... on the principle of rolling over large, resistent objects thereby producing less breakage than ... be encountered in a rigid-framed plow. In heavy sod or deep duff, a satisfactory break ... two trips with a harrow which results in higher construction costs; this is offset, however, by ... it has no gouging effects which are undesirable in surfaces with a 5% or greater grade; ... conditions, the plowed firebreak is conducive to erosion. The firebreak constructed by two ... in tandem, with the forward set to discs throwing the dirt outward and the rear set pulling ... the gouging effect made by the plow and also aids vehicles in crossing the break.

... equipment has its limitations in fire suppression for the reason that when fires burn

Photo by Hester Plow Company

Figure 34

A--Five-disc plow

fiercest, there is always a deficiency of water; small streams have ceased to run and the ground water table has been lowered to depths which demand special equipment for making it available. To be used at their maximum efficiency, heavy-duty water pumping equipment requires tremendous quantities of water. When small streams have dried to the point where very little water is available, the only genuine utility of the pumping equipment is along logging trams to prevent the bridges from burning, provided water is available at some other point and can be transported in tank cars.

The smaller pumps, which deliver water at a rate of approximately 25 gallons per minute, require only one-quarter the volume of water which the larger pumps, which deliver 100 gallons per minute, demand for their efficient operation. When water must be transported by vehicles to the proposed point of use, the large pumps are of little value and the small ones have limits, even though tanks mounted on trucks are able to deliver 500 gallons, at one loading. This volume of water would keep the pump operating for only twenty minutes. When water must be packed by animals or man, the heavy duty equipment is impracticable.

All of the heavy duty pumping equipment, which has been designed for forest use is allegedly portable, but when units weigh as much as 125 pounds, the range of transportation by hand is extremely limited. Smaller units which weigh approximately forty pounds are truly portable for short distances.

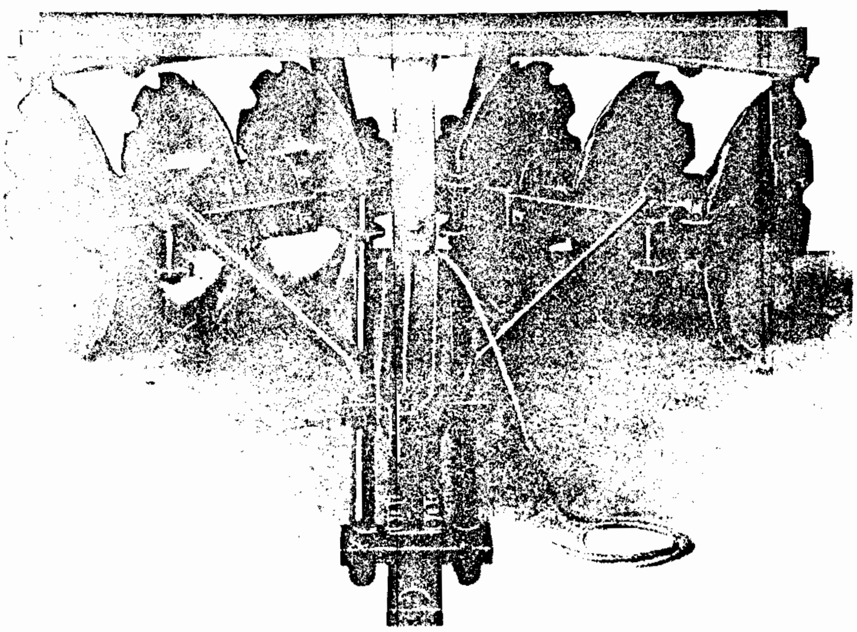


Photo by Athens Plow Company

Figure 35

B--Six-disc reversible harrow

Firebreak Construction Equipment Adapted To Coastal Plain Topography and Soils

Most of the pumps are able to develop a nozzle pressure of 100 pounds, some as much as 200 pounds even with a 400-foot lift through 2000 feet of 1½" rubber-lined hose. (143)

The use of pumps demands availability of hose which is manufactured in 50-foot lengths for the purpose of facilitating the handling. The weight of a length of 1½" hose varies between 13 and 30 pounds. Where packing is required, weight is an important item.

Where direct attack can be made from trucks, tanks and pumps have been mounted on light as well as heavy trucks. A light power pump has been devised whereby the power necessary to operate the pump is obtained from the fan-belt of the motor. Another type is driven by a connection with the transmission or drive shaft. The former type is of particular value on light, mobile units such as ½ and 3/4 ton "pick-ups." The latter type is better adapted to heavier jobs such as 1½ ton and 2 ton trucks which are able to carry greater quantities of water but are essentially less mobile than the lighter trucks. The nozzle pressure generated by each type of pump is approximately the same.

In the development of the heavier type of pumper tank truck, California has contributed considerably.

[illegible] have utilized this type of [illegible] protection against farm fires as [illegible] fires. Metcalf (150) has outlined [illegible] development and the advantages of [illegible] produced. Davis (151) has [illegible] specifications for the equipment on [illegible] in use in California. The equipment [illegible] over the several types of [illegible] from the lighter type 1½ ton [illegible] heavy duty type the principal [illegible] is in having considerable quanti- [illegible] available from its 600 gallon [illegible]

[illegible] in the flatwoods of the coastal [illegible] where drainage is poor resulting [illegible] soils which must be crossed, 1½ [illegible] with 250 gallon tanks have proven [illegible]. The light ½ ton pickup, with a [illegible] unit and tank capacity not in [illegible] gallons, which will permit con- [illegible] operation for approximately [illegible] superior value. It is [illegible] sorts of conditions; this fact, [illegible] considerable difference in cost [illegible] purchase of a pickup and a 1½ ton [illegible] as the cost of the equipment to [illegible] given preference to the lighter [illegible]

Photo by U. S. Forest Service-311971
Figure 36
Portable Heavy Duty Power Pump With 1½" Hose

Where there is unusual soil softness or [illegible] sand making greater traction [illegible], a device has been placed on the [illegible] whereby the traction can be greatly [illegible]. This permits greater use of pump- [illegible] equipment on fires. The "Tractioneer" [illegible] increases the ground contact of the car by approximately 240 percent.

Stewart (109) has devised means whereby adequate supplies of water are made readily available from the [illegible] water table in the Lake States Region. The technique, however, is limited in its utility to [illegible] flat topography such as is found in the Lake States Region and the Coastal Plains. The pumping [illegible] as designed by Stewart makes water available by the jetting method of sinking a shallow well, [illegible], one which is able to get water to the surface from depths not greater than approximately 26 feet [illegible] sufficient quantities to supply 30 to 65 gallons of water per minute. Stewart designed a portable rig for jetting wells which will produce ample supplies of water within 15 minutes after the rigging is [illegible]. To be able to procure water locally by this method eliminates the necessity for long water hauls for supplying water to the pumps.

With the jetting system, firefighting by direct attack becomes possible even when the heat generated by the fuel combustion is too great for smaller water-using equipment such as the back-pump. Swamp and [illegible] fires can also be completely encircled with wells and pumps so that the fire can be drowned out and [illegible] the necessity of a long vigil, deep trenching, and the constant threat of the fire breaking out of its confines be eliminated.

[illegible]ility

[illegible] avoid situations in which the man-power available is considerably in excess of the equipment on [illegible] firefighting, tool units or assemblies will vary by regions, but one point is fairly common to them all - they are kept apart from all other tools so that they are always available for fire. Since fires demand prompt action, no delay in the form of a search for tools can be tolerated.

Equipment assemblies are formed on the basis of the number of men who will use them - equipment for 1-man, 10-man, 25-man crews - all assembled and ready for instant use. Local practice will dictate the specific items which will be included. For a one-man crew, such as is used by a smokechaser and fireman, the variety of equipment will be less than where the crew is composed of several men; when the crew is operating from a vehicle, the various types as well as the quantity can be greater per man in the crew than in the case where everything requires back-packing.

At one time equipment caches were used extensively. These were scattered at various points throughout the forest to speed foot travel. To avoid carrying equipment enabled the firefighters to make better progress and arrive at the destination in better physical condition than if they had been burdened with tools for several miles of foot travel.

With the great increase in road construction, making forest areas much more accessible by truck, there is today much less need for the caches. The tendency has been to concentrate the equipment at the regular equipment depots, of which there is usually one for each administrative unit, with a few tools scattered over the balance of the area charged to road crews and other forest officers who, if they encounter a roadside class A or B fire, will have some equipment available for instant use.

## Service Condition

After service on a fire, tools should be reconditioned and again sorted into units available for immediate use. There is very seldom an occasion when tools which are taken from the equipment depot for suppression work are returned in the condition in which they were removed. Hand pumps will have nozzles lost from them or valves broken, hose for heavy duty pumps will have developed leaks, couplings will be missing, axe and shovel handles will be broken, flashlight batteries will have burned out, and a multitude of small items in need of reconditioning or replacement in order to make the equipment of value on the next fire. The more severe the fire season, the more necessary it is to recondition the equipment imme-

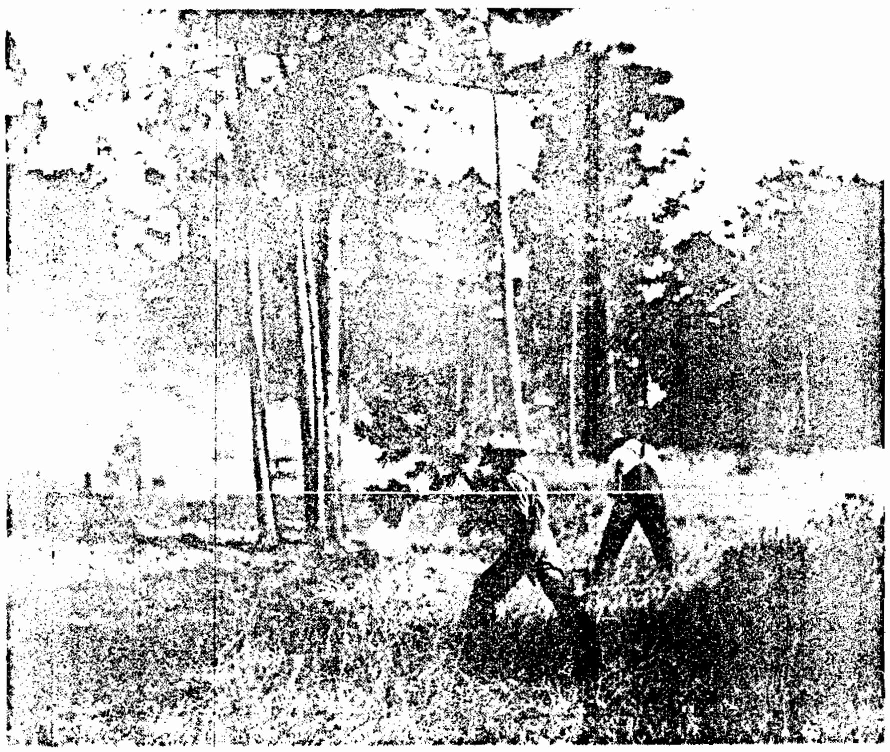


Photo by American Forestry Ass'n.
Figure 37
The Old Style Of Direct Attack With A Pine Top

[illegible] each fire. This requires [illegible] most frequently requiring [illegible] be kept on hand, available for [illegible] need develops. Nothing is [illegible] pick a heavy duty [illegible] miles, set it up, and [illegible] the motor will not fire [illegible] has not been overhauled since [illegible] used.

[illegible]

[illegible] the earliest investigations [illegible] use of chemicals in prevention of [illegible] suppression of forest fires [illegible] Jarrett who carried out a [illegible] this subject with a commercial- [illegible] solution. The work was con- [illegible] and brush fields which [illegible] burned prior to planting with [illegible]. The chemical solution was [illegible] means of back pumps. Its [illegible] suppression agent was [illegible] in which water was [illegible] Jarrett (147) found that for [illegible] with which he was working, the [illegible] extinguished a chain [illegible] only [illegible] of the time required [illegible] with water. On a [illegible], the chemical was more ef- [illegible] that only 52% of the quantity [illegible] was required compared with [illegible] water needed. The deaden- [illegible] of the chemical solution was [illegible] the water. Flare-ups along [illegible] were much more numerous with [illegible] regard to the relative merits [illegible] and the chemical solution as a [illegible], in their use as liquid [illegible] lowering the kindling point of [illegible], the chemical solution was also [illegible] to water. The chemical solution remained effective in stopping fires which burned up to the [illegible] even after 0.16 inches of rain had fallen on the fuels.

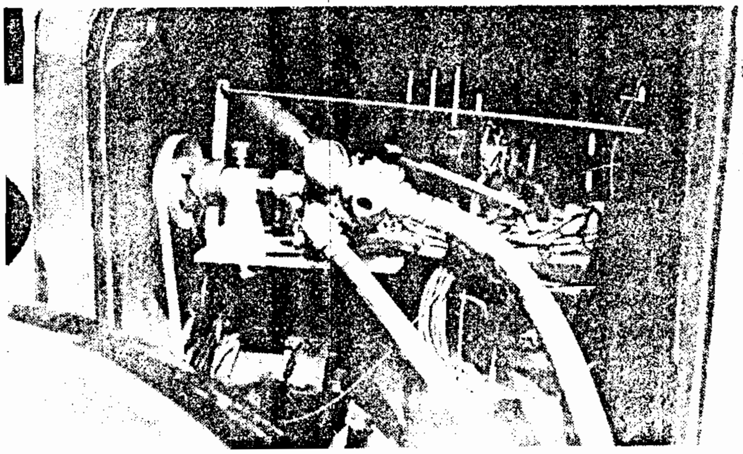


Photo by Fan-Belt Pump Company

Figure 38

Close Up Of Light Pump In Which Power Is Obtained From The Fan-Belt

The Fan-Belt Power-Take-Off Pump Mounted On A ½ Ton Pickup With 70 Gallon Tank Capacity

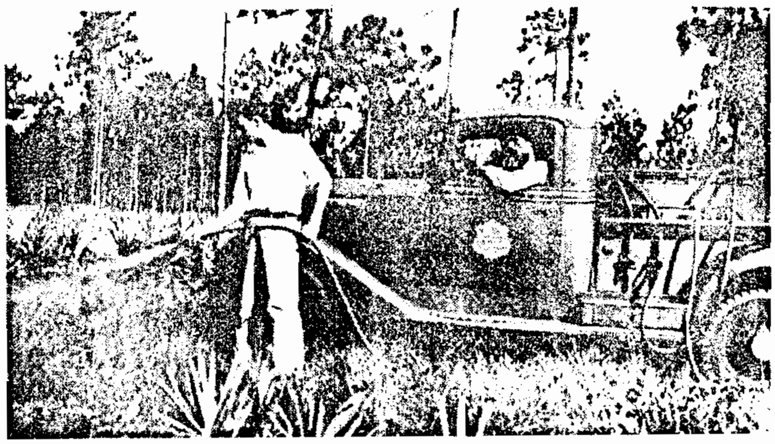


Photo by Florida Forest Service

Figure 39

The Modern Method In Which Water Is Used To "Cool" the Fire, The Swatter To "Kill" It, And The Rake To "Follow-Up".

[illegible] Stickel's work with chemicals in the Northeast, he approached the subject from the standpoint of determining (a) the influence of the chemical on the moisture content of the fuel, (b) its influence in [illegible] inception and the lowering the rate of spread after inception; and (c) its toxic effect on [illegible] such as grass and weeds. Stickel's (148) project was confined to the use of calcium chloride, [illegible] chemical. Because of its peculiar physical properties, calcium chloride has limitations in [illegible] no longer effective after a rain which leaches it from the fuels. In the absence of precipita- [illegible] increases the moisture content of the litter in amounts varying from 29 to 119 percent, depend- [illegible] quantity of calcium chloride applied. Although the application of calcium chloride to such [illegible] as grass will not prevent a fire from starting, there is less likelihood of fire starting in [illegible] and the rate of spread and severity of burn is much less than on the untreated areas. The [illegible] also displayed toxic properties in that it killed grass five days after the solution was [illegible] not only died, but it remained moist which made it less dangerous as a fuel than if

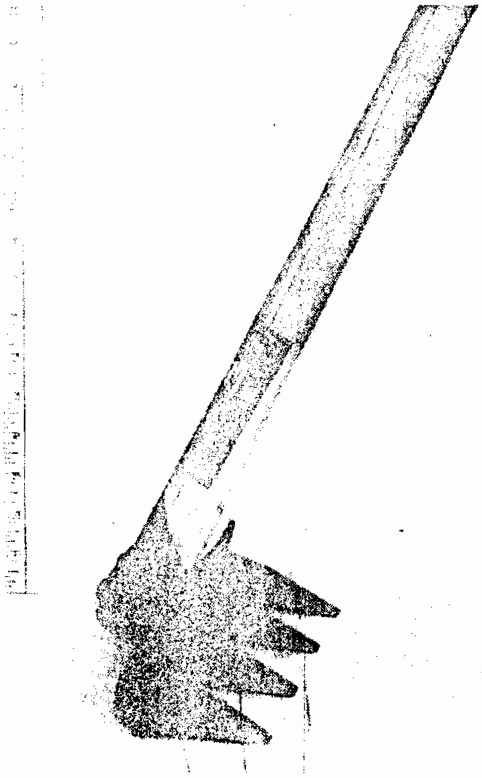


Photo by U. S. Forest Service-317973

Figure 40

Fire Rake

Teeth Made of Replaceable Mowing Machine Blades

Photo by Fenwick-Roddaway

Figure 41

Knapsack Pump

Four-Gallon Water Proof Bag and Single-Action Pump

Two Popular Types of Forest Fire Fighting Hand Tools

it had died due to natural causes.

One of the most extensive investigations in the field of determination of chemicals valuable in fire control from the standpoint of effectiveness and cheapness was that conducted by Davis and Benson (148) of the Los Angeles County Forestry Department. Because forest fires have such an important influence on its potable water supply, Los Angeles County is vitally interested in exploiting every means of controlling fires. The investigators approached the subject to determine (a) what chemical agents were efficient, (b) the cost and availability, (c) the biological effects, and (d) metallurgical activity. The investigators concluded that alkaline solutions or dusts had superior spreading properties when compared with the acids; some of the chemical solutions were 25 times as efficient as water only in their slowing up of the rate of spread, and the order of utility of chemical elements and ammonium compounds investigated with availability, effectiveness and cost all considered, grouped themselves as shown in Table 34.

**Table 34**
RELATIVE VALUE OF SOME CHEMICAL ELEMENTS AND COMPOUNDS FOR FIRE CONTROL PURPOSES

| Desirable | Mediocre | Undesirable |
|---|---|---|
| (1) Ammonium Arsenite | (1) Nickel | (1) Aluminum |
| (2) Antimony | (2) Copper | (2) Calcium |
| (3) Ferric Chloride | (3) Fluorine | (3) Sodium |
| (4) Magnesium Chloride | (4) Phosphorus | |
| (5) Boron | (5) Potash (Potassium Carbonate) | |
| (6) Aluminum Sulphate | (6) Zinc | |
| (7) Arsenic | (7) Bismuth | |
| (8) Chlorine | (8) Tin | |
| (9) Bromine | | |
| (10) Phosphorous Oxychloride | | |
| (11) Magnesium Fluosilicate | | |

The results of the investigation, as reported by Davis and Benson, were not too conclusive, but credit must be given them for pioneering in a relatively unknown field. Unfortunately the California investigators seemed to attach no value to calcium chloride which had attracted Stickel and Mitchell.

In a rather recent work with calcium chloride in the Lake States, Mitchell (145) found that, when applied dry, the chemical is ineffective because it falls to the ground too readily. When applied in water solution, at the rate of one-quarter pound per square yard of surface, it stopped fires in grass. In the absence of precipitation, calcium chloride remains indefinitely effective. Where it is used as a liquid fire break, a back pump will generally be ineffective as an applicator because the rate of delivery to a unit area of fuels is too low. It must be noted, however, that calcium chloride is a retardant, not an extinguisher.

With the recent stimulus given to forest fire control by the United States Forest Service, there has been an investigative project set up by the research and administrative branches for the exploitation of chemicals. One of the most recent developments is fire "foams." These consist of a mixture of sodium bicarbonate, aluminum sulfate, and a bubble-former or fixer such as licorice. Carbon dioxide is produced which acts as the retarding agency for the spread of fire. For the limited number of experiments which have been conducted to date, Godwin (146) has listed a few conclusions relative to fire foams.

1. Water used in combination with foam is more effective than water alone in suppressing fire.
2. Foams are valuable for "cooling" and "mop-up" purposes when used with water in back-pack pumps.
3. There is a ratio of 8 to 1 in fire line effectively controlled, per unit of time, between foams and water and water only, in favor of foams and water.
4. The use of foams for boosting fuel resistance to combustion has possibilities of revolutionizing flame suppression technique.
5. In reinforcing backfire procedure, foams are superior to water.
6. Foams have a more deadening and lasting suppression quality than water.

## Chapter XII

## FIRE SUPPRESSION

### Fire Behavior

With no wind movement, with fuel density, volume, and moisture content equally present on all sides, and level topography, fire spreads in a circular manner; that is, the rate of spread is equal in all directions. With a change in any one of the above items, the rate of spread of the fire will be altered. Fire spreads most rapidly in the direction in which the wind is blowing, where the fuels are densest and driest, and uphill.

In his investigations on the behavior of small fires in second-growth ponderosa pine on level ground, Curry (211) found that three basic factors influence perimeter increase. These are the wind direction and velocity, the moisture content of the fuels, and time period.

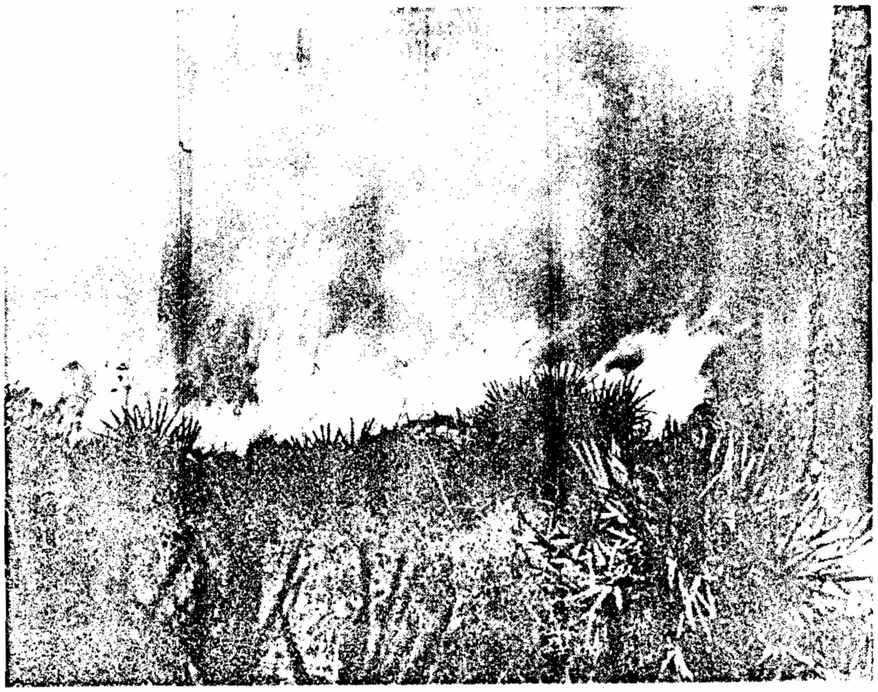


Photo by U. S. Forest Service

Figure 42

Surface Fire Burning Into The Wind

### Types of Fires

There are three generally recognized types of forest fires; they are (a) surface, (b) ground, and (c) crown.

SURFACE FIRES are those which consume the fuels on the surface of the soil. Only those fuels are burned which are in the "L" and "F" layers of the $A_0$ horizon, using the $A_0$ in the sense that it refers to all the organic material lying upon the $A_1$ horizon, or first mineral layer. Frequently the "F" layer is absent. If the "H" layer, sometimes called the $A_1$ horizon, is present to any degree of depth wherein it contains numerous surface roots of the plants occupying the site, the fire burns deeply and produces the effect of a ground rather than a surface fire.

The tendency of those roots that supply nutrients to the tree is to establish themselves where the food supply is most abundant. In some forest types, where there is food material in the "H" or $A_1$ layer of the soil, there are many feeding roots located in this layer. When fires burn slowly and there is a [illegible] in this layer, most of the organic material is burned and along with it the roots, [illegible], are so badly damaged that they are useless to the tree for procuring food. Thus fires that [illegible] to the A horizon may take on the nature of ground fires when the H or $A_1$ layer supports [illegible].

[illegible] difference between a surface fire and a ground fire is its behavior in relation to the [illegible]. When the "H" layer is absent, or is burned hardly at all, the fire is confined to the surface [illegible] so-called.

Surface fires usually increase their perimeter rapidly. The damage done by surface fires is generally [illegible] that produced by the other two classes, because the volume of heat generated and its duration [illegible] the damage characteristic of crown and ground fires.

[illegible] fuels, which produce a high rate of spread but are easily controlled, are typical surface fires. [illegible] grass in the west and in wire-grass on longleaf ridges of the south are good examples of [illegible] surface fires.

[illegible] burn deep because the "H" layer of the A horizon is thick. There is a large layer of [illegible] organic matter which in times of high hazard has a very low moisture content. When this [illegible] matter dries out to the point where it can be ignited, it produces fires which burn slow- [illegible] difficult to control and expensive to extinguish. As fuels, they would be described as "LE", [illegible] low rate of spread but an extreme resistance to control. When trenches are dug to control them, [illegible] to see that they are perfect. Duff which looks cool even in absence of smoke, may be [illegible] to the touch. If trenches are safely constructed, the side of the trench away from the [illegible] touch. A rule of thumb for trench construction is to make the trench twice as wide [illegible].

[illegible] line is patrolled for several days, ground fires may easily burn under or through the [illegible] all the work required to control the fire in the first instance. Ground fires are peculi- [illegible] which there are heavy accumulations of undecomposed or partly decomposed organic material, [illegible] in swamps where organic residue decomposes slowly and the water table permits fires to burn [illegible] intervals.

[illegible] are those in which the perimeter extends itself in the crowns as well as on the surface. [illegible], rapidly spreading crown fires, the rate of spread in crowns is greater than on the surface. [illegible] is generated because the crowns as well as the surface fuels contribute combustible ma- [illegible]. Sometimes the surface fuels are burned hardly at all.

This type of fire occurs only in coniforous, dense stands situated on a slope, on level topography as in [illegible] plain, or in stands with a low canopy; one or several of these conditions make it possible for [illegible] surface fire flames to kindle the tops. Crown fires are common in the dense coniferous slopes of [illegible], and in the sapling pine stands of the Lake States and Atlantic and Gulf Coastal Plains.

[illegible] are the result of the tremendous convection currents generated by other going fires. These [illegible] currents project fire forward aerially. Crown fires especially display tendencies to spot. [illegible], cones, small bits of wood -- embers of any sort -- are picked up by convection currents [illegible] forward by the wind movement to distances varying from several hundred feet to a mile or more. [illegible] a fire is capable of spotting is largely determined by topography and the size of the fire [illegible] the height to which the convection current can carry embers. The horizontal wind movement [illegible] embers forward.

The occurrence of spot fires frequently has a demoralizing influence on the suppression personnel. Fire fighters who have been straining every muscle and nerve to control a headfire have their morale broken [illegible] the fire on which they have been working jumps across the line and spots. When a large fire is [illegible] distinct tendencies to spot, as is frequent in periods of high hazard, suppression forces may as [illegible] withdrawn from the headfire until those conditions subside which make excessive spotting possible. [illegible] occurs several hours after sunset when wind velocities fall and relative humidity rises. [illegible] conditions, it is often desirable to have the firefighters work on the flanks until such time [illegible] possible to work on the headfire where the perimeter is extending itself most rapidly.

## Parts of a Fire

With normal fire behavior, where one part or side of the fire spreads with greater rapidity than any other part, a definite fan-like formation develops, resulting in (a) the headfire, or that part of the perimeter enlarging itself most rapidly, (b) the side-fire or flanks, moving at right angles to the direction taken by the headfire, but spreading at a rate less rapid than that of the headfire, and (c) the tail fire, or that side burning against the wind or downhill part. Very frequently the tail fire dies out of its own accord.

Because of variations in rate of spread due to fuels, topography, or wind movement, fires may break into several "heads" which represent that part of the perimeter of the fire increasing the most rapidly. These are the points where attack is most necessary for speedy control. The head is always located on the wind-driven side of the perimeter of the fire. (See figures on pp. 126, [illegible], [illegible], [illegible]).

Good control technique requires that the head be handled first, unless there is good reason to believe that the wind direction will change so that one of the sides will become the head and the head will then become a flank.

To attack a fire only at its flanks and ignore the head is a waste of time because in most cases the

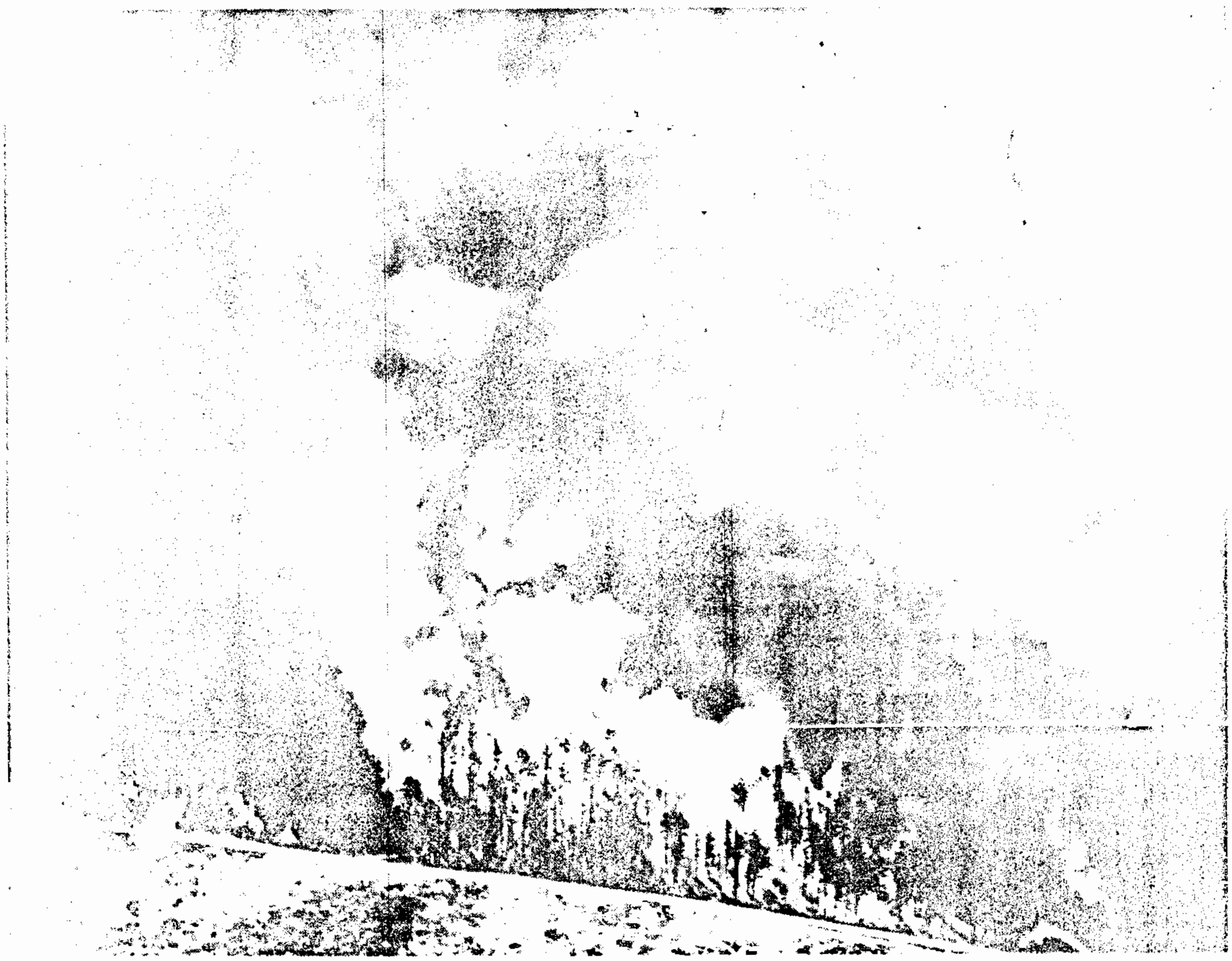


Photo by New Jersey Forest Fire Service

Figure 42a

A Crown Fire "On The Boom"

head fire as an-distance the speed of the suppression work on the flanks. As mentioned above, however, there are occasions when heat is so intense that the head fire cannot be attacked.

**Methods of Attack**

The objective of all suppression work is to control the fire in a minimum of time, with a low loss of ... at an expenditure of man-power and materials sufficient to include a factor of safety, ... if control conditions deviate somewhat from the normal, reenforcements will not be required.

The method of attack employed in controlling a fire will be determined entirely by the behavior of the fire. For the purpose of the discussion below, it is assumed that the necessary requisities for control (i.e. adequate man-power and equipment) are available.

The methods of attack are (a) direct, (b) indirect, and (c) backfiring.

(a) THE DIRECT ATTACK is any means whereby the fire fighting is done directly on the line of fire.

Smothering devices are frequently used in the direct attack; these include beating, watering, and sanding ... whereby oxygen is excluded from the fuels. Water is the most extensively used and is ... beating and sanding are slow, tedious procedures and cut down the linear feet of line constructed in a unit of time. These smothering devices remove oxygen from the fuels and thus prevent continued combustion. They are particularly valuable in the suppression of flash fuels which are easy to control.

An effective means of attack consists of "cooling" the line with water sufficiently so that work can be ... with mattocks, rakes and swatters. The action of the water slows down the rate of spread and lowers the temperatures to a point where direct action can be taken with other equipment.

Large accumulations of litter are sometimes encountered. To effectively control the spread of these surface fires, it may be necessary to push the fuels just beginning to ignite back into the burned portion or pull them back with a rake. Heavier fuels such as decayed logs and sticks, both capable of carrying the fire from the burned to the unburned fuels, require attention, especially the decayed logs in which fire may remain in a semi-dormant condition resembling "cold" fuels, but with the first opportunity, i.e., with increased wind movement, solar radiation, or any other variable factor conducive to increasing the combustion rate, it may carry the fire across the line which has temporarily controlled the rate of spread, ... actually requires additional work to make the fire line "safe".

(b) THE INDIRECT ATTACK is that method where control is executed by work on the fuels in the immediate vicinity of the fire-line. It is employed where the rate of spread is low but the fuels are deep. The only adequate way to control the fire is to dig or plow a trench to mineral earth to prevent the continued ... of the fire. In surface fires too hot to handle with direct attack and where water is unavailable for "cooling" purposes, the indirect attack can be used by removing the fuels to mineral soil ...) and for whatever width is necessary to make it possible to prevent the fire from crossing the barrier.

The term "indirect" attack as here used differs in principle from "direct" attack by attempting to control the fire by removing the fuels down to mineral earth. In the case of direct attack, the fuels are worked on at the point where they are in active stage of combustion. The most simple way of obtaining the desired effect, i.e., cessation of active and violent combustion of the fuels in direct attack, is by the ... of oxygen from the atmosphere immediately surrounding the actively burning fuels. This direct attack may be accomplished by several means, as mentioned under the discussion above.

(c) BACKFIRING is a method of remote control wherein a fire is deliberately set to consume the fuels in the path of the on-coming fire, regardless of whether it be a head or side fire. Backfires are set to impede the forward movement of a head fire by removing the fuels in front of it by means of a controlled fire. In other words, a backfire is a controlled fire moving in a direction opposite to that taken by the head fire or side fire that it is supposed to meet, and set the purpose of stopping the forward movement of the ... fire.

This method of attack is used to stop head fires when the heat produced by the head fire is so excessive ... the direct and indirect methods of attack are impracticable or the use of them would jeopardize ... the lives of the firefighters who make the attack. Conditions which warrant the use of the backfiring method are produced by extreme fuel dryness and an extreme rate of wind movement causing the fire to generate terrific heat and/or move at very rapid rates.

Backfiring should be used only as a last resort for checking the spread of a headfire, because of the skill and experience demanded in its use. Unless carefully handled, a backfire may easily get out of control and become another headfire. Extremely good judgment on the part of the fire boss, the highest type of organization, and close liaison are required for successful backfiring on a headfire. The backfire as a method of control is used all too frequently by volunteer and amateur firefighters, because it requires much less expenditure of effort to kindle a fire than to beat one out. When used by inexperienced men, the backfire seldom accomplishes its purpose, frequently aids the perimeter increase of the fire by letting the backfire get out of control, and is often used when direct attack would be more effective and would result in less area burned. Promiscuous backfiring done by people uninformed about fire behavior is recognized as being potentially very dangerous. There exist in some states statutes prohibiting the use of this means of attack on forest fires, except by those persons appointed by a state agency to act as fire wardens.

The backfire method is also used on the flanks of fires to speed up the burning out of strips of fuel lying between a slow-moving flank fire and a trench or break which has been constructed between two outside points along a sinuous perimeter.

Quite often the fuels are such that all three methods as outlined above can be employed on one fire. Combinations of variable factors also may be such that the direct attack only is used. In a circular letter concerning fire control for the Northern Rocky Mountain Region, Kelley (105) has stated that those factors which determine the method of attack to use are (a) man-power available, (b) depth of duff, (c) presence or absence of green vegetative matter on the ground, (d) inflammibility of the fuels, (e) resistance of the fuels to control, (f) amount of heat produced by the fuels, (g) rate of spread, (h) topography, (i) position on a slope, i.e., on upper or lower side,(j) going and anticipated wind direction.

The above terminology has been used to simplify and clarify the underlying principles used in each method of attack, altho the "Glossary of Terms used in Fire Control" (104) has listed the "parallel" and the "two-foot" methods of attack and has referred to "backfiring" synonymously with indirect attack.

### Factors Affecting The Quality of The Suppression Work

Within a given forest region where there are recognized certain well-defined fuel types, an index of the efficiency of a suppression organization may be based on size of the average fire over a decade. It must be recognized at the outset that those variable factors which in their aggregate determine the degree of fire danger for any administrative unit are never identical in their magnitude. Just as twin trees are very seldom found in nature, i.e., have almost identical taxonomic and vigor characteristics, so there is a similar degree of scarcity of administrative units having identical fire problems. In fire control work, however, the degree in which each variable is present must be determined and effective fire control is largely based on recognizing the presence or absence of the variables and arranging the suppression pattern accordingly as dictated by the needs of the particular administrative unit's requirements.

There are some foresters who seriously doubt whether the size of the average fire may be taken as an index of control efficiency; they prefer the size of the average class "C"* fire as indicative of the fire fighting ability of a unit, and wish to separate dispatching from suppression effort. Inasmuch as the control of any fire within a given region is to a large extent dependent upon good pre-suppression work, such as effective tower location, speedy detection and dispatch, as well as effective performance on the fire-line, the size of the average fire over a period of several years will tend to eliminate the chance that "luck" may have aided one administrative unit when compared with another.

If the quality of control work for an organization can be measured by the size of the average fire and this today one accepted index of efficiency, there are several factors which contribute toward the results produced. These factors have been listed below.

A. Compliance with elapsed time standards for (1) detection, (2) communication, (3) get-a-way, and (4) travel.

B. Use of man-power by (1) organization before and during the fire, (2) effectiveness of action, (3) quantity of man-power available for initial attack and reinforcement purposes, and (4) morale main-

* Fires have arbitrarily been grouped by size classes, as follows: "A", 0-¼ acre; "B", ¼-10 acres; and "C", 10- acres (104).

... of suppression crews.

2. ... the suppression work is done.

3. ... and supplies from the standpoint of (1) adaptability, (2) availability, and (3) service ... in Chapter XI).

... Time Standards

... is the difference in time between the start of any specified activity and the accom- ... There are several ways in which the elapsed time is applied to fire control. It may re- ... or a fire, reporting time, get-away time, travel time, control time, patrol time, or ...

... of elapsed time standards is based on past experience correlated with current objectives. If ... for fires in fuels with a high rate of spread is 25 minutes, and the size of the aver- ... this fuel type is 20 acres, by cutting down on the elapsed time for travel, obviously there ... reduction of size of the average fire.

... time standards should always be correlated with the fire control objective so that the ... returns is not exceeded. It is poor economics to spend an additional $200 on the ... to arrive on it only five minutes quicker when the difference in values saved will average ... The increased $200 per fire could easily be incurred with the construction of several miles of ... which would permit lower travel time per average fire.

... standards have practical value in stimulating personnel to perform their fire func- ... prescribed limits. The hour control studies in the California Region of the United ... (40) serve as an example of the practical application of elapsed time standards.

... TIME refers to the amount of time which is permitted to elapse between the time a fire ... the time a lookout detects it. Data on this may be unreliable because it is difficult to ..., with any degree of accuracy, precisely when fire inception occurs. Because of the intensity of ... now existing in regions where lightning storms are prevalent, lightning strikes are ... checked. Vigilence is exercised for smoke detection during ensuing days for evidence of a ... started where strikes were recorded. If a smoke rises where the probability is low of its ... caused by man, location of strikes within a recent time period can be consulted and time of ... taken from the record of the recorded strikes, one of which should be almost identical with the ... of the fire which developed.

... case of man-caused fires, the actual time of inception is difficult to fix. There is seldom direct evidence as to the precise minute of a given hour when a fire starts. If there is evidence which leads ... to believe that the fire was started by a locomotive, and the exact time can be determined for the ... of the locomotive, then the inception time may be arrived at with a fair degree of accuracy.

Where the fuels have a rapid rate of spread, detection time standards should be lower than where the fuels have a low rate of spread. The prevailing fuel type in any given protection area should influence the detection time standards.

... REPORTING TIME is the time which elapses between discovery and the report to the agent who is re- sponsible for suppression. The standard here varies from two to five minutes. This is an elapsed time ... which can be made uniform for all regions because the operation is determined by factors entirely ... the control of the administrative personnel.

... GET-AWAY TIME is the elapsed time involved between the receipt of the report of the fire by the unit taking initial action and its actual departure for the fire. The commonly accepted standard here is ..., but it varies partly with the mode of travel. When horses are used for transportation, more time ... permitted to elapse than in the case of motorized transportation facilities.

... TIME standards vary not only with the mode of travel, but with the type of transportation ... Travel time standards with pack animals will be approximately the same as for foot ... latter will be lower off a trail than on a trail. Two miles per hour is considered reasonably ... travel over way-trails.

... motorized travel, the standards will vary with the quality of the roadbed, gradient, frequency of turnouts, etc. For averago truck trail conditions, 20 m.p.h. is considered good time, especially with a loaded truck.

5. CONTROL TIME is the time which elapses between the arrival of the suppression unit and the time when the perimeter of the fire is no longer extending itself. The time required to control a fire is not identical with suppression time. In a surface fire, control and suppression are almost identical; in a ground fire, control time may be one-half or one-tenth the suppression time. In a groundfire although the perimeter of the fire is not enlarging, the smouldering embers may at any time break into flame and enlarge the perimeter if the line is not gone over and "mopping up" done to corrall small or incipient outbreaks.

6. MOP-UP TIME is the amount of time which elapses between the control of a fire and the time when it is actually extinguished, that is, when there are no live or potentially live points on the perimeter.

"Mop-up" means extinguishing the last threatening embers whereby the fire is secured. It demands careful, painstaking effort. Careless mop-ups have frequently been the cause of lost line.

7. HOUR CONTROL is the time which elapses between the time a fire commences and suppression work begins.

**B. Use of Man-Power**

(1) Organization before and during a fire.

Organization of man-power on a going fire is based on principles and specifications laid down by the Fire Plan (see p. 101), consisting of an assembly of standards of action to be taken. The Fire Plan has sketched out a pattern of action to be taken. The man-power on a fire must be organized in such a manner that the pattern previously conceived is executed. Action that is deficient from standards prescribed by the Fire Plan is as serious a blunder as to have no plan at all.

The recruiting of large bodies of men at labor centers the transporting men, supplies, and equipment from depots may be impressive from an organization standpoint, but it is likely to be ineffective in preventing losses when started after a fire has made a big run. Situations of extreme fire danger can and should be anticipated so that adequate man-power is on the job before the fire gets completely out of control. To be able to recognize a situation of extreme fire danger in which large bodies of man-power may be required indicates ability on the part of the administrator to intelligently interpret those physical factors which create extreme danger.

The plan for the organization of man-power is essentially a job to be done prior to the occurrence of a fire; consequently it falls under the heading of "Pre-Suppression" so far as the plans for man-power are concerned. It has been discussed in detail under the Pre-Suppression heading.

(2) Effectiveness of action

"OVERHEAD" is comprised of the several forest officers and others of experience and training who are responsible for the conduct of a suppression crew. The efficiency with which the "overhead" works is reflected in suppression results. With unsatisfactory performance of "overhead", the size of the average fire is large; with efficient performance, the size of the average fire is low. Kelley (167) has stated that the "overhead" performance is the key to suppression success or failure. The "overhead" is responsible for deciding the method of attack and its execution. The larger the fire, the more important it is that there be experienced adequate "overhead".

Supervision of man-power is accomplished by having a sufficient amount of overhead on the job. Unless the unskilled labor on the fire-line is adequately supervised, it is valueless. A small crew of experienced men with good morale, tools adapted to the job, and well supervised is infinitely superior to large numbers of inexperienced men with poor supervision. The more inexperienced the firefighter, the more intense the supervision needed. All too frequently the fire control executive thinks in terms of number of men and supplies and equipment for them instead of in terms of overhead required to handle the men on the fire line. The adequacy of the overhead is the first item to be considered on a going fire which has good chances of making a run or developing into an extra period of fire. Ample overhead, each unit of which clearly understands its duties, is the key to successful handling of inexperienced men on the line.

The organization of man-power on a class "C" fire is fairly uniform for most forest regions; this

...ion consists of advance arrangements whereby firefighters function under supervisors or overhead, each of whom has definite authority.

Overhead Positions and Duties.

The number of overhead, or positions of authority, all depend upon the size of the fire; the larger the fire, the more units are necessary. The overhead positions are as follows: (1) fire boss, (b) fire scout, (c) sector boss, (d) foreman, (e) straw boss, (f) camp boss, (g) time-keeper, and (h) cook.

With overhead so important in the success or failure of suppression work, those men who occupy the most important positions, such as the fire boss, scout, and sector boss in particular, should have a number of personal qualities that will enable them to perform satisfactorily their duties. These qualities may be summed up among the following: (a) organizing ability, (b) knowledge of fire behavior, (c) ability as a strategist, (d) technical skill, (e) ability to undergo severe physical strain, (f) calm temperament so that excitement will not stampede good judgment, (g) willingness to expend physical and mental energies, (h) ... in decisions made, (i) lack of fear of fire, and (j) qualities as a leader, so that the most ... out of subordinates.

The FIRE BOSS is the forest officer in full authority on a fire project. His duties are numerous, ... he is concerned with handling man-power as well as planning and executing suppression tactics. His duties largely fall under the following items: (a) Upon arrival on the fire, size up the situation. This ... personally scouting, or having scouted, the fire to determine the location of the critical ..., ... the suppression needs, and checking with the man-power dispatched to ascertain whether ... to control the fire within the suppression standards which have been set up. (b) Organize ... the earliest possible moment after the situation has been appraised. (c) Arrange for the ... liaison so there will be coordinated action among the several suppression units and that ... adequate service of supply for them. (d) Personally direct or control the tactics of suppression ... fire; see the whole situation in perspective so that sector bosses, with a limited viewpoint, ... when making false moves. (e) Make provision for the relief of overhead and man-power if the fire ... extends beyond eighteen hours. (f) Provide for, or personally inspect the fire line to ... whether sector and straw bosses are working on the basis of the standards established, such as effective ... work on the fire-line and speedy mop-up, keeping the men constantly moving forward on the fire-line so that there will be no bunching-up and no straggling, and that the firefighters are provided with adequate food and water.

THE FIRE SCOUT is the aide to the fire boss. He keeps him constantly informed of the spread of the fire, what effect the suppression tactics are having, what type of fuel is ahead, locates new camp sites, and acts in general as eyes and ears of the fire boss who makes decisions on the basis of the information presented to him. The fire boss should find time, however, to determine whether his scout is providing him with correct information.

THE SECTOR BOSS is an aide of the fire boss on the fire-line itself; he is directly responsible to the fire boss in carrying out the suppression tactics on a specific, assigned sector of the fire's perimeter.

THE FOREMAN operates under the direction of the sector boss in suppression work on the fireline.

THE STRAW BOSS works under the direction of the foreman. His crew seldom numbers over ten men.

THE CAMP BOSS supervises all operations in the fire camp. This position is necessary only when there are more than 50 men operating out of a camp. He handles all commissary work, accounts for time, maintains the communication and transportation system, and keeps an adequate stock of supplies, tools and equipment. He is responsible to the sector boss if the man-power on the fire is scattered through several camps.

A TIME KEEPER is necessary only when there are more than 60 men in a fire camp. His principal job is clerical ... accounting for time, supplies, and equipment. He may also act as telephone or radio operator.

Liaison

A central control point and liaison are other essentials for the successful handling of a class "C" fire ... of control. All activity on a fire must be coordinated. To secure this coordinated ... control and liaison with this control point on the part of detached units is demanded. ..., the line on which a crew is working is lost due to carelessness in construction or be... shift of wind, the control should immediately be notified of the change in status, a statement made of proposed action, and request for confirmation or change of this proposed action in event of a different point of view on the part of the control or fire boss. The necessity for this continual communication between the fire line and the control is so that man-power can be deployed to the best possible advantage for the current and anticipated situation. If a line is lost, and the fire boss planned on using the man-power on another sector the following day, those plans would have to be changed because there would be a need for additional instead of fewer men.

Liaison can be conducted by scouts, messengers, a combination of messengers and telephone, or radio. With light, portable radio sets available, liaison of the highest order can be had on a going fire. The fire boss can be informed at all times of the status of things on the line and can regulate his activity accordingly.

For a fire control organization to function most effectively, it is necessary for the fire boss to know continuously of all activity on a fire where the whole situation can change in a few minutes. Satisfactory liaison is the means by which all effort is correlated; without it, there is serious waste of man-power and high forest losses are entailed.

(3) Quantity of man-power available for initial attack and reinforcement purposes.

INITIAL AND REINFORCEMENT ACTION refer to the manner in which suppression work is conducted.

"Initial Action" is the attack on the fire by the first suppression unit to arrive on the job. The initial attack is usually conducted by one man, a few men, or a small crew of seven to ten. The size of the man-power unit making the initial attack is determined by the manner in which the forest unit is organized. In several western forest regions, where firemen are used for initial attack, one man generally attempts the control job. In the South, where flash fuels are frequently located close to young stands of timber which may produce crown fires quickly, six or ten men may be in the crew which takes the initial action.

"Reinforcement action" is the attack made by a crew of men to supplement the initial action when the latter has failed to corral the fire. The first reinforcement crew to arrive may also be ineffective in controlling the fire, but all reinforcement crews on the job thereafter still operate under the heading of "reinforcement action".

The basis for determining the man-power required for initial action is similar to that employed for reinforcement action. From the standpoint of losses to timber and costs of suppression, it is important that careful control be exercised in man-power dispatch.

Reinforcement action is always necessary on extra period fires. "Extra period" fires may be defined as those which occur after 10 a.m. of any day and are still out of control by 10 a.m. of the day following. This type of fire is important in that the stage is always set for a blow-up when situations of this nature develop. When a fire is out of control by 10 o'clock of a morning following the day it started, it means that the burn in the extra period, i.e., subsequent to 10 a.m., will, in the majority of cases, result in serious loss of area, much in excess of what burned the first day.

SUPPRESSION CREW DISPATCH plays an important part in the costs of suppression and losses entailed. The forest manager is continually confronted with the economics of forestry practice. With sufficient expenditure, it is conceivable that all fires can be controlled while in the class "B" size so that no fires will get into the "C" size class. To make such a situation possible, however, tremendous sums, would have to be expanded; these expenditures would be justifiable in very few, if any, instances due to the relatively low values entailed.

To have just enough man-power, allowing for a reasonable safety factor, to control a fire for whatever current fire danger exists, is a problem that requires a balancing of physical factors with human judgment. When the fire danger is low, the job of man-power dispatch is simple. In periods of high fire danger, however, the dispatch of man-power demands the highest order of good judgment so that the dispatcher will not permit himself to be stampeded into over-manning a fire. In periods of high fire danger, calm judgment is necessary to prevent the suppression machinery from being thrown out of balance by dispatching a large number of men to a fire in fuels having a low rate of spread and a low resistance to control. With an outbreak of a fire in fuels with a high rate of spread and extreme resistance to control in a period of unusual fire danger, the over-manning of the first fire may cause an undermanning of [illegible] fire with the development of a large size class "C" fire. To avoid such situations, technique [illegible] man-power can be and has been devised.

[illegible] (16[illegible]) has stated that those factors to be considered in man-power dispatch, whether for [illegible] reinforcement action, are (1) rate of spread as determined by (a) fuels, (b) topography, [illegible] fuel moisture content; (2) resistance to control influenced by (a) fuels and (b) topography; [illegible] of held line output dependent upon (a) size of crew, (b) character of crew and overhead, [illegible]

[illegible] of the above items to be considered in the dispatch of man-power, there is need for a high [illegible] on the part of the individual who determines the strength of the attack so that it will be [illegible] neither wasteful of man-power by having too many men on hand nor of natural resources by [illegible] attack so weak that the area burned is excessive.

[illegible] GUIDE CHARTS, (166) have been devised by the Northern Rocky Mountain Region (R-1) of the [illegible] Forest Service. These charts are comprised of four units. Unit I is a fire danger meter [illegible] p. 71) for computing rate of spread mentioned above. Unit II is made up of two charts (see [illegible] Chart I is for computing rate of perimeter increase for the fuel types as applied to the rate [illegible] factors (I above). Chart Two of Unit II is for computing the probable perimeter for a fire [illegible] danger and corral time objectives. Unit III (see fig. 42c) is a chart for determining man-[illegible] based on the factors listed above in Units I and II. The use of these Dispatcher Guide [illegible], pre-supposes that there are available to the dispatcher all the data that he needs for [illegible], particularly on such variable elements as moisture content of fuels and wind velocity [illegible] of the specific fire for which he is dispatching.

[illegible] made by Abell (209) for several common fuel types of the southern Appalachian and North-[illegible] forest regions formed the basis for the preparation of tabulations that serve as a guide for sup-[illegible] crew dispatch. Although the results of the study were not as highly refined as those of Sutliff, [illegible] involved were essentially the same. Table 34a below represents the man-power requirements for [illegible] burning conditions for the Appalachian hardwood forest type, timber over three inches in diameter [illegible] height.

**Table 34a**

[illegible] REQUIREMENTS, APPALACHIAN HARDWOODS

| [illegible] | Burning Conditions | | | |
|---|---|---|---|---|
| [illegible] | Ordinary | Moderate | Severe | Extreme |
| [illegible] | No. Men | No. Men | No. Men | No. Men |
| [illegible] | [illegible] or less | 7-9 | 13 or less | 14-37 |
| [illegible] | [illegible] or less | 9-12 | 15 or less | 16-42 |
| [illegible] | [illegible] or less | 12-16 | 17 or less | 18-48 |
| [illegible] | [illegible] or less | 16-21 | 19 or less | 20-54 |
| [illegible] | [illegible] or less | 35-49 | 25 or less | 26-72 |
| [illegible] | | | 34 or less | 35-98 |
| [illegible] | | | 49 or less | 50-141 |
| [illegible] | | | 80 or less | 81-228 |

In Table 34a, the corral time, or that time period within which the fire would be controlled after arrival was two hours for ordinary and moderate burning conditions and four hours for severe and extreme burning conditions. Separate tabulations were prepared for the most common forest types, for the perimeter of a fire increase is determined not only by the burning conditions such as volume and inflammibility of the fuels, slope, wind, etc., but also by the character of the fuel, whether it is composed of hardwood litter only, whether some coniferous slash is present, or whether the forest type is coniferous rather than hardwood.

With so many variables to account for, and with meagre information available on so many of these, crew dispatch is difficult. As was observed by Matthews (210), the per man [illegible] of controlled perimeter is a matter which varies considerably even on one fire. The record showed that the production rates varied from 0.02 chains per man hour to 0.13 chains, with an average of 0.05 chains per man hour. This calculation included allowance for travel time but excluded the man-hours con-[illegible] by the service of supply. As in the case of all statistics, however, too much significance can [illegible] to reports on the output of held line per man hour. There are so many variables involved. [illegible] (212) has raised the question as to the value of data on held line construction. In the one [illegible] type of labor may have been of high quality, in another low. Again, there may have been hand [illegible] available precisely adapted to the requirements; in another instance, there may have been a serious [illegible] of the type of tool needed.

[illegible], the item of dispatching for initial as well as reinforced action can be placed on a [illegible] basis, provided there are sufficient data available whereby the computations can be made to set [illegible] accurate tables. With so many variables to account for, the dispatcher will be more nearly

## DISPATCHER'S GUIDE CHART - PERIMETER-INCREASE DATA

**CHART ONE**

| Spread Danger Class | Fuel Type: Low | Med. | High | Ext. |
|---|---|---|---|---|
| | Perim. Incr. Factor (Pl. [illegible] For [illegible]) | | | |
| 2 | .[illegible] | .[illegible] | .1[illegible] | .2 |
| 3 | .[illegible] | .2 | .[illegible] | .[illegible] |
| 4 | .6 | .[illegible] | 1.0 | 1.8 |
| 4.5 | [illegible].0 | 1.[illegible] | 1.6 | [illegible].8 |
| 5 | [illegible].6 | [illegible].0 | 2.8 | 4.8 |
| [illegible].4 | [illegible].[illegible] | [illegible].8 | [illegible].0 | 8.1 |
| [illegible].7 | [illegible].7 | [illegible].8 | [illegible].[illegible] | 1[illegible]. |
| 6 | [illegible].6 | 8.4 | 11. | 17. |
| 6.3 | 8.2 | 1[illegible]. | 16. | [illegible]5. |
| 6.6 | 11. | 1[illegible]. | 20. | 33. |
| 6.8 | 1[illegible]. | 18. | 23. | 39. |
| 7 | 14. | 20. | 26. | 46. |
| 7.2 | 16. | [illegible]3. | 30. | 51. |
| 7.4 | 17. | 25. | 33. | 56. |
| 7.5 | 18. | 26. | 35. | 59. |

**CHART TWO**

Time Objectives — Perimeter-Increase Factor Multipliers - According to Time Objectives [illegible]

| Time of Discovery | 1[illegible] [illegible] | 1[illegible] p.m. | 11 p.m. | 10 p.m. | 9 p.m. | 8 p.m. | 7 p.m. | 6 p.m. | 5 p.m. | 4 p.m. | 3 p.m. | 2 p.m. | 1 p.m. | 12 [illegible] | 11 a.m. | 10 a.m. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 9 a.m. | 82 | 78 | 75 | 70 | 63 | 56 | 49 | 42 | 35 | 28 | 21 | 15 | 10 | 6 | 3 | 1 |
| 10 a.m. | 79 | 72 | 69 | 63 | 56 | 49 | 42 | 35 | 28 | 21 | 15 | 10 | 6 | 3 | 1 | |
| 11 a.m. | 68 | 65 | 61 | 56 | 49 | 42 | 35 | 28 | 21 | 15 | 10 | 6 | 3 | 1 | | |
| 12 noon | 61 | 58 | 54 | 49 | 42 | 35 | 28 | 21 | 15 | 10 | 6 | 3 | 1 | | | |
| 1 p.m. | 49 | 47 | 44 | 39 | 37 | 27 | 21 | 15 | 10 | 6 | 3 | 1 | | | | |
| 2 p.m. | 39 | 37 | 34 | 30 | 25 | 20 | 15 | 10 | 6 | 3 | 1 | | | | | |
| 3 p.m. | 29 | 27 | 25 | 22 | 18 | 14 | 10 | 6 | 3 | 1 | | | | | | |
| 4 p.m. | 21 | 19 | 17 | 14 | 12 | 9 | 6 | 3 | 1 | | | | | | | |
| 5 p.m. | 18 | 16 | 14 | 12 | 9 | 6 | 3 | 1 | | | | | | | | |
| 6 p.m. | 15 | 13 | 11 | 9 | 6 | 3 | 1 | | | | | | | | | |
| 7 p.m. | 12 | 10 | 8 | 6 | 3 | 1 | | | | | | | | | | |
| 8 p.m. | 8 | 7 | 5 | 3 | 1 | | | | | | | | | | | |

Night Fires: For discoveries between 5 a.m. and 9 a.m. increase the discovery hour by the required number of hours to advance it to 9 a.m. Then advance both the estimated arrival time and the corral objective the same number of hours and work out probabilities on the basis of a 9 a.m. discovery. Example: 6 a.m. discovery, 8 a.m. arrival and 10 a.m. corral would be worked thus - 9 a.m. discovery, 11 a.m. arrival and 1 p.m. corral.

For all other night fires (between 9 p.m. and 5 a.m.) simply reverse a.m. hours to p.m.'s and p.m. hours to a.m.'s and use charts direct as for a daytime discovery. Example: 11 p.m. discovery, 1 a.m. arrival and 6 a.m. corral would be worked out as an 11 a.m. discovery, 1 p.m. arrival, and 6 p.m. corral. Remember - the danger class used must represent night conditions at site of fire.

Fig.42b (The data contained herein is intended for use as a guide for dispatching)



## DISPATCHER'S GUIDE CHARTS - CORRAL-LINE OUTPUT DATA

SMOKECHASER OUTPUT FIGURES BASED UPON ESTIMATES OF APPROXIMATELY 150 EXPERIENCED MEN, 1000 ESTIMATES TAKEN IN 1930 AND 600 IN 1935 AND 1936.
OUTPUT = EXTREME, .75 CH.; HIGH, .8 CH.; MEDIUM, 2.0 CH.; LOW 3.3 CH.

SMOKECHASER UNITS OF OUTPUT ACCORDING TO SIZE OF CREW EMPLOYED AND NUMBER HOURS WORKED

| HOURS OF WORK | NUMBER OF MEN: 1 | 2 | 3 | 4 | 5 | 7 | 10 | 15 | 20 | 25 | 30 | 40 | 50 | 75 | 100 | 125 | 150 | 175 | 200 | Fatigue Factor Applicable According to Number Hours Worked |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.0[illegible] | 2.00 | 3.00 | 4.00 | 4.95 | 6.66 | 9.50 | 12.7 | 14.0 | 15.0 | 15.9 | 19.2 | 22.5 | 30.0 | 35.0 | 40.6 | 45.0 | 48.7 | 50.[illegible] | [illegible] |
| 2 | 2.00 | 4.00 | 6.00 | 8.00 | 9.90 | 13.7 | 19.0 | 25.5 | 28.0 | 30.0 | 31.8 | 38.4 | 45.0 | 60.0 | 70.0 | 81.3 | 90.0 | 98.3 | 100. | [illegible] |
| 3 | 2.97 | 5.94 | 8.91 | 11.[illegible] | 14.7 | 20.4 | 28.2 | 37.9 | 41.6 | 44.6 | 47.2 | 57.0 | 66.8 | 89.1 | 103. | 121. | 133. | 143. | 149. | [illegible]7 |
| 4 | 3.82 | 7.64 | 11.5 | 15.[illegible] | 18.9 | 26.2 | 36.3 | 48.7 | 53.5 | 57.3 | 60.7 | 73.3 | 86.0 | 115. | 134. | 155. | 172. | 184. | 191. | [illegible] |
| 5 | 4.[illegible] | 9.0[illegible] | 1[illegible].[illegible] | 1[illegible].[illegible] | [illegible].3 | 30.9 | [illegible]2.8 | 57.5 | 63.1 | 67.7 | 71.7 | 86.6 | 101. | 135. | 158. | 183. | [illegible] | 2[illegible]. | [illegible] | [illegible] |
| 6 | 5.0[illegible] | 10.1 | 1[illegible].[illegible] | [illegible] | [illegible].0 | 34.7 | 48.1 | 64.5 | 70.8 | 75.[illegible] | 80.[illegible] | 97.1 | 114. | 152. | 177. | 205. | 228. | 243. | 253. | [illegible] |
| 7 | 5.52 | [illegible].0 | 16.5 | 22.[illegible] | 27.[illegible] | 37.9 | 52.4 | 70.4 | 77.3 | 82.8 | 87.8 | 106. | 124. | 166. | 193. | 224. | 248. | 260. | 276. | [illegible] |
| 8 | 5.92 | 11.8 | 17.8 | 23.7 | 29.3 | 40.6 | 56.2 | 75.5 | 82.9 | 88.8 | 94.1 | 114. | 133. | 178. | 207. | 241. | 266. | 285. | 296. | [illegible] |
| 9 | 6.27 | 12.5 | 18.8 | 25.1 | 31.0 | 43.0 | 59.5 | 79.9 | 87.7 | 94.0 | 99.7 | 120. | 141. | 188. | 219. | 255. | 282. | 301. | 313. | 35 |
| 10 | 6.60 | 13.2 | 19.8 | 26.4 | 32.7 | 45.3 | 62.7 | 84.1 | 92.4 | 99.0 | 105. | 127. | 149. | 198. | 231. | 268. | 297. | 318. | 330. | 33 |
| 11 | 6.91 | 13.8 | 20.7 | 27.6 | 34.1 | 47.4 | 65.6 | 88.1 | 96.7 | 104. | 110. | 133. | 155. | 207. | 242. | 281. | 311. | 333. | 345. | 31 |
| 12 | 7.21 | 14.4 | 21.6 | 28.8 | 35.7 | 49.6 | 68.5 | 91.9 | 101. | 108. | 115. | 138. | 162. | 216. | 252. | 293. | 324. | 347. | 361. | [illegible] |
| 13 | 7.50 | 15.0 | 22.5 | 30.0 | 37.1 | 51.4 | 71.2 | 95.6 | 105. | 113. | 119. | 144. | 169. | 225. | 263. | 305. | 337. | 361. | 375. | [illegible] |
| 14 | 7.78 | 15.6 | 23.3 | 31.1 | 38.5 | 53.4 | 73.9 | 99.2 | 109. | 117. | 124. | 149. | 175. | 233. | 272. | 316. | 350. | 374. | 389. | [illegible] |
| 15 | 8.05 | 16.1 | 24.1 | 32.2 | 39.9 | 55.2 | 76.5 | 103. | 113. | 121. | 128. | 155. | 181. | 241. | 282. | 327. | 362. | 387. | 403. | 2[illegible] |
| 16 | 8.31 | 16.6 | 24.9 | 33.2 | 41.1 | 57.0 | 78.9 | 106. | 116. | 125. | 132. | 159. | 187. | 249. | 291. | 338. | 374. | 400. | 415. | [illegible] |
| 17 | 8.56 | 17.1 | 25.7 | 34.2 | 42.4 | 58.7 | 81.3 | 109. | 120. | 128. | 136. | 164. | 193. | 257. | 300. | 348. | 385. | 412. | 428. | [illegible] |
| 18 | 8.80 | 17.6 | 26.4 | 35.2 | 43.6 | 60.3 | 83.6 | 112. | 123. | 132. | 140. | 169. | 198. | 264. | 308. | 357. | 396. | 423. | 440. | [illegible] |
| 19 | 9.03 | 18.0 | 27.0 | 36.1 | 44.7 | 61.9 | 85.8 | 115. | 126. | 135. | 144. | 173. | 203. | 271. | 316. | 367. | 406. | 435. | 451. | [illegible] |
| 20 | 9.25 | 18.5 | 27.7 | 37.0 | 45.8 | 63.4 | 87.9 | 118. | 129. | 139. | 147. | 178. | 208. | 277. | 324. | 376. | 416. | 445. | 463. | [illegible] |
| | 100 | 100 | 100 | 100 | 99 | 98 | 95 | 85 | 70 | 60 | 53 | 48 | 45 | 40 | 35 | 32.5 | 30 | 27.5 | 25 | ← Size of Crew Factor |

Output Figures shown are based upon daylight work. Overhead has been assumed to consist of one qualified foreman and three qualified strawbosses per 25-man unit with corresponding number of fire or sector foremen, forest officers, etc. This data for use as a guide.

Fig.42c (Divide chains of work by sq. output rate before using this chart to get man-power)

## INSTRUCTIONS FOR USING REGION ONE DISPATCHER GUIDE CHARTS - WESTERN FORESTS

... must be carefully considered in any method of calculating fire probabilities or determining man-power needs. The influence ... factors has been given consideration in the region one charts, insofar as possible to determine from the limited amount of data ...

| | | | |
|---|---|---|---|
| ... | 2. TOPOGRAPHY: | 3. WIND: | 4. FUEL MOISTURE: |
| ... ent | A. Slope<br>B. Exposure | A. Velocity<br>B. Direction<br>C. Duration | A. Humidity (Existing)<br>B. $\frac{1}{2}$" and less Fuels<br>C. Precipitation (Previous)<br>D. Large Fuels (2" Plus) |
| ...EW: | 6. CHARACTER OF CREW AND OVERHEAD: | 7. FUEL RESISTENCE: | 8. FATIGUE: |
| ... Men<br>... through Place-<br>... and Supervision) | A. Experience<br>B. Training<br>C. Adaptability | A. Same as 1-A,B,C,D except as each affects held-line output | A. Length of work period (varies greatly with type of men used) |
| ... TIME: | 10. ARRIVAL TIME: | 11. CORRAL TIME: | 12. METHOD OF ATTACK: |
| ... | A. Estimated (sufficient force to deter spread as calculated) | A. Objective (Established arbitrarily) | A. Frontal<br>B. Flanking |

... METHODS OF OBTAINING TIMELY MEASUREMENTS OF FACTOR INFLUENCE

... OBSERVING AGENCIES: Lookouts, smokechasers, crewmen - glasses or telescope may be used.
... PERSONAL KNOWLEDGE of dispatcher or other persons immediately available.
... INFLAMMABILITY STATIONS: Wind gauges, psychrometer locations, etc. Several readings daily.
... MAP: For general information and to be relied upon when 1 & 2 fail to serve need.
... WEATHER RECORDS: Fuel moisture, wind, humidity, rainfall, etc., as recorded several times daily.

... PROBABILITIES WITH REGION ONE GUIDE CHARTS

... DANGER CLASS from spread danger meter. Adjust actual measurements, secured from sources nearest to fire, by carefully com- ... slope, exposure, timber stand (dense, average or open), exposure to wind, elevation, rainfall (recent and past), time of day.

... RATE OF SPREAD FACTOR from chart I. Select proper danger class, in first column, then refer to proper rate of spread (fuel ... on same danger class line, and rate of spread factor will be indicated. Determine proper rate of spread (fuel type) by ... suggested under B 1, 2 & 4 above.

... PERIMETER INCREASE FACTORS from chart II. In first column select time of discovery of fire (to nearest preceding hour), ... across chart to proper arrival time and corral time columns. Thereunder will be indicated the proper multipliers to be used in ... the probable free burning perimeters from discovery to arrival and from discovery to corral time. The percentage of the ... between the arrival time perimeter and corral time perimeter which should be allowed depends entirely upon strength of at- ... force and the method of attack anticipated. The arrival time perimeter plus the corral period allowance equals total job size ...

... MAN-POWER NEEDS from chart III. Divide total chains of anticipated perimeter by the smokechaser output rate for the fuel type ... This gives the number of smokechaser hours of work to be done. In first column select number of hours calculated in corral ..., follow this line to right until an output figure equal to number of hours of smokechaser work is found. At top of column will ... number of men required to do the job, with allowance made for factors, A 5,6,7 and 8, as set forth above.

... FIRES: Between 9 p.m. and 9 a.m. chart II may be used in the same manner as for daytime discoveries except for multipliers shown ... two. These are for daytime discoveries only and are applicable when a dispatcher desires to determine the probable perimeter ... fire which has escaped corralling throughout the first day. To determine job size for second a.m. corralling.

...: August 7, normal slopes, normal humidity, 4-5 mile wind, 9% fuel moisture - D.C. 5. Fuel type is medium spread and medium re- ...; discovery time is 10 a.m.; arrival time is 12 noon; corral objective is 2 p.m. Chart I gives a spread factor of 2.0. Chart II ... arrival time multiplier of 3 and a corral time multiplier of 10. Thus probable perimeter on arrival is 2.0 x 3 or 6 chains. ... to corral time perimeter is 2.0 x 10 or 20 chains. 20 minus 6 is 14 chains or free burning increase during corral period. ... attack is planned 25% should be sufficient allowance. Thus 6 chains plus 25% of 14 chains equals 9.5 chains or probable ... job size.

... in his estimate of man-power requirements if he uses carefully prepared tables than if he guesses at what is needed. The Dispatcher Guide Charts eliminate the guesswork.

Detection planning should arrange for the fire to be detected within a short time after it starts. It should be picked up while still definitely a Class A fire. Visibility will determine how readily the fire is located, but it must be assumed that detection planning has arranged the location of the lookouts in such a manner that even under conditions of low visibility, the smoke will be detected while the fire is still class "A" in size.

Travel time is not a serious item if it may be assumed that man-power placement has been correlated with fuel characteristics so that even with extreme fire danger, sufficient man-power can arrive in the necessary amount of time to prevent a serious "run".

It is conceivable--and such conditions have occurred--wherein the number of men arriving at the fire within the time specified will be unable to control it when the variables represented are extreme, such as ... high wind velocities, 30 m.p.h. or more; low moisture content of the fuels, 6% or less; and extreme ... conditions, 60% or more. To have the detection system, man-power strength and organization, and ... system to prevent a fire from reaching class "C" size during a period of extreme danger ... most careful planning, quick accurate decisions, prompt action by the dispatcher, and high ... control work.

(4) The Maintenance of Morale

The morale of the firefighters can be held at a high or low level dependent upon the leadership of the supervisory personnel on the fire. Undoubtedly such factors as adequate messing and sleeping facilities, when necessary, play an important role; but more important than these is whether the firefighters have confidence in the men who direct the work. It is of extreme importance that morale be maintained at a high level in order that output of effort be high. Morale of man-power on size class "A", "B", and small class "C" fires up to 200 acres in size is generally good, but when they exceed this area or develop into extra periods, overhead shortage generally occurs and frequently, by the time the fire has completed its first big run, the overhead which was on the fire originally is so exhausted and discouraged that intelligent mental processes are no longer possible. Relief for tired overhead seldom arrives soon enough. Because of the fatigue due to physical excesses, the let-down in work output is reflected all along the line from the fire chief to the man who uses a backpack pump or a hazel-hoe. The defeatest attitude which attends fatigue causes low morale. There is all too frequently too great a gap in time between the period when morale begins to ebb and replacements take over the job of leadership from the tired sector bosses and crew leaders. To avoid this sudden slump in morale the fire boss should requisition more overhead the moment he becomes aware of the fact that the fire will probably go into an extra period. This, too, is a matter which can be greatly facilitated by adequate liaison between the sector leaders, the fire boss, and his superior.

It is of especial importance that the fire boss be periodically relieved because tired minds result in sluggish decisions, incoherent orders, and poor judgment.

Occasionally morale breaks down because the fire boss does not recognize that his primary concern is with the progress made on the fire line. He may permit himself to become absorbed in the procurement of foodstuffs or the repair of broken-down equipment or the protection of a bridge which has no real value in suppressing the going fire. This is serious error in judgment on his part.

Cooperation among the overhead is essential for good morale. When there is petty bickering among the overhead itself, this is soon reflected in the performance of the men because their confidence in the leaders is lowered when they realize that the overhead is quite apparently not in agreement on procedure. Still worse is the situation in which each sector boss operates under his own ideas without regard for the others. There is consequently no coordination among the several leaders. Such situations always develop with a fire chief who is either too tired to function, inexperienced, or temperamentally unqualified. Good fire bosses will maintain morale merely by their aggressiveness and qualities of leadership.

Length of work period also influences morale maintenance. Total man-power on a fire should not be exhausted in control because there is always mop-up work to be done immediately following the period the fire is corralled. It is not unreasonable to work men to a 24-hour period provided there is positive assurance that the fire can be controlled in this period. It must be borne in mind however, that the efficiency of man-power decreases quickly after a 6 to 8 hour period of exhaustive labor.

On a fire which cannot be controlled with one shift of man, a shift of less than 12 hours should be used; this includes travel time.

Good practice demands that men commence work on the fire line at break of day and remain on duty until nightfall unless the heat of the fire or a rapid run and frequent spotting makes firefighting too hazardous.

**C - Time of Day and Suppression Work**

Class "A" and "B" Fires

Fires should be worked on as soon as practicable after they have been detected, regardless of the time of day of discovery. An instance in which it might be advisable to put off work on a fire immediately after its inception would be during a night lightning storm with numerous strikes concentrated in a small watershed. After the strikes have been located by the fireman in his capacity as an observer, the rule to follow ordinarily would be to leave for the vicinity of the strike at once. With no blazes evident after the storm, however, to attempt to locate smokes before daylight would be futile. It would be much more desirable to notify the dispatcher of the situation, and have him send to the points of strike on the following morning several crews equipped with radio sets to work on the probable fires started by the storm the night before and report the situation upon their arrival on the fire. By remaining on the [illegible] moreover, the firemen could spot the smokes readily and notify the suppression crews [illegible] radio channels of their precise location.

[illegible] reinforcement action is extremely important in preventing small "C" fires from becoming [illegible] of suppression should be placed on initial attack because it is the results of this [illegible] will produce a successful or unsuccessful fire season. Adequate initial attack is an [illegible] element in successful fire control.

[illegible]

[illegible] fire weather conditions exist while a fire burns, the light fuels become moistened by [illegible] atmospheric moisture. This factor, plus lessened wind movement, lower temperatures with [illegible] the production of convection currents, and lower evaporation rates, result in a lowered [illegible] an opportunity for direct attack. In crown fires, the blaze usually degenerates into [illegible] several hours after sundown, thus producing an opportunity for direct attack which is not [illegible] day period.

[illegible] standpoint of the production of effective suppression work in periods of high fire danger, [illegible] tendency to crown during the mid-day period, direct attack must be done when the fire [illegible] surface. It is in this mid-day period that fires make their big runs and enlarge [illegible] many times. Unless effective control is accomplished, the fire will crown if it is burn- [illegible] coniferous stand. This work must be done between daylight and the time the fire will crown [illegible] between 9:30 and 11:00 a.m. When the fire cannot be controlled within this period, the [illegible] attack on the head fire may as well be withdrawn and backfiring resorted to or a rest [illegible] until the excessive rate of spread diminishes and there is a tendency to subside into a [illegible]

[illegible] a fire should be attempted under very limited conditions. These conditions are (a) [illegible] "A", "B", or small "C" class, (b) for the purpose of saving an area of high value or [illegible] would require considerable outlay for replacement, (c) when there is ample overhead [illegible] direct the crews, (d) when the topography does not jeopardize the lives of the men on the [illegible] there is a light of some sort available for each worker, (f) and when the perimeter is [illegible] only by night work can the fire be corralled with the men available, before going into an [illegible]

[illegible] work, approximately twice the overhead is required on the line as in day work.

## "OUT"

There is a very great difference between "under control" and "out". The former implies that the [illegible] period of rapid rate of spread has been checked, but there are still many points [illegible] fire, although for the time being they may be dormant. No fire is "out" until it is impossible [illegible] of the fire to enlarge itself.

In organizations where part-time or volunteer workers are used in suppression, a single fire may be [illegible] two, three, or more fires. Actually it is probably only one fire, but at some point [illegible] the suppression work had not been efficient with the result that the fire line was [illegible] itself along this point of the perimeter. Rather than blame themselves for careless work, [illegible] prefer to place the responsibility on an alleged incendiarist and report that, while the [illegible] crew was busy with the fire, the person reponsible for its origin rekindled the fire behind [illegible] crew.

[illegible], for example, are easy to control but extremely difficult to extinguish. They may be [illegible] for weeks before they are "out" . The more organic matter there is in a semi-decomposed [illegible] ground, the more time will be required to patrol its perimeter, after it is gotten under con- [illegible] that it does not eat under the trench which has been constructed, or eat under trees and [illegible] over the fire line and thus carry fire over the trench.

[illegible] control demands that fires be controlled in the shortest possible time; corrallary [illegible] however, is that all corralled fires must remain under control until they can definitely [illegible] "out". To control a fire quickly is commendable, but to neglect it after it has been con- [illegible] sort of technique.

## Some Fire Suppression Rules

I - Preliminary

(a) Upon arrival at the fire, size up the situation by scouting to determine the conditions under which the fire is burning so that suppression tactics may be formed.

(b) Commence the attack immediately on the flanks until the situation can be appraised. After a plan of attack has been formed, the man-power may be deployed as necessary. If reinforcements are required, requisition them immediately.

II - Control Action

(a) Control the hot-spots and heads, provided there is a chance of controlling the rapid extension of the perimeter without endangering the lives of the suppression crew.

(b) Commence work at the center of the head extending flankward from its center.

(c) Take immediate follow-up action to prevent dormant hot-spots from becoming active.

III - Miscellaneous

(a) If the fire has a tendency to crown or spot, work on the spots immediately; if there are insufficient men in the crew for an adequate factor of safety, obtain more help at once.

(b) In the follow-up work, fell snags carefully so that the felling will not extend the perimeter; if it does, act on the new hot-spot at once.

(c) String the firefighters out along the line; bunching of firefighters is a good index of poor leadership or insufficient overhead.

(d) The fire boss should maintain liaison with his subordinates as well as superior officer. The fire boss has no time for actual firefighting, even under stress of excitement.

## Chapter XIII

## ANALYSIS OF FIRES

[illegible] those conditions which attend large as well as small class C fires is generally fruitful [illegible] possible the discovery of deficiencies. Only by repeatedly making these analyses is it [illegible] the suppression system, educate men who may have used poor judgment because of inex- [illegible] place responsibility for failure if such action is considered desirable. This [illegible] atively handled, can always be used as the means of strengthening defects, regardless [illegible] nesses appear in organization, planning, equipment, or personnel. Weaknesses develop [illegible] by fires. The analysis of each large fire should bring about desirable changes.

[illegible] poor judgment is the cause of a "blow-up"; if such is the case, analysis of an [illegible] expose such a situation. To be of greatest value, the analysis should be used not to [illegible] of the individuals concerned, but to bring to their attention these facts which lead [illegible] the size of the fire due to faulty judgment so that, if ever again confronted [illegible] situations, the decisions they make will be less disastrous.

[illegible] which analyses can be placed is to dig out those facts which can be used to strengthen [illegible] work. If one or several weaknesses consistently develop in analyses of fires within a [illegible] evidence that insufficient attention has been given to that point. The deficiency may be [illegible] prominence in the fire plan or overlooking it during those periods that the fire plan [illegible] periods.

[illegible] several fire analyses which are in the nature of post mortems, but nevertheless [illegible] under specific circumstances. The basic information and maps of the fires, from which [illegible], were supplied thru the courtesy of the Regional Offices of Regions 5, 6, 8, and 9 [illegible] Office of a Western National Forest. These analyses are not supposed to be typical [illegible] represented. When received they should be considered from the standpoint of forest [illegible] technique only.

### BIG HENRY FIRE

[illegible] acres burned between 11:40 a.m. and 5:45 p.m.

[illegible] to rolling, relatively few streams present.

[illegible]

[illegible] leaf pine (Pinus palustris) and scrub pine (Pinus clausa).

[illegible] of spread and low to medium resistance to control for surface fires, but when the fire [illegible] in the "scrub," there is extreme resistance to control.

[illegible]--Few definite data available on fire danger; wind velocity, approximately 35-45 m.p.h.; [illegible] humidity, probably low, but no measurements available; wind direction, southwest; few [illegible] content, probably low because of high evaporation rate and very porous soil; visibility, [illegible] taken; time of year, March 12, the peak of the fire season.

[illegible]; burning out to stump incidental to land clearing.

[illegible] started as a surface fire in the "scrub," probably around 11:40 a.m. Suppression action [illegible] when two acres in size; eight men involved in this initial action. At 1:00 p.m. went [illegible] crowns; confined to surface for 1 hour and 20 minutes.

[illegible] PLANNING AND DEVICES--(1) Fire plan called for the manning of secondary towers and the [illegible] of crews when wind velocity is high and relative humidity low, (2) fire breaks had [illegible] (see map of burn).

[illegible]

[illegible] time

[illegible] Discovery--11:40 a.m.--11:48 a.m.; 8 minutes, fire 12 mi. away

[illegible] Reporting--11:48 a.m.--11:49 a.m.; 1 minute

[illegible] Get-a-way--11:49 a.m.--11:50 a.m.; 1 minute

4. Travel time--11:50 a.m.--12:30 p.m.; 40 minutes.
5. Control time--12:30 p.m.--6:15 p.m.; 5 hrs. 45 minutes

B. Man-Power Dispatch and Arrival

**Table 35**

| | Time of Leaving | Time of Arrival | Number of Firefighters | Cumulative Number Firefighters |
|---|---|---|---|---|
| a | 11:50 | 12:30 | 8 | 8 |
| b | 12:10 | ... | 32 | 40 |
| c | ? | ... | 37 | 64 |
| d | ? | ... | 19 | 88 |
| e | 1:30 | ... | 21 | 109 |
| f | 1:50 | ... | 27 | 136 |
| g | 2:00 | ... | 42 | 178 |
| h | 4:35 | ... | 45 | 223 |
| | 5:45 Rain commenced to fall | | | |

C. Equipment--No information available regarding hand tools; trucks transporting men were able to travel only 6 to 8 m.p.h. because of the deep, dry sand; a large 2-ton fire truck broke down. No information available as to the type of equipment used by the crew taking initial action.

## Comments

A. CAUSE--The fire resulted from land clearing which had stopped presumably on February 28. On March 12, the date of the fire, a stump was burning on the edge of the cleared land, as reported by the men doing the clearing. They took action consisting of digging round the stump and throwing dirt on it to prevent the spread of the fire to adjoining land, but around noon it had ignited the fuels nearby. These three men were attempting to control the fire at the time of arrival of the crew taking the initial action.

It seems rather questionable for a stump to have continued to burn for approximately two weeks after clearing ceased. It seems more likely that the stump was probably fired on March 11 or 12 and the dirt-throwing was coincident with the attempt to control the fire. Because there was nobody to contradict them, the land-clearers probably decided to protect themselves and refuse to admit that the stump had been fired under questionable weather conditions.

One of the Forest Jobs as set up for the Forest consisted of an effort to have all burning done before January 1 and to obtain the cooperation of all adjoining landowners to see that a notice is sent to the forest ranger in event they decide to burn after the January dead-line. Inasmuch as burning was definitely done on February 28, the smoke should have been followed up by some Forest Service representative and the burner cautioned. When extreme fire danger developed, or was anticipated, the old burning should have been investigated.

Inadequate public relations work is evident in that the land-clearers were not contacted and requested to cooperate relative to concluding their burning prior to January 1.

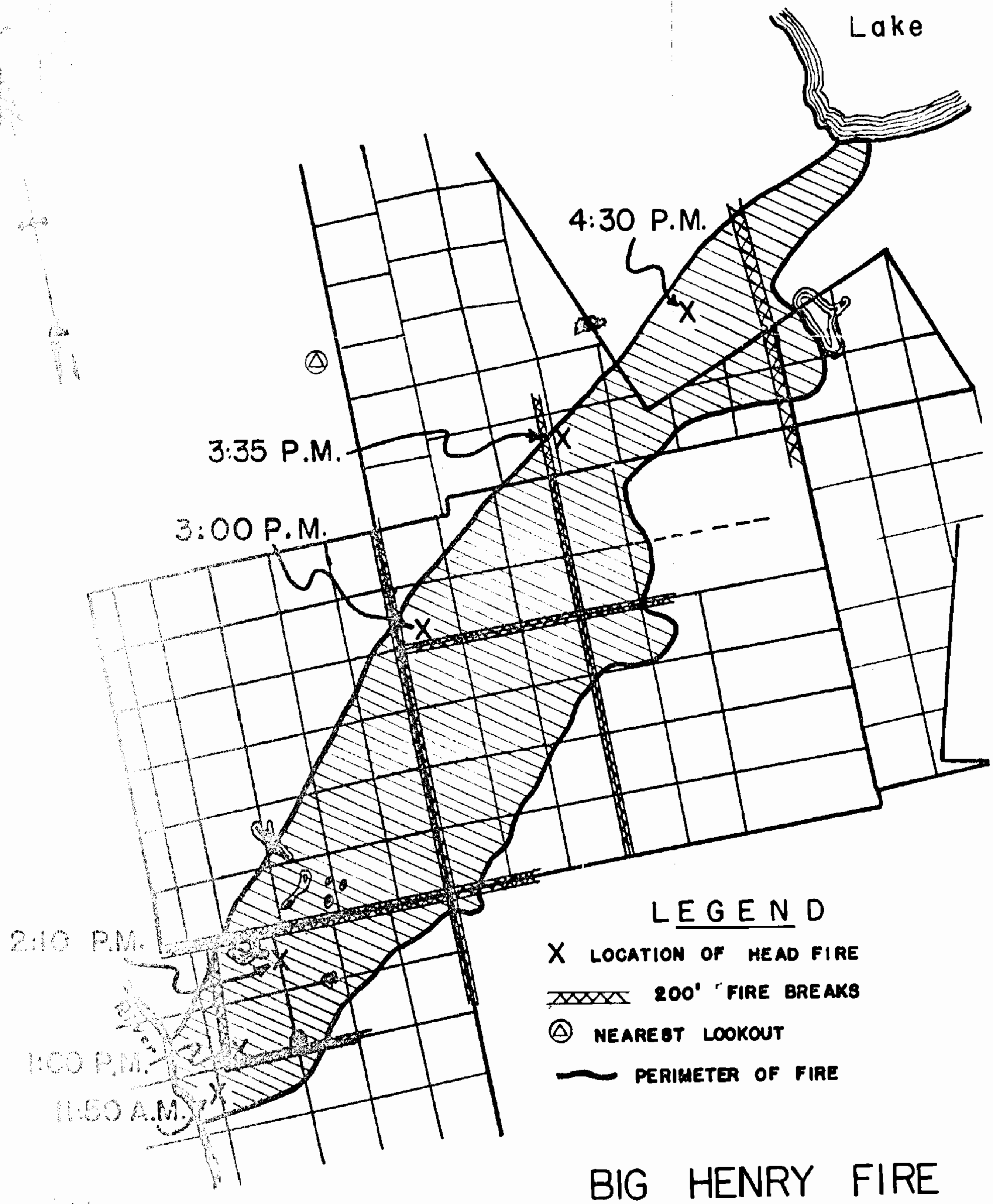
B. LIAISON--Another Forest Job consisted of taking extra precaution relative to fires when wind velocities became high and visibility low; these precautions to consist of the manning of additional towers and increasing the size and number of standby crews.

The wind velocities for the day preceding and during the fire were as follows:

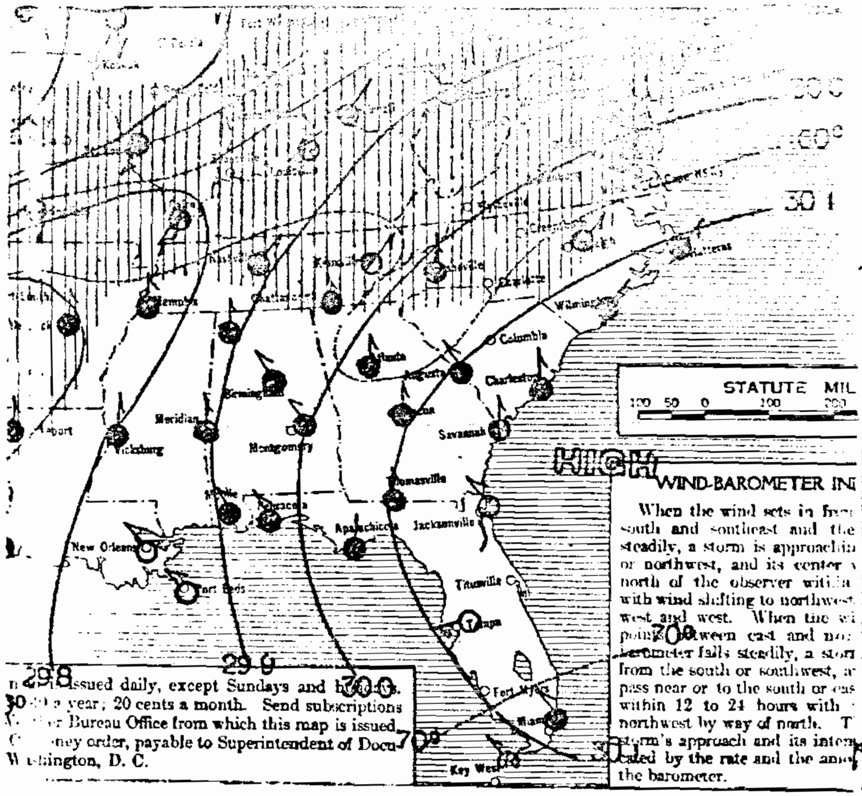
4 p.m. of March 11 to 8 a.m. of March 12--9.8 m.p.h. average
8 a.m. of March 12 to 12 noon of March 12--23.0 m.p.h. average
noon of March 12 to 2 p.m. of March 12--37.5 m.p.h. average
2 p.m. of March 12 to 4 p.m. of March 12--42.0 m.p.h. average

Either the dispatching tower had not been informed of the grave necessity for communicating with the Ranger when wind velocities were high, or he neglected to do so. The result is, however, that no action was taken to man additional towers or to increase the number of standby crews.

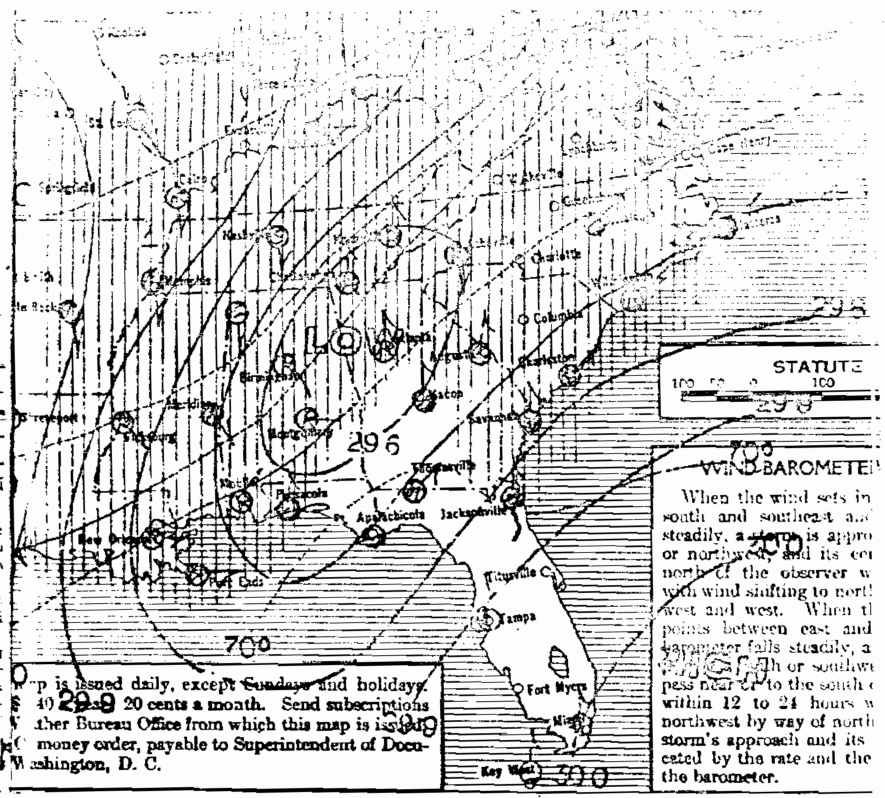
Had there been adequate liaison between the Ranger and the central dispatching tower, the former would have become aware of the high wind velocities; he was probably in his office where he could have




BIG HENRY FIRE



Section of 8 A. M. weather map of Mar. 11



Section of 8 A. M. weather map of Mar. 12

(Big Henry Fire located on the Florida Peninsula approximately 100 miles below the state line.)

On this day, there was a high-pressure area centered over the forest area on which the Big Henry Fire occurred. Accompanied by high temperatures and considerable solar radiation on the fuels, the atmosphere undoubtedly exerted tremendous dry power on the forest fuels.

During the latter part of March 11 and the early morning of March 12, a low-pressure area moved eastward and pushed the "high" into the ocean. This resulted in producing atmospheric tension, indicated by the numerous isobars per land area unit, and caused the high wind velocities, responsible for the rapid rate of spread of the fire.

Figure 44 WEATHER MAPS EXPLANATORY OF CONDITIONS CAUSING BIG HENRY FIRE [illegible] readily. Had he been on the Forest somewhere, undoubtedly he would have known that the [illegible].

[illegible] inadequate liaison between the dispatching tower and the work crews on the Forest, [illegible] extreme fire danger which existed. In the absence of radio equipment, the work crews [illegible] assigned to jobs close to a telephone line where messenger travel would have been at a [illegible] have reduced the time element insofar as the dispatch of the crew to the fire was [illegible].

[illegible] to the peculiar nature of the roads on the forest, the travel time was excessive. [illegible] high travel time, it was especially desirable to have numerous standby crews scattered [illegible] Forest so that there would have been low hour control time in event of an outbreak of fire. Had [illegible] initial action been able to arrive 15 minutes sooner, which would have been possible had [illegible] to travel at a rate of 20 m.p.h. instead of 6 to 8 m.p.h., it is likely that it could have [illegible] fire from crowning.

[illegible] sand roads were inadequate as arterial truck trails for fire control purposes; the clay [illegible] roads permit satisfactory rates of speed, but in weather of high wind velocities, a [illegible] factor toward high fire danger, the ruts become filled with fine sand which seriously im[illegible] travel. A system of arterial fire control truck trails should have been planned and con[illegible] order to speed up travel time in periods of high danger.

[illegible]--The fire had little difficulty in crossing 200'- wide firebreaks at six different [illegible] run of only three-quarters of a mile from the point of inception, a wide firebreak was [illegible] these wide breaks which were used to block up the area into tracts approximately [illegible], each section (640 acres) was surrounded by a five-foot fire break. In this fire, the [illegible] lines were of no value.

[illegible] by the spread of the fire, the wide breaks were valueless from the standpoint of acting [illegible] or as a base from which to backfire. The breaks were constructed presumably to [illegible] spread of crown fires, but they did not function as had been hoped for. The sugges[illegible] after the fire, and it may have been advanced before the fire, that a better means of [illegible] to create barriers whereby the movement of crown fires could be checked, would have [illegible] for several hundred feet on each side of narrow breaks or truck trails. Dense [illegible] make crown fires possible; with an open stand created by the thinning, crown fires would [illegible] because the fuels would not be sufficient to continue to carry the fire in the crowns [illegible] had been opened. With the fire on the surface, it could be controlled before spreading [illegible].

[illegible] OR LACK OF MEANS OF INTERPRETING FIRE DANGER AND ANTICIPATING THE SAME--An agreement was [illegible] exist between the Forest Ranger and the nearby station of the Weather Bureau whereby the [illegible] advise the former relative to impending conditions which would produce fire danger. No warn[illegible] by the Weather Bureau that unusually strong winds could be expected. The Forest, more[illegible] not equipped with instruments and methods whereby fire danger could be measured so that adminis[illegible] might be taken to avoid a repetition of the conflagration.

[illegible] also demonstrated a lack of sufficient information regarding fire behavior. The fire illus[illegible] power was not on the job quick enough to suppress the fire. Too much travel time was in[illegible] fuels concerned. If the elapsed time standards are adequate for the fuels and the danger [illegible] contributing factors, they were adequately met for detection, communication, and getaway [illegible] were not close enough to the fire, however, when it broke out. Obviously the remedy is either [illegible] roads or greater dispersion of man-power, or maybe both, so that travel time can be [illegible] point where man-power can get on the job in less than 15 minutes in periods of high fire [illegible].

[illegible] METHODS--There is nothing of record to indicate the equipment used in attacking the fire, [illegible] power-driven, water-using equipment was available or whether hand tools only were used.

[illegible] initial-action crew of eight men arrived, the fire was only approximately two acres in [illegible] with a perimeter of approximately 825 feet. If it may be assumed that only 1/4 of the perimeter was "hot", creating the head fire, there were approximately 200 feet of line for 11 [illegible] control; this man-power included the three natives plus the eight men taking initial action. With [illegible] pumps and a small surplus of water, 200 feet of fire line could probably have been controlled within the forty minutes elapsing between the arrival of the initial action crews and the [illegible] of the fire. In the absence of a responsible forest officer, it is somewhat questionable as to whether the best attack method was used, whether the crew was equipped with the tools best adapted for the job, or whether the man-power had the type of leadership necessary for combatting extreme fire danger as produced by a 30 m.p.h. wind. It must be admitted that wind velocities of 30 m.p.h. widen the line of fire to the extent that considerable water is required to "cool" it.

## ANDERSON VALLEY FIRE

A. RESULTS--12,000 acres burned in approximately two days.

Lack of specific information prevents the presentation of facts such as were submitted under the Big Henry Fire. The large size of this fire in the ponderosa pine type, however, was the result of inadequate suppression action; adequate action would have prevented it from becoming an extra-period fire. Although the fuels produced by ponderosa pine are characterized by rapid spread, there is usually low real resistance to control. During the early part of the night following the day on which the fire started, the fire was only nine acres in size.

Initial action was good, but it was by no means sufficient.

B. COMMENTS--

(a) The control line around the original nine-acre area was lost because there did not exist among the forest officers in charge of the fire a sufficient appreciation of the abnormal fire danger which existed whereby rapid spread, vigorous night burning, and long-distance spotting was possible. Had the fire boss been aware of the real fire danger, it is probable sufficient precautions would have been taken to prevent the fire going over into an extra period.

(b) Because of inaccurate knowledge of the real fire danger, the plan of attack was changed too frequently. The original plan was indirect attack; this was changed later to direct attack but when it was found that the fire spread rapidly even at night, the plan of attack was again changed to indirect, but too late to be effective with the limited number of men available for the job.

(c) With fuel conditions such as they were, and the possibility of the fire going over into an extra period, more men should have been available for the job. Had there been more men on hand, it is doubtful whether the fire would have remained out of control and developed into an extra period.

(d) With poor line inspection, much of the constructed line did not hold. Inspection should have been made by regular forest overhead. The fact that the line did not hold made it possible for the fire to get out of control.

(e) When it became evident that the fire could not be controlled during the night, and there existed a good possibility for the fire going into an extra period, additional man-power was requisitioned, but it did not arrive on the fireline at the point needed until several hours after it was due and therefore could not perform effective work when the fuel moisture content was higher than it is during the day period.

(f) Two modern devices for fire control work were not utilized when the fire extended into an extra period. An airplane was not used for scouting, and the mobile weather forecasting unit was not brought into service. The use of one or both of these facilities would probably have reduced the final acreage lost.

(g) There was too much independent action among the several suppression units; this was due to a lack of aggressiveness on the part of the fire boss who should have issued definite, positive orders so that a concerted action could be taken on the several parts of the fire.

(h) The fire chief acted too much in the capacity of a camp boss. He should have been in more intimate contact with the bosses on the job and should have designated a subordinate to look after supplies.

# McKENZIE FIRE

RESULTS--Gross area burned, 1,715 acres; total perimeter, 15.95 miles or 1,276 chains.

[illegible] PERIODS IN WHICH FIRE EXTENDED PERIMETER--Three.

[illegible] terrain; fire commenced near the base of a 3,000 foot steep south slope with a gradient [illegible] percent, with some parts 100 percent or more. Steep cliffs made it necessary to [illegible] fire-line perimeter because indirect attack was necessary.

[illegible] commenced in a Douglas fir single-burn where brush and snags were numerous. A large [illegible] fire burned in immature Douglas fir 16"-40" d.b.h.

**Table 36**
FOREST CROWN PRESENT ON PERIMETER

| Crown Type | % of Total Perimeter |
|---|---|
| [illegible] Balsam Fir, 16"-30" d. b. h. | 33 |
| [illegible] Balsam Fir, Saplings and Poles | 7 |
| [illegible] d. b. h. | 25 |
| [illegible]-40" d. b. h. (Second Growth) | 15 |
| [illegible]-40" d. b. h. (Old Growth) | 11 |
| [illegible] | 9 |
| | 100 |

**Table 37**
GROUND COVER CLASSES ON PERIMETER

| Ground Cover | % of Total Perimeter |
|---|---|
| [illegible] Litter | 54 |
| [illegible] | 19 |
| [illegible] Open | 17 |
| [illegible] | 1 |
| [illegible] | 9 |
| | 100 |

FUELS--Rate of spread "High" (H) for fuels on the area burned the first day. For the average perimeter, however, rate of spread class would be "Medium" (M) and "Low" (L). Resistance to control estimate on the control line or perimeter was Medium, 44%; High, 28%; Low, 27%; Extreme, 1%. These ratings are based on the assumption that if one man-hour is required to construct and hold a chain of "low" resistance to control fuels, two man-hours are required for "medium" fuels, four for "high", and eight for "extreme."

FIRE DANGER FACTORS--At noon of the day the fire started, the relative humidity was 15% and probably remained fairly low until sundown. During the night period, [illegible], even under the forest canopy, the humidity remained low, with a 44% reading at 3:15 a.m. [illegible] a.m. There was no record of wind velocities during the afternoon periods, but for [illegible] on September 4, the velocity was only 6 m.p.h. and at 5:00 p.m. of the same day, only [illegible]. The direction was extremely variable. September 5, the relative humidity was somewhat [illegible], fluctuating between 25% and 35% even for the day period. The highest wind velocity was [illegible] at 10:00 a.m. of September 10.

CAUSE--[illegible] incendiary.

[illegible]--Approximately noon. At 3:41 p.m. of the same day, another fire, either set or due to [illegible], was sighted in a canyon two miles east of the main fire. These two fires burned together [illegible] 6. The fire could have spotted because the wind direction was from the west and tremendous [illegible] currents were generated due to the steep slope on which the main fire was burning.

[illegible]--Approximately half of the area which burned in the fire occurred noon and 7:30 p.m. of the [illegible]. (See Figure 45a for periodic and daily estimated progress of perimeter enlargement.) [illegible] area had been added by 10:00 a.m. of the second day, September 5. This was the end of [illegible] period. All burned area occurring after 10:00 a.m. of September 5 was classed as "extra [illegible] burn.

[illegible] rough topography and convection currents produced, control was difficult because of a [illegible] to spot.

[illegible]--

[illegible] Time Periods

| | |
|---|---|
| [illegible]covery--15 (?) min. | (11:45 a.m.-noon) |
| [illegible]tting--1 min. | (noon-12:01 p.m.) |
| [illegible]y--2 min. | (12:01 p.m.-12:03 p.m.) |
| [illegible]--67 min. | (12:04 p.m.-1:10 p.m.) |
| [illegible]trol--93 hrs. | (Sept. 4, noon-Sept. 8, 10 a.m.) |

B. Man-Power Dispatch and Deployment

**SEPTEMBER 4**

11:03 p.m.--Fire guard and another man leave Ranger Station for fire.
12:15 p.m.--Forest Supervisor assumes full control at Ranger Station.
12:45 p.m.--Camp boss detailed to select camp site to accommodate large crews.
12:50 p.m.--CCC foreman with crew of 20 dispatched to fire to cut out way trail to fire lines.
1:10 p.m.--Fire guard reaches fire when 100 acres in size; sends man with him to contact supervisor and request 300 men be made available for control. Guard commences to scout fire.
1:15 p.m.--Supervisor requests Regional Office to send additional tools and two hundred CCC enrollees.
1:35 p.m.--First reinforcement commences action on fire which is spreading rapidly up slope and crowning in green timber.
1:40 p.m.--More men dispatched to scout fire.
2:10 p.m.--Supervisor requests six additional overhead, and the scouting unit made up of a chief, communication man, radio operator, draftsman, and scouts.
3:41 p.m.--Spot fire "A" is reported in N W 1/4 Sec. 12. A crew boss with 10 men is dispatched to handle it.
4:00 p.m.--Second reinforcements made up of 50 men commence work on southeast corner of main fire.
6:05 p.m.--Spot fire "B" is reported.
7:03 p.m.--Twenty-five CCC enrollees leave for Spot "B".
Midnight--1,100 men on job or enroute; fire encircled with scouts.

**SEPTEMBER 5**

A base camp has been established near Ranger Station.
5:30 p.m.--Spot "B" and Sectors 9 and 11 controlled.
Estimate of needs, 1,680 men to construct 7 miles of line.
Spot "A" has resisted control; also several parts of perimeter of main fire.

Deployment of Man-Power
- Spot "A"--1 sector boss, 4 foremen, 168 firefighters
- Spot "B"--1 sector boss, 3 foremen, 62 firefighters
- Main fire, North side--1 sector boss, 6 foremen, 210 firefighters
- Main fire, East side--1 sector boss, 8 foremen, 220 firefighters
- Main fire, West side--1 sector boss, 5 foremen, 120 firefighters
- Total--5 sector bosses, 26 foremen, 800 firefighters

**SEPTEMBER 6**

At end of day, Sectors 9, 11, and Spot "A" remained under control; Sectors 10, 8, and 6 were corralled; mopping up commenced on these sectors.

Total Man-Power on Fire Lines--
5 sector bosses, 32 foremen, 1,161 firefighters.

**SEPTEMBER 7**

Firefighters concentrated on Spot #1 and corralled.
Sector 8 corralled, sectors 3, 4, 7, and 12 backfired and corralled with small loss of line.

**SEPTEMBER 8**

Sector 1 became more active, but was finally corralled. All other sectors quiet.

Man-Power on Fire Lines--
6 sector bosses, 37 foremen, 1,078 firefighters

**SEPTEMBER 9**

All sectors quiet and mop-up going on at a rapid rate. Only small amount of water available for mopping up.
210 men were released from fire duty.

**SEPTEMBER 10**

All sectors quiet; mop-up still progressing.

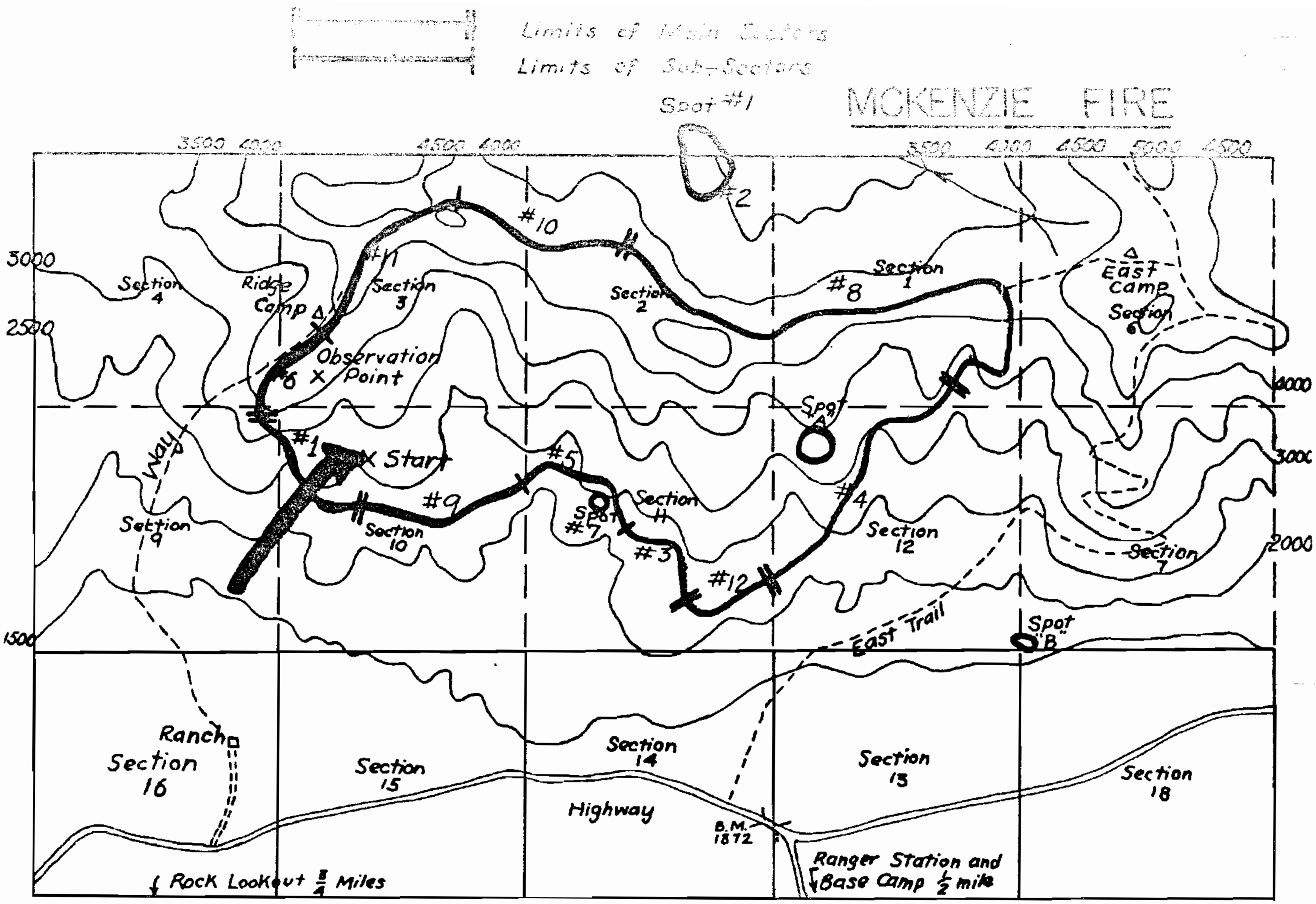
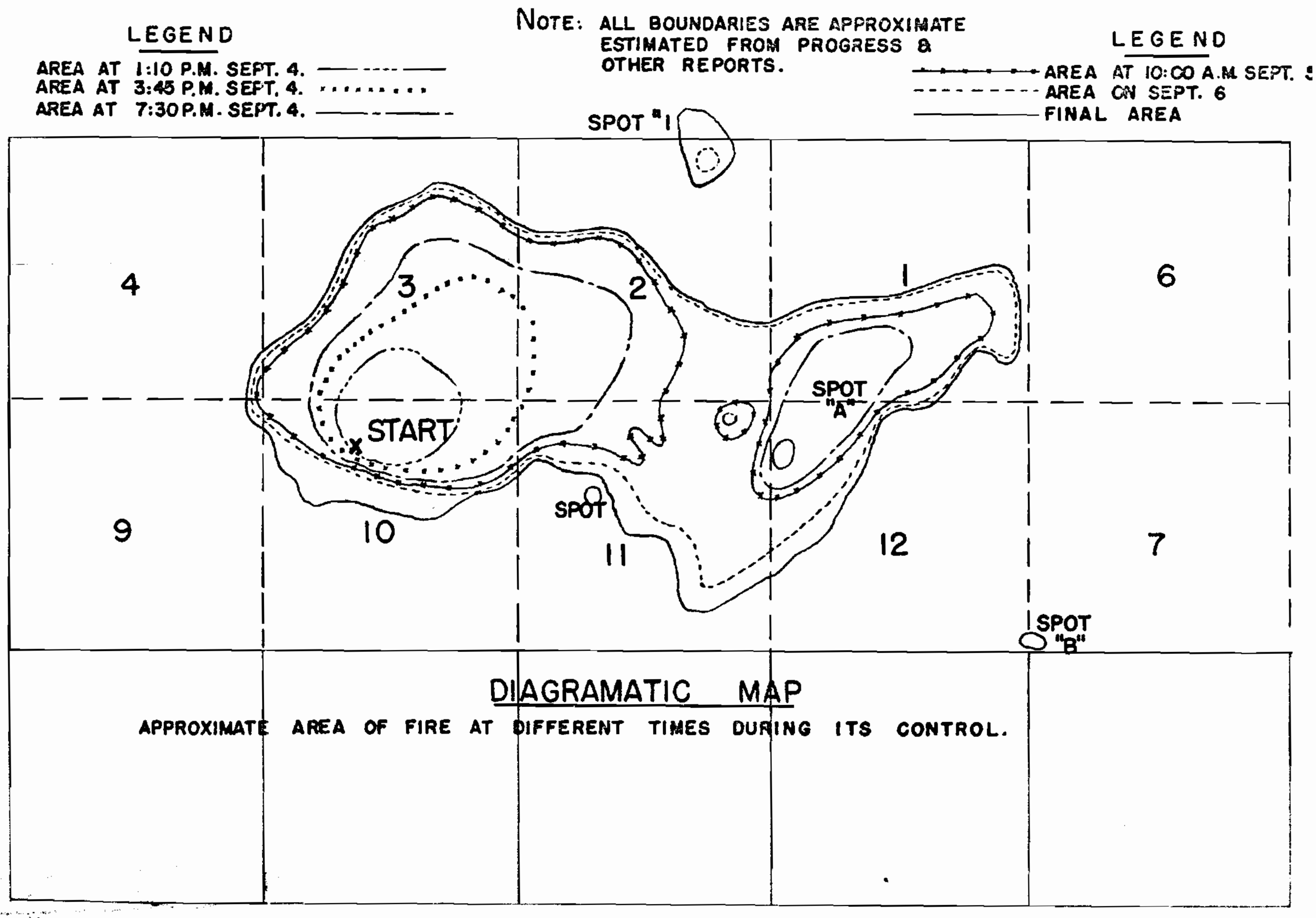



Figure 45

Diagrammatic Map Showing Approximate Location of Sectors




MCKENZIE FIRE

... men were released.

## SEPTEMBER 11

... Total fire duty strength, 520 men.

---

... tools used almost exclusively. These consisted of hazel hoes, axes, saws, shovels, ... back pumps.

... was used for approximately 30 hours on Spot "#1"; a pumper was also used effectively on ...

...--

A. With the fire burning in very rugged topography, characterized by steep slopes, cliffs, and rock ..., suppression was conducted under a great deal of difficulty, attended by a high rate of ... fatigue and resultant reduced output per man.

B. The presence of snags contributed considerably in slowing down the work of corralling the fire.

C. The tendency to spot and crown, coupled with very rough topography made it necessary to evacuate ... on several occasions to avoid being trapped. With the wind shifting direction continuously, it was difficult to do much planning.

D. The presence of the regional scouting unit, however, coupled with a communications network of ... telephone made close liaison possible. Radio sets of the voice types S P and P F were ... the sectors and camps and M type at the base camp. This communications system proved in... in making quick shifts of man-power, supplies, and equipment.

E. With good supervision, ample man-power, the highest type of liaison, and adequate service of ..., a good job of control was done under very difficult conditions.

## BUNYAN FIRE

...--Gross area burned, 2,000 acres in a 42-hour burning period.

... PERIODS THRU WHICH FIRE BURNED UNCONTROLLED--One.

...--... glacial moraine formation.

...--... drained in the depressions, well drained on the higher ground, typical of glaciated ...

...--Northern hardwoods, ash, and cherry in mixture with hemlock, balsam fir, and spruce.

...--Rate of spread, medium to high. Resistance to control, high to extreme. Logging slash present ... fire started.

... PRECEDING AND DURING FIRE--Altho there were no fire danger stations in the vicinity, ... to be as follows: Air temperature, 85 degree Fahrenheit; relative humidity, 40%.

...--Either the exhaust from a tractor on the logging job where the fire started, or a firebrand tossed ... by the tractor operator.

TIME ...--1:55 p.m., July 9.

...--Tendency to crown and make "runs" almost from inception. Spotting frequent, 100 acres in ... hours after inception. Head fire two miles from point of inception in 1-3/4 hours. Jumped ... stream late in afternoon, somewhere between 5:00 p.m. and 11:00 p.m. Allegedly spotted for ... one-half mile in front of head fire.

...

A. ... Time Periods

| | |
|---|---|
| 1. Discovery--8 minutes | (1:55 p.m.-2:03 p.m.) |
| 2. Reporting--3 minutes | (2:04 p.m.-2:07 p.m.) |
| 3. Getaway--12 minutes | (2:08 p.m.-2:20 p.m.) |
| 4. Travel--50 minutes | (2:21 p.m.-3:10 p.m.) |
| 5. Control--41 hours | (July 9, 3:10 p.m.-July 11, 8:00 a.m.) |

B. ... Dispatch and Deployment

... of this action is complicated for the reason that the circumstances were unusual. ... logging job conducted on private land, two miles from the nearest national forest land, but the wind was blowing from a direction which carried the fire toward the national forest.

With the fire approaching the national forest, its control became the responsibility of two District Rangers because it threatened to burn on lands located in each District. There were, therefore, three separate suppression units acting independently of each other, concerned with the control of the fire. These units were lead by the logging superintendent of the job where the fire started, and two District Rangers, each of whom had equipment and man-power at his disposal. There was a limited amount of coordination displayed between Ranger Allen's force and those at the disposal of the logging superintendent.

## JULY 9

2:15 p.m.--22 men from the logging job commence work on the fire.
2:40 p.m.--18 teamsters from the logging job reinforce the others.
3:00 p.m.--30 men from a nearby logging camp arrive to assist the others.
3:10 p.m.--56 CCC men arrive with a pump and hose.
Forest overhead on fire, five.
3:45 p.m.--Ranger Denby personally arrives at the starting point of the fire with a pump and S type radio.
5:10 p.m.--Ranger Denby, a crew of 50 men, and one pump arrive at what is probably the head fire, the center of Section 15.
6:00 p.m.--Fire Boss Lynn, one of Ranger Allen's men, takes a 40-man crew, a pump, tank cars, and two scouts to what he considers the head fire in center of Section 15.
Fire Boss Lynn sends a messenger thru woods to contact Ranger Denby; also sends one scout in each direction around perimeter of fire to report at fire headquarters at Pole Creek Camp.
Overhead on fire, 18 men.
6:30 p.m.--Ranger Denby's pump breaks down.
6:45 p.m.--Fire Boss Lynn's messenger contacts Ranger Denby.
7:30 p.m.--Ranger Denby leaves his crew to personally contact Fire Boss Lynn.

## JULY 10

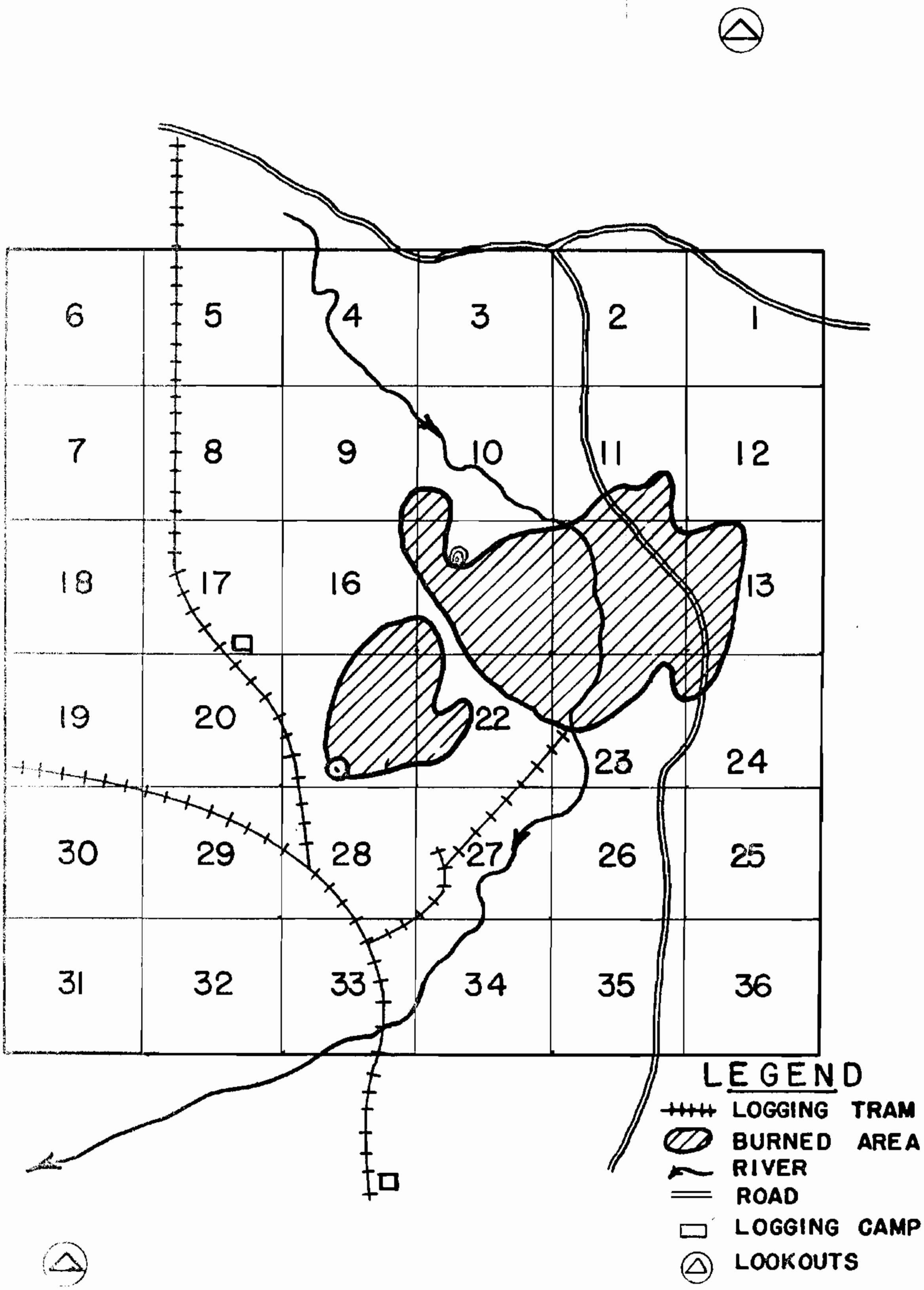
12:20 a.m.--Scouts report to Fire Boss Lynn that fire has crossed river and burned 100 acres in Section 14; also numerous spots developing in Section 14; burning hard and crowning.
5:00 a.m.--Tractor and plow arrive near head fire, Section 14, but are unable to function because of soft swamp. 250 men also arrive on east flank near head but are ineffective because of intense heat, soft ground, and frequent spotting.
Overhead on fire, 31 men.
9:30 a.m.--Radio sets get into operation.
10:00 a.m.--Ranger Denby scouts from airplane; this results on new deployment of man-power.
11:00 a.m.--Fire shows tendency to drop from crowns to surface; less spotting.

## JULY 11

10:00 a.m.--Corralled with 1,410 men on duty.

COMMENTS

1. Physical and Uncontrollable Factors
   - A. Frequent spotting and undiminished intensity of burning of fire during night of July 9 and morning of July 10; tendency to spot indicated by map which shows an unburned strip caused by inability of surface fuels to become ignited; fire spotted east of the moist fuels.
   - B. Lack of adequate transportation facilities; no roads or trails.
   - C. Mechanical defect of Ranger Denby's pump.
2. Human and Controllable Factors
   - A. Lack of early coordination of effort expended by the two District Rangers and the logging superintendent. No one person assumed full control of man-power and equipment soon enough.
   - B. Lack of good leadership on the fire.
     1. Too much effort expended on line which could not be held.
     2. Unnecessary trenching in wet swamps.
     3. Insufficient tools for crew members when work commenced on line.




BUNYAN FIRE

Figure 46

4. Use of tools not adapted to working conditions.

5. Insufficient water and food for men on the fire line.

6. Too many generalized orders resulting in misunderstandings.

C. Forest Supervisor's indecisive orders to the Regional Purchasing Agent relative to shipment of additional equipment to the fire.

3. Procedure for Overcoming Deficiencies

1. Better training of all personnel for fire duty.

2. More intensive transportation systems.

3. More available mechanical fire equipment.

4. More orderly planning and precision of execution in conformity with the Chief Forester's (165) fire suppression policy letter which urges speedy, strong, and thorough control action in dangerous fire weather. If speedy control cannot be attained, then the situation demands a review so that organization can be perfected within the first work period. The letter emphasizes the objective of keeping the size of the fire small.

## CEMENT GULCH FIRE

RESULTS--Gross area burned, 660 acres.

NUMBER OF EXTRA PERIODS IN WHICH FIRE EXTENDED PERIMETER--None.

TOPOGRAPHY--Very rugged with fire starting at the 3,200 contour and rising to a 5,200 foot elevation within one mile and advancing up a gulch which served as an ideal chimney for generating air currents to help the rate of spread of the fire.

FOREST TYPE--Of the area burned, 100 acres was white pine type and the balance brush type, the result of a previous severe burn.

FUELS--Rate of spread medium (M) to high (H) and resistance to control low (L) to medium (M).

FIRE DANGER FACTORS--For the ten days previous to the inception of the fire, the fire danger rating averaged class 4, with one class 6 day among them and several class 3. With class 1 representing the lowest fire danger class, and class 7 as the highest, the danger class was only moderate, but much of the herbacous material had dried out to the point where it probably aided the rate of spread rather than retarded it.

CAUSE--The flames of a burning mine building spread to the forest.

TIME OF INCEPTION--12:30 p.m. (?), August 29.

The fire was not actually discovered, however, until 1:00 p.m. because it originated in a large "blind" area which was not directly visible to the lookout who was located fourteen miles southwest of the fire with the wind taking the smoke up the gulch and away from the observer. It was necessary for the smoke to rise nearly 600 feet before it became visible to the observer who detected it. The lookout estimated the size of the fire at one-fourth acre at the time he first observed it at 1:00 p.m.

FIRE BEHAVIOR--The fire made its first big "run" on the afternoon of the day on which it started. There was considerable tendency to spot, as shown on the map, but with only 100 acres of the 660 made up of a forest type which would produce crown fires readily, there was no great danger of making a run which would spot it miles away into adjacent watersheds. With the numerous spots on the north side, however, much man-power had to be expended in controlling apparent spots as well as actually looking systematically for spots which were not apparent but which might get out of control unless they were quickly detected.

CONTROL TECHNIQUE

A. Elapsed Time Periods

| | |
|---|---|
| 1. Discovery--30 minutes | (12:30 p.m.-1:00 p.m.) |
| 2. Reporting--10 minutes | (1:00 p.m.-1:10 p.m.) |
| 3. Get-a-way--12 minutes | (1:10 p.m.-1:22 p.m.) |
| 4. Travel--38 minutes | (1:22 p.m.-2:00 p.m.) |
| 5. Control--20 hours | (Aug. 29, 2 p.m.-Aug. 30, 10 a.m.) |

B. Man-Power Dispatch and Deployment

**August 29**

2:00 p.m.--Initial action taken by a 25-man crew of CCC enrollees with one foreman in charge. Upon arrival at the fire, the size was estimated at 50 acres.

[illegible]--Reinforcements arrived, 17 men.

[illegible]--Reinforcements arrived, 45 men

[illegible]--Reinforcements arrived, 300 men

The dispatcher and the ranger in charge of the fire had sized up the situation accurately and correctly. The large reinforcements which arrived late in the afternoon were messed and bedded down for the night to be available for early action the following morning.

As shown on the map, fire camps were also strategically located for effective man-power deployment, with approximately equal man-power strength in each camp.

**AUGUST 30**

8:00 a.m.--Reinforcements arrive, 200 men

[illegible] p.m.--Fire corralled, mopping up commenced

August 31--September 11--Fire patrolled.

[illegible] OF MAN-POWER

**FIRE BOSS**
**DISTRICT RANGER**

| | Camp #1 | Camp #2 | Camp #3 |
|---|---|---|---|
| Sector Boss | District Ranger Adjoining District | District Ranger Adjoining District | Junior Forest Supervisor's Office |
| Asst. Sector Boss | CCC Project Supt. | CCC Project Supt. | Blister Rust Control Foreman |
| Camp Boss | Brush Disposal Foreman | E R A Camp Foreman | Blister Rust Control Foreman |
| Scout | Prevention Project Contact Man | Blister Rust Control Foreman | Blister Rust Control Checker |
| One Foreman Per | 10 CCC and E R A | 10 CCC and E R A | 8 CCC and Blister Rust Control |
| Crew Total | 200 Firefighters (CCC and E R A) | 200 Firefighters (CCC and E R A) | 150 Firefighters (E R A) |

Total full-time overhead on fire line--Four Forest Officers with Ranger status and Supervisor and Asst. Supervisor for inspection and liaison.

The fire required the construction of 658 chains of line and the expenditure of 6,600 man hours.

There was one mop-up man for approximately each five chains of held line.

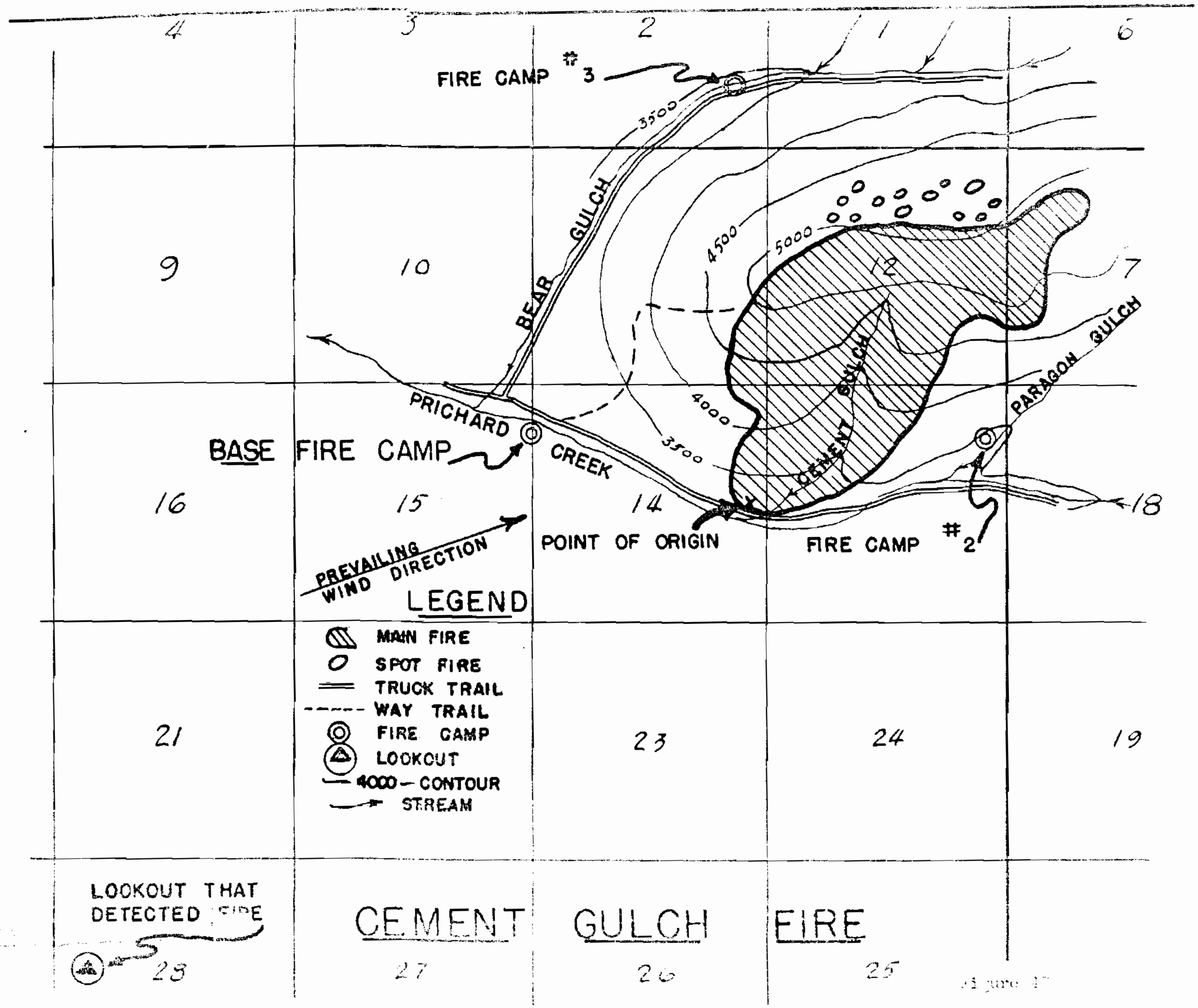
Direct attack and parallel methods were used chiefly. Indirect attack was used to a very limited extent.

COMMENTS

The fire showed the value of a fire plan and the ability of the Dispatcher and the District Ranger to appraise the situation accurately and execute the plan.

Several factors were directly responsible for the low control time. These were as follows:

a. Strategic location of fire camps
b. Clear-cut responsibility assigned to sector bosses
c. Experienced forest officers as sector bosses
d. Speedy dispatch and deployment of man-power
e. Conservation of man-power strength for early morning attack
f. Prompt arrival of equipment
g. High morale
h. No outside help required; all overhead and firefighters obtained from the Forest itself.
i. Little tendency of the fire to get out of control after it had made its first rapid run on the afternoon of the day on which it had started.



FIRE CAMP #3
BEAR GULCH
PRICHARD CREEK
BASE FIRE CAMP
POINT OF ORIGIN
FIRE CAMP #2
PARAGON GULCH
CEMENT GULCH
PREVAILING WIND DIRECTION
3500
4000
4500
5000
4
3
2
1
6
9
10
12
7
16
15
14
18
21
23
24
19
28
27
26
25
LEGEND
MAIN FIRE
SPOT FIRE
TRUCK TRAIL
WAY TRAIL
FIRE CAMP
LOOKOUT
4000 — CONTOUR
STREAM
LOOKOUT THAT DETECTED FIRE
CEMENT GULCH FIRE

[illegible] were employed by each sector boss. Close liaison was made possible between the fire boss and [illegible] by the presence of a radio in each camp, in nearby towers, and in the Forest Headquarters. [illegible] was also fortunate in having abundant man-power available, but without excellent organization [illegible], this man-power might easily have remained out of control for several days because of the [illegible] topography which made suppression work difficult. With a higher Fire Danger Rating, such [illegible] class V day, it is questionable whether the Rangers from adjoining Districts could have [illegible] sector bosses. The availability of men of this calibre without question elevated the morale [illegible] fighters above the average for so large a number of men on one fire.

# PART III

# FOREST FIRE ECONOMICS

## Chapter XIV

## FOREST FIRE ECONOMICS

### Fire Control Policies

### A - The Responsibility for Protection from Forest Fires

Although the forest land in private ownership constitutes a much larger percentage of the total in the country than is held by the Federal and State Governments, relatively little is spent per acre on the private lands for protection from forest fires. It is not the purpose of this discussion to attempt to explain this condition, but rather determine whether the expenditure of funds for protection from fire is justifiable, and if it is, just who should be responsible for the protection and to what extent funds should be made available and expended for the purpose.

For at least two or more decades, the national forests have been managed from the standpoint of sustained yield. The personnel which constitutes the United States Forest Service which administers the national forests is dominated by men who have been technically trained in forestry; consequently they think, plan, and act to improve the composition and productivity of the timber stands on the national forests. Their viewpoint is not dominated by economic stresses. They need not manage the land so that in one specific decade, or the current, or next decade, they must produce a certain cash income. The activity of the Forest Service is geared to the period of time which is required to produce a crop of timber. This is 25 years in some regions, 300 years in others. Because of the long time viewpoint demanded for timber production and difficulty of replacement, the forest capital must be protected from destructive agencies, one of which is fire. With protection from uncontrolled fire, forestry is possible; without it, forestry is impossible.

With an increasing interest on the part of private owners to practice forestry, protection from fire is one of the first problems which confronts them. No private owner, once he has committed himself to the task of investing capital in timber growing, is willing to jeopardize his investment by permitting fire to destroy it. Fires, because of their destructive nature, are intolerable to this type of owner and he generally takes steps to control their inception on his own land. There are, however, large areas of private land on which there is no protection. If a landowner with a second crop of timber on his land adjoins a forest on which no attempt is made to control fire the protected lands are constantly subjected to the risk produced by being located adjacent to an area where fires may occur frequently and burn unprotected. In urban areas, there are organizations maintained by the public for the immediate suppression of fires on all improved property, but in forest areas, each land owner must assume this responsibility himself, except for those few states where protection is afforded uniformly or in those counties within a state where there is countywide protection.

Regardless of whether the fires are man-caused, as in the East, or predominately lightning caused, as in the West, the problem of their suppression remains the same. The fires may start anywhere at any time regardless of whether the owner is interested in protecting the area, or indifferent to it. Generally the fires are caused by some agency over which the owner has no control. Where a menace to improved property exists, such as floodwaters from the Mississippi River in Louisiana, or dust storms in the Great Plains, over which the owners of the land subject to the danger have no control, public funds have been made available for the protection of the property lying in the exposed regions. Similarly, private owners as individuals are unable to cope adequately with the problem of forest fires. There is a public responsibility for the control of fires on private lands since the problem is too large for an individual owner to handle. The forested States and the Federal Government, as public agencies, have assumed some of the responsibility to varying degrees through the passage of legislation which enables these agencies to co-operate with private owners in protection.

In California, the farmer who depends on water for irrigating his lands is vitally concerned with the control of fire on the watershed which supplies the water for his irrigation ditches; but the watershed

... miles or hundreds of miles away so that it is impossible for him to personally help control ... watershed even though he definitely has something at stake. The State of California ... prosperous as its people are. If a fire menaces the water supply of a group of farmers who ... the fire, they have a right to demand that their source of water, upon which they de- ... their crops, receive protection from some public agency (120). California had 19,000,000 ... forest land protected from fire in 1925, but in that year, the state had not recognized ... as a public agency, should contribute something toward the protection of the remaining ... acres from fire.

... enactment of the Clarke-McNary Law by Congress in 1924, the Federal government assumed some ... toward the protection of private forest land from fire. The law specified that, for the ... protecting the private forest land from fire, a sum not in excess of $2,500,000 could be spent ... such expenditures had to be made through the several state agencies set up to administer ... The law further specified that in no state could the sum spent by the Federal Government ... subsidy be greater than the combined funds expended for the same purpose by the state and ... owners.

... 25-25-50 Ratio

... United States Forest Service has set up what has been referred to as the 25-25-50 ratio, whereby ... would be expected to furnish not less than 25% of the funds for cooperative fire control, the ... not less than 25%, and the Federal government not more than 50%. This ratio was an ideal ... a rigid formula. In 1925, the private expenditure in the Northwestern States was in excess of ... states were not producing the funds expected of them (121). The reason, moreover, that there ... interest on the part of the private owners was due to need for protection of commercial timber ... been acquired for speculative purposes. Their interest did not lie in the protection of young, ... timber or in sustained yield for a continuous cutting operation, but rather in merchantable ... they hoped to save from conflagrations for future exploitation.

... agent for the Forest Service, responsible for the policy of the Bureau in the allotments to ... Morrell (122) stated the policy which formed the basis. His contention was that fire control ... interest. Merely because a state was a large contributor of taxes to the Federal Govern- ... New York and North Carolina, did not necessarily mean that the Federal expenditures within ... should be on a pro rata basis. Those states which are in greatest need of the funds in order to ... degree of fire control are the states which should receive the greatest amount from the ... so long as the amount provided by the Federal Government did not exceed that produced by the ... the private owners. The largest areas of forest land lie in the region south of the Potomac, ... Missouri Rivers. It is in this region that most of the damage is being done by fires because of ... expenditures for protection. With the protection of timber, a renewable natural resource, of ... interest the Federal Government would, according to Morrell's policy, be justified in spending ... per state in this region than in any other region because of the greater losses there.

... states are fortunate enough to be very wealthy in comparison to some others which are relatively ... which have large forest areas requiring protection. Morrell figured out ratios between the ... of states and the estimated sum required to give reasonable protection; the former figure or state ..., divided by the latter, or forest area needing protection, produced the ratio which would serve as ... to gauge the relative amount of assistance a state should receive from the Federal Government for ... protection of private forest lands. The lower the ratio, the greater was the state in need of ... The data in Table 36 are a few examples.

... basis of the data in Table 36 Florida would be entitled to a larger ratio of Federal funds ... other state listed; Ohio would be given the least. Although the ratios as prescribed were not ... precisely in the distribution of Federal funds, they at least served as a guide.

... some states such as Oregon, which in Table 36 is listed as contributing 15%, and New York as ... the total funds spent for protection in the states, actually much of the states contribution goes ... protection of state lands rather than private (124).

... component of the cooperative arrangement is the state or the private owner. Whether it

Table 36
RELATIVE NEED FOR FEDERAL ASSISTANCE IN PROTECTION OF PRIVATE FOREST LANDS FROM FIRE

| Region | State | Ratio | Source of Funds in Percentage | | |
|---|---|---|---|---|---|
| | | | State | Private | Federal |
| South | Florida | 2,881 | 25 | 25 | 50 |
| Northern | Idaho | 3,431 | 25 | 57 | 18 |
| Pacific Northwest | Oregon | 5,855 | 15 | 61 | 24 |
| Northeast | Maine | 5,867 | 86 | 0 | 14 |
| California | California | 15,512 | 62 | 17 | 21 |
| Northeast | New York | 97,976 | 83 | 0 | 17 |
| Central States | Ohio | 308,159 | 65 | 0 | 35 |

Be the former or the latter is generally determined by the region. In the West, the private owner contributes 44% of the funds while in the South, only 20%, in the West, the states put up 34%, while in the South, 38%. The State should actually be the strongest cooperator in that it has a considerable stake in fire control. It can pass legislation which will be an aid to protection; it levies and collects tax assessments which encourage or discourage the practice of forestry; it has police power which the landowner cannot possibly exercise; it should be interested in any activity which will build up its own wealth and resources. Because of these factors, the states, more so than any of the other co-operators, should redeem their responsibility fully.

## FIRE CONTROL OBJECTIVES

In Chapter II, under the head of "Effect of Fire", there was a discussion relative to the desirability of protecting forest land, with or without merchantable stands on it, from uncontrolled fire. The loss which results from uncontrolled fire in stands of timber may occur in direct form. Before the fire there may be 30 cords of pulpwood per acre, after the fire there may be 15. The difference is due to the fact that 15 cords were consumed by the fire. The remaining 15 cords, because of their charred condition, cannot command as high a price at the mill as clean material. The value of the remaining 15 cords, therefore, is less than before the fire.

Losses of a less direct nature also occur. Burned watersheds have less ability to cut down runoff. In the absence of forest cover over the watershed supplying water to a dam, silting takes place rapidly. Burned areas also are of less value for recreational purposes than unburned areas.

In connection with the matter of protection of forest land, this question always rises: What is protection worth or how much is the owner justified in spending for the protection of his forest land?

In some fire control planning, the composite objective has been set to control each fire which occurs within the first work period, or before 10 a.m. subsequent to its inception. If this objective were attained, the number of fires which produce such tremendous losses by burning large areas of forest land would be lowered to a point where timber losses would be much less than they have been.

Table 37
RELATION OF LARGE ACREAGE BURNS TO LOW EXPENDITURE FOR FIRE CONTROL PURPOSES ON FOREST LAND PROTECTED FROM FIRE

| Region | Ratio of Actual Burn to Allowable Burn | | Expenditure Deficiency, per Acre per Year Basis | | | |
|---|---|---|---|---|---|---|
| | Within National Forests | Outside National Forests | National Forests | | Outside Nat'l Forests | |
| | | | Actual | Deficiency | Actual | Deficiency |
| New England | 0.015 | 1.84 | 4.05¢ | ... | 1.94¢ | 0.92¢ |
| Middle Atlantic | 3.78 | 2.97 | 7.73¢ | 0.88¢ | 2.77¢ | 0.59¢ |
| Lake | 0.85 | 2.70 | 5.56¢ | 1.47¢ | 2.01¢ | 2.23¢ |
| Central | 1.03 | 5.36 | 10.26¢ | 1.12¢ | 0.40¢ | 2.15¢ |
| South | 1.02 | 14.19 | 9.30¢ | 1.03¢ | 0.43¢ | 5.00¢ |
| Pacific Coast | 2.78 | 4.96 | 7.50¢ | 2.32¢ | 3.28¢ | 3.15¢ |
| North Rocky Mts. | 0.87 | 0.99 | 6.79¢ | 0.80¢ | 5.90¢ | 2.49¢ |
| South Rocky Mts. | 0.70 | 0.56 | 1.56¢ | 0.06¢ | 0.89¢ | 0.50¢ |

**Table 40**

DISTRIBUTION OF EXPENDITURES FOR FOREST FIRE CONTROL
PERIOD 1910-1926, REGION 1, USFS

| Presuppression (P) | Suppression plus Loss (S plus L) | Total Cost (P plus S plus L) |
|---|---|---|
| 1.0¢ per acre | 4.4¢ per acre | 5.4¢ per acre |
| 1. | 3.5 | 4.7 |
| 1.4 | 2.7 | 4.1 |
| 1.6 | 2.2 | 3.8 |
| 1.8 | 1.6 | 3.4 |
| 2.0 | 1.2 | 3.2 |
| 2.2 | 0.9 | 3.1 {Least cost expenditure for presuppression |
| 2.3 | 0.8 | 3.1 |
| 2.4 | 0.8 | 3.2 |
| 2.5 | 0.8 | 3.3 |
| 2.6 | 0.8 | 3.4 |
| 2.7 | 0.8 | 3.5 |

[illegible] similar situation has been shown by Coyle (125) to exist in New Jersey. For each $100 value of property in fifteen cities in New Jersey, 49¢ was expended by the municipality for protection; this was [illegible] money spent for the same purpose by private owners. For the same property, losses were 42¢ [illegible] value. For the city property values, the pre-suppression, suppression, and loss totalled [illegible] value. The New Jersey Forest Service expends 31¢ per $100 of forest value, but there is [illegible] of $2.50 for the same value. From these data, it may be assumed that if the expenditure [illegible] suppression on forest values were more nearly in line with that spent for the same purpose for city [illegible] loss would be materially less. For city values, the sum of fire control expenditures plus [illegible] approximately 1% of values protected; for forest values, it is 2.81%, or almost triple.

[illegible] reasonable to conclude, therefore, that with more money spent for pre-suppression purposes [illegible] protection of forest values, the losses would be reduced.

[illegible] the factors in the economic formula is "L" or loss; it is this item which exerts a considerable [illegible] on the result produced by the application of the least cost theory. The item of values destroyed [illegible] in which there is considerable room for extensive study. Loss can occur through (a) damage [illegible] values, present and future, (b) lowered site values, (c) difficulty of stand regeneration, and [illegible] in hazard. In Flint's calculations, item (a) above, or timber values only was considered. [illegible] could include lowered values for forage purposes, recreational purposes, and stream flow [illegible] this might be large or small. It is generally recognized that the influence on stream flow is [illegible], but to date no satisfactory means has been devised whereby its effect could be converted in- [illegible] appraisals. For this reason, foresters have been compelled to use such tangible valuations as [illegible] by actual or potential stumpage prices of timber destroyed.

[illegible] consideration of the economic formula in fire control planning, Hornby recognized that "L" [illegible] a considerable influence; he stated that the higher the values at stake, the greater is the [illegible] for quick, effective action, or for expenditure of P funds, so that each part of the peri- [illegible] fires is under control before burning conditions become worse. To further illustrate the [illegible] (88) showed that for two time periods for the same region, by the doubling of the suppres- [illegible] small fires and quadrupling the cost of large fires, the size of the average burn was re- [illegible] acres to 31.5 acres. This merely meant that with stronger initial action and prompt rein- [illegible] suppression crews, the result became apparent with lower size for the average fire.

## EXPENDITURES

[illegible] establishment of the Civilian Conservation Corps, there has been expended for forest fire [illegible] of money which has made a much better quality of protection possible. Some question may [illegible] in regards to the genuine economy of some of the spending, i.e., whether the money spent has been in line with the values at stake. A conclusion regarding the economy of the Civilian Conservation Corps forestry spending can never be arrived at because, fundamentally, the original objective of the Civilian Conservation Corps was the conservation of human values; that this was accomplished, the forestry practiced was merely a means to an end. The fact remains, however, that the Civilian Conservation Corps has made possible the forestry improvements necessary for more successful forest fire protection. Facilities for the detection of fires, for communication of information on fires, for transportation of man-power and equipment for suppression, have, in some localities been doubled, trebled, and quadrupled.

From the standpoint of economics in the practice of forest fire protection, the CCC has beclouded the picture. If expenditures made for forest fire protection by the Civilian Conservation Corps on some private lands were balanced against the values protected, instances could be found where the funds spent for protection were in excess of the productive capacity of the area. Because the productive capacity of the low-value areas cannot be raised, large expenditures for the protection of these values is poor economy. There has been little or no effort made to correlate CCC protection expenditures with the value of the forest land.

Because Emergency Conservation Funds have distorted the expenditures for forest fire protection, the data on moneys spent for protection prior to the establishment of the CCC will be used in this discussion.

**Distribution of Expenditures**

From the reports published by the various Federal, State, and private forestry agencies engaged in the administration of forest land, it is difficult to determine the relationship which exists between spending for prevention, pre-suppression, and suppression work. For the period 1926-1930, the national forests spent annually $1,804,148 for prevention and pre-suppression, $1,780,840 for improvements such as trails, roads, and other items, and $1,852,610 for suppression. Unfortunately, there was no separation of prevention and pre-suppression items.

A repetition of terminology at this point is desirable to avoid misunderstandings. "Prevention" work consists of action taken whereby fire inception is lessened. "Pre-Suppression" is concerned with keeping the size of the fire small by action in anticipation of the fire. These items include detection systems whereby the fires are discovered within a few minutes after they start and a communication and transportation system to place men on fires quickly to permit man-power to arrive for suppression work before the fire makes a large "run".

The Cap Cod Fire Prevention Experiment proved that prevention and pre-suppression expenditures pay big dividends. In the three-year period covered by the experiment, the burned area was reduced by 86%, with total expenditures for all three phases of forest protection from fire 20% lower than for the previous three-year period when emphasis was placed on suppression.

One year's results of a special man-caused prevention project on the Coeur D'Alene National Forest in Idaho showed that with the expenditure of $2,760, the number of man-caused fires were reduced by approximately half. For the period 1931-1935, 54% of the Coeur D'Alene's fires were man-caused. In 1936 and 1937, the man-caused fires were reduced from the previous 54% average to 24%. In the case of the Coeur D'Alene's prevention expenditures, it might be pointed out that the construction cost of an L-4, a 40' or 50' lookout tower, with quarters in the cabin, would have cost approximately the same amount but have contributed nothing in the prevention of fires. It is not unlikely that there has been too much emphasis in the past on pre-suppression without sufficient attention to prevention.

A southern state forestry department has for several years used the budget-making policy of devoting 10% of its fire protection budget to fire prevention projects. The policy is commendable, but the amount could well be raised to 15% or 20% of the total protection budget.

On a western national forest where the values at stake, the hazard, and the risk are high, and the gross area protected approximately 800,000 acres, the forest fire protection costs have averaged 11¢ per acre per year. On western national forests, where the values, risks, and hazard are low, the protection costs may be as low as 1.02¢ per acre per year. On others, where all the items are high, the costs may be as high as 14.16¢ per acre annually.

## Table 41

DETAILED PROTECTION COSTS PER 100,000 ACRES PRIVATE FOREST LAND
VALUES PROTECTED, RISK, AND HAZARD BETWEEN AVERAGE AND MAXIMUM

| [illegible] Description | Capital Investment | | Average Annual Charges | | | Cost Per Acre Per Year (Sum of columns C,D,E) |
|---|---|---|---|---|---|---|
| | Maximum (A) | Minimum (B) | Obsolescence (C) | Maintenance and Operation (D) | Personal Services (E) | (F) |
| Prevention | | | | | | 3.23¢ |
| [illegible]ing, 30 miles | $ 4,500 | $ 1,925 | $ 450 | $ 50 | $ 50 | |
| [illegible] rangers, full time | | | | | 1,680 | |
| [illegible] projects | | | | | 1,000 | |
| Pre-Suppression | | | | | | 6.73¢ |
| [illegible]tion & lookout [illegible] 100' | 6,500 | 5,000 | 300 | 25 | | |
| [illegible]men, 3 Mo. each | | | | | 540 | |
| [illegible]ication 60 mi. [illegible] line | 4,000 | 1,500 | 230 | 150 | | |
| [illegible] broadcasting and re[illegible] | 2,200 | 1,500 | 200 | 80 | | |
| [illegible]tation High speed [illegible] trail, 80 mi. | 48,000 | 10,400 | 400 | 240 | | |
| [illegible] speed truck trail, [illegible] mi. | 12,000 | 3,600 | 450 | 500 | | |
| [illegible] duty truck, one | 1,200 | 900 | 300 | 200 | | |
| [illegible], three | 900 | | 60 | 60 | | |
| [illegible]breaks, 1000-2500 miles | 7,500 | 3,000 | | 3,000 | | |
| Suppression | | | | | | 2.08¢ |
| [illegible] Pickups, two | 2,000 | 1,200 | 400 | 600 | | |
| [illegible] duty fire truck | 1,600 | 1,100 | 250 | 200 | | |
| [illegible] tools, special equipment | 1,800 | 300 | 150 | 30 | | |
| [illegible] labor, standby crews | | | | | 450 | |
| Overhead | | | | | | 1.95¢ |
| [illegible] Manager (1/3 services) | | | | | 1,200 | |
| [illegible] and dispatcher (1/2 [illegible]) | | | | | 750 | |
| [illegible] | | | | | | 13.95¢ |

[illegible] in Table 41, are theoretical detailed protection costs for a tract of private forest land [illegible] values protected, the risk, and the hazard are higher than average. The total annual protec[illegible] amount to 13.95¢ per acre gross. The net protection costs, dependent upon reimbursement from [illegible] Government through the Clarke-McNary Section 2 funds, might be 7¢ to 12¢, dependent upon the [illegible] property is located.

[illegible] longleaf region, where full protection can be conducted on a part-time basis, the cost per [illegible] less since it appears advisable that longleaf stands in the grass stage be burned over with [illegible] fire periodically. With longleaf out of the grass stage, it is believed that periodic control[illegible] may be preferable to complete protection on some sites. Accurate accounts of controlled [illegible] large scale are difficult to obtain, but it probably can be practiced for approximately 3½¢ [illegible] assuming that the area requires burning only every third year.

### [illegible] Costs

[illegible] costs of suppressing fires are generally expressed in terms of dollars required to pay fire[illegible] No funds are included for the depreciation and operation of equipment incident to fire-fighting. [illegible] is probably due to an almost total lack of equipment in pioneer fire-fighting. With all [illegible] modern effort becoming merchanized, forest fire control has followed the general social pattern [illegible] suppression costs are in some regions chiefly chargable to mechanical devices, but for [illegible] purposes, suppression funds are listed as having been expended for labor only, especially in [illegible] where mechanical equipment is seldom used.

[illegible] cost of fire suppression varies considerably with the size of the fire. On an acre basis, small [illegible] expensive to control and large ones relatively cheap. Fire suppression costs, however, should [illegible] from the standpoint of total costs rather than on a per acre basis. If suppression costs [illegible] in terms of perimeter units, such as chains, large fires will cost considerably more to [illegible] small ones, because large fires generally are worked on in some degree of confusion which [illegible] efficiency.

Suppression costs will vary tremendously even on individual classes of fires. In a state [illegible] tion, for example, where local residents are generally relied upon for all action, initial [illegible] reinforcement, the costs of Class A and Class B fires will be relatively high compared with [illegible] classes of fires on public areas where speed of initial attack is low because full-time men [illegible] immediately for the purpose. In the case of a temporary organization, the initial attack will [illegible] and the strength greater. In the case of large fires where rapid runs are made and where areas in excess of 1000 acres burned, temporary organizations will accumulate less cost than will permanent organizations chiefly because they do not have the facilities to mobilize much man-power rather than because of their desire to keep costs low.

In an eastern state organization where local residents are employed at a per diem or per hour rate for fire-fighting, with the hourly rate of pay ranging from 25¢ to 50¢ per hour, the following were the average costs in 1926:

| Size Class | Total Cost | Size Class | Total Cost |
|---|---|---|---|
| 0-10 acres | $ 7.54 | 100-500 acres | $113.26 |
| 10-50 | 20.07 | 500-1000 | 220.97 |
| 50-100 | 44.38 | 1000+ | 734.24 |

The above costs represented expenses for labor, warden supervision, auto hire, and lunches on the larger fires. For the average fire, of 99 selected at random, the costs per acre were as follows: (a) warden hire, 7¢; (b) helper hire, 3.76¢; (c) auto hire, 3.8¢; (d) lunches, 0.26¢.

The total expenditures in any single year for suppression will vary greatly from the average for previous years due to the many variable factors involved. The ratio which is produced by dividing the sum of the prevention and pre-suppression costs into the fire-fighting costs is low for some protection organizations and high for others. If the least cost theory discussed previously can be relied upon, the more money which is spent for prevention, the less money is required for suppression. Exclusive of loss considerations, some organizations spend more for fire-fighting than for prevention and pre-suppression; others spend four times as much for pre-suppression alone than they spend for fire-fighting.

Expenditures for suppression should be considered as a part of the whole fire protection picture. Some are of the opinion that strong initial suppression action is justifiable when there are high values at stake. When there are low values to be protected, fire-fighting expenditures should be kept at a low level. The most economical action may be to send as quickly as possible to each fire enough men to place all parts of the perimeter under control before worse weather conditions occur.

A correlation between accumulated excesses in air temperatures, suppression costs, and damage from forest fires has been worked out by Gray (82) for California. In 1907 an accumulation of mean annual temperature excesses commenced. Those excesses levelled off in 1923 and since then, they have gradually diminished. The same situation is displayed in loss and suppression costs. The period from 1907 to 1923 covers sixteen years. Unfortunately this period does not conform to the sun-spot eleven year cycle or the precipitation seven year cycle, so no immediate conclusions may be drawn from Gray's investigations until there is a repetition of the temperature cycle and further confirmation of the damage and suppression cost correlation with it.

## SUB-MARGINAL FORESTS

If the economic or "least cost" theory is to be taken seriously, it is necessary to recognize that there is "sub-marginal" forest land, just as within recent years there has been attention focused to sub-marginal agricultural lands. There has probably always existed this type of farm land, but we have not been acutely conscious of its existence until recently. Attention has been focused to the possibility of the existence of sub-marginal forest lands and questioned the advisibility of making continued expenditures for their protection from fire. Koch (126) reasoned that if there are no real forest values, there is no justification in protection. His attitude was prompted by the Selway conflagration in 1934. The Selway conflagration occurred in the "back-country" in the Northern Rocky Mountain Region and resulted in the loss of timber by fire on 186,000 acres of national forest land. Conflagrations have occurred periodically in the Selway from 1910 - or maybe before - through 1934. Large fires have burned and will probably continue to occur there. The results seem to be approximately the same regardless of the number of men available or degree of organization. In 1910, 1919, 1929, and 1934 there were conflagrations in [illegible] most recent one occurred with fires starting in the vicinity of lookouts and with 2,000 [illegible]. As an "old timer" in the region, Koch is of the opinion that conflagrations are [illegible] consequently there should be a limit to the expenditure of funds for protection in the [illegible]". He proposed for serious consideration the entire withdrawal of protection funds from the [illegible] where low values predominate.

[illegible] point on the same situation is expressed by Loveridge (127). He has stated that the [illegible] was due to sluggish initial action, inexcusable under the circumstances. That poor [illegible] occurred in the Selway under extreme fire danger was a matter of chance. The initial ac- [illegible] four hours instead of one hour which the conditions demanded. There was also poor dis- [illegible]-power and poor fire-fighting judgment. All of these faults, however, are due to human [illegible] they occur not only on the Selway, but everywhere and are likely to occur again on the Selway [illegible] unless the human factor can be eliminated. In spite of the economic formula, possibly [illegible] should be given to the "back-country" from the standpoint of protecting watershed values, [illegible] the fact that a conflagration in the "back-country" will lower visibility to such an extent [illegible]-country" of high values that the detection system will be seriously impeded, thereby expos- [illegible]-country" to serious danger of a conflagration.

[illegible] is today a tendency to ignore values insofar as fire protection expenditures are concerned on [illegible]. It appears that forest values can be ignored so long as public funds are plentiful, but [illegible] limitation of funds, they may again be observed. This policy is open to question when viewed [illegible] of the economic formula. If there is no economic justification for the expenditures of [illegible] protection in 1932, there is certainly no justification in 1935 if values are still the same. [illegible] of protection given to any property should be commensurate with the values entailed.

[illegible] protection costs are justifiable as long as their expenditure protects high values which are ex- [illegible] high risk and hazard. In the absence of real values, high protection costs are not warranted. [illegible] values, which result in a low rate of return, high protection costs are uneconomic. When the [illegible] costs jeopardize the rate of return or profit from forest land, they should be reduced to a [illegible] they are in line with the productive capacity of the property.

[illegible] forestry practice might be used as a guide for protection expenditures in the United States. [illegible], where low interest rates are used, 6-1/4% of the gross annual cost of production is applied for [illegible] against forest fires. This amounts to approximately 25¢ per year (128)

**FOREST FIRE INSURANCE**

[illegible] term forest fire insurance as used in this discussion is an agreement between an owner of forest [illegible] an insurance company whereby the latter agrees to indemnify the former, if and when standing [illegible] destroyed in whole or part by fire. Insurance against forest fires probably will become popular [illegible] there is a considerable acreage managed for the continuous production of timber; this will [illegible] demand for protection against the loss of forest capital, just as any other business today tries [illegible] itself against losses.

[illegible] the United States, forestry is going through a transitional phase. Capital was at one time in- [illegible] forest lands purely from the exploitation incentive, characterized by the "cut-out and get-out" [illegible] mining" operations. Some forest land exploitation companies, commonly known as "lumber" com- [illegible] have within recent years changed their viewpoint in that the capital which was reclaimed or re- [illegible] their original investment was reinvested in some other wood-using industry which required the [illegible] use of their forest land for the production of raw materials. Private capital which pursues [illegible] today, however, represents only a small percentage of the money invested in forest land, but, [illegible] limited in amount, it definitely indicates a change of attitude of forest land owners to the [illegible] some degree of forestry is practiced. This is evidence that some forest land owning companies [illegible] the speculative phase and have something at stake in reproducing their cutover lands and [illegible] second crop from fire so that the utilization plants will be assured of a supply of raw [illegible] If the timber crops produced are conifers, which are susceptible to crown fires in the younger [illegible], it would be especially desirable, from the standpoint of the owners, to insure their invest- [illegible] growth against loss, either in part or entirely. An enterprise, such as paper manufactur- [illegible] requires timber which can be grown on a short rotation with attendant dense young stands, would be particularly in need of insuring against loss. There are few enterprises so well [illegible] to expose their investment in timber to total destruction which is frequently possible [illegible] probable. With the practice of forestry, therefore, insurance against loss by fire [illegible] necessity for private capital invested in forest land used for growing crops of timber, [illegible] those companies which are not financially able to withstand a serious loss of assets.

If forest fire insurance were available at a low rate, so that private capital engaged [illegible] or could afford to purchase this protection, a large hurdle in the financing of forestry [illegible] would be jumped. Anyone who invests capital demands some protection against its sudden liquidation. Without forest fire insurance, capital invested in stands of timber is exposed to this unprofitable liquidation. The business of making forest fire insurance available, however, is dependent on insuring [illegible] and scattered risks. Today private capital will avoid commitment where the risk of loss, in whole or in part, is possible. On the other hand, insurance is not possible at low rates until a considerable demand for insurance is evident. Forestry practice, and sustained yield in particular, would be strengthened considerably by having forest fire insurance available. This would reduce the risk of capital loss considerably.

To a landowner such as the Federal Government, with its risks spread over a large part of the continent, self insurance is practicable, but with an industry which has its timber lands located within a limited part of a region, exposed simultaneously to the same hazards and of the same timber type, insurance should be highly desirable. Murphy (111) states that owners of large tracts of forest land in the Northeast feel that there is too much risk involved to practice forestry without protection to their investment in the form of timber insurance at a reasonable rate.

Some **Principles of Insurance**

All business enterprises are concerned with overcoming risks which may be few or numerous, dependent upon the business, and vary greatly in magnitude and character. In order to reduce the possibility of being forced to discontinue operations because of some loss of capital in the form of improvements such as buildings, manufactured goods, merchandise, or raw materials such as cotton in a warehouse or pulpwood in the yard, these forms of capital goods are generally insured against loss. In his discussion of this subject, Herbert (112) stated that private capital could hardly be attracted to growing timber when the funds invested in the enterprise are constantly exposed to high risk.

The whole business of insurance is based on wide spread of risks. The greater the number of insured risks and the greater the geographical spread, the greater is the stability afforded, or, to put it another way, the less is the probability of heavy loss to the insurer at any one time.

Because of the desirability of wide spread in the possible losses, one form of insurance company, known as the mutual, is not desirable. The success of the mutual is largely based on having low administrative costs with attendant small area coverage. Limited geographical distribution, i.e., the insured [illegible] confined to a small geographical radius, the greater the likelihood of loss from the conditions productive of high hazard. When there is high hazard due to meteorological conditions in eastern Minnesota for example, there is high probability that western Wisconsin and even the northern peninsula of Michigan are exposed to the same conditions. If the risks could be spread so that some would be located in the Lake States Region, some in the New England States, and some in the eastern Gulf States, and the balance in northern California, there would be less probability of high loss in any one year than if the risks were concentrated within a single region.

Lovejoy (118) has stated that the theory of insurance assumes that there will be fires, that the fires will cause damage, and that the number of fires and resulting damages can be statistically forecast so that premiums can be charged which will conform to the probable losses. There is an essential difference between insurance and protection costs. Admittedly they must both be levied against the income from the forest, but they are by no means identical. Insurance provides indemnity in event of damage. The protection given a property by a fire control organization reduces the losses, or should, but there is no provision for reimbursement for loss incurred because of fires. The costs of a fire control organization are legitimate costs of the business of growing timber, just as much so as insurance against loss by fire and the maintenance of suppression devices by a manufacturing plant. Insurance against loss by forest fires does not eliminate the need for a protection organization. A satisfactory insurance rate

... is possible only after an effective protection organization is operative.

... forest owning companies may have some form of protection against fires, it would also be ... to be able to have insurance against loss at reasonable premium rates. Precedent for ... found among many business enterprises which not only carry insurance against loss but ... depend on the local fire department for suppression of fires. Merely because a suppres- ... available does not mean that the possibility of loss is eliminated; it is merely a ... contributes toward the reduction of the size of the loss. Insurance costs cannot be classed ... for a fire suppression organization because the latter is merely a factor affecting the ... be charged for indemnification in event of loss.

..., a serious undertaking of the matter of insuring a stand of timber against forest ... difficult not only because of a distinct lack of good risks, since there was very ... practiced on private lands, but also because of a decided lack of data on risks, relative ..., and understanding of good and poor fire control practices, and the effect of forest ... numerous forest types and age classes within the individual types. Certain variable factors ... considered in rating the liability of a forest area to loss by fire. Liability, as used by ..., consists of a combination of probable cost of suppression plus the liability to loss.

... as he was concerned with the two factors just mentioned from the standpoint of planning ..., and not with loss alone, he was concerned with the problem of pegging the point of ... in his protection organization costs.

... recent thorough study of forest fire insurance has been made by H. B. Shepard of the United ... Service. The results of Shepard's investigation were recently published. Because of the ... of the publication, it will be referred to frequently in the discussion below.

... the tallest hurdles to overcome before forest fire insurance is generally accepted, is the ... of timber. There can be no indemnification without agreement between the parties con- ... values covered and procedure for determination of values destroyed. When the timber is ... size, there exists a good means of establishing stumpage value based on the local market. ..., the market value of stumpage will be affected by current conditions such as the establishment ... of nearby roads or railroads. There is considerably more difficulty, however, in fixing ... second-growth timber which is more susceptible to damage or complete loss by fire than in ... mature or merchantable stands. On the West Coast, where Shepard's study was conducted, a ... is regarded as the size class between merchantable and non-merchantable. This arrangement ... provided there is no market for smaller material and there exists a sawlog market only. ..., with its numerous pulp mills, timber five inches in diameter at breast height is regarded ...

... a definite need for the insurance of second growth stands, regardless of whether they were ... naturally or planted. Forestry practice implies continuous use of forest soil; this demands ... production of young trees which, although not merchantable, are progressing annually toward ... in their developmental stage, young, unmerchantable stands of timber represent tangible value ... it cannot be profitably liquidated until it reaches "merchantable" size. Shepard (119a) has ... the value assigned to second growth, unmerchantable stands be equal to what the owner had ... them. The value of the stand would also include cumulative maintenance costs with in-

... study, Shepard used a procedure which was a departure from the usual method employed by fire ... companies in determining rates. The accepted procedure is the trial and error, or "experimental" ... with a considerable volume of data on forest types, damage by fires, frequency of fires, as well ... behavior, it seemed desirable to avoid the accepted method for determination of rates, chiefly ... large factor of safety which insurance companies required in making up rates for new types ..., and the time element involved to secure a satisfactory statistical base on which to make ... accurate premium calculations. Timber growing enterprises, however, are not sufficiently ... afford the large safety factor demanded by the trial and error method. With the available ..., premium rates could be fixed without going through an extended waiting period to ... might be satisfactory rates from an insurance standpoint.

In his report, Shepard has used some terminology which is novel, but the meaning [illegible] new. There is used "physical hazard" in referring to timber size, density, forest type, [illegible] presence of snags, topography, and logging debris present; "climatic hazard" is the effect [illegible] factors such as relative humidity, precipitation, rate of evaporation, air movement, and [illegible] have on the "physical hazards"; "causative hazards" are the groups of risks; "conflagration hazard" refers to the probability of large fires exemplified by the Tillamook and Selway. The last named item, "conflagration hazard", produced jointly by the "physical" and "climatic" hazards, is of especial [illegible] forest fire insurance because large reserves have to be accumulated by insurance companies to provide for such situations which periodically develop in spite of the best efforts of good protective forces. Confronted with this situation, an insurance company covering timber must set aside a considerable part of the premiums to take care of such contingencies.

**What Has Been Done and Experience Gained**

The insurance of standing timber in the United States was started in the form of a mutual in New Hampshire in 1917. The company was formed for the primary purpose of insuring timber; it was known as the Timber Lands Mutual Fire Insurance Company. Business was conducted for two years at a flat rate varying from 2% to 1½% of the values insured. The enterprise was short-lived; in 1919 the business of the company was liquidated and the business acquired by the Globe-Rutgers Company of New York City.

As principle mover of the original mutual, W. R. Brown (114), of the Brown Company of Berlin, New Hampshire, has listed several points relative to forest fire insurance which were gained from his experience with the Timber Lands Mutual Fire Insurance Company.

a) Data on forest fires are not accurate enough.
b) High premium rates which small companies are obliged to charge are not attractive, even at 1% of the value of the insured timber.
c) Those having immature stands were most interested; with insurance coverage, these lands could be used for financing purposes.
d) Merchantable timber is a much better risk than immature timber because of high salvage value.
e) Risks should be scattered in relatively small units.
f) Rates should vary with the seasonal hazard; in extremely dry periods, the rates should be higher than for periods with normal precipitation.
g) Where risks are high, coverage should be avoided.
h) The rates should vary with the degree of hazard and risk which exists.

It was Brown's belief that if standing timber insurance is to be effective on a large scale, it must have the backing of either immense capital, or be subsidized by the state or federal government for a period of time to make it a going concern.

In the boom days prior to 1929, the United States Chamber of Commerce showed an interest in forestry to the extent of appointing a committee to investigate the possibilities of forest fire insurance in standing timber. The committee submitted its report to the Commercial Forestry Conference held at Chicago in November, 1927. Several recommendations were made (116). These have been listed below:

a) Determine whether landowners are interested in protecting holdings with forest fire insurance coverage.
b) Investigation to be made of those factors which affect forest fire insurance so that equitable rates can be devised.
c) The investigation for the above facts should be limited to that part of the country where there has been real interest displayed in forest fire insurance.
d) Where there is a favorable attitude toward insurance, the insurance companies should proceed to make an investigation and confer with associations of forest owners.

Subsequent to the report of the Forestry Conference committee headed by Kaul, there was little work done toward developing facts relative to forest fire protection until Shepard commenced his work for the United States Forest Service regarding insurance in the Pacific Coast Forests.

In 1936, approximately ten years after Mr. Brown made the above pronouncements, Shepard (119) arrived at the opinion that lack of forest fire insurance is due more to poor understanding on the part of all

... rather than to prohibitive conditions; furthermore, that insurance in the Douglas fir ... be instituted whenever the owners really want it, at rates comparable to the cost of fire in... other forms of property; also, that successful forest fire insurance could be conducted at an ... premium rate of 45¢ per $100 of insurable timber values. Based on his investigation, ... that forest fire insurance in the Pacific Coast States could be profitable and feasible. ... expectancy he fixed at 0.082 percent per year, but he recommended an average premium rate ... The wide spread between normal loss expectancy and the recommended fixed premium rate is ... consideration to those variable factors such as conflagration hazard and safety margins in... enterprise. With a business volume in excess of a quarter million dollars per year, the ... reduced substantially. The suggested rate for the Pacific Coast Douglas fir type is detailed ...

| | |
|---|---|
| ... allowance for probable normal losses . . . . . . | 4.7¢ per $100 |
| ... expenses and profits . . . . . . . . . . . . . . . | 4.7¢ |
| ... conflagration reserve. . . . . . . . . . . . . . | 13.8¢ |
| ... margin. . . . . . . . . . . . . . . . . . . | 26.8¢ |
| | 50.0 |

... countries other than the United States have tried forest fire insurance. In Japan the ... insurance in effect is quite limited. In 1931, only 0.36 percent of the forest area was insured. ... forest area could have been insured, but there was excessive caution displayed in the selec... by the insuring companies. Yatagai (116) states that the slow progress made in the in... standing timber in Japan is due to (a) the necessity for the accumulation of large reserves ... damage done by fires, (b) incomplete fire statistics, and (c) high rates. The rates ... upon location, type, and age class. Hardwoods have lower premium rates than conifers and ... have a lower rate than young stands less than 10 years of age. Rates for conifers in the ... class are 3.375% as against 1.35% for hardwoods. Some localities have a much lower risk ... than others. This is reflected in the rates. In one district, hardwoods of 50 years and up ... rate of .05%. In another locality the same timber type and age class has a rate of 9.3%.

... Scandinavian countries have an unusual amount of insurance in effect and are probably more ad... any other forest regions not only in their forestry practice but in such attendant matters as ... Baldwin (117) reports that approximately 50% of insurable forest land in Sweden and Finland is ... 70% of the insured value. As the risks have increased in number and the volume of business ..., the premium rates have been lowered. An inovation in the Swedish insurance is the paid up ... "perpetual" insurance. The premium may be paid in a lump sum or may be spread over several ... in installments. Low rates are available on the perpetual coverages because of the reduc... costs necessary in renewing the temporary insurance. Perpetual insurance, however, is pos... the stands are operated on a sustained yield basis.

... Appraisals

... appraisal of damages caused by fires is as integral a part of forest fire insurance as is the ... the stand as a part of the procedure preparatory to the insurance against loss by forest ... procedure followed in the determination of damage is of tremendous importance to the assured ... because of the coverage of loss sustained. The damage appraisal procedure is important to ... company from the standpoint of paying the assured what is equitable rather than an amount in ... the real value of the timber.

... discussion in an earlier chapter, "Effect of Fire", it was pointed out that fire damage is not ... apparent a week, a month, or even a year after a fire. In some timber types, a considerable lapse ... necessary to arrive at the true damage done by fire. This procedure would be particularly to ... of the assured. Because of this principle, quick adjustment is of no great benefit to the ... speedy adjustment procedure on the part of the insurance company is commendable only when the ... on which the adjustment is based is accurate. For the Pacific Coast Region, it has been ... that appraisals based on examinations conducted at the end of the growing season which follows ... which the fire occurred. If a fire occurs in August, 1936, for example, the examination for ... be conducted in October, 1937. For young stands, less than twenty feet tall, the elapsed ... can be shorter.

In his discussion of principles underlying damage appraisal, H. H. Chapman (153) states [illegible] may be appraised on the basis of (a) capital value, (b) cost value, and (c) market value. The [illegible] value method is undesirable because it depends on estimating future values and in choosing [illegible] rate. In spite of the objections, it has been the most popular, especially in determining [illegible] young, unmerchantable stands. The cost value method is predicated on experience; it [illegible]. [illegible] costs can be determined with considerable degree of accuracy, and the general procedure [illegible] understood by all parties concerned. Since this method, however, yields a premium for extravagant [illegible] ment and penalizes the thrifty timber grower, it, too, has undesirable elements. The market value method, where merchantable timber is destroyed, is the most satisfactory since it is approximately equal to true value.

The appraisal of damages sustained by an unmerchantable stand is a complicated one as viewed by the [illegible] which consider a stand of timber as part and parcel of the land. When damage appraisals to unmerchantable stands can be conducted, as suggested by Shepard, as separate entirely from land values, then the whole procedure of valuation becomes relatively simple, provided the method has been agreed upon by all parties of the agreement. Chapman (155-p.166) cited an excerpt from a law case as follows: "If trees have no value when separated from the land, the only cause of action which arises from their destruction [illegible] one for damages for injury to the land, the measure of damage in such case being the difference in value of the land before and after the injury". Obviously, a tract of land with a stand of seedlings and saplings, although not of merchantable size, is worth more than bare land devoid of tree cover. With forest land sales so scattered and infrequent, going market values of land, with young timber as an integral part of it, can hardly be equitably established. Because of this, the capital value method for unmerchantable stands is the most desirable.

In the case of merchantable stands, damage appraisal is relatively easy. The value of the stand before the fire can be determined from the policy agreement. A cruise of the timber to determine salvage value can be made by any experienced regional cruiser. The salvage value subtracted from the value prior to burning, is the amount of damage sustained by the assured.

Although the United States Forest Service has made estimates of damages caused by fires on national forest lands for many years, the procedures used were numerous and produced questionable values. In [illegible], the Chief Forester (154) set up a procedure designed to standardize damage appraisals. The means recommended for appraising young stands was the capital value method. The value at maturity of stands now young is the product of average yield for the type and estimated future stumpage for the region.

The value of young stands is based on the actual rate of interest earned on expenditures by the owner. In the case of the United States Forest Service, the regional protection and administrative expenditures for the period required to start new stands form the basis. Regional tables of values for young stands were prepared on the basis of the procedure given below:

a = Annual administrative cost and protection charge

n = Rotation and regeneration period

y = Gross yield

.op.= Interest rate

$$y = \frac{(a)\ (1.op^{n-1})}{.op}$$

X = Present value, unmerchantable stands

M = Present age, unmerchantable stands

$$x = \frac{(a)\ (1.op^{m-1})}{.op}$$

**Table 42**
**VALUE PER ACRE OF YOUNG GROWTH**
**INTERMOUNTAIN REGION, U.S. FOREST SERVICE (143)**

| Timber Type | Good Sites | | | Medium Sites | | | Poor Sites | | |
|---|---|---|---|---|---|---|---|---|---|
| | 20 | 40 | 60 | 20 | 40 | 60 | 20 | 40 | 60 |
| (a) Ponderosa Pine | $2.00 | $3.50 | $7.00 | $2.00 | $3.50 | $5.50 | $2.00 | [illegible] | $4.50 |
| (b) Douglas and mixed fir | 2.00 | 3.50 | 6.00 | 2.00 | 3.00 | 5.50 | 1.50 | [illegible] | [illegible] |
| (c) Lodgepole Pine | 1.50 | 2.50 | 4.50 | 1.50 | 2.50 | 4.50 | [illegible] | [illegible] | [illegible] |
| (d) Woodland | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | 1.50 | [illegible] |
| (e) Protection | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| (f) Grass and brush | 30¢ | | | 20¢ | | | 20¢ | | |

The use of the above procedure has resulted in the construction of tables of value for unmerchantable stands in the several western regions. Table 42 above has been prepared by R-4, the Intermountain Region of the United States Forest Service and has been included in the Region's Fire Manual.

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