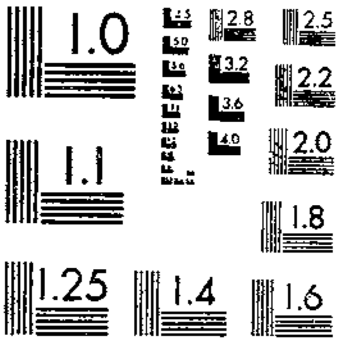
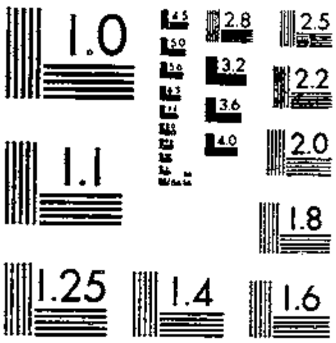
TB 209 (1930) USDA TECHNICAL BULLETINS UPDATA
THE DETERMINATION OF HOUR CONTROL FOR ADEQUATE FIRE PROTECTION IN THE
SHOW, S B ; KOTOK, E I 1 OF 1

START



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

TECHNICAL BULLETIN No. 209 — AUGUST, 1930

UNITED STATES DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

THE DETERMINATION OF HOUR CONTROL FOR ADEQUATE FIRE PROTECTION IN THE MAJOR COVER TYPES OF THE CALIFORNIA PINE REGION

By S. B. SHOW, *Regional Forester, California National Forest Region, and* E. I. KOTOK, *Director, California Forest Experiment Station, Branch of Research, Forest Service*

CONTENTS

THE FIRE-PROTECTION PROBLEM

Successful fire protection on the national forests or elsewhere requires the solution of four major questions. These are: (1) A determination and statement of a specific objective; (2) determination of the speed or hour control necessary in attacking fires in order to hold burned acreage to the accepted objective; (3) determination of the size and distribution of man power and of fire protection improvements required to attain the needed hour control; (4) the methods, technic, and training needed to use most effectively the man power and equipment after its arrival at the fire.

FIXING THE OBJECTIVE

Without a clear-cut and readily measurable objective (2) and (3) can not be determined in a real way, and the difficult problems of fire finance can not be so handled as to obtain the maximum reduction in burned acreage per dollar expended. That is, unless a constant checking is carried on unit by unit and region by region, an inevitable tendency will develop for overexpenditure in certain units and regions in which the objective has been attained, at the expense of others in which high values are at stake and in which the goal has not been approached.

The simplest and most usable statement of the fire-control objective is in terms of acreage burned. For the national forests in the California pine region this is now set at an annual average of 0.2 per cent for the commercial and potential timber types and at 0.5 per cent for the nontimbered types in which the principal value is for watershed protection and grazing. The figure for timbered types is determined by the length of timber rotations in the region and the loss which can be endured without disrupting sustained-yield management plans. A similar line of analysis has been employed in deciding on the objective in the nontimbered types. Possible future increases in timber and watershed values and a progressive refinement of management plans on the national forests may require a stepping up of these objectives. At present they are accepted as the needed and attainable goal in fire control. To state the same thing in a single figure for the two groups of types, with due regard to their proportionate representation, it may be said that successful fire protection is attained for the whole region when not over 0.26 per cent is burned annually.

HOUR CONTROL

The principal purpose of this bulletin is to answer the second of the major questions confronting the national-forest fire-control organization in northern California, that of the speed of attack needed in order to hold burned acreage to the accepted minimum. The speed-of-attack factor is usually termed "hour control," and includes the total time elapsing from the start of the fire until the first suppression forces start work on the fire. It thus includes four generally recognized steps in the functioning of a fire-control machine: (1) Discovery, or the time from start to discovery; (2) report, or the time from discovery until the individual responsible for first attack is notified of the fire; (3) get-away, or the time spent by the control force after the report is received before actually starting for the fire; and (4) travel time, or the time consumed in getting to the fire.

It has been urged that because of difficulty in determining the exact time at which some fires start, and because the time of discovery is always definitely known, hour control should ignore the time elapsing between start of fire and its discovery (discovery time). Evidently any such procedure is erroneous and omits an element vital to effective suppression; the fire is spreading from the very start, even if its existence is not immediately discovered. It is the total time during which the fire has spread that is the important factor.

It has already been sufficiently established [1] that cover type rather than any geographical unit is the proper basis for analysis of fire problems. The hour-control problem to be discussed in this bulletin

[1] SHOW, S. B., and KOTOK, E. I. COVER TYPE AND FIRE CONTROL IN THE NATIONAL FORESTS OF NORTHERN CALIFORNIA. U. S. Dept. Agr. Bul. 1495, 36 pp., illus. 1929.

will be considered solely in the light of its relationship to the nine major types in the California pine region, namely, the western yellow pine, the mixed conifer, Douglas fir, sugar pine-fir, pure fir, brush field, chaparral, woodland, and grass. These are the types recognized and described in previous studies of the California pine region.[2]

VARIATIONS IN HOUR CONTROL

Significant variations in rate of spread of fires and hence in the hour control required have long been recognized in practice, and rough measures of these variations have been worked out by analyzing the history of many fires. The years of experience and the analyses agree in proving that the major controls of rate of spread are (1) the cover type in which the fire occurs, (2) the character of the season during which it occurs, and (3) the exact conditions of wind and atmospheric humidity while it burns.

Of these, the character of the cover type is relatively constant, whereas the other two vary enormously from time to time. In a very broad way, differences in rate of spread within a given cover type, as between a very difficult and less difficult fire season, may be fully as great as differences between the more inflammable and less inflammable types in a given season. Likewise, differences in spread between very dry, windy days and less dry, calm days, within a given type and season, may equal differences due to type alone. The highest rates of spread occur on fires starting on the worst days in the worst season in the most inflammable types. As a matter of general practice for the entire region, the level of protection effort can not now attempt to hold all such fires to a small area. It should aim at controlling fires under the average worst conditions as represented by the most difficult years, rather than under the absolute worst conditions as represented by the most difficult days. Good organization will, however, include plans and machinery for sudden expansion to meet short-time emergencies beyond the capacity of the regular organization.

PRESENT EFFORTS TO ESTABLISH HOUR CONTROL

The statement of the fire-control objective in terms of an acceptable minimum of burned area (agreed loss rate in acres for a given unit) has been in effect for many years. Variation in spread of fires and hence in hour control required has also been generally recognized and has been translated into material differences in intensity of protection in the several types. It has not been possible, however, to state specifically the hour control necessary in any one type in order to hold burned area to the accepted minimum.

This is accounted for in several ways. For one thing, until now the enormous mass of accumulated experience from which the answer must come was not available for analysis. For another, a skeleton fire-control organization was all that the insufficient funds available for this work permitted and hence no urgent need for an immediate determination of hour control has existed. In addition to these conditions the opinion prevailed up to 1923 that approximately adequate protection had already been attained and could be

[2] See appendix for detailed discussion of types.

maintained. Beginning with 1924 the increasing severity of fire seasons and increasing use of the forests have resulted in unacceptable losses.

A simple and direct measure of the effectiveness of present efforts is obtained by determining the average percentage of fires attacked within one-half and one hour after start, for each major type. (Fig. 1.) The average for the entire 6-year period from 1923 to 1928 is, of course, not fully representative of the speed in attack during the more recent years, because some increase in protection effort has since taken place. It is, however, a reliable general picture of comparative performance.

As will be fully shown later, the attack necessary to attain the minimum burned-area objective must be most rapid in the yellow pine, mixed conifer, brush, woodland, and grass types. In the aver-

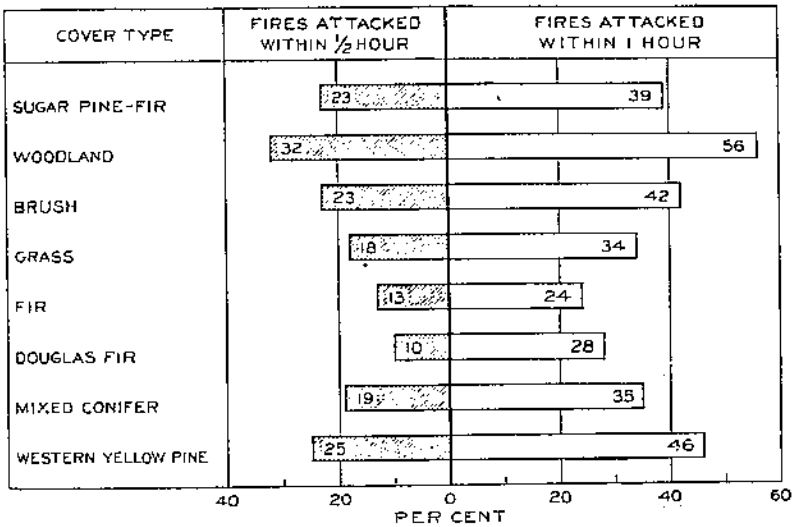


FIGURE 1.—Percentage of fires under ½-hour and 1-hour control in major cover types, 1923–1928

ages for fires attacked within one hour, all of these types are relatively high and nearly all are high for fires attacked within one-half hour; but so is the sugar pine-fir type, in which it will be found that extreme speed is unnecessary. Apparently, however, the present averages represent not unnecessarily great speed in the sugar pine-fir type but inadequate speed in the others. At any rate, the sugar pine-fir type is relatively much better protected than the others.

In the same analysis, the white fir type shows the lowest percentage of fires reached within one hour, and this reflects in general the correct practice, since this type permits of the slowest hour control of all. The Douglas fir type ranks next to white fir, and the findings of this study show this to be the proper position.

In general practice, therefore, the differences in rate of spread of fires have been recognized, although apparently not to the degree or with the consistency that will here be indicated as desirable.

IMPORTANCE OF FOCUSING ON THE MOST DIFFICULT YEARS

A glance at the burned-area records of the individual years (fig. 2) is sufficient to indicate the importance of the most difficult years (1924, 1926, and 1928) in the fire problem. Clearly, for the entire group of years, fire control has not nearly attained the specified objective in area burned. The existing level of fire-control effort can thus only be regarded as generally insufficient. It is equally evident that in the less difficult years (1923, 1925, and 1927), individually and as a group, the objective has been attained.

Evidence that attention should be focused on the difficult years is found in the very large increase in the number of large fires in the difficult years as compared to the number in the less difficult

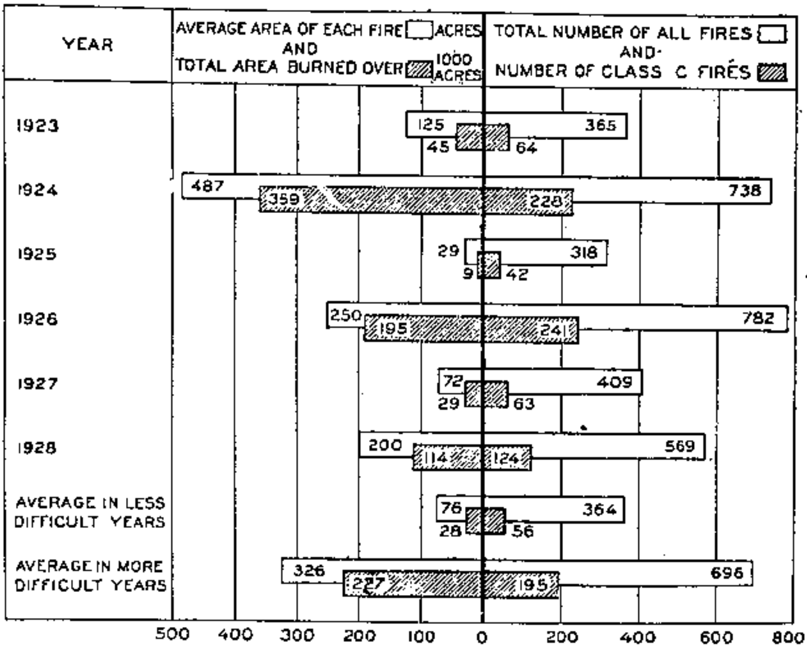


FIGURE 2.—Index of character of different fire years, yellow pine, mixed conifer, and brush-field types, 1923–1928

years. (Table 1 and Figs. 3 and 4.) These figures reflect not only the higher percentage of class C fires (fires that reach over 10 acres in size), but the greater total of man-caused fires. Detailed figures on the occurrence of large fires in the different hour-control groups are given in Table 2. The ratio between the number of fires of 100 acres and over in the more difficult and less difficult groups of years is over 4 to 1 for the yellow pine and mixed conifer types combined; 12 to 1 for the Douglas fir; nearly 3 to 1 for the fir and sugar pine-fir types combined; 4 to 1 for the brush type; 2 to 1 for grass and woodland combined. For 1,000-acre fires, the ratios are even higher—10 to 1 for yellow pine and mixed conifer combined; 7 to 0 for Douglas fir; 5 to 0 for fir and sugar pine-fir; 3½ to 1 for brush; 6 to 1 for grass and woodland combined. One way to state the fire-control problem is to say that the number of 100-acre or 1,000-acre fires in bad years must be reduced to the number occurring in the less difficult years.

TABLE 1.—*Data on average fire, C fires, fires of 100, 500, and 1,000 acres, and fires requiring over 24 hours to control, all forests*

MORE DIFFICULT YEARS (1924, 1926, AND 1928)

Type	Average fires	Average C fires	Average 100-acre fires	500-acre fires	1,000-acre fires	24-hour fires
	Acres	*Acres*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
Western yellow pine	157	751	12	6	4	6
Mixed conifer	545	1,511	23	14	9	16
Douglas fir	182	513	19	10	6	15
Fir	90	652	7	2	1	4
Grass	400	938	24	12	10	12
Brush	392	1,180	22	11	7	10
Woodland	232	1,282	6	4	3	6
Sugar pine	387	1,677	12	8	6	6
Average	298	1,090	16	9	6	9

LESS DIFFICULT YEARS (1923, 1925, AND 1927)

Type	Average fires	Average C fires	Average 100-acre fires	500-acre fires	1,000-acre fires	24-hour fires
Western yellow pine	20	169	5	1		1
Mixed conifer	134	855	9	3	2	4
Douglas fir	19	200	3			3
Fir	17	274	5			2
Grass	113	371	15	3		6
Brush	99	415	11	6	4	6
Woodland	233	887	11	5	4	3
Sugar pine	75	566	8	3		3
Average	71	457	8	2	1	3

If fire conditions were never more difficult than they have been in the odd years the fire problem could be regarded as already satisfactorily met. This is, however, an unwarranted assumption; indeed, it must be expected that years as difficult as 1924, 1926, and 1928 will recur with some regularity. The problem of fire control for the region is, then, to hold losses to the accepted minimum in such years. It follows that, in analyzing performance and in determining the hour control required in the different types, attention must be focused on the critical years as constituting in effect the normal years in fire protection. The principal importance of the less difficult years is, then, to check and confirm the conclusions reached from experience in the normal years.

Clearly, the fire-control organization must be gaged by the same standard—the ability to cope with the situation in the most difficult, or normal years. It does not follow that additional effort will be required everywhere. Indeed, to justify additional effort it must be shown that each type as a whole, and each national forest as a whole or in part, is now inadequately protected. For example, in the analysis here presented, no attention is given to two national forests in the California pine region totaling 3,000,000 acres, where the fire-control objective has already been consistently attained and total fire expenditures per acre are far lower than on any of the national forests here studied.

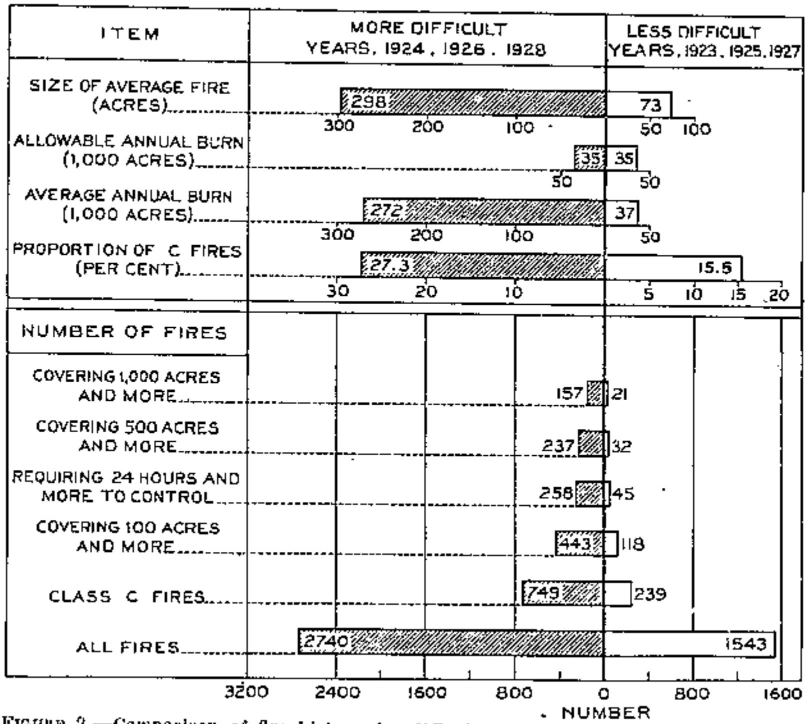


FIGURE 3.—Comparison of fire history for difficult group of years (1924, 1926, and 1928) and less difficult group (1923, 1925, and 1927)

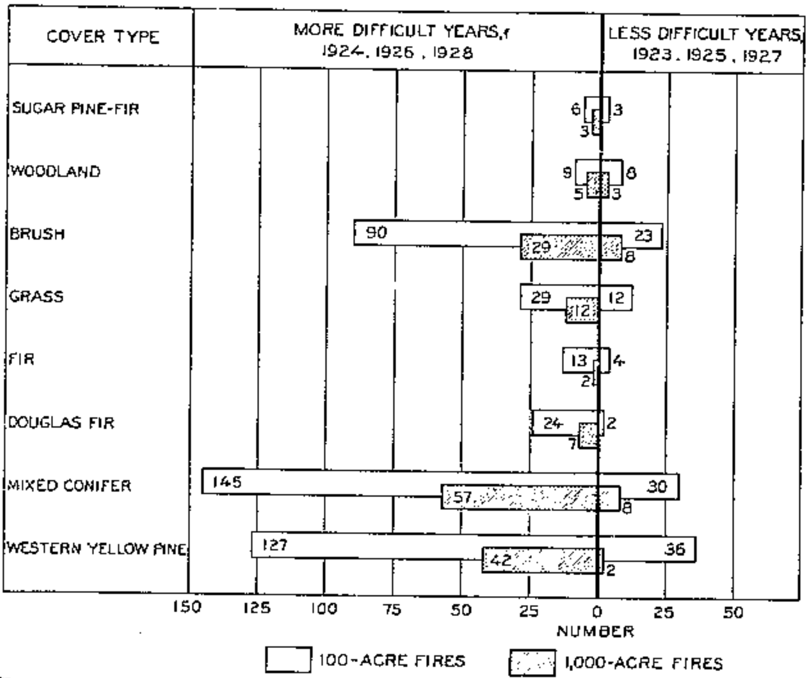


FIGURE 4.—Number of fires of 100 and 1,000 acres and over, by types, grouped by more difficult and less difficult years

TABLE 2.—*Distribution of 100, 500, and 1,000 acre fires by type and elapsed time, all forests*

WESTERN YELLOW PINE TYPE

Hour control	1924, 1926, and 1928				1923, 1925, and 1927			
	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Half hour or less	21	7	3	6	2	1	1	1
½ to 1 hour	22	12	8	13	12	1	1	4
1 to 2 hours	27	15	10	10	3	1		
2 to 3 hours	12	6	4	6	5			2
3 to 4 hours	11	5	2	8	2			
More than 4 hours	34	21	15	19	12	1		2
Total	127	66	42	62	36	4	2	9

MIXED CONIFER TYPE

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	18	11	4	10	3	1	1	1
½ to 1 hour	28	18	10	15	4	1		2
1 to 2 hours	26	18	12	23	6	2	2	3
2 to 3 hours	10	6	6	8	2			1
3 to 4 hours	9	9	6	8	3			1
More than 4 hours	54	24	19	39	12	5	5	4
Total	145	86	57	103	30	9	8	12

DOUGLAS FIR TYPE

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	2	1		1				
½ to 1 hour	1	1		1				
1 to 2 hours	2	2	1	3	1			1
2 to 3 hours	2	1		3				
3 to 4 hours	3			1				
More than 4 hours	14	7	6	9	1			1
Total	24	12	7	18	2			2

FIR TYPE

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	3							
½ to 1 hour	1			1				
1 to 2 hours	2	2	1	1	1			1
2 to 3 hours	1							
3 to 4 hours								
More than 4 hours	6	2	1	5	1			1
Total	13	4	2	7	2			2

GRASS TYPE

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	2							
½ to 1 hour	8	5	4	4				
1 to 2 hours	4	1	1	2	5	1		4
2 to 3 hours	3	1	1	2	1			
3 to 4 hours								
More than 4 hours	12	8	6	7	6	1		1
Total	29	15	12	15	12	2		5

TABLE 2.—*Distribution of 100, 500, and 1,000 acre fires by type and elapsed time, all forests*—Continued

BRUSH TYPE

Hour control	1924, 1926, and 1928				1923, 1925, and 1927			
	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
Half hour or less	14	9	7	7				
½ to 1 hour	11	5	2	3	3	1	1	1
1 to 2 hours	17	7	5	8	4	4	4	3
2 to 3 hours	6	2	2	3	4	2		1
3 to 4 hours	7	4	1	2				
More than 4 hours	32	17	12	18	12	5	3	7
Total	90	44	29	41	23	12	8	12

WOODLAND TYPE

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	1			4				
½ to 1 hour	1	1			2			
1 to 2 hours	4	2	2	2	1			
2 to 3 hours	1	1	1	1	1	1		
3 to 4 hours					1	1	1	
More than 4 hours	2	2	2	2	3	2	2	2
Total	9	6	5	9	8	4	3	2

SUGAR PINE-FIR TYPE

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	2			2				
½ to 1 hour	1	1	1			1		
1 to 2 hours	1	1		1				
2 to 3 hours	1	1	1		1	1		1
3 to 4 hours								
More than 4 hours	1	1	1		1			
Total	6	4	3	3	2	2		1

ALL TYPES

Hour control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control	100-acre fires	500-acre fires	1,000-acre fires	Over 24 hours control
Half hour or less	63	28	14	30	5	2	2	2
½ to 1 hour	78	43	25	37	21	4	2	7
1 to 2 hours	83	48	32	50	21	8	6	12
2 to 3 hours	36	18	15	23	14	4		5
3 to 4 hours	30	18	9	19	6	1	1	1
More than 4 hours	155	82	62	99	48	14	10	18
Total	443	237	157	258	115	33	21	45

METHODS OF STUDY

DATA USED AND METHODS OF HANDLING

The determination of hour-control needs for a type, group of types, or region can obviously best be made by analysis of widespread and abundant actual experience—that is to say, the detailed records of thousands of individual fires throughout the region. No prior basis exists for such determination, and even the most detailed knowledge of fuels and of combustion may be only indirectly helpful in this respect. In the California pine region such records have been made systematically by the Forest Service for many years, to include as soon as possible after each fire the essential facts of the fire, including its origin, its history, the factors affecting its spread, and its cost. This mass of information, when properly assembled in significant categories, develops unmistakable trends that would often lie concealed in less comprehensive data.

Another outcome of this assembling of abundant data is a greater dependability of results. In quality, accuracy, and completeness the data collected were certain to be far from perfect. Of the hundreds of individuals who have been connected with fire control and who are responsible for the data here employed, many were unaccustomed to recording notes in the field or to assembling facts on paper. The pressure of work made it impossible for many of the field officers to prepare the reports for some days after a fire; and for the same reason detailed examination and survey of many large fires has been impracticable. But such a study as this is not contingent on perfection of data. Whereas data clearly inaccurate have been discarded, it has been assumed with reason that the ordinary human errors are sufficiently counterbalanced in the mass to give approximately true final values. This tendency toward compensation is a matter of fact, as demonstrated by test, and not one of assumption.

Many of the original reports did not specify the types in which the fire originated. To determine the type with substantial accuracy, the location of each fire was referred to a map prepared for the purpose showing the major forest types. Although some errors in determining the type in which particular fires have occurred may have crept in, these errors again are probably compensatory. It has been necessary to charge the acreage and cost of each fire to the type in which it originated. This is not invariably correct, as for example when a fire starting in chaparral is controlled at the edge of western yellow pine and burns over a small area in that type. However, with few exceptions the major run and character of a fire are determined by the type in which it started. A fire starting in brush, for example, will ordinarily attain such size and such momentum that it will still be very difficult to combat after it spreads into western yellow pine timber or into woodland areas, and can be classified as characteristically a brush fire. The use of the data in this manner probably affects the figures for total area burned, by types, but is immaterial in other relationships.

Because this study is aimed at a particular problem—hour control as required in the major types—only part of the data on each individual fire report were abstracted and used. These consisted of the following items: Date and year of fire, class (A, B, or C), final area, area when reached by suppression forces, elapsed time from start of fire until suppression work was begun, travel time going to the fire, time to control the fire, distance traveled to the fire, and means of travel used. On a small percentage of the individual reports, one or another of these items was not recorded, and the total number of cases is therefore not constant in the different phases of analysis.

These data have been assembled in various ways, the cover type always being used as the major and controlling basis for classification of the facts. In all, 4,283 fires have been used, and these have been taken from 12 national forests in the California pine region for the period 1923 to 1928, inclusive.

OMISSION OF LIGHTNING-FIRE DATA

In this study data on man-caused fires only have been used, and lightning-fire data have been omitted. Man-caused fires were selected because they occur in all the principal cover types of the region, they contribute the major share of the acreage burned annually, and their records furthermore present homogeneous data covering the action taken by the first line of defense. Common experience and previous study[3] show that lightning fires, because of temporary favorable fire-weather conditions, permit of an hour control for the first line of defense materially longer than any limits that may be set up for man-caused fires for a given type or region. Also, other serious problems in control confront an organization because of the frequent bunching of lightning fires, which may require auxiliary forces and a secondary line of defense.

TABLE 3.—*Comparison of elapsed time on man-caused and lightning fires, California region, 1921 and 1922*

[Basis, 1,753 man-caused (MC) and 443 lightning (L) fires]

Elapsed time (step) (cumulative)	Discovery		Report		Get-away		Travel		Discovery—arrival		Control	
	MC	L	MC	L	MC	L	MC	L	MC	L	MC	L
	P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
1	35	15	51	49	81	71	32	8	49	24	43	41
1 and 2	49	21	67	66	80	81	51	20	71	43	76	83
1 to 3	62	28	78	76	94	87	70	35	86	64	84	90
1 to 4	86	39	86	82	98	93	93	77	91	73	90	95
1 to 5	96	68	100	100	100	99	96	87	93	75	100	100
1 to 6	100	100				100	100	100	95	82		

Table 3, based on some 2,200 man-caused and lightning fires occurring in the California region in 1921 and 1922, illustrates how impossible it is to combine these two types of fires for study. The steps numbered 1, 2, 3, etc., are those adopted by the Mather Field Conference in 1921.[4]

Thirty-five per cent of man-caused fires are discovered within the first period (0–15 minutes), and but 15 per cent of lightning fires;

[3] SHOW, S. B., and KOTOK, E. I. FOREST FIRES IN CALIFORNIA, 1911–1920: AN ANALYTICAL STUDY. U. S. Dept. Agr. Circ. 243, 80 pp., illus. 1923.

[4] The elapsed time intervals as recognized by the Mather Field Conference are as follows:

Step	Discovery	Report	Get-away	Travel	Control	Discovery to arrival
1	0–15 minutes	0–5 minutes	0–15 minutes	0–15 minutes	0–1 hour	0–1 hour.
2	16–30 minutes	6–15 minutes	16–30 minutes	16–30 minutes	1+–6 hours	1+–2 hours.
3	31 minutes–1 hour.	16–30 minutes	31 minutes–1 hour.	31 minutes–1 hour.	6+–12 hours	2+–4 hours.
4	1+–6 hours	31 minutes–1 hour.	1+–2 hours	1+–4 hours	12+–24 hours	4+–6 hours.
5	6+–24 hours	1+hours	2+–6 hours	4+–6 hours	24+hours	6+–8 hours.
6	24+ hours		6+–24 hours	6+hours		8+–12 hours.

and in the last period (over 24 hours), the difference is even greater—4 per cent and 32 per cent, respectively. This, of course, is due to the recognized fact that many lightning fires hold over for hours or days before they show up, and the great difference between the two major causes of fires is certainly an inherent and constant one.

In report time no noteworthy differences appear, the slight differential in favor of man-caused fires being due to the occasional going out of telephone lines on account of lightning strokes.

In get-away time, action is faster on man-caused than on lightning fires, since it is recognized practice for control forces to wait for fairly complete reports on a storm, rather than to dash instantly to the first fire reported.

Travel time, like discovery, shows striking differences between the two groups. Of man-caused fires 32 per cent are reached within 15 minutes of travel, and only 4 per cent require more than four hours to reach, whereas the corresponding figures for lightning fires are 8 per cent and 13 per cent. As a matter of experience it has been found that man-caused fires spread far more rapidly than lightning fires and consequently require a closer hour control. Also, many man-caused fires are along routes of travel, and are reached by automobile, whereas to reach lightning fires typically requires horse or foot travel.

The discovery-to-arrival figures show twice as high a percentage of man-caused fires as of lightning fires reached within one hour, and the difference would be still greater if all preliminary action from start of fire were included.

Previous study, too, has shown that the rate of spread of man-caused fires in a given season is many times that of lightning fires. It follows then that an adequate hour control for man-caused fires for a given type or geographical unit will readily take care of lightning fires within the lightning zone in the same type. If large zones have exclusively lightning fires, an additional analysis of such areas may be needed.

SELECTION OF PERIOD FOR STUDY AND GROUPING OF YEARS

In selecting the material to be employed in this analysis, it was considered undesirable to go any further back than the year 1922, since before that time not all of the detailed facts regarding each fire were systematically collected and recorded. From 1922 on, however, the information recorded on the individual fire reports has been more uniform, consistent, and detailed, particularly in the elapsed-time steps. Starting with 1923, these seasons have alternated in intensity, the odd years being less difficult and the even years more difficult. (Table 4.) This coincidence has furnished an admirable basis for comparisons. By using the data for the three alternating pairs of years, any material variations in intensity of organization and deficiency of performance are automatically disposed of. The gradual scaling up in both of these factors is presumably equally effective in both groups. The average scale of protection and efficiency for the less difficult group must be comparable to that of the more difficult group simply because the individual years have alternated. Similarly, several other major difficulties in the historical analysis of fire control are avoided at the start.

TABLE 4.—*Distribution of man-caused fires by types and groups of years, all forests*

Type	More difficult years (1924, 1926, and 1928)					Less difficult years (1923, 1925, and 1927)				
	A fires	B fires	C fires		Total	A fires	B fires	C fires		Total
	Number	*Number*	*Number*	*Per cent*	*Number*	*Number*	*Number*	*Number*	*Per cent*	*Number*
Western yellow pine	448	378	218	21	1,044	390	208	80	12	678
Mixed conifer	246	157	227	36	630	172	103	51	16	326
Douglas fir	44	36	44	35	124	33	24	6	10	63
Fir	120	42	30	15	198	60	16	5	6	81
Grass	29	41	52	43	122	26	29	24	30	79
Brush	138	139	138	33	415	72	82	48	24	202
Woodland	60	61	28	18	155	38	18	20	26	76
Sugar pine-fir	25	15	12	23	52	21	12	5	13	38
Total	1,122	869	749	27	2,740	812	492	239	15.5	1,543

Further justification for using the two groups of years is found in the detailed characteristics of the individual years and of the groups. An examination of the data for total area burned, average area per fire, total number of all (man-caused) fires, and total number of class C fires shows (fig. 2) in each particular an alternation between a low value in the odd year and a high value in the succeeding even year. An evident tendency for absolute values to decrease, particularly in the even years, may be taken as evidence of the progressive improvement in performance which has been made during the period. In the further comparisons of these two natural groups afforded in Figure 3 for all types—number of fires of 1,000 acres and over, number of fires of 500 acres and over, number of fires of 100 acres and over, total number of man-caused fires, and number of fires requiring over 24 hours for control—the more difficult group ranks very much higher than the less difficult group. That these differences are due, not to variations in fire-control effort or performance, but to differences in rate of spread of fire and in difficulty of control, is made clear by Figure 5 and Table 5. In this graphical representation of speed of attack on fires in the two groups of years, it is evident that when elapsed time is taken group by group, the average speed is almost identical, the maximum difference in each group being 2 per cent.

TABLE 5.—*Comparative speed in reaching fires, in more difficult and less difficult years, all forests*

MORE DIFFICULT YEARS (1924, 1926, AND 1928)

Type	Percentage of fires reached in each hour-control period						
	0-½	½-1	1-2	2-3	3-4	4+	Total
Yellow pine	25	21	20	9	6	19	100
Mixed conifer	19	15	20	10	8	28	100
Douglas fir	10	10	19	13	10	38	100
Fir	13	11	15	14	9	38	100
Grass	22	14	25	8	6	25	100
Brush	23	19	20	10	7	21	100
Woodland	28	25	19	9	5	14	100
Sugar pine	23	15	12	6	8	30	100
Average	22	18	20	10	7	23	100

LESS DIFFICULT YEARS (1923, 1925, AND 1927)

Type	0-½	½-1	1-2	2-3	3-4	4+	Total
Yellow pine	28	20	17	10	7	18	100
Mixed conifer	20	16	20	10	9	25	100
Douglas fir	8	35	13	12	8	24	100
Fir	18	4	27	9	6	36	100
Grass	11	19	17	14	10	29	100
Brush	25	18	19	10	4	24	100
Woodland	40	22	18	7	4	9	100
Sugar pine	24	16	21	8	5	26	100
Average	24	19	18	10	7	22	100

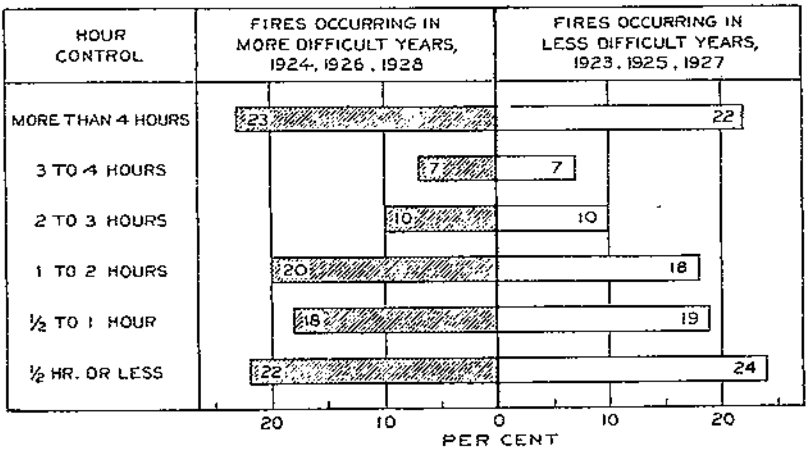


FIGURE 5.—Comparative speed of attack in difficult and less difficult years

BASIC RELATIONSHIPS IN DETERMINING HOUR CONTROL

The method employed in this bulletin to determine the hour control required to obtain specified burned-area objectives rests on two readily established direct relationships. These are (1) area burned and percentage of C fires, and (2) speed of attack and percentage of C fires. These have long been recognized as broad general relationships, but little use has been made of them in analyzing the fire problem.

The chain of reasoning and analysis used for establishing these two relationships is best illustrated by grouping together several cover types having similar hour-control requirements. In this way minor irregularities found in the regular progression of values for a single type, with its relatively small basis of data, are smoothed out without curving. It will later be established that the yellow pine, mixed conifer, and brush types have identical hour-control requirements and can thus properly be grouped.

RELATION BETWEEN AREA BURNED AND PERCENTAGE OF C FIRES

The three types are first grouped to bring out strikingly what the actual burned area has been in the several years of record and what the percentage of C fires has been in each of these years, and to determine whether a consistent relationship exists between the two. It is evident that, for this homogeneous mass of data, such a relationship does exist, and that, within reasonable limits of variation, if one factor is known the other can be calculated.

That the relationship of area burned to percentage of C fires is a very consistent and important one is indicated in Figure 6.

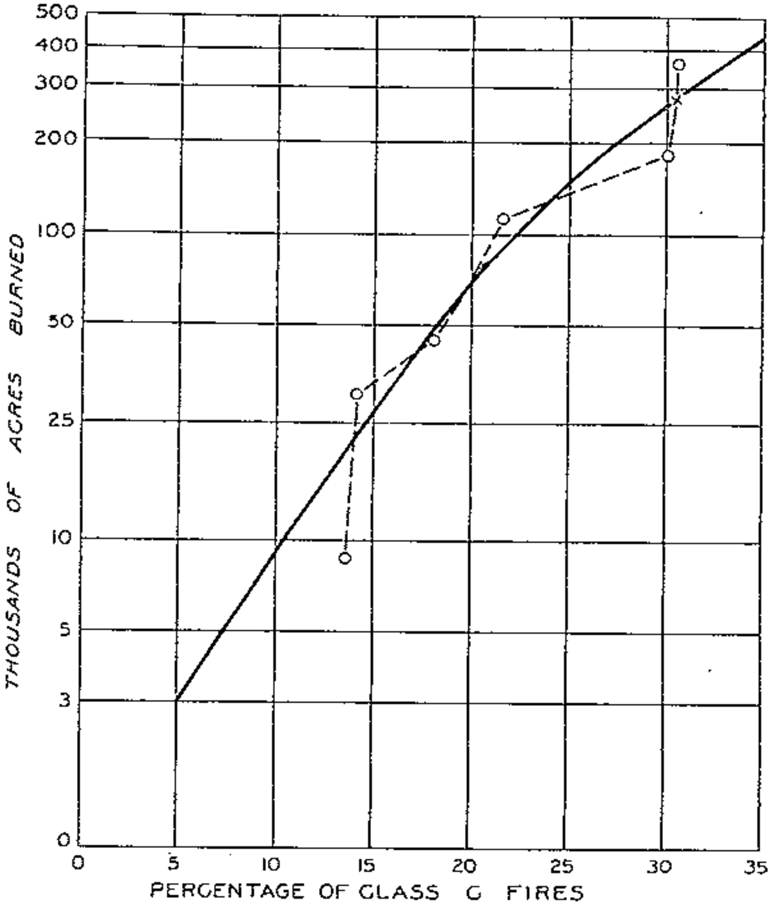


FIGURE 6.—Relation of percentage of class C fires to total area burned, western yellow pine, mixed conifer, and brush-field types combined

Evidently the area burned increases very much more rapidly than does the percentage of C fires, and a small percentage increase in C fires means a large and significant increase in burned area. Thus, C fires are important not only because they contain the large fires which contribute most to the final acreage burned, but because they are the simplest and most easily ascertainable index by which a fire-control organization can measure currently its accomplishment and performance.

RELATION OF PERCENTAGE OF C FIRES TO SPEED OF ATTACK

The second important relationship is that between percentage of C fires, for a homogenous mass of data, and speed of attacking fires.

Speed in reaching fires is the first essential in fire control. This general relationship is amply illustrated by the fire records for 1923 to 1928 from the Shasta National Forest. (Fig. 7.) Here

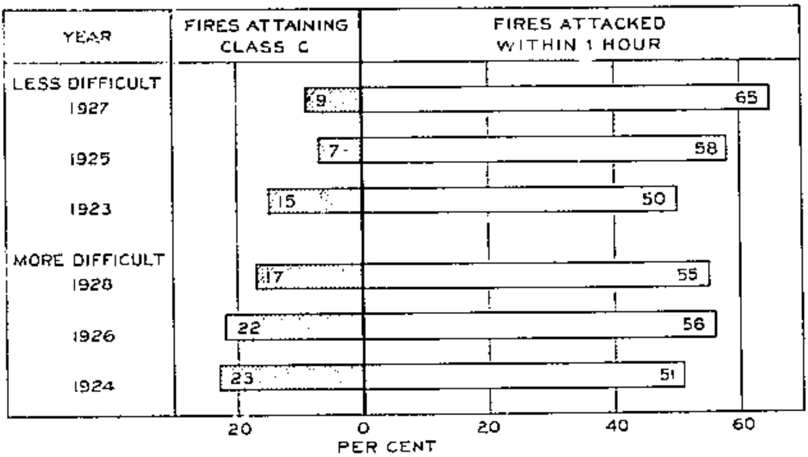


FIGURE 7.—Speed of attack and percentage of class C fires (all man-caused), Shasta National Forest, 1923–1928

speed is measured by the percentage of all fires that were reached by suppression forces within one hour after start of the fire. The degree of success is measured by the percentage of class C fires. The reciprocal relation between these two is clearly evident. When average speed decreases, average percentage of class C fires increases, and vice versa. Within reasonable limits of variation, if one factor is known, the other can be calculated. Naturally, because of variation in weather from year to year, no exact mathematical expression of this relationship can be given.

This illustration, typical of every national forest in the California region, establishes a general relationship of the utmost significance in fire protection. The invariable recurrence of this relationship, whether the basis is cover type, national-forest unit, an individual year, or a group of years, makes it generally useful in this discussion.

The relation between speed of attack and percentage of C fires is further illustrated and elaborated by averaging similar types together for the two groups of difficult and less difficult years. (Fig. 8.) Examination of this comparison leads to two conclusions.

They are:

(1) With a given speed of attack, the percentage of C fires, and hence area burned, cost, and damage, vary with the severity of the fire season.

(2) Within a given season or group of similar seasons, the percentage of C fires, area burned, cost, and damage vary inversely

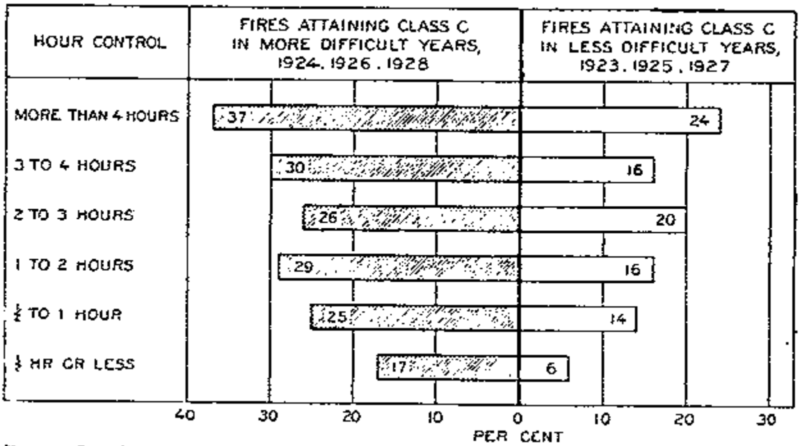


FIGURE 8.—Comparative percentage of class C fires in relation to elapsed time, difficult and less difficult groups of years, average of all types

with hour control. Progressive slowing down in speed means progressive increase in percentage of C fires.

These relationships substantiate the conclusion already discussed, that adequate fire control is a problem of hour control for the most difficult seasons. Total areas of fires reached by present hour control for the individual types and the difficult and less difficult year groups are given in Table 6.

TABLE 6.—*Areas burned, by types and elapsed time interval, all forests*

Type	0-½ hour	½-1 hour	1-2 hours	2-3 hours	3-4 hours	4+ hours	All fires
MORE DIFFICULT YEARS (1924, 1926, AND 1928)							
	Acres	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
Yellow pine	20,370	23,943	34,401	13,004	8,159	63,789	163,666
Mixed conifer	33,571	59,238	87,676	17,275	84,567	60,740	343,067
Douglas fir	800	800	6,065	2,375	465	12,089	22,594
Fir	1,085	221	14,337	138	16	3,701	19,558
Grass	605	18,032	3,355	1,938	72	23,761	48,753
Brush	37,803	30,203	14,256	13,055	3,498	63,974	162,789
Woodland	425	829	12,380	12,145	25	10,085	35,889
Sugar pine	18,038	575	690			825	20,128
Total	112,787	134,741	173,160	59,930	96,802	239,024	816,444
Distribution per cent	14	17	21	7	12	29	100
LESS DIFFICULT YEARS (1923, 1925, AND 1927)							
Yellow pine	1,364	4,467	1,105	1,055	246	5,307	13,544
Mixed conifer	2,655	863	4,265	831	2,502	32,500	43,616
Douglas fir		100	440	25	20	612	1,197
Fir	18		1,050			300	1,368
Grass		310	1,042	577	50	6,914	8,899
Brush	390	5,410	8,855	1,245	60	3,940	19,915
Woodland	175	227	285	970	1,650	14,435	17,742
Sugar pine		200		2,500		132	2,832
Total	4,602	11,569	17,042	7,203	4,528	64,149	109,113
Distribution per cent	4	11	16	6	4	59	100

LEGITIMATE C FIRES AS THE BASIS OF DETERMINATION

Before illustrating the method of determining needed hour control, the question must be asked whether all C fires became C fires either solely or principally because of lack of speed in attacking them.

In using percentage and number of class C fires as a basis for determining required hour control, it is essential to eliminate C fires which would not have reached this size provided the average best present suppression practice had been brought into use when they were first reached.

Through inspection of going fires, through detailed analyses by boards of fire review of action on fires, and from study and interpretation of data on the individual fire reports themselves, it is clearly established that some fires which reach class C size could have been held to Class B (less than 10 acres in size). The most common reasons for failure to hold all class A and B fires, as well as the smaller C fires, to the minimum possible acreage are faulty and

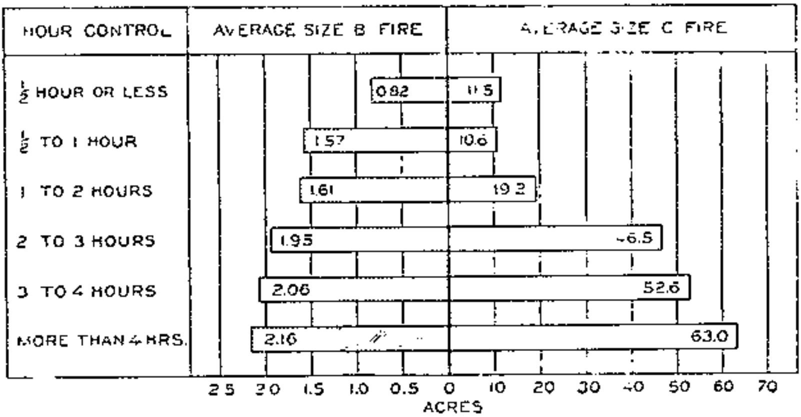


FIGURE 9.—Average size of class B and Class C fires when reached by suppression forces, western yellow pine type, Plumas and Shasta National Forests, 1923–1928, inclusive

inadequate action by the first line of defense after reaching the fire; failure to have available or to use in the first attack special equipment such as back-pack pumps; and premature abandoning of patrol after the fire is surrounded. For the purposes of this study, those fires were eliminated on which detailed and convincing information indicated poor practice in attack.

This still left a large number of C fires, among which, presumably, there were still a considerable number that might, with proper suppression practice, have been kept from reaching class C size. The most common failure to catch fires small occurs in certain very inflammable types, in bad years, or on bad fire days, when fires spread rapidly from the very start. Under these conditions it is generally only those fires that are reached within one hour of starting that are still small enough to give the first line of defense a chance to hold them as class B. Fires which have spread for a longer period are usually class C in size when reached. Analysis of the man-caused fires used in this study shows that on the Plumas and Shasta

National Forests (both of which have had a high level of fire-suppression accomplishment), for the inflammable western yellow pine type and the period of 1923 to 1928, the average size of the fires reached in half an hour and held as class B fires was 0.82 acre, and that the average size of those reached in one-half to one hour and held as class B fires was 1.57 acres. (Fig. 9.) The average of these hour-control groups is 1.2 acres.

Since these are among the more rapidly spreading fires, on which the best type of suppression work must be done if they are to be caught and held as class B fires, it is reasonable to assume that nearly all fires in this and similar types that are reached when they are 1 acre or less in size should, with correct suppression practice, be held to class B size. Therefore, all C fires that were 1 acre or less when reached were eliminated from consideration.

The C fires remaining after these two eliminations had been made have been termed "legitimate class C fires." They are those which, because of very rapid spread due to condition of cover or weather conditions, or because of long-elapsed time from start of fire to attack by control forces, could not have been held to a smaller size. The total number of class C fires and the number of legitimate C's are given in detail in Table 7.

TABLE 7.—*Distribution by types and elapsed time interval (hour control), between start of fire and work begun, all forests*

YELLOW PINE TYPE

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	263	34	13	10	4	189	10	5	6	3.2
½ to 1 hour	215	40	19	36	17	138	20	14	14	10.1
1 to 2 hours	214	55	26	45	21	116	9	8	6	5.2
2 to 3 hours	90	20	22	18	20	66	8	12	6	9.1
3 to 4 hours	66	21	32	18	27	49	7	14	7	14.3
More than 4 hours	196	48	24	43	22	120	26	22	26	21.7
Total	1,044	218	21	170	16	678	80	12	65	9.6

MIXED CONIFER TYPE

Hour control	All fires (1924, 1926, 1928) Number	C fires Number	C fires Per cent	Legitimate C fires Number	Legitimate C fires Per cent	All fires (1923, 1925, 1927) Number	C fires Number	C fires Per cent	Legitimate C fires Number	Legitimate C fires Per cent
Half hour or less	122	29	24	15	12	64	6	0	4	6.2
½ to 1 hour	96	34	35	23	24	54	5	9	4	7.4
1 to 2 hours	126	47	37	40	32	64	12	19	12	18.8
2 to 3 hours	65	17	26	15	23	33	6	18	4	12.1
3 to 4 hours	47	17	36	15	32	29	6	21	5	17.2
More than 4 hours	174	83	48	76	44	82	16	20	15	18.3
Total	630	227	36	184	29	326	51	16	41	13.5

DOUGLAS FIR

Hour control	All fires (1924, 1926, 1928) Number	C fires Number	C fires Per cent	Legitimate C fires Number	Legitimate C fires Per cent	All fires (1923, 1925, 1927) Number	C fires Number	C fires Per cent	Legitimate C fires Number	Legitimate C fires Per cent
Half hour or less	13	3	23	3	23.1	5				
½ to 1 hour	12					22	2	9	2	9.1
1 to 2 hours	23	7	30	7	30.4	8	2	25	2	25.0
2 to 3 hours	16	7	44	7	43.8	8				
3 to 4 hours	13	6	46	6	46.2	5				
More than 4 hours	47	21	45	21	44.7	15	2	13	2	13.3
Total	124	44	35	44	35.5	63	6	10	6	9.5

TABLE 7.—*Distribution by types and elapsed time interval (hour control), between start of fire and work begun, all forests*—Continued

FIR

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	26	2	8			15	1	7	1	6.7
½ to 1 hour	22	4	18	4	18.2	3	1	33	1	33.3
1 to 2 hours	30	4	13	3	10.0	22	2	9	2	9.1
2 to 3 hours	28	4	14	3	10.7	7				
3 to 4 hours	17					5				
More than 4 hours	75	16	21	15	20.0	29	1	3	1	3.4
Total	198	30	15	25	12.6	81	5	6	5	0.2

GRASS

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	27	6	22	4	14.8	9				
½ to 1 hour	17	10	59	9	52.9	15	2	13	2	13.3
1 to 2 hours	30	10	33	10	33.3	13	6	46	6	46.2
2 to 3 hours	10	3	30	3	30.0	11	5	45	5	45.5
3 to 4 hours	7	2	20	2	28.6	8	1	12	1	12.5
More than 4 hours	31	21	68	21	67.7	23	10	43	10	43.5
Total	122	52	43	49	40.2	79	24	30	24	30.4

BRUSH

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	93	23	25	12	13	50	6	12	4	8
½ to 1 hour	79	22	28	18	23	37	6	16	5	14
1 to 2 hours	83	28	34	27	33	38	10	26	10	20
2 to 3 hours	43	14	33	14	33	21	7	33	7	33
3 to 4 hours	30	9	30	9	30	8	1	12	1	12
More than 4 hours	87	42	48	42	48	48	18	38	17	35
Total	415	138	33	122	29	202	48	24	44	22

WOODLAND

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	44	2	5			30	1	3		
½ to 1 hour	38	11	29	9	23.7	17	5	29	5	29
1 to 2 hours	30	4	13	3	10.0	14	3	21	3	21
2 to 3 hours	14	2	14	2	14.3	5	4	80	4	80
3 to 4 hours	8	1	12	1	12.5	3	2	67	2	67
More than 4 hours	21	8	38	8	38.1	7	5	71	5	71
Total	155	28	18	23	14.8	76	20	26	19	25

SUGAR PINE-FIR

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	12	2	17			9				
½ to 1 hour	8	3	38	2	25	6	1	17		
1 to 2 hours	6	2	33	2	33	8				
2 to 3 hours	3	2	67	2	67	3	1	33	1	33
3 to 4 hours	4	1	25	1	25	2				
More than 4 hours	10	2	11	2	11	10	3	30	3	30
Total	52	12	23	9	17	38	5	13	4	11

TOTAL, ALL TYPES

Hour control	1924, 1926, and 1928					1923, 1925, and 1927				
	All fires	C fires		Legitimate C fires		All fires	C fires		Legitimate C fires	
	Number	Number	Per cent	Number	Per cent	Number	Number	Per cent	Number	Per cent
Half hour or less	600	101	17	44	7	371	24	6	15	4
½ to 1 hour	487	124	25	101	21	292	42	14	33	11
1 to 2 hours	542	157	29	137	25	283	44	16	41	14
2 to 3 hours	269	69	26	64	24	154	31	20	27	18
3 to 4 hours	192	57	30	52	27	100	17	16	16	15
More than 4 hours	650	241	37	228	35	334	81	24	70	24
Total	2,740	749	27	626	23	1,543	230	15	211	14

It will be evident from Table 7 that even with half-hour control and the very rapid attack thereby represented, some C fires must be expected. These occur mainly on the worst fire days in the worst fire years. For the period 1923–1928 the average size at time of attack of C fires on the Shasta and Plumas Forests, when reached within one-half hour, was 11.5 acres. (Table 8.) In other words, they were already of class C size, on the average. For the mixed conifer and western yellow pine types, on all forests, the average was even higher. (Table 9.)

TABLE 8.—*Size when reached of those fires in each hour-control group which became class C and class B, western yellow pine type, Plumas and Shasta National Forests, 1923–1928*

Hour control	Class B fires		Class C fires	
	Fires	Average size	Fires	Average size
	Number	*Acres*	*Number*	*Acres*
Half hour or less	77	0.82	27	11.5
½ to 1 hour	70	1.57	25	10.6
1 to 2 hours	51	1.61	28	19.2
2 to 3 hours	21	1.95	13	40.5
3 to 4 hours	18	2.06	8	52.6
More than 4 hours	37	2.16	24	63.0

TABLE 9.—*Size when reached of those fires in each hour-control group which became class C, mixed conifer and western yellow pine types, all forests, 1923–1928*

Hour control	1924, 1926, and 1928		1923, 1925, and 1927		1923–1928	
	Fires	Average size	Fires	Average size	Fires	Average size
	Number	*Acres*	*Number*	*Acres*	*Number*	*Acres*
Half hour or less	62	17.4	14	11.7	76	16.3
½ to 1 hour	75	19.2	27	12.7	102	17.5
1 to 2 hours	100	16.6	20	16.0	120	16.5
2 to 3 hours	35	23.0	14	42.0	49	28.4
3 to 4 hours	39	30.4	12	40.9	51	32.9
More than 4 hours	118	131.5	44	73.7	162	115.8

For the purpose of determining what speed of attack is necessary to attain a specified percentage of class C fires, only these legitimate C fires are used. Otherwise, the indicated control, and hence the transportation and personnel needed to attain it, would be unnecessarily elaborate, being determined by average present practice rather than average best present suppression practice, which should be generally attained in the future. The capital investment and annual expense required to build up transportation and protection improvement to the point of attaining or even approaching the indicated hour controls will necessarily be large, and they should not be distended to cover class C fires, which with the best suppression practice and the fullest use of special equipment might have been kept to class B size.

DETERMINATION OF HOUR CONTROL BY PERCENTAGE OF C FIRES

The two basic relationships of area burned to percentage of C fires and percentage of C fires to speed of attack must be clearly understood before any definite answer to the question, "What is adequate hour control?" is attempted. The method used for determining hour control, a graphic method of analysis, is illustrated in Figure 10 for three similar types combined. Since the area of the combined types is 10,171,000 acres, the allowable burned area per year may be set at 25,000 acres, or 0.25 per cent. It is then evident from the chart that in only two of the six years has the objective been attained. When the percentage of C fires for each year (left side of chart) is plotted opposite the burned area for the same year, an "allowable percentage" determination inserted in the same relative position as "allowable acreage" on the other side falls at approximately 15 per cent. The exact position of this line must be deter-

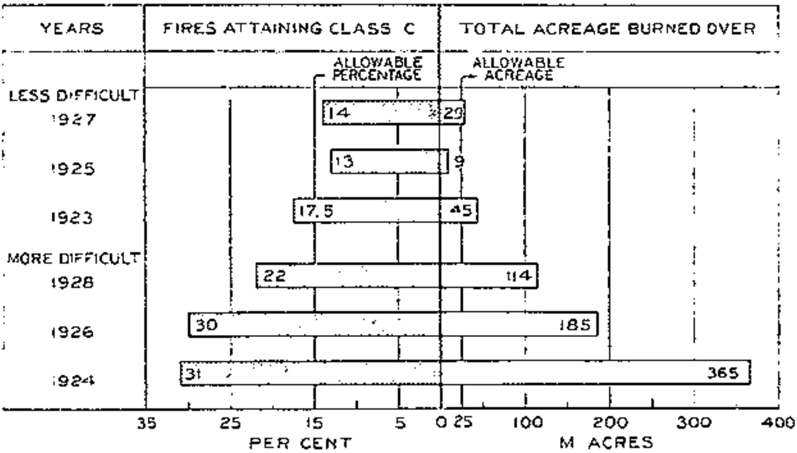


FIGURE 10.—Relation between percentage of class C fires and area burned, western yellow pine, mixed conifers, and brush-field types combined, 10,171,000 acres, 1923–1928

mined by inspection of the chart, by judgment, and by balancing the quantities outside and inside of the allowable-acreage line. As so fixed, however, it constitutes a very general statement of an objective for the group of types in this region. This figure, or a lower one, indicates successful protection; a higher figure indicates that the burned-area objective is not attained.

This figure (for the data being discussed) answers the question, "What percentage of class C fires will represent attainment of the burned area objective?"

A second question must then be answered: "What hour control is necessary to attain the allowable percentage of class C fires?" The next step—using the same data—is to determine what speed of attack, or hour control will result in 15 per cent or less of class C fires.

In the group of difficult years for similar types only 8 per cent of the fires reached in a half hour after start should become legitimate class C's as shown by shaded bars in Figure 11. This is well within the allowable limit of 15 per cent and indicates that ½-hour control will not be generally necessary in these types. Of the fires reached between a half hour and one hour after start, 20 per cent become class C's, and thus something less than 1-hour control is needed. Three-quarter-hour control evidently will closely fit the data, and will for the entire area of the types insure a realization of the minimum burned-area objective. Subject to later analysis of the individual types, this figure can be regarded as correct.

By way of contrast, in the same group of types in the less difficult group of years, anything up to 4-hour control gives satisfactory results.

The importance of using only legitimate class C fires is well illustrated in Figure 11 by comparing these fires with all class C fires. The open bars standing for all C fires would indicate that even half-hour control is not rapid enough in the difficult years. To

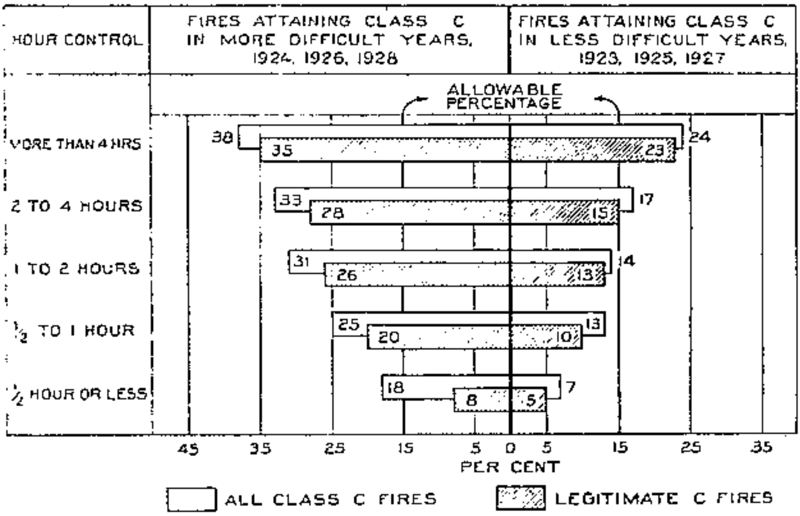


FIGURE 11.—Relation of percentage of legitimate and all class C fires to speed of attack, western yellow pine, mixed conifer, and brush-field types combined, 1923–1928

accept such a conclusion would involve either a willingness to accept losses in bad years greater than the agreed-upon minimum, or the necessity for building up an unnecessarily elaborate and costly fire-control plant and organization.

A more direct comparison for the more difficult and less difficult years, and for hour controls up to two hours is shown in Figure 12. This makes it clear that the relation between acreage burned by fires within an hour-control group and the percentage of C fires within the same group is direct and consistent for both groups of years.

DETERMINATION OF HOUR CONTROL BY NUMBER OF C FIRES

Estimating the fire-control problem in terms of percentage of C fires, as has just been done, tends to direct effort toward speeding up attack on fires, since speed is the principal controllable factor.

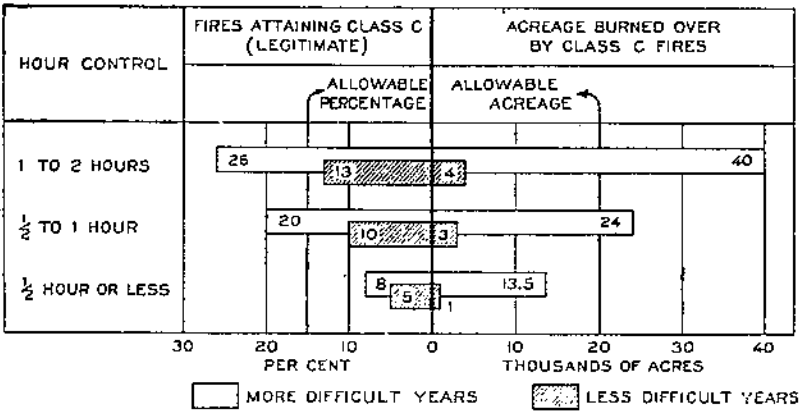


FIGURE 12.—Comparison of percentage of legitimate class C fires with acreage burned over under varying hour control in more difficult and less difficult years

Another equally realistic way to think of the problem is in terms of number of C fires. This approach tends to focus attention on reduction in number of fires as well as on speed. Although the consistent relation between speed of attack and percentage of C fires is used generally in this bulletin as a basis for determining needed hour control, the relation between speed of attack and number of C fires could be used equally well.

As an example of the latter relationship, Figure 13 presents data, for the yellow pine, mixed conifer, and brush-field types combined for individual years, on acreage burned and the total number of C fires. Here it appears that, in order to attain the burned-area objective, the number of C fires must be held to about 50 per year. This figure is determined by the same method of inspection of graphic data previously used.

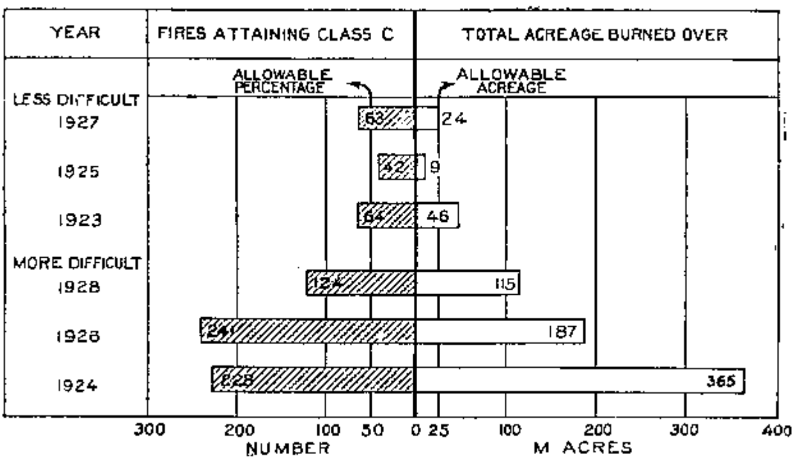


FIGURE 13.—Relation between total number of class C fires and area burned, western yellow pine, mixed conifer, and brush-field types combined, 1923–1928

The total allowable number of C fires for the group of three most difficult years is thus 150. With ½-hour control (fig. 14) the number has been 86, and with 1-hour control, 182, for this group of years. Three-quarter-hour control would thus most nearly insure holding the number of C fires to the desired minimum. If instead of the total number of C fires, only the number of legitimate C's is used, the allowable number will be less than 50 per year. It will lie between 32 and 36, and the total for the 3-year period will be between 96 and 108. This objective is not attained with 1-hour control (fig. 14), where 114 legitimate C fires occurred, and is more than attained with ½-hour control, with only 37 fires. This points to something between ½-hour and 1-hour control as needed, a conclusion identical with that reached by the other methods of analysis. As in the other method also, 4-hour control appears generally satisfactory in the less difficult group of years.

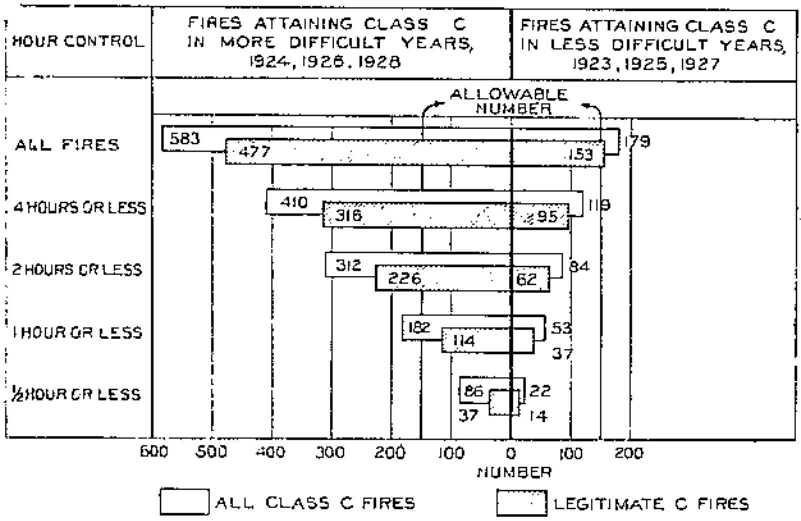


FIGURE 14.—Relation between the number of legitimate class C fires and speed of attack, western yellow pine, mixed conifer, and brush-field types combined

There is no apparent reason to repeat the confirmatory process for all the individual types. On the whole, the use of number of C fires as the basis for analysis will lead to the same conclusions as if percentage of C fires were used.

DETERMINATION OF HOUR CONTROL FOR DIFFERENT TYPES

WESTERN YELLOW PINE TYPE

Using the graphic method previously illustrated and explained, determination of needed hour control for any distinct type is made by the two steps already described: (1) Determination of the percentage of C fires that will attain the burned-area objective, and (2) the speed of attack necessary to hold the percentage of legitimate C fires to this figure.

In the western yellow pine type (fig. 15) the total area is 4,526,000 acres and the annual allowable burned acreage (0.2 per cent for timber types) is therefore about 9,000 acres. This acreage was attained in three of the six years, in which the corresponding C-fire percentages were 10, 11, and 17. The C-fire percentages for the three

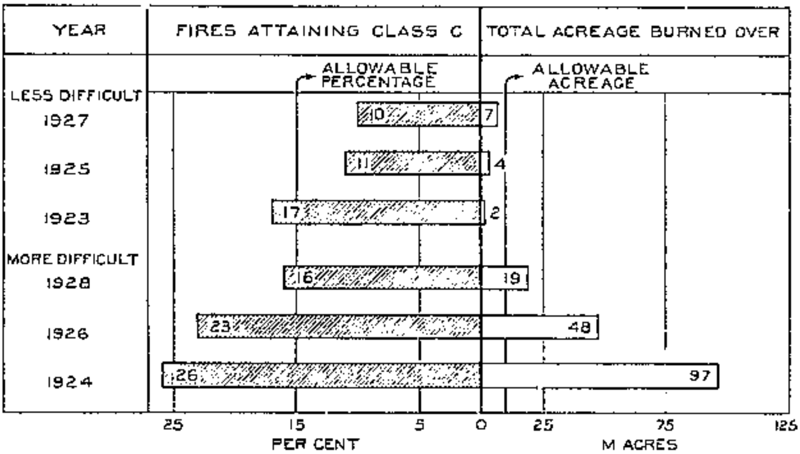


FIGURE 15.—Relation between area burned and percentage of class C fires, western yellow pine types

years in which excess acreage was burned over were 16, 23, and 26. Apparently the best approximation of allowable percentage of C fires is 15.

The comparison between speed of attack and percentage of legitimate C fires (fig. 16) shows that with ½-hour control the percentage

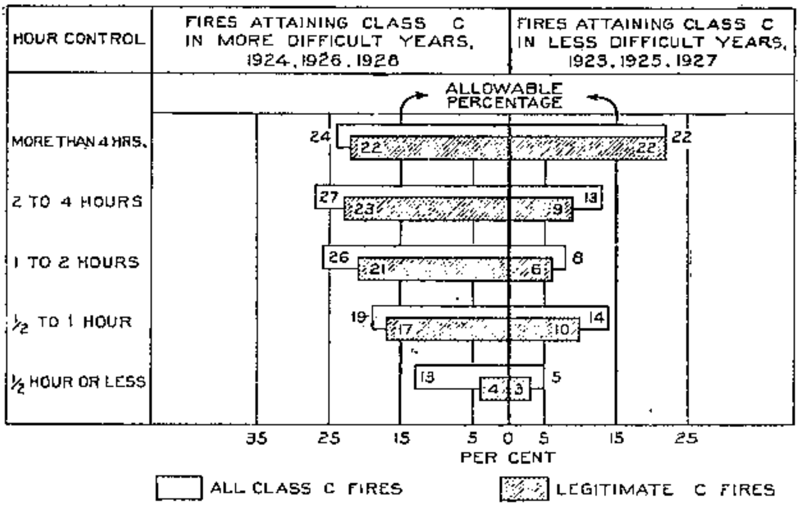


FIGURE 16.—Relation of percentage of legitimate and all class C fires to speed of attack, western yellow pine type

of C fires in difficult years is 4, and with ½-hour to 1-hour it is 17. The required hour control is thus between these two, and ¾-hour control is the best approximation. If the percentage of all C fires were used, a similar conclusion would be reached. In the less difficult group of years, on an average, 4-hour control is adequate.

MIXED CONIFER TYPE

In the mixed conifer type, with an acreage of 3,207,000 acres, the allowable annual burned area (0.2 per cent) is approximately 6,500 acres. This has been attained (fig. 17) in two of the six years, with a percentage of C fires of 12 and 17, and has been exceeded in four years, with percentages of 18, 24, 39, and 40. The allowable percentage of C fires is at or about 15, possibly 17.5.

The comparison between speed of attack and percentage of legitimate C fires (fig. 18) shows that with ½-hour control the percentage of C fires is 12, and with ½-hour to 1 hour control it is 24. The goal of 15 per cent of legitimate C fires will be attained with ¾-hour control. Here the percentage of all C fires (24 per cent) for ½-hour

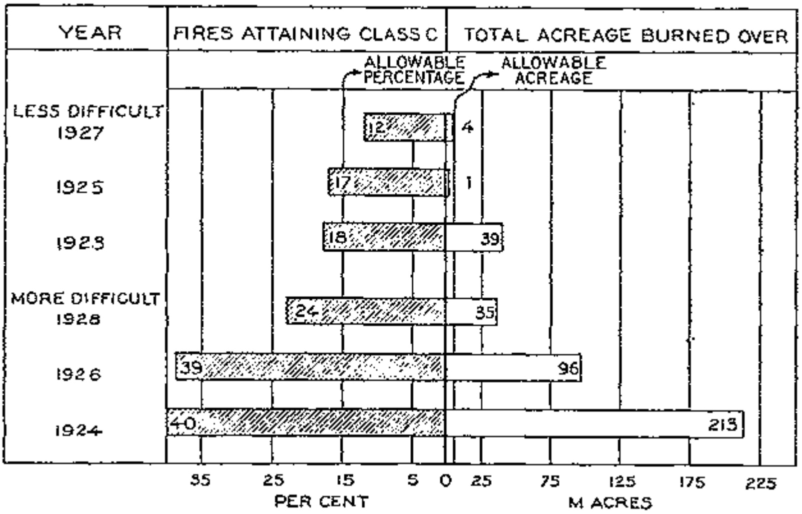


FIGURE 17.—Relation between area burned and percentage of class C fires, mixed conifer type, 1923–1928

control in the more difficult years would give a false and unnecessarily exacting idea of the hour control needed. In the less difficult group of years, 1-hour control is, on the average, sufficient.

BRUSH-FIELD TYPE

The area of the brush-field type is 2,438,000 acres, and the allowable annual acreage (0.2 per cent) is 5,000. This goal has been attained according to Figure 19, in two of the six years; in the other four years the C percentages were 28, 28, 36, and 41, an excess acreage burned. The detailed relation between percentage of C fires and area burned is not so consistent as in the yellow pine and mixed conifer types, but holds sufficiently well to permit an estimate of 20 as the allowable percentage of C fires.

Relation between speed of attack and percentage of legitimate C fires is consistent in both the more difficult and less difficult group of years. (Fig. 20.) In the more difficult years less than 1-hour and more than ½-hour control is required to hold C fires to 20 per cent, and ¾-hour control is indicated. In the less difficult years

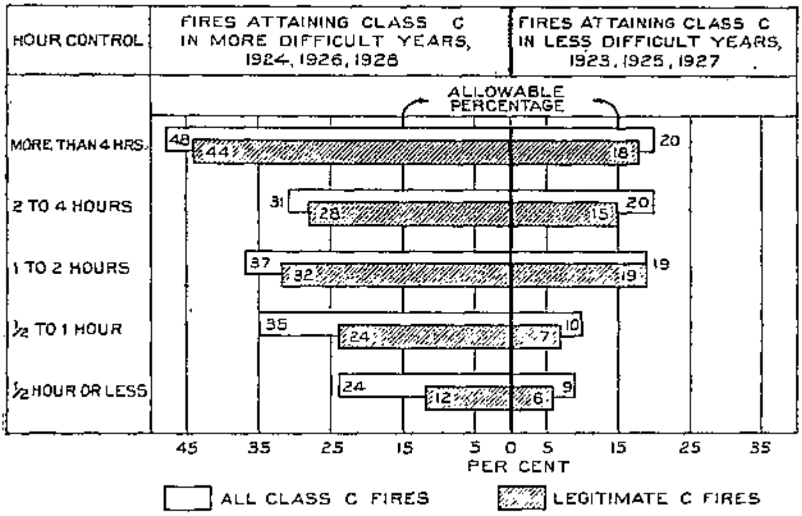


FIGURE 18.—Relation of percentage of class C fires to speed of attack, mixer conifer type

anything up to 2-hour control is adequate. Use of all C fires would lead to the unwarranted conclusion that something even more rapid than ½-hour control is required in the brush-field type.

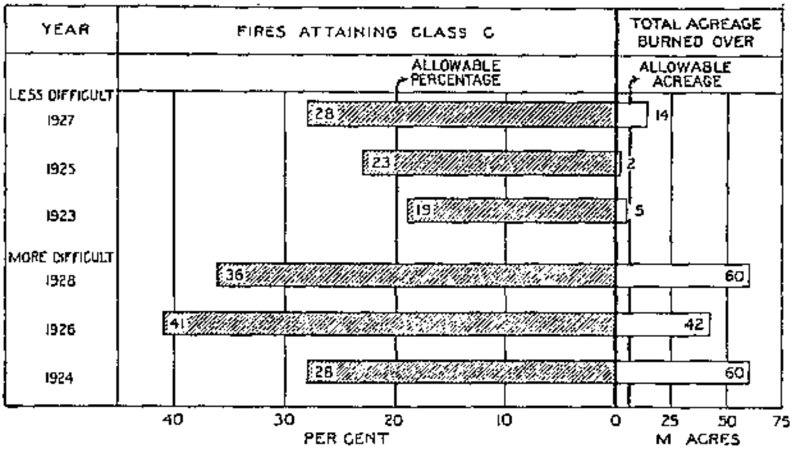


FIGURE 19.—Relation of area burned to percentage of class C fires, brush-field type, 1923–1928

This detailed analysis of the yellow pine, mixed conifer, and brush-field types shows unmistakably that all have the same requirement for ¾-hour control. The earlier combination of these types, in the discussion of the method for determining hour-control needs, can therefore be accepted as proper and the conclusions as valid.

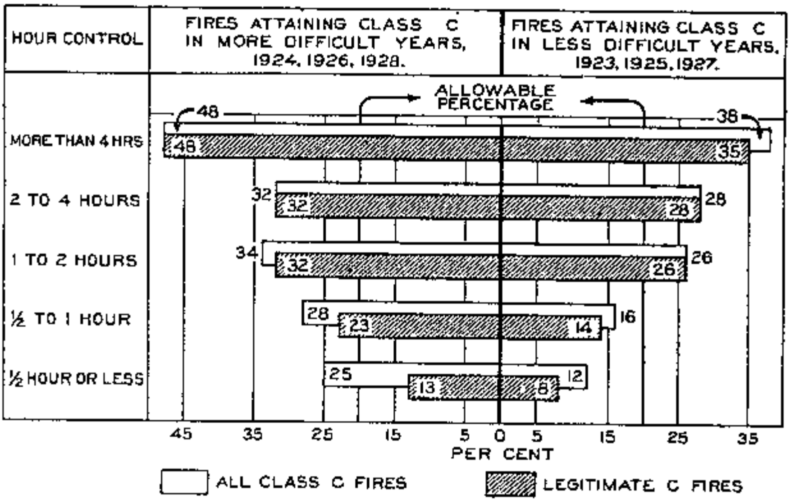


FIGURE 20.—Relation of percentage of legitimate class C fires to speed of attack, brushfield type

DOUGLAS FIR TYPE

The area of the Douglas fir type is 1,145,000 acres, and the allowable annual burned area (0.2 per cent) is, roughly, 2,500 acres. The figures for four of the six years (fig. 21) have been at or below this figure, with C percentages of 8, 8, 11, and 26, the last-mentioned corresponding to an even 2,500 acres. In the other two years with excess acreage, the percentages have been 36 and 48. The allowable percentage is thus about 20, or possibly a little higher.

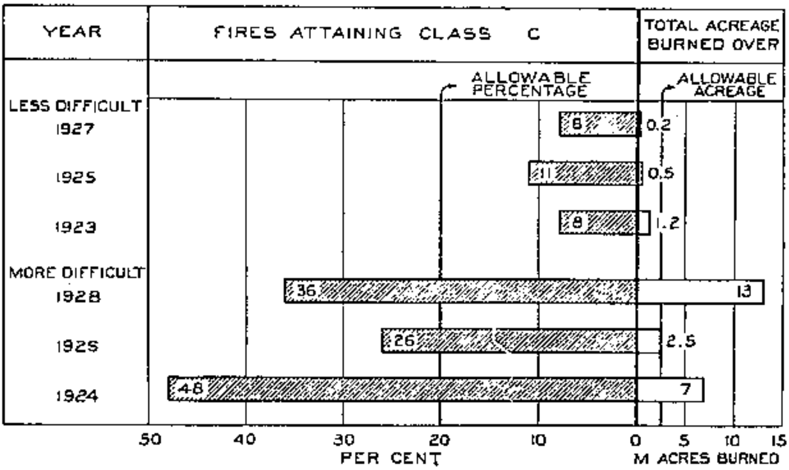


FIGURE 21.—Relation between area burned and percentage of class C fires, Douglas fir type, 1923–1928

The speed of attack necessary to hold legitimate C fires to 20 per cent of the total number in difficult years is clearly indicated as 2-hour control. (Fig. 22.) There should be no C fires among those reached within a half hour after start. In the less difficult years, anything up to 4-hour, or even longer, control is sufficiently rapid.

In the records for the Douglas fir type only a very few fires could be eliminated because of questionable suppression practice. This is perfectly natural in a type where fires spread slowly. The greatest chance for a mistake in initial attack on a small fire occurs when the fire is spreading rapidly and there is usually only one chance to do the right thing, which must be done immediately. The problem of attaining the burned-area objective in the Douglas fir type is therefore almost entirely one of adequate speed of attack.

FIR AND SUGAR PINE-FIR TYPES

A detailed analysis of the fir type and of the sugar pine-fir type showed that the two have similar hour-control needs, and they have therefore been combined. The acreage of the two types is 2,120,000,

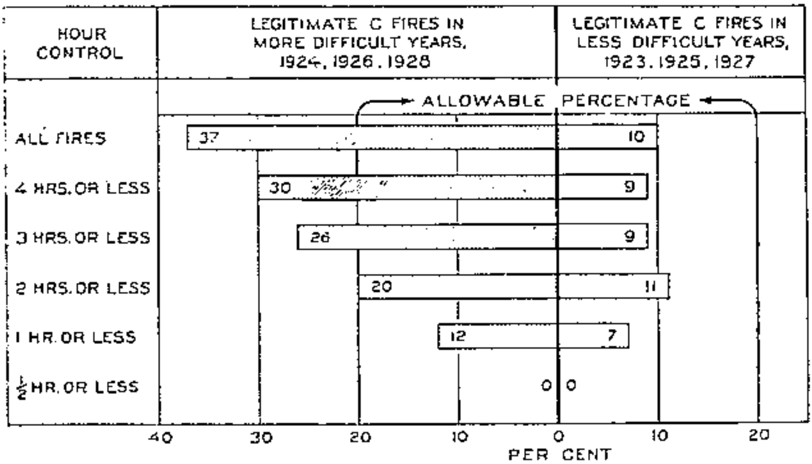


FIGURE 22.—Relation between percentage of legitimate class C fires and speed of attack, Douglas fir, 1923–1928

and the allowable annual burn is thus about 4,500 acres. (Fig. 23.) In three of the six years this figure has been attained, with corresponding C fire percentages of 8, 9, and 10. The 1928 record, with 12.5 per cent C fires and 14,500 acres burned, is clearly out of line with the records of the other years in this and the other major types. The reason is that two poorly handled fires in 1928 burned a considerable acreage. Taking the data as a whole, the allowable percentage of C fires may be fixed at 15.

The percentage of legitimate C fires (fig. 24) is low, regardless of speed of attack, even in the more difficult group of years. Assuming that future rate of spread of fire will be no greater than in the period under review, 4-hour control is rapid enough for these types.

GRASS AND WOODLAND TYPES

These two types can properly be grouped, for in both the spread of fire is very rapid and fuels and weather conditions are essentially alike. The total acreage involved is 1,506,000 acres, and the allowable annual burned area is 7,500 acres (0.5 per cent). Previous investigation and general experience combine to show that a system of fire lines and fire breaks is generally needed in addition to hour control if burned area is to be held to a reasonable figure.

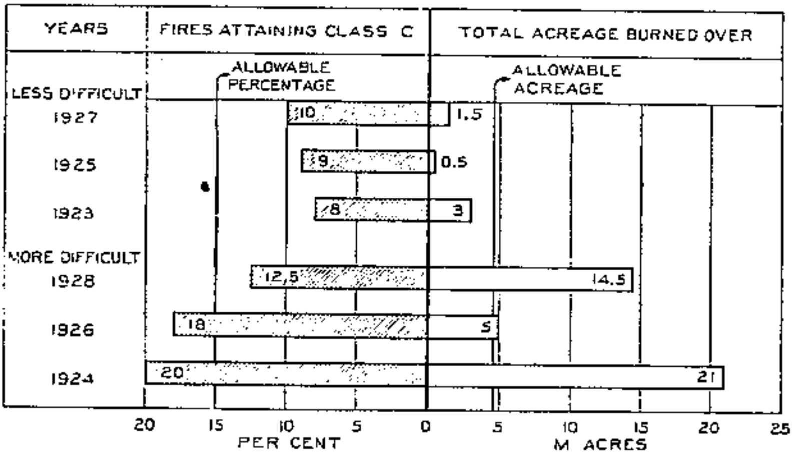


FIGURE 23.—Relation between acreage burned and percentage of class C fires, fir and sugar pine-fir types combined

The existence and use of a partial system of fire breaks in these types has somewhat obscured the relation between area burned and percentage of C fires. Superficially, this relation is fairly consistent (fig. 25), and it appears that the best approximation of allowable

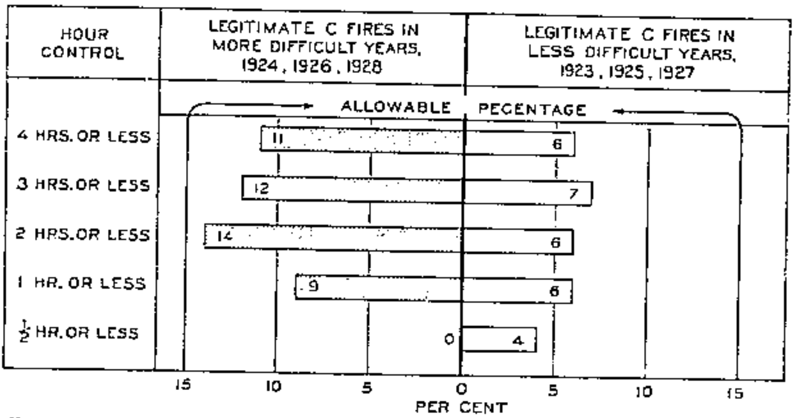


FIGURE 24.—Relation between percentage of class C fires and speed of attack, fir and sugar pine-fir types combined

percentage of C fires is 20 per cent. This figure is out of line, however, with the 15 per cent limit determined for the western yellow pine type, characterized, like the grass and woodland types, by rapid spread of fires. It seems much safer to say that 15 per cent should be the goal in all of these types.

The relation between speed of attack and percentage of C fires is fairly consistent and regular. (Fig. 26.) For the difficult years something between ½-hour and 1-hour control is needed—¾-hour control best fits the data. In the less difficult years 2-hour control will be generally adequate.

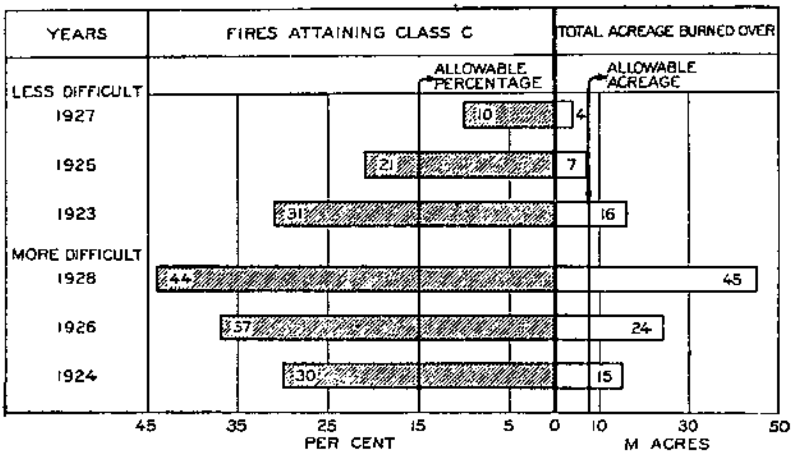


FIGURE 25.—Relation between area burned and percentage of class C fires, grass and woodland types combined

ALL TYPES

The detailed analysis of individual types leads to the conclusion that ¾-hour control will on the average be required for the yellow pine, mixed conifer, brush, grass, and woodland types; 2-hour con-

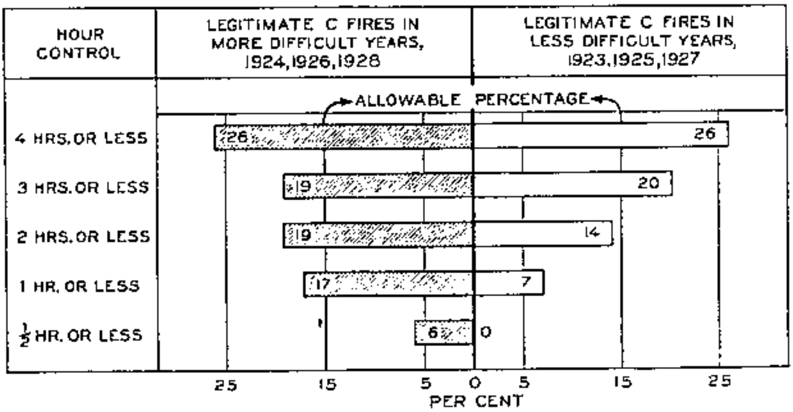


FIGURE 26.—Relation between percentage of class C fires and speed of attack, grass and woodland types combined

trol for the Douglas fir type; and 4-hour control for the sugar pine-fir and fir types.

It should require little argument to justify the statement that under the conditions whereby detection and guard forces, protection improvements, and transportation systems are actually planned and put into effect on the ground, inflexible adherence to these hour-control standards will be impossible and undesirable.

For one thing, each of the major types embraces a multitude of local variations, and these differences can and should be recognized. Obviously, the detailed local analyses to accomplish this do not come within the scope of this bulletin.

It would, however, be a serious mistake to regard these proved hour-control needs as merely a rough guide to general judgment. Regardless of the fact that local variations in hour control and percentage of area covered will have to be taken into account, the figures represent the safest available guide in making fire-control allotments.

TIME ALLOWANCE FOR TRAVEL IN SETTING UP HOUR CONTROL

Hour control, by definition and as used in this bulletin, means total time elapsing from start of fire until suppression work is started. It therefore includes, as mentioned earlier, discovery, report, get-away, and travel time.

In the process of translating hour control for each type into a fire-control organization capable of delivering the specified protection, it is necessary to subdivide the total time into its elements. It is particularly urgent to know, for example, what part of the three-quarters of an hour set up as the objective for the western yellow pine type must be used for the discovery, report, and get-away steps. When this allowance is known, the local officers can use the remaining time as the basis for planning the transportation system, and determining the number and placement of fire guards. It will obviously make a vast difference in mileage and cost of the transportation system whether a half hour will be available for travel or only 15 minutes.

The problem can best be stated by asking the question, "What is the average minimum allowance needed for discovery, report, and get-away time?" This question may be further restricted by noting that when these steps combined have totaled more than three-quarters of an hour the opportunity for ¾-hour control has passed. On many fires discovery time alone is over one hour.

Evidently, when ¾-hour control is the objective, the time allowance for the discovery, report, and get-away steps should be based on the average best of present performance. This would mean direct visibility, and consequently short discovery time; an efficient telephone system, and consequently short report time; an alert and prepared guard force, and consequently short get-away time. These conditions are met on those fires which, with the existing organization and protection-improvement system, have been reached within one hour after start.

The average time used in travel has been determined for the mixed conifer and western yellow pine types on the Shasta and Plumas National Forests, for each of the hour-control groups. (Table 10.) A separate figure is given for each of the two groups of years, as well as the average for the six years. Similar figures for the pine type alone are presented in Figure 27. Except for the travel time on fires which were not reached until three hours or more after they started, the figures are practically identical for corresponding hour-control steps in the two groups. This shows, again, that the mechanics of fire control have been practically the same in the more difficult and less difficult years.

TABLE 10.—*Travel time in each elapsed-time group in two 3-year groups, Shasta and Plumas National Forests, western yellow pine and mixed conifer types, combined*

Hour control	1924, 1926, 1928		1923, 1925, 1927		1923 to 1928, inclusive	
	Fires	Average travel time	Fires	Average travel time	Fires	Average travel time
	Number	*Hours*	*Number*	*Hours*	*Number*	*Hours*
Half-hour or less	180	0.14	133	0.13	415	0.14
½ to 1 hour	120	.33	87	.31	261	.32
1 to 2 hours	90	.55	68	.52	206	.50
2 to 3 hours	36	.60	39	.55	90	.65
3 to 4 hours	29	.64	35	.40	74	.60
More than 4 hours	62	1.24	55	3.40	165	2.20

The average travel time going to all fires in the ½-hour or less and ½-hour to 1-hour control groups was, respectively, 0.14 and 0.32

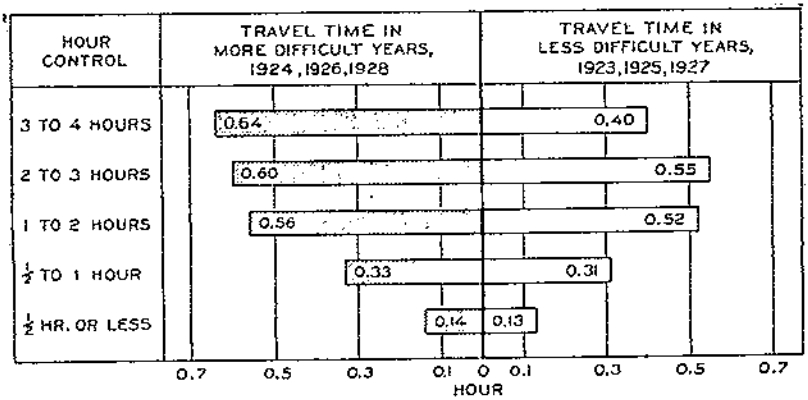


FIGURE 27.—Comparative distance traveled in different hour-control groups by auto and by foot, western yellow pine type, Shasta and Plumas National Forests, 1923–1928

hour, averaging 0.22 hour. The average total elapsed time from start of fire to work begun corresponds closely to the median values of 0.25 and 0.75 hour for the 2-hour-control groups, or 0.50.

The difference between travel time and hour control for the two groups, or 0.28 hour, is thus the average best time for the combined discovery, report, and get-away steps. This amounts to 17 minutes, or approximately one-quarter hour. With ¾-hour control, therefore, it can be concluded that a half hour is available for travel time. The road and trail system and the protection personnel in types where ¾-hour control is needed can, therefore, be planned on this basis.

The figures given indicate clearly the truth of the generally recognized conclusion that travel time is by no means the only factor contributing to delay in reaching fires. Among man-caused fires reached over four hours after they started, travel time is in fact, on the average, not the major factor. The principal delay is in discovery time. Though it is not proposed to discuss the detection system in detail at this time, it is well to note that the increased speed in reaching fires attainable through increased mileage of roads and trails is not by itself the complete answer to adequate hour control. If the median time is taken for each of the control steps under four hours, the following values are expressed in hours: 0.25, 0.75, 1.5, 2.5, 3.5, and the corresponding travel times as 0.13, 0.32, 0.50, 0.65, and 0.7 hour. The percentages of travel time in each hour-control group are thus 52, 43, 33, 26, and 20 per cent, respectively. The travel time obviously is increasingly more important as higher hour-control standards are set.

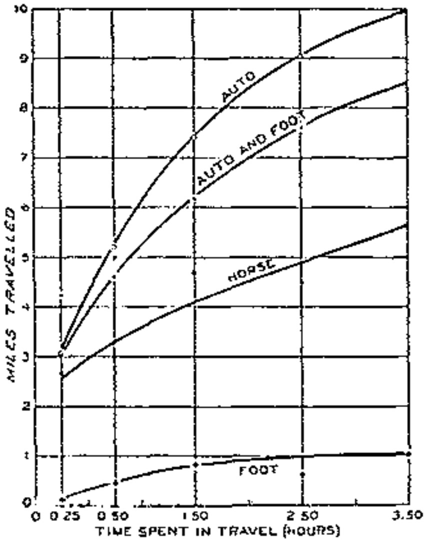


FIGURE 28.—Relation between means of travel and distance covered, western yellow pine and mixed conifer types combined, all national forests, 1923–1928

CONDITIONS AFFECTING TRAVEL TIME

The time consumed in travel is governed by two major factors, the distance covered and the means of transportation. Some consideration of these is desirable as part of the present study. The average distances covered by the four major means of travel, foot, horse, auto, and auto-foot are given in Figure 28 and Table 11 for fires in each of the hour-control groups and covering the western yellow pine and mixed conifer types on all national forests for the years 1923 to 1928. The expected relationships between relative speed and method of travel evidently exist in practice. With auto the average distance that was covered in half an hour, or the allowance for ¾-hour control, is approximately 5¼ miles, with horse nearly 3¼ miles, and on foot about one-half mile.

Further analysis of the comparative average distance covered where auto and foot travel are used in the western yellow pine type on the Shasta and Plumas National Forests confirms the magnitude of these differences. (Fig. 29.) The auto increases the distance that is covered in a given time within the smaller hour-control groups from ten to twenty times the distance covered by foot travel alone.

TABLE 11.—*Comparative distance traveled, western yellow pine, mixed conifer types, all forests, 1923–1928*

Hour control	By auto		By auto and foot		By horse		By foot	
	Fires	Average distance	Fires	Average distance	Fires	Average distance	Fires	Average distance
	Number	*Miles*	*Number*	*Miles*	*Number*	*Miles*	*Number*	*Miles*
Half hour or less	251	3.04	15	4.3	7	2.7	149	0.17
½ to 1 hour	212	5.32	44	4.6	7	3.0	61	.49
1 to 2 hours	202	7.8	54	6.4	19	4.7	43	.80
2 to 3 hours	90	9.03	26	7.7	9	4.4	28	.60
3 to 4 hours	54	8.4	24	9.0	10	8.0	8	1.0
More than 4 hours	161	10.4	81	12.7	23	7.2	35	1.24

To determine whether these average figures can be accepted as criteria of attainable distances for a given hour control, a further analysis was made of distances covered by auto in the less than ½-hour control group. (Fig. 30.) This shows that the distance

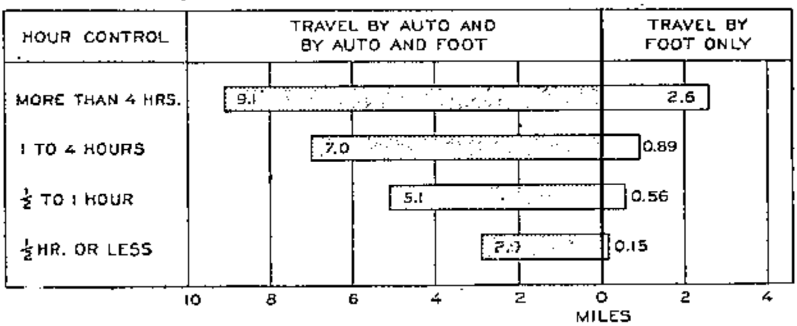


FIGURE 29.—Comparative distances traveled in different hour-control groups by auto and by foot, western yellow pine type, Shasta and Plumas National Forests, 1923–1928

traveled was less than 5 miles on 84 per cent of the fires handled in the less than ½-hour control group for the two forests and two types, and below two miles on 60 per cent. The average distances shown in Figure 28, therefore, represent reasonably usable averages of performance for the types of road now generally available. Changes in road standards would change the speed.

The average area covered by a fire guard in a given length of time will vary about as the square of the speed per hour.[5] Using the figures derived here, the comparative areas within one hour of travel time would be as follows:

	Acres
Foot travel	0.25
Horse travel	9.0
Average	4.6
Auto and foot	13.7
Auto	18.5
Average	16.1

[5] This is a rough approximation of the relation of radius and area and will naturally vary within a given guard unit.

On an average, where roads were available and autos and auto and foot could be used, the index was 16.1 (the average of 13.7 and 18.5) as compared with an average of 4.6 (the average of 0.25 and 9) where trails only are available and horse or foot travel must be used. On an average, therefore, the existence of a road system multiplies by nearly four times the area that a guard can cover in a given length of time. In the data, the exceedingly slow time for foot travel is

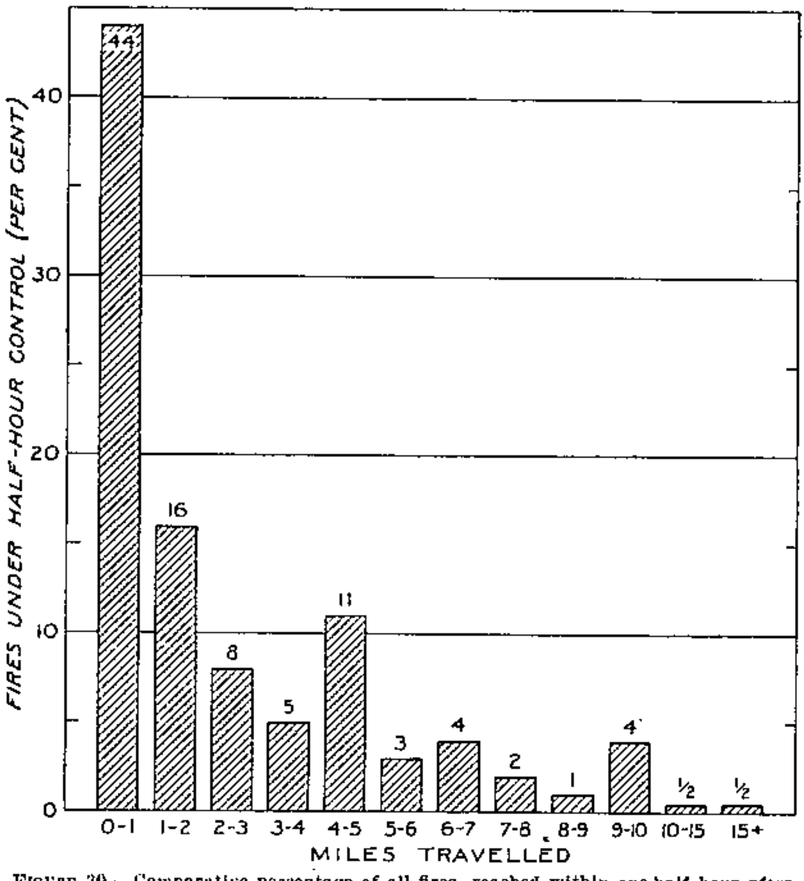


FIGURE 30.—Comparative percentage of all fires, reached within one-half hour after start, in which different distances were traveled by auto, western yellow pine type, Plumas and Shasta National Forests, 1923–1928

probably due in the main to absence of both roads and trails and the consequent necessity of cross-country travel through heavy cover.

The means of travel used to reach man-caused fires during the 6-year period have been segregated for five of the more important types. (Tables 12 and 13 and fig. 31.) From these data it appears that the western yellow pine type is at present the most accessible, having a higher percentage of fires reached by auto than has any other type. The mixed conifer is somewhat behind it, and the Douglas fir, fir, and brush-field types form a third group considerably lower in the scale of accessibility. This explains in part why major variation in speed of attack exists in the different types (fig. 1), for obviously where the automobile can be used speed of attack as governed by travel time is greatly reduced.

TABLE 12.—*Fires reached by different typical means of travel, by types, all forests, 1923–1928*

Type	Auto		Auto and foot		Horse		Foot		Other		Total
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number
Western yellow pine	926	58	250	16	78	5	318	20	22	1	1,603
Mixed conifer	413	42	155	16	131	13	258	27	16	2	973
Douglas fir	42	27	37	23	34	21	44	28	1	1	158
Fir	83	32	44	17	49	19	81	31	3	1	260
Brush field	105	29	96	26	52	14	105	29	8	2	366
Total	1,569	47	591	18	344	10	806	24	50	1	3,360

TABLE 13.—*Fires reached by different typical means of travel, western yellow pine, mixed conifer, and brush-field types combined, all forests*

Year	Auto		Auto and foot		Horse		Foot		Other		Total
	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent	Number
1923	178	48	65	18	50	13	72	19	6	2	371
1924	394	54	104	14	78	11	134	19	14	2	724
1925	166	56	43	14	18	6	65	22	6	2	298
1926	496	63	72	9	60	8	149	19	6	1	783
1927	285	52	99	18	27	5	135	24	4	1	550
1928	269	49	121	22	28	5	120	23	8	1	552
Total	1,788	55	504	15	261	8	681	21	44	1	3,278

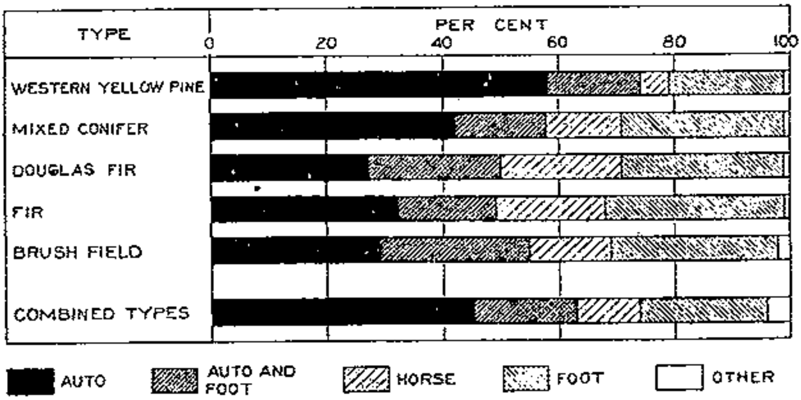


FIGURE 31.—Comparative percentage of fires reached by different means of travel for different types, all national forests, 1923–1928

There have been progressive changes during the 6-year period in the relative proportion of fires reached by the different means of travel. (Fig. 32.) A slow increase in the percentage of fires reached by auto and auto and foot combined has about absorbed the slow decrease in percentage of fires reached by horse travel.

These figures alone probably do not give a complete picture of changes in travel during the period. For one thing, the progressive spreading out of recreational travel has meant an increasing percent-

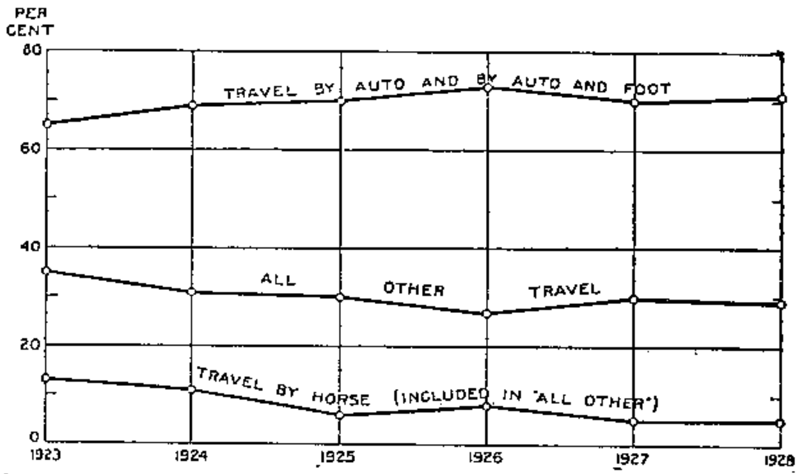


FIGURE 32.—Comparison of auto and auto and foot with all other modes of travel, in percentage of all fires so reached, western yellow pine, mixed conifer, and brush-field types, 1923–1928

age of smoker and camper fires in inaccessible territory. As between absolutely comparable groups of fires for the years 1923 and 1928, the percentage reached by auto would have increased more than is indicated above.

FACTORS AFFECTING APPLICATION OF METHOD

The hour control needed for each major type as determined in this bulletin and the portion of that time that can be devoted to travel, obviously can not be fixed inflexibly.

In studying an individual national forest or an individual ranger district several special considerations would have to be taken into account. These would include:

Whether the entire area was subjected to risk, as indicated by occurrence of fires. If, as is commonly the case, considerable areas have had no fires for a period of 5, 10, or more years, no immediate necessity would exist for including them within the hour-control net.

Whether local variability exists within the type. If, for example, areas of cut-over land are present within the western yellow pine type it may be necessary to plan for even better than a ¾-hour control.

Whether areas of specially high risk, hazard, or values are present, which should be given adequate protection at all costs. The existence of such areas would probably dictate early construction of the needed protection improvements rather than a change in hour-control standards.

Whether local weather conditions indicate need for variation in hour control. If, for example, a part of the Douglas fir type is within the fog belt, where fires consequently spread more slowly than the average rate for the type, a lower than average hour control may give satisfactory results. Or, if a portion of the western yellow pine type lies in a basin which is a wind gap, and consequently fires usually spread more rapidly than the average for the type, a faster than average hour control may be indicated.

whether complete dependence must be placed on the first line of defense. If, for example, because of the complete absence of potential fire fighters, fires over a large area must be handled by Forest Service employees alone, a safety factor in the form of faster than average hour control may be desirable. In such situations the alternatives are ordinarily to catch fires small with the employees present, or to accept very large and costly fires, on which labor must be imported from long distances.

All of these local factors can be determined and their importance and significance weighed by analyzing the local fire history for the particular area. It is unnecessary and generally undesirable to measure them by assumption. The general approach to local studies should be that the average values for hour control, which are based on all available data, are correct for individual situations, except where definite demonstrable and sufficient reasons for departure exist. These departures are likely to be less numerous than the agreements.

In using this method the entire allowable burned acreage in each type has been assigned to man-caused fires. The assumption has therefore been that the detection, communication, personnel, transportation, and suppression practice that will deliver the hour control indicated for each type will at the same time hold lightning fires to a negligible acreage. This assumption very clearly leads to a conservative determination of hour-control needs, but is proper and correct to the degree that lightning and man-caused fire zones coincide, and to the degree that human failure in suppressing lightning fires can be eliminated in the future. In this region are only a few large zones in which lightning is the sole risk. On such areas an analysis of lightning fires can readily be made to determine the needed hour control.

Obviously, even after average hour-control objectives have been translated into local objectives to meet the needs of particular areas, further work must be done to determine the exact protection improvements and protection personnel needed to attain these objectives. A method or technic for translating the hour-control objective into a transportation and personnel system has been developed by T. W. Norcross, chief engineer of the Forest Service, but has not yet been published. The systematic use of this method will insure the most economical and best balanced fire-control organization.

CONCLUSIONS

Continued advance toward the ultimate solution of the fire problem on the national forests and elsewhere requires additional protection, additional knowledge of how best to use the resources obtainable, and better execution of known steps and jobs. The fire problem can no longer be regarded as a simple proposition for which a ready solution in terms of things to be done can be set forth. It is, on the contrary, an exceedingly complex group of overlapping and intertwined problems, and each of these must be isolated and a separate solution worked out before fire-control organizations can guarantee reasonable and systematic success under every set of circumstances.

The best and, indeed, the only method by which phases of the whole problem can be examined and by which specific needs, financial and other, can be met is that of test and analysis. Actual experience is the only guide. But experience, if it is to serve adequately, must be analyzed critically and systematically. Otherwise, important and critical relationships which would furnish leads to more successful performance may easily be obscured.

All fire-control organizations now collect and record more or less detailed facts regarding each fire that they handle. These facts furnish the indispensable basis for analytical studies, such as this, dealing with one phase or another of the fire problem. Further, such studies as this accentuate the importance of a sustained and systematic effort to obtain and record accurately the complete facts regarding each fire. Great differences exist in this respect between different fire-control organizations. It is to be doubted whether full understanding of the fire-control problem either regionally or nationally will be attained until the complete facts on each individual fire are systematically recorded.

But it is to be doubted whether full use is being made by any fire-control agency of the records of experience that are now steadily accumulating. Certainly it appears that such an available and useful tool for a comprehensive attack on the fire problem should be more generally employed. Indeed, a clear obligation rests on fire-control agencies, both to determine their complete needs by means of such analyses, and to control expenditures and direct them into the most profitable channels by taking full account of analyzed experience.

Whether the exact method of analysis developed in this bulletin would be applicable to another and different region is a matter of conjecture. Only scientific analysis of adequate records can answer that question.

APPENDIX

COVER TYPES OF NORTHERN CALIFORNIA

The region studied is one of varied and rough, broken topography with a great range in elevation varying from 1,000 feet above sea level in the valleys to 14,000 feet at the crest of the Sierras. Cover type consequently varies enormously. The nine major cover types employed in this study are those used in national-forest administration. (Table 14.) They may be summarized briefly, as including (1) the western yellow pine type, of which western yellow pine (*Pinus ponderosa*) is the principal tree, and (2) the mixed conifer type, in which western yellow pine grows in mixture with sugar pine (*P. lambertiana*), and in which Douglas fir (*Pseudotsuga taxifolia*), incense cedar (*Libocedrus decurrens*), and white fir (*Abies concolor*) occur as associate trees in varying proportions. Douglas fir also occurs as a distinct type (3). The sugar pine-fir type (4) is composed of white and red fir (*A. concolor* and *A. magnifica*) in mixture with sugar pine. In some places Jeffrey pine (*Pinus jeffreyi*) takes the place of the western yellow pine in the stands or may grow with it in mixture with other species. The pure fir type (5) includes white fir, mixtures of white and red firs, and red fir alone. Within the timber belt a temporary association, the brush field (6), has in many places captured the land following the destruction of the forests by fire, logging, or both. This type is in general considered separately from the even less promising chaparral type (7).

TABLE 14.—*Distribution of cover-type areas in national-forest groups*[1] *of northern California*

[Thousands of acres; i. e., 000 omitted]

Cover type	Northern forests	East side forests	North Sierra forests	South Sierra forests	All forests	
					Total	Per cent
Western yellow pine	1,491	1,244	1,049	770	4,554	30.2
Mixed conifer	1,328	138	635	1,026	3,127	20.7
Douglas fir	1,101	6	35	3	1,145	7.6
Sugar pine-fir	91	43	341	-------	475	3.1
Fir	341	266	567	470	1,644	10.9
Grass	105	277	76	97	555	3.7
Chaparral	258	38	12	95	403	2.7
Woodland	248	332	39	332	951	6.3
Brush	1,045	213	385	596	2,239	14.8
All types	6,008	2,557	3,139	3,389	15,093	100.0

[1] Northern, Klamath, Trinity, Shasta, and California National Forests; east side, Modoc and Lassen National Forests; north Sierra, Plumas, Tahoe, and Eldorado National Forests; south Sierra, Stanislaus, Sierra, and Sequoia National Forests.

Grouped for the sake of simplicity and because of similarity are several woodland types (8), including the oak (*Quercus douglasii*), oak-digger pine (*Pinus sabiniana*) and digger pine of the western Sierra Nevada slopes, the juniper (*Juniperus occidentalis*) and juniper-mountain mahogany (*Cercocarpus ledifolius*) of the eastern slopes, and the California black oak (*Q. kelloggii*) and madroño (*Arbutus menziesii*) mixtures of the north Coast Ranges. The grassland type (9) includes areas on which occur sage (*Artemesia tridentata*), bitter brush (*Kuntzia tridentata*), and the rabbit brushes (*Chrysothamus* sp.). The alpine and subalpine types are practically free from fires and are not considered.

In a broad way the major types succeed each other. On the Sierra foothills are grass and chaparral; eastward, oak and digger-pine woodland, followed by commercial forests of western yellow pine, mixed conifer, sugar pine-fir, and pure fir; then across the summit are scattered alpine protection forests; lower on the east slope, pure fir, commercial mixed conifer, pure western yellow and Jeffrey pine forests and juniper woodland; and on the eastern plateau, sagebrush and grassland. An exception is the Douglas fir type, which is largely confined to the northern group of forests. Locally the types follow no simple successive altitudinal arrangement, but, because of minor variations in topography, aspect, or soil, are intermingled. The normal zonation is further upset and in places obscured by the presence of brush fields.

The important physical differences between cover types in climatic factors, fuels, and behavior of fires—particularly the composition of the commercial timber stands and forage types—exhibit great variation within the region, and indicate the complexity of the fire problem and the extreme flexibility necessary in a control organization designed to cope with the problem. Even the individual types, because of site differences and effect of previous fires, vary enormously within themselves. Density, height, and age of the timber; degree and direction of slope; amount and character of associated vegetation; and presence or absence of young growth, all vary at times from acre to acre and hence affect the spread and severity of fires. With given fuel, slope, and soil, the spread of fires also varies greatly from time to time as the moisture content of the fuel and the velocity of the wind vary. The behavior of fire in each type is controlled not only by the amount and kind of fuel, but also directly by the climatic elements of which the type itself is an expression.

DIFFERENCES IN TEMPERATURE, SOIL MOISTURE, AND PRECIPITATION

An investigation[6] conducted by the Forest Service, which covered the relation of air temperature and soil moisture to the principal timber types, except

[6] No comprehensive study of types and climate has been completed for this region. The only published studies are: VARNEY, B. M. MONTHLY VARIATION OF THE PRECIPITATION-ALTITUDE RELATION IN THE CENTRAL SIERRA NEVADA REGION OF CALIFORNIA. U. S. Mo. Weather Rev. 48: 648–650, illus. 1920.

——— SEASONAL PRECIPITATION IN CALIFORNIA AND ITS VARIATION. U. S. Mo. Weather Rev. 53: 148–163, 208–218, illus. 1925.

Douglas fir, in the central portion of the Sierra region, has brought out the differences between the upper and lower portions of the commercial timber belt. (Table 15.) The frostless season ranged in length from 97 days in the fir types to 162 days in the western yellow pine and length of the growing season from 135 to 200 days. But neither length of frostless season nor that of the growing season can be regarded as directly controlling the length of the fire season; rather, each is a useful indicator thereof. The difference between the two extremes, 65 days for the frostless season and 65 days for the growing season, both exceeded the difference between the same types in length of fire season, which is 42 days. (Table 16.)

TABLE 15.—*Climatological data from stations characteristic of various forest types on Plumas National Forest, 1914–1917*

Cover type	Elevation of station	Aspect	Mean temperature, August	Frostless season	Growing season	Hours during growing season— Above 85° F.	Hours during growing season— Above 70° F.	Soil temperature, August	Soil moisture, August
	Feet		*°F.*	*Days*	*Days*	*No.*	*No.*	*°F.*	*Per cent*
Western yellow pine	2,700	South	74.4	162	200	498	1,396	72	3
Mixed conifer	4,000 5,000 4,000	do do North	70.4	158	180	262	1,070	69	5
Sugar pine-fir	5,000	do	66.5	108	155	84	841	66	6
Fir, white	6,000 6,000	South North	66.3	104	150	14	360	63	8
Fir, red	7,000 7,000	South North	58.7	97	135	1	219		

TABLE 16.—*Average length of fire seasons by types* [1]

Type	Opening date	Closing date	Length in days	Type	Opening date	Closing date	Length in days
Western yellow pine	May 20	Oct. 31	164	Grass	June 10	Oct. 20	132
Mixed conifer	do	do	164	Chaparral	May 20	Nov. 10	174
Douglas fir	do	do	164	Woodland	June 10	Oct. 20	132
Sugar pine-fir	June 10	Oct. 10	122	Brush	May 10	Oct. 31	174
Fir	do	do	122				

[1] Basis: Occurrence of fires at rate exceeding 1 fire to 100,000 acres per 10 days, 12 timbered forests.

The same study gave further information on type differences. The mean temperature for August, a peak month of the fire season, ranged from 58.7° F. in fir to 74.4° in western yellow pine. The temperature differences between types are also expressed by the comparative number of hot hours (over 85°) during the growing season, which range from 8 in fir to 498 in western yellow pine. The direct effect of temperature on spread of fire has not been fully analyzed, although undoubtedly it has some effect. In so far as temperature modifies relative humidity, it has a direct bearing on the spread of fire.

Soil moisture is important because of its effect on moisture content of the litter, and hence on inflammability and rate of spread. Experiments in California[7] and Idaho[8] indicate that with a litter moisture content of over 8 per cent (on an air-dry basis) fires do not start readily from sparks or matches, and with over 25 per cent litter moisture even bonfires do not spread. In the fir type the low soil-moisture content for the season is reached in August at 8 per cent; whereas in the western yellow pine the moisture drops to 3 per cent during the same month. Thus even at the peak of the fire season the high-elevation timber types do not dry out to the degree that the western yellow pine type does. The litter in the fir type becomes dry enough so that fires start readily, but do not spread as rapidly as in the western yellow pine and are more readily controlled. Direct measurements of litter moisture

[7] SHOW, S. B. CLIMATE AND FOREST FIRES IN NORTHERN CALIFORNIA. Jour. Forestry 17: 965–979, illus. 1919.

[8] GISBORNE, H. T. MEASURING FOREST-FIRE DANGER IN NORTHERN IDAHO. U. S. Dept. Agr. Misc. Pub. 29, 64 pp., illus. 1928.

are so fragmentary that the differences between types are by no means certain. Those available indicate that for the period from June to October the moisture of the litter in fir and sugar pine-fir types was higher than the danger point (8 per cent) 40 per cent of the time, as compared to 29 per cent of the time in the western yellow pine and mixed conifer types.

TABLE 17.—*Seasonal and annual rainfall and length of rainless season at northern California stations*[1]

Type	Station	Period of record	Annual precipitation	Seasonal precipitation, May to October	Duration of dry season
			Inches	*Inches*	*Days*
Grass	Sacramento Valley (2 stations)	1874–1923	29.01	2.65	123
Chaparral	Mokelumne Hill Shingle Springs	1882–1922 1849–1912	33.18	3.68	122
Woodland	Sonora	1887–1922	35.02	4.51	121
Western yellow pine	Placerville Georgetown Grass Valley Nevada City	1874–1922 1872–1923 1872–1923 1863–1923	51.30	6.43	108
Mixed conifer	Cisco Colfax Iowa Hill North Bloomfield Emigrant Gap	1870–1916 1870–1923 1879–1910 1870–1923 1888–1923	51.56	7.03	105
Fir	Summit Bowman's Dam	1870–1923 1871–1916	59.93	8.26	87

[1] From summary of the climatological data for the United States, U. S. Weather Bureau Stations 14 and 15.

The long-period records of the United States Weather Bureau (Table 17) show that total annual precipitation is least in grassland (29.01 inches), followed by that in the chaparral and in the woodland, with a substantial increase of approximately 22.5 inches in the western yellow pine and mixed conifer, and a further increase of over 8 inches in the fir type. Thus the total precipitation at higher elevations (59.93 inches) is over twice as great as in the grasslands of the foothills.

Of even greater importance from the standpoint of fire control is the amount of precipitation during the fire season (May to October, inclusive). The quantities received ranged from 2.65 inches in grassland to 8.26 inches in fir, an increase of 200 per cent. Increases in precipitation in the intervening types were in the same order as those for total precipitation.

The length of the fire season, as well as the ease of start and spread of fires during that time, are determined quite as much by the duration of the rainless season as by the total annual precipitation. The average length of rainless season as given in Table 17, ranges from about 123 days for grass, chaparral, and woodland to 87 days for fir. This, when coupled with the temperature differences and the greater total and seasonal precipitation already noted, explains the shorter fire season at the higher elevations.

FUELS AND BEHAVIOR OF FIRE

The nine major types in this region are recognizable as well by the character of associated herbaceous and woody plants as by the principal key-tree species. All of this plant life, together with the accumulation of partially decayed vegetable matter in the form of mulch, duff, and humus, determines the amount and character of the fuel.

Within the commercial timber belt the densest stands are found near the upper edge, where precipitation is greatest, in the fir types; and the most open forest is found at the lower edge, where precipitation is least, in the western yellow pine type. In heavy stands, the annual fall of needles and twigs soon becomes compacted into a dense layer of duff, poorly aerated and moisture-retaining. Close stands of timber, moreover, prevent the growth of annual plants, brush, and tree reproduction, so that the duff remains the principal fuel. In the more open western yellow pine stands the duff is less compact, dries out more rapidly, and is better aerated. Because of the general openness of this forest, the subordinate vegetation of annuals and brush is relatively abundant and in late summer, when the plants dry out and burn briskly, becomes an important element in the spread of fire. Young tree growth also may be present to add to the fuel. Hence, whereas fires generally creep slowly in the fir type, where duff is the chief understory fuel, in the pine type they spread rapidly through the considerable understory of vegetation. The form in which the fuel occurs is often more important than the total quantity in controlling spread and severity of fire.

The mixed conifer type is usually an all-aged forest, with a considerably heavier volume per acre than is generally found in the western yellow pine type. The forest forms an irregular canopy, pierced by innumerable snags, which are a serious source of trouble in the control of fires. This type is richer in secondary vegetation than the western yellow pine or fir types, and openings are rapidly occupied by brush species, these forming the nuclei of future brush fields. Disintegration of fallen leaves and humus proceeds almost as rapidly as in the western yellow pine type, but on the whole the mixed conifer type has a slightly higher fuel content than has the western yellow pine type. Surface and ground fires are characteristic of this type, and crown fires are uncommon.

The amount and kind of fuel present in the woodland type vary greatly. In the drier situations the oaks, the principal species, occur as isolated trees, with widespreading crowns. This form of woodland type merges with the grassland type throughout its range; the ground is carpeted with grasses and weeds in profusion, and these form the principal fuel. Fires, as in the grassland type, spread with great rapidity over the surface, though rarely running up to the tree crowns. Where precipitation is heavier, the woodland type forms a close canopy of many hardwood species, and the ground is heavily covered with a layer of dried and decayed leaves, and lacks any understory of grasses and weeds. Fires in the denser stands eat their way slowly through this semicompacted mass of organic material, flaring up occasionally through the trees under increased wind velocity.

In the brush fields, where fires have been excluded, new coniferous stands are making a start, and a heavy layer of humus and duff forms under the closed canopy of the brush. The brush fields have the highest fuel content of any type, and fires sweep through them with great fury. Also, the progress of any given fire is far more uncertain and difficult to check than in the chaparral. In the brush fields the heavy layer of humus retains smouldering embers for long periods, and these flare up at the first wind that may arise and start a new conflagration.

In the chaparral the density and height of stand depend mainly upon the frequency with which past fires have swept the area. Where fires have been absent for a decade or more there is an uninterrupted, impenetrable cover of multistemmed individual shrubs. The principal species being evergreen and small-leaved, comparatively small quantities of dead material fall to the ground, and the dense shade prevents the establishment of grasses and weeds. Fires race with fury through this unbroken canopy of chaparral when high winds and low humidities prevail. On the other hand, fires subside quickly during calm weather and rising humidities, and finding little fire-holding fuels on the surface, frequently burn themselves out. Thus, a fire in chaparral may at one moment be a raging crown fire and the next almost completely subdued.

The three major kinds of forest fires—those in the branches and tops of forest trees, or crown fires; those confined to the subordinate cover of grass, weeds, and litter, or surface fires; and those that run through the duff, or ground fires—occur at times in all types. Nevertheless, without overgeneralizing, each cover type may be characterized in fire control by the frequent occurrence of one kind of fire, in the following manner:

Crown fires:
- Chaparral type.
- Brush type.

Surface fires:
- Grass type.
- Woodland type.
- Western yellow pine type.
- Mixed conifer type.
- Douglas fir type.

Ground fires:
- Sugar pine-fir type.
- Fir type.

Fires which race through the crowns of dense stands of brush or chaparral have very properly been classified as crown fires in this region, although the term "crown fire" has been almost entirely restricted in other regions to fires which run through the crowns of trees. Crown fires develop where a continuous closed canopy is found, and the chaparral and brush types are distinctly of such character. Only rarely in the daytime, more commonly at night, do fires burn as surface fires in these types, particularly the chaparral, and then only to burst into crown fires with the first considerable decrease in relative humidity or increase in wind velocity. Crown fires sometimes occur in the virgin-forest types, but if so they are localized, except in the severest fire years; they are more common in second-growth forest. Crown fires generally spread the most rapidly, surface fires less rapidly, and ground fires least rapidly; and the degree of damage is ordinarily in the same sequence. The rapidity with which crown fires spread is indicated by the average of 55 acres per hour in the chaparral type, and by 13.79 acres in the brush-field type, in both of which most fires are crown fires.

Surface fires generally develop where an irregular low canopy of flash fuels exists, such as characterizes the grass, woodland, western yellow pine, mixed conifer, and Douglas fir types. In the first two of these, grasses and weeds are the most important fuels, and the average rate of spread is greater than in the commercial timber types, where needles and twigs are the important fuels. This difference in fuels is reflected in the average rates of spread of 17 and 5.3 acres per hour, respectively, for the grass-woodland and timber groups.

Ground fires occur where a compact and poorly aerated layer of humus and duff permits only a small supply of oxygen to reach the fire and where there is a scarcity of flash fuels. Under normal conditions ground fires eat their way slowly. The observed rate of spread for the sugar pine-fir type is 4.33 acres per hour, and for the fir, the lowest in the entire scale, 1.07 acres per hour.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

August 8, 1930

Secretary of Agriculture	ARTHUR M. HYDE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Personnel and Business Administration.	W. W. STOCKBERGER.
Director of Information	M. S. EISENHOWER.
Solicitor	E. L. MARSHALL.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Dairy Industry	O. E. REED, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	R. Y. STUART, *Chief.*
Bureau of Chemistry and Soils	H. G. KNIGHT, *Chief.*
Bureau of Entomology	C. L. MARLATT, *Chief.*
Bureau of Biological Survey	PAUL G. REDINGTON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Agricultural Economics	NILS A. OLSEN, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Plant Quarantine and Control Administration	LEE A. STRONG, *Chief.*
Grain Futures Administration	J. W. T. DUVEL, *Chief.*
Food and Drug Administration	WALTER G. CAMPBELL, *Director of Regulatory Work, in Charge.*
Office of Experiment Stations	———, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*

This bulletin is a contribution from

Forest Service	R. Y. STUART, *Chief.*
Branch of Research	EARL H. CLAPP, *Assistant Forester, in Charge.*
Division of Silvics	E. N. MUNNS, *in Charge.*
Branch of Operation	ROY HEADLEY, *Assistant Forester, in Charge.*
Branch of Engineering	T. W. NORCROSS, *Chief Engineer.*

U. S. GOVERNMENT PRINTING OFFICE: 1930

END