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Forest Fires in the Northern Rocky Mountains

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IN THE

NORTHERN ROCKY MOUNTAINS

By

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PREFACE

This is a report on an analysis of 36,000 forest fires in the northern Rocky Mountains. The analysis was made to gain a better understanding of the occurrence, behavior, control, and effects of fires, and in turn to obtain essential information required for improved planning and management of fire protection systems.

The results present answers to these questions:

1. What is the magnitude of the regional fire problem?

2. What are the basic features of fire behavior under various topographic, fuel, and weather conditions?

3. What have been the results of organized fire control programs including fire prevention, detection, communication, transportation, and suppression action?

4. What special factors are of outstanding importance?

During the course of this study a principal aim has been to seek basic facts that will guide foresters engaged in fire control planning. Two phases of the planning job were in mind: First, the fire control engineering phase which concerns the design of the protection systems; and second, the management phase which involves the planning of suppression action on individual fires.

The data presented have been drawn mainly from individual fire reports. In analyzing problems of a broad regional nature, such as total fire occurrence and area burned, the reports of 13 federal, state, and private agencies were used. For technical problems, such as rate of spread in various fuels, only the Forest Service reports were used. The latter were coded and placed on punch cards to enable automatic machine sorting and tabulating. Availability of the coded Forest Service fire reports enabled hundreds of detailed compilations on thousands of fires to be made quickly and at relatively low cost.

The 15-year period 1931 through 1945 was used for most of the analysis. In some phases of the study the necessary fire reports were not available from all agencies for this entire period. In studying burned area, records of fires dating back to 1908 were used. Other phases of the analysis include reports of fires through 1949. The total of some 36,000 individual fire reports that were available provided an adequate sample of the forest fire problem.

The splendid cooperation of the following agencies which supplied fire reports contributed measurably to the comprehensive nature of the analysis: Blackfoot Forest Protective Association, Clearwater Timber Protective Association, Northern Montana Forestry Association, Pine Creek Timber Protective Association, Pend d'Oreille Timber Protective Association, Potlatch Timber Protective Association, Priest Lake Timber Protective Association, Washington State Division of Forestry, Idaho

State Forestry Department, Montana State Forestry Department, U. S. Indian Service, and U. S. National Park Service. Special thanks are also due to the field personnel of 17 national forests who provided detailed fire reports for a 19-year period.

The author is indebted to many men and women in the Forest Service and in cooperating agencies for their active assistance and stimulating guidance. The project was suggested and guided in its initial stages by the late H. T. Gisborne, former Chief of the Division of Fire Research at the Northern Rocky Mountain Forest and Range Experiment Station. Directors Chas. L. Tebbe and George M. Jemison and Regional Forester P. D. Hanson provided constant guidance and inspiration for the over-all project.

The machine sorting and tabulating of over 22,000 coded Forest Service fire reports were performed by Mrs. Mildred M. Moler of the Washington office. Mrs. Edna Campbell typed and assisted in editing the manuscript and supervised much of the compiling work. Duplimat plates for printing were typed by Mrs. Bernice Beall. Statistical computations, compiling, and general clerical work were performed by William C. Grater, Thomas E. Smith, Attlee Weinmann, Mary Balsam, Edith Kelley, Elma Brees, Elaine O. Llewelyn, and Joanne Orvis. Drafting work was done by W. E. Dunstan. The cover illustration was prepared by John LaCasse.

Technical assistance was given by the Region 1 Division of Fire Control and personnel from several national forests. Clayton S. Crocker, Ralph L. Hand, and Herbert K. Harris assisted throughout the project as technical advisers. C. K. Lyman served as a special assistant in fuel classification, George R. Fahnestock in rate-of-spread studies, and E. J. Jost in fire detection. Advice on statistical methods was given by A. E. Squillace.

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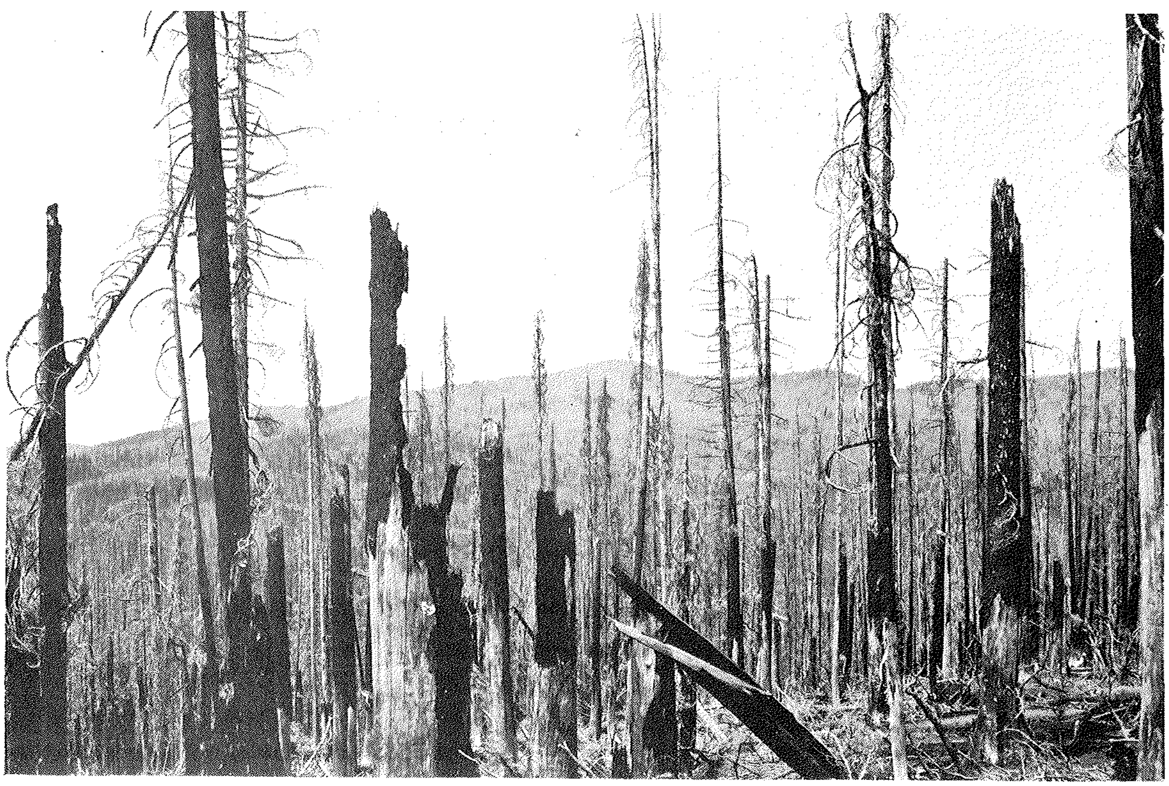


Forest fires create the difference between prosperity and poverty in the forest.

PART I

THE REGIONAL FIRE PROBLEM

Protection of forest and range lands in the northern Rocky Mountains is a challenge to Man's skill in wildland management. In the relatively short time since civilization has come to this region there have been forceful demonstrations of the far-reaching effects of forest fires and of the need for efficient control programs. To a large degree fire control is a regional problem requiring cooperative efforts by the various federal, state, and private agencies responsible for protecting wildland resources. The benefits of these efforts accrue to the people who live and make their livelihood in the region. To gain a better understanding of the regional fire problem, this analysis deals, first of all, with these specific questions:

1. How big is the fire control job?

2. How many fires must be handled?

3. What is the history of area burned?

4. What protection standards are called for?

1. THE FIRE CONTROL JOB

Scope of the Job

Fire control is big business in the northern Rocky Mountains. Here on a gross area of 117,683,000 acres covering all of Montana and parts of four other states 77 percent, or 90,600,000 acres, is forest and range land. All of this great forest and range empire requires some degree of protection against fire. To do the job 15 federal, state, and private agencies spend 6 to 7 million dollars yearly. In addition to these annual operating costs over 45 million dollars are invested in fire control equipment and improvements.

The fire control organizations are busy outfits. They fight an average of 2800 fires annually. In years of high occurrence the load is over 4000 fires. Nearly 250 full-time employees have fire control as their major job. These ranks are swelled during fire season by some 3000 temporary employees who man the lookout and guard stations; serve as smokejumpers, dispatchers, aerial observers, and crew members; or perform the many other specialized jobs required in the business of fire control. For short periods when conditions are critical upwards of 10,000 additional workers may be needed to man the fire lines and handle the service of supply.

The fire control stakes are high. To a very large degree the success of Man's efforts to manage and utilize wildland resources depends upon his ability to control fires. The margin between success and failure is small. The threat of great conflagrations is periodically present in a vast, rugged territory such as the northern Rocky Mountains. Since the devastating three-million-acre burn of 1910 it has been evident that superbly organized and executed fire control programs are essential. No less an effort can assure the safety of the region's resources or the lives and property of its people.

The requirements for successful fire control are clearly evident. Forty years' experience by the various agencies engaged in organized fire control, plus the results of the specific analysis reported here, shows these requirements:

1. A thorough understanding of the factors influencing the start of fires and their subsequent behavior.

2. A clear evaluation of the capabilities of men and machines in combating fires under the wide range of conditions peculiar to the region.

3. A rating of the relative values of the various areas to be protected and measurement of the damage that fires may do to these values.

4. Fire protection systems that are designed in accordance with rated factors of fire behavior, evaluated capabilities of control forces, and measured variances in values at stake.

5. Full public appreciation of the magnitude and importance of fire control coupled with a willingness to support aggressively the necessary action programs.

Nature of the Country

Sharp contrasts characterize the Northern Rocky Mountain Region. It is a big country, embracing more than 200,000 square miles. It extends from northwest South Dakota across northwestern Wyoming, Montana, and northern Idaho to include six counties in northeastern Washington. The extremes of altitude (700 to 12,000 feet), annual precipitation (5 to 50 inches), topography (plains to the crest of the Rockies), vegetative cover (grasslands to mixed forest and range to dense timber stands), lightning occurrence, accessibility, and use of forest lands are such as to introduce extreme variability in factors affecting the outbreak and spread of fires.

Fire conditions vary greatly in two major zones. (Figure 1.) The eastern zone, lying to the east of the Continental Divide, has relatively low fire occurrence; flashy fuels of grass and scattered ponderosa pine on the foothills; and extensive stands of lodgepole pine, Douglas-fir, and Engelmann spruce on the mountain slopes. The western zone, containing some of the roughest country in the United States, has high fire occurrence, heavy fuels over much of the area, and a range of vegetative conditions from semi-arid sage through great stands of white pine to subalpine forests near eternally snow-clad summits.

The design of fire control systems is complicated because of the great variations. To illustrate:

1. In 1910 -- a critically dry year -- forest fires in the national forests burned nearly three million acres; and during the great blowup in August, conflagrations raged over an area 120 miles long. In 1948 -- a very wet year -- only one fire in the national forests reached a size larger than 300 acres.

2. In July 1940 over 2100 fires occurred in the national forests, and 14 of these reached sizes larger than 300 acres. On the same areas in July 1943 less than 300 fires occurred, and only one of these burned more than 300 acres.

Flexibility is the most fundamental requirement in the design of fire control systems for this region. Our ability to identify and measure the variables in order to expand or contract protection forces to meet existing conditions will determine the success or failure of the fire control job.

Fire Control Agencies

Federal, state, and private agencies share the fire control job. As shown in table 1, 3 federal, 3 state, and 7 private agencies provide organized protection on over 53 million acres. In addition the Montana Rural Fire Fighters Service provides volunteer-type protection on some 20 million acres, mostly in the eastern zone. The Bureau of Land Management of the Department of Interior cooperates in extending this type of protection to widely scattered holdings of public domain lands.

Cooperative protection by the various agencies promotes efficiency. Protection boundaries have been established wherever feasible on a geographical rather than a strict ownership basis. (Figure 1.) In the western zone the Forest Service protects some 4,000,000 acres of private lands, and the private associations protect over 275,000 acres of national forest lands. This arrangement permits effective consolidation of the various control units into solid blocks.

Table 1. Organized Fire Protection Units in the Northern Rocky Mountains

Unit	Acres Protected	
Beaverhead National Forest	2,947,708	
Bitterroot National Forest	2,092,005	
Cabinet National Forest	1,734,579	
Clearwater National Forest	1,103,871	
Coeur d'Alene National Forest	1,076,539	
Colville National Forest	1,096,515	
Custer National Forest	1,689,702	
Deerlodge National Forest	1,808,075	
Flathead National Forest	2,539,714	
Gallatin National Forest	2,503,713	
Helena National Forest	1,738,326	
Kaniksu National Forest	2,103,343	
Kootenai National Forest	2,315,805	
Lewis and Clark National Forest	2,533,377	
Lolo National Forest	2,438,669	
Nezperce National Forest	2,147,201	
St. Joe National Forest	1,482,590	
U. S. FOREST SERVICE TOTAL		33,351,732
Glacier National Park	1,013,129	
Yellowstone National Park	2,221,772	
NATIONAL PARK SERVICE TOTAL		3,234,901
Blackfeet Indian Reservation	1,525,712	
Crow-Tongue River Indian Reservation	2,727,037	
Flathead Indian Reservation	746,126	
Fort Belknap-Rocky Boy Indian Reservation	924,425	
Fort Peck Indian Reservation	2,094,144	
INDIAN SERVICE TOTAL		8,017,444
Idaho State Forestry Department	2,709,458	
Montana State Forestry Department	185,000	
Washington Division of Forestry	2,500,000	
STATE FORESTRY TOTAL		5,394,458
Blackfoot Forest Protective Association	986,104	
Clearwater Timber Protective Association	506,256	
Northern Montana Forestry Association	485,000	
Pend d'Oreille Timber Protective Association	248,100	
Pine Creek Timber Protective Association	57,000	
Potlatch Timber Protective Association	464,316	
Priest Lake Timber Protective Association	223,907	
ASSOCIATION TOTAL		3,226,844
GRAND TOTAL		53,225,379

2. FIRE OCCURRENCE

Fire occurrence is one measure of the regional fire problem. Other factors, especially fuel, weather, topographic conditions, and accessibility, must be evaluated carefully in spelling out the magnitude of the fire control job. The concept of organized protection demands that every fire receive some degree of action. Therefore, considerations of how many fires; when, where, and how they occur; and who is responsible for control action are essential factors in an analysis of the regional problem.

Annual Occurrence

The Northern Rocky Mountain Region rates fourth in the Nation in number of fires per million acres. This rating is based upon a 5-year average for all Forest Service regions. As shown in table 2, the Region 1 load for all causes of fires is exceeded by Regions 8, 9, and 3. Only Region 3 has a greater number of lightning fires per million acres. The Region 1 man-caused load is the lowest of any Forest Service region.

Table 2. Fire Occurrence in Forest Service Regions, 1940-1944, inclusive 1/

Forest Service Region		Average Annual Number of Fires			Average Annual Number of Fires Per Million Acres		
		Lightning Fires	Man-caused Fires	Total Fires	Lightning Fires	Man-caused Fires	Total Fires
Northern 2/	(R-1)	1235	123	1361	45	4	49
Rocky Mountain	(R-2)	256	177	433	12	8	20
Southwestern	(R-3)	1454	225	1679	65	10	75
Intermountain	(R-4)	476	179	654	15	5	20
California	(R-5)	586	501	1087	25	21	46
Pacific Northwest	(R-6)	1001	220	1220	37	8	45
Eastern	(R-7)	26	365	391	2	35	37
Southern	(R-8)	200	2289	2489	9	106	115
North Central	(R-9)	33	1822	1855	2	92	94
FOREST SERVICE AVERAGE		5266	5905	11,170	25	28	53

1/ Includes only those fires occurring inside national forest boundaries.
2/ Official Forest Service name for the Northern Rocky Mountain Region.

An average of over 2800 fires occur annually in the northern Rocky Mountains. As illustrated in tables 3 and 4, nearly 2600 of these fires occur on areas handled by the 13 organized protection agencies. It is estimated that some 250 fires occur on lands protected by volunteer-type units such as the Montana Rural Fire Fighters Service. The occurrence density of 122 fires per million acres on the lands protected by private associations is the highest in the region. The Forest Service handles 60 percent of the fires that occur on organized protection units.

Fire occurrence in the western zone is 5 times greater than in the eastern zone. The western zone average of 45 lightning fires per million acres is nearly 6 times greater than the load of 8 fires per million acres in the eastern zone. Likewise, the western zone man-caused fire load of 28 is 4 times greater than the eastern zone average of 7. The average annual lightning load of 114 fires per million acres on the Clearwater National Forest is clearly the heaviest in the region. Lands protected by the Washington Division of Forestry in northeastern Washington have the heaviest man-caused load with 92 fires per million acres.

Variability is an outstanding feature of annual fire occurrence. As illustrated in figure 2, fire occurrence varies widely from year to year in both zones, although the fluctuations are most pronounced in the western zone. The regional peak load in the national forests of 3595 fires in 1940 is 134 percent above the annual average and 2767 more fires than the low of 828 in 1943. If 1948 were included in the analysis, this spread would be even greater. Adjustment of the regional fire organization to meet such greatly different extremes is one of the critical factors in obtaining successful control and saving money.

The greatest variability is in number of lightning-caused fires. As illustrated by figure 3, there have been no great peaks in the number of man-caused fires in any year since 1931. A gradual reduction in number of man-caused fires has taken place, but there have not been major fluctuations even in critically dry years. The great yearly variations, such as the high in 1940 and the low in 1943, are due almost entirely to the occurrence or non-occurrence of lightning fires.

Broad lightning zones are evident. While lightning fires occur in all parts of the region, the southwest corner (Clearwater and Nezperce forests, Clearwater and Potlatch Associations) clearly leads in the number of fires per million acres. In the western zone no correlation is evident between lightning fire occurrence and critical burning conditions. However, in the eastern zone each critical or very dangerous season has also been a season of abnormally heavy lightning fire occurrence.

Table 3. Fire Occurrence in the Western Zone 1931-1945, inclusive 1/

(Basis 31,547 fires)

Fire Control Unit and Agency	Average Annual Number of Fires: Lightning Fires	Average Annual Number of Fires: Man-caused Fires	Average Annual Number of Fires: Total Fires	Average Annual Number of Fires Per Million Acres: Lightning Fires	Average Annual Number of Fires Per Million Acres: Man-caused Fires	Average Annual Number of Fires Per Million Acres: Total Fires	Years of Record
Bitterroot National Forest	120	15	135	57	7	64	15
Cabinet National Forest	64	55	119	37	32	69	15
Clearwater National Forest	126	6	132	114	6	120	15
Coeur d'Alene National Forest	48	28	76	45	26	71	15
Colville National Forest	32	12	44	29	11	40	15
Flathead National Forest	93	15	108	37	6	43	15
Kaniksu National Forest	104	33	137	49	16	65	15
Kootenai National Forest	89	28	117	38	12	50	15
Lolo National Forest	127	40	167	52	16	68	15
Nezperce National Forest	139	17	156	65	8	73	15
St. Joe National Forest	87	30	117	59	20	79	15
FOREST SERVICE AVERAGE	1029	279	1308	51	14	65	
Glacier National Park	16	12	28	16	12	28	15
Flathead Indian Reservation	37	25	62	50	34	84	14
DEPARTMENT OF INTERIOR AVERAGE	53	37	90	30	21	51	
Montana State Forestry Dept.	10	9	19	54	49	103	15
Idaho State Forestry Dept.	21	113	134	8	42	50	8
Washington Div. of Forestry	58	230	288	23	92	115	14
STATE FORESTRY AVERAGE	89	352	441	16	65	81	
Blackfoot Forest Prot. Assn.	85	76	161	68	61	129	14
Northern Montana Forestry Assn.	26	24	50	54	49	103	15
Clearwater Timber Prot. Assn.	40	38	78	79	75	154	15
Potlatch Timber Prot. Assn.	33	21	54	71	45	116	15
Pine Creek Timber Prot. Assn.	3	4	7	53	70	123	8
Priest Lake Timber Prot. Assn.	12	2	14	54	9	63	15
Pend d'Oreille Timber Prot. Assn.	9	23	32	36	93	129	11
ASSOCIATION AVERAGE	208	188	396	64	58	122	
ZONE AVERAGE	1379	856	2235	45	28	73	

1/ As indicated in the years-of-record column, data does not include entire 15-year period for all agencies.

Table 4. Fire Occurrence in the Eastern Zone 1931-1945, inclusive 1/

(Basis 4886 fires)

Fire Control Unit and Agency	Average Annual Number of Fires			Average Annual Number of Fires Per Million Acres			Years of Record
	Lightning Fires	Man-caused Fires	Total Fires	Lightning Fires	Man-caused Fires	Total Fires	
Beaverhead National Forest	15	9	24	5	3	8	15
Custer National Forest	24	5	29	14	3	17	15
Deerlodge National Forest	28	39	67	15	22	37	15
Gallatin National Forest	15	17	32	6	7	13	15
Helena National Forest	33	19	52	19	11	30	15
Lewis and Clark National Forest	20	6	26	8	2	10	15
FOREST SERVICE AVERAGE	135	95	230	10	7	17	
Yellowstone National Park	18	18	36	8	8	16	15
Crow-Tongue River Indian Reservation	16	16	32	6	6	12	14
Fort Belknap-Rocky Boy Indian Reservation	3	5	8	3	5	8	14
Fort Peck Indian Reservation	1	10	11	0.5	5	5.5	14
Blackfeet Indian Reservation	1	12	13	0.6	8	8.6	14
DEPARTMENT OF INTERIOR AVERAGE	39	61	100	4	6	10	
ZONE AVERAGE	174	156	330	8	7	15	

1/ As indicated in the years-of-record column, data does not include entire 15-year period for all agencies.

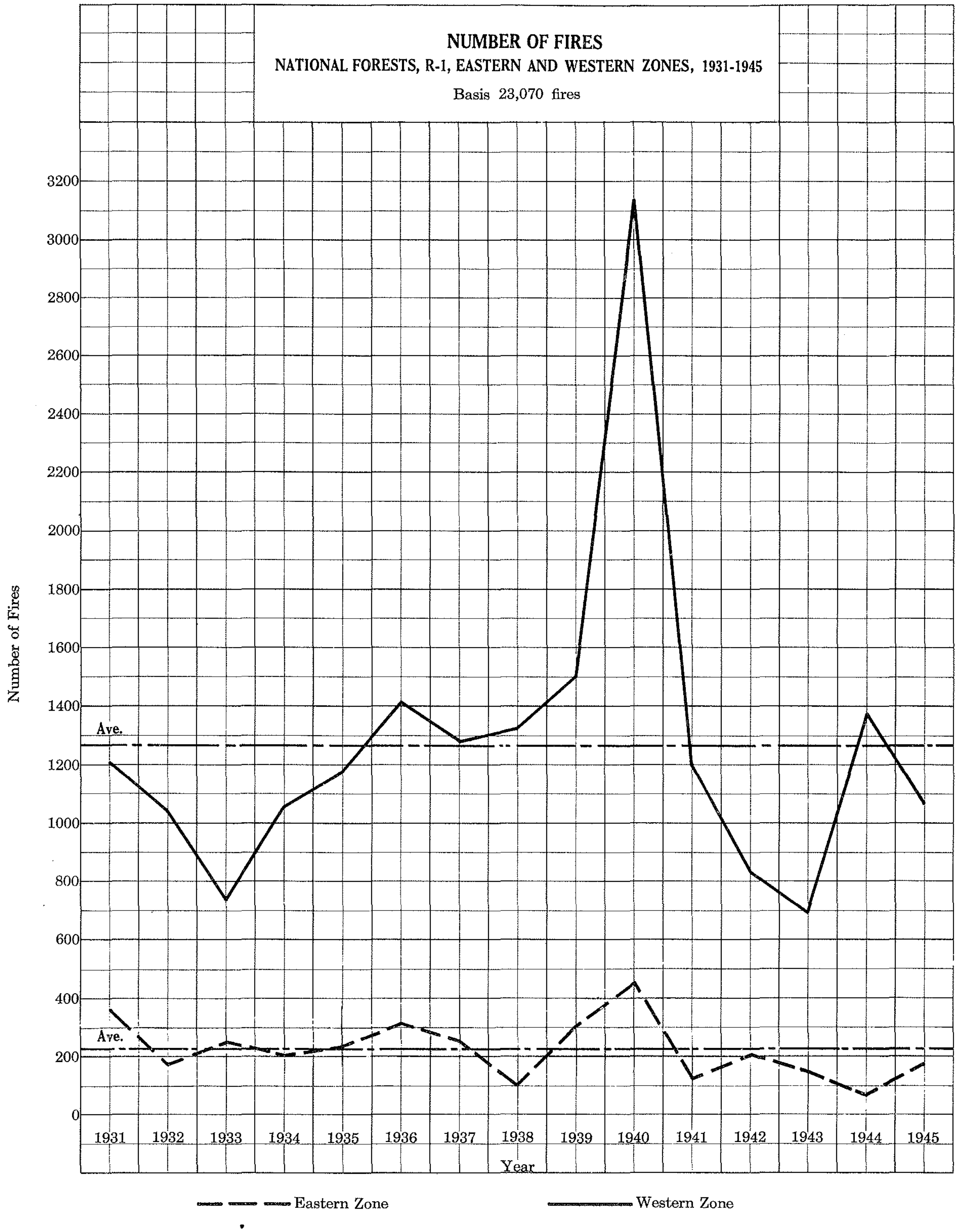

NUMBER OF FIRES
NATIONAL FORESTS, R-1, EASTERN AND WESTERN ZONES, 1931-1945
Basis 23,070 fires
Number of Fires
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Ave.
Ave.
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
Year
Eastern Zone
Western Zone

Figure 2.

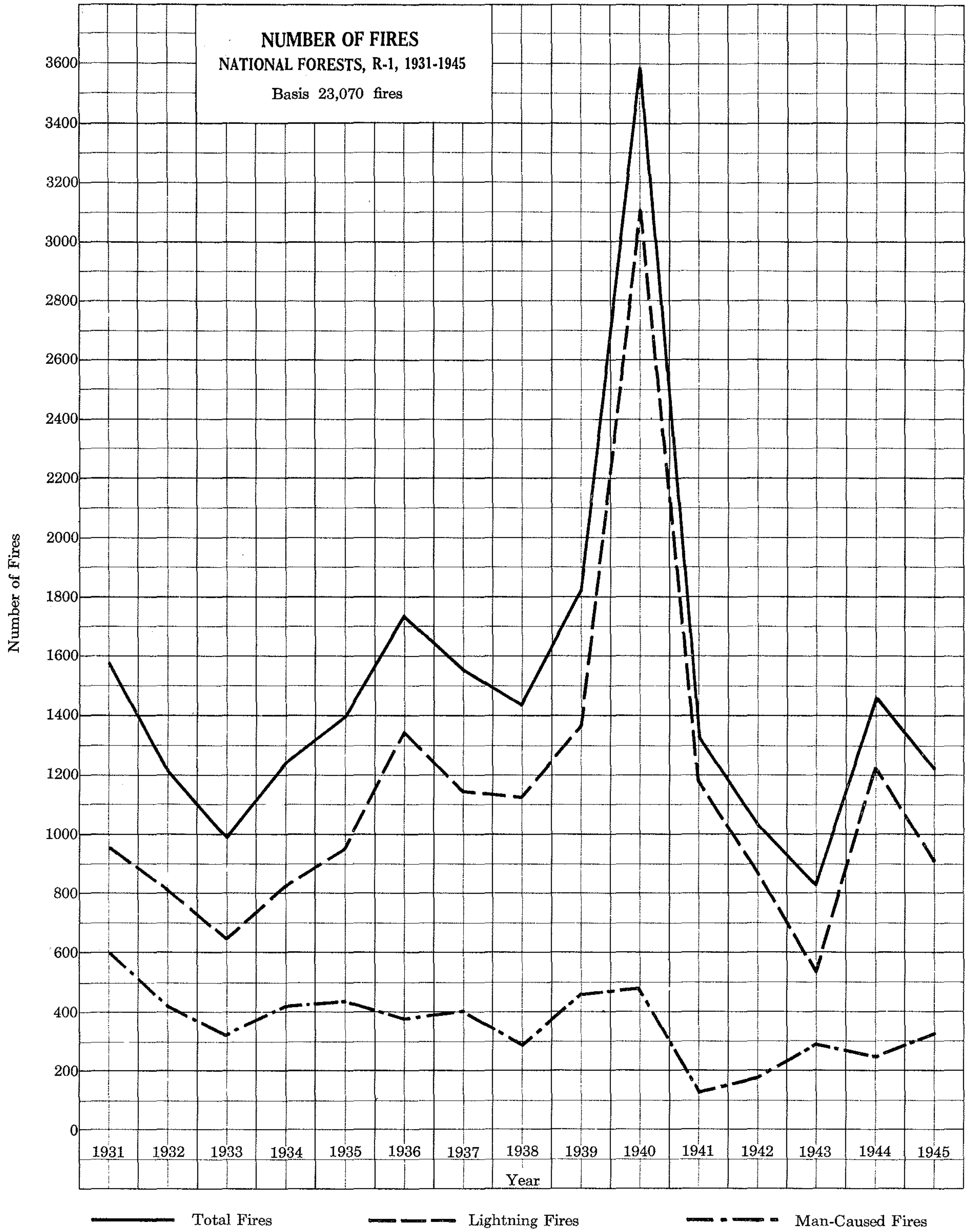

NUMBER OF FIRES
NATIONAL FORESTS, R-1, 1931-1945
Basis 23,070 fires
Number of Fires
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
Year
Total Fires
Lightning Fires
Man-Caused Fires

Figure 3.

Fire Occurrence by 10-Day Periods

The number of man-caused fires builds up and tapers off smoothly. As shown in figure 4, man-caused fires occur on a nearly even level from May 1 through the second 10-day period of June. They then build up gradually to a peak in the middle 10-day period of August. Thereafter there is a gradual tapering-off through September.

The number of lightning fires builds up in three stages. Figure 4 illustrates the striking difference between the 10-day lightning and man-caused fire occurrence patterns. Lightning fire occurrence rises steadily through the last of May, then falls off slightly before building up to the seasonal peak reached in the last 10-day period of July. After this peak there is a remarkable mid-season slump in lightning fire occurrence followed by a third build-up lasting through August. The reason for this remarkable decrease during the first 10 days of August is not obvious. It may be due to a decrease in occurrence of lightning storms. No data are available concerning that feature. In 11 out of 15 years this mid-season slump was observed. Similarly, in 12 out of 15 years the last 10 days of July brought above-average lightning fire occurrence.

Peak 10-day lightning loads exceed average year-long occurrence. In 1940 an all-time record of 1488 lightning fires occurred on the national forests in the middle 10-day period of July. This is a greater number of lightning fires than normally occur in an entire year. The next greatest 10-day lightning load of 760 fires occurred in the last decade of August 1939. The occurrence of such heavy loads emphasizes the great need for flexibility in the fire organization to permit rapid expansion in dealing successfully with emergencies.

Peak lightning periods develop at different times in various parts of the region. As shown in figure 5, most peak lightning loads have occurred during the second 10-day period of July in the northwestern corner of the region. In the Flathead National Forest and Glacier National Park the peak lightning occurrence has come most often during the last 10-day period of August. In the remainder of the region the last decade of July has brought the greatest number of lightning fires.

Daily Occurrence

Lightning fires produce great variations in daily loads. One of the most critical features of lightning occurrence is the bunching of great numbers of fires in a 24-hour period. As illustrated in figure 6, even a 15-year average will not smooth out this feature. On the other hand, there are no significant changes in the day-to-day man-caused load. The Fourth of July produces a slightly greater number of man-caused fires than the daily average for that decade of the month, but this variation is of minor significance when compared to great peaks caused by lightning fires.

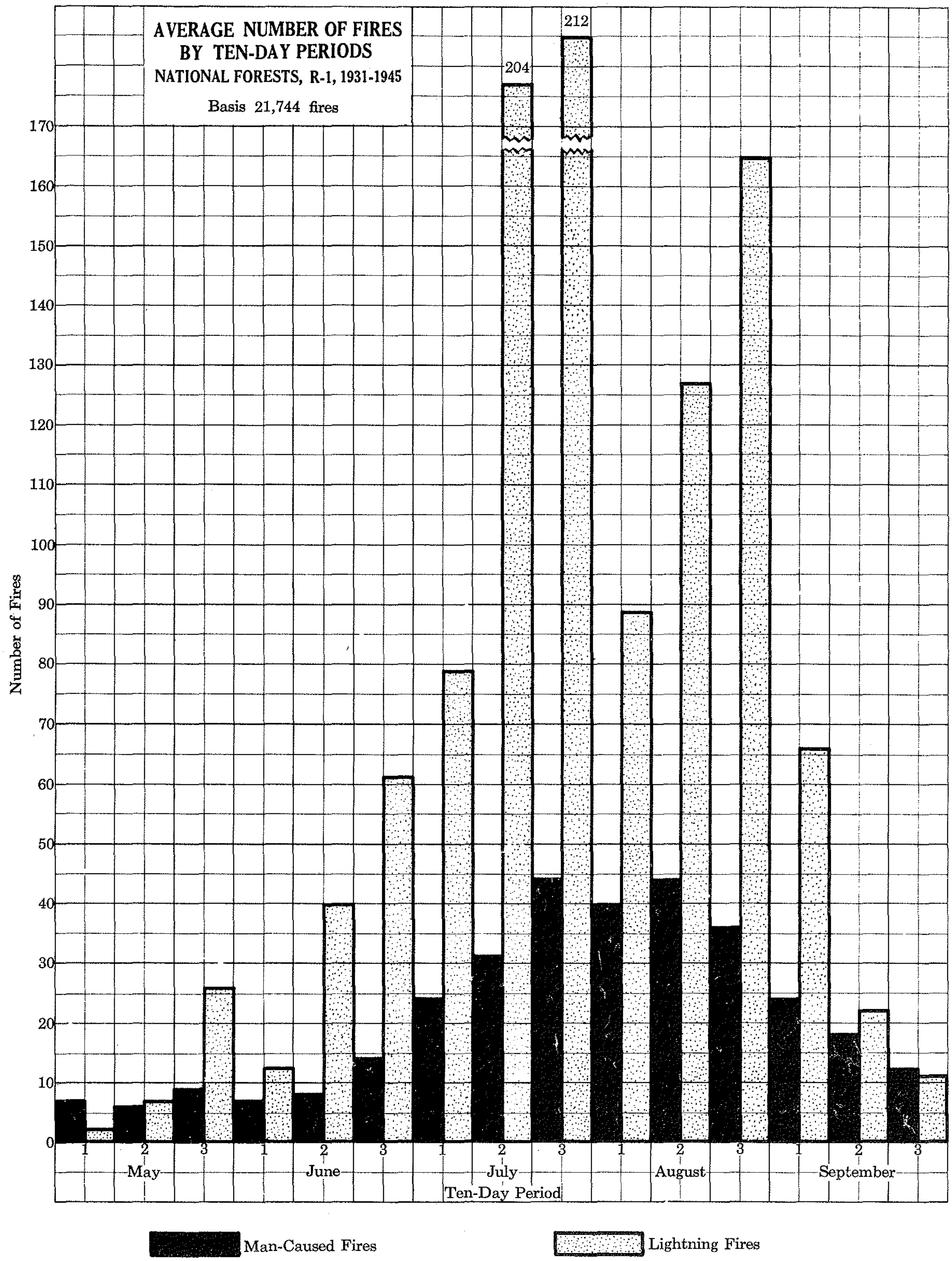

AVERAGE NUMBER OF FIRES
BY TEN-DAY PERIODS
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,744 fires
Number of Fires
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
204
212
1
2
3
May
June
July
August
September
Ten-Day Period
Man-Caused Fires
Lightning Fires

Figure 4.

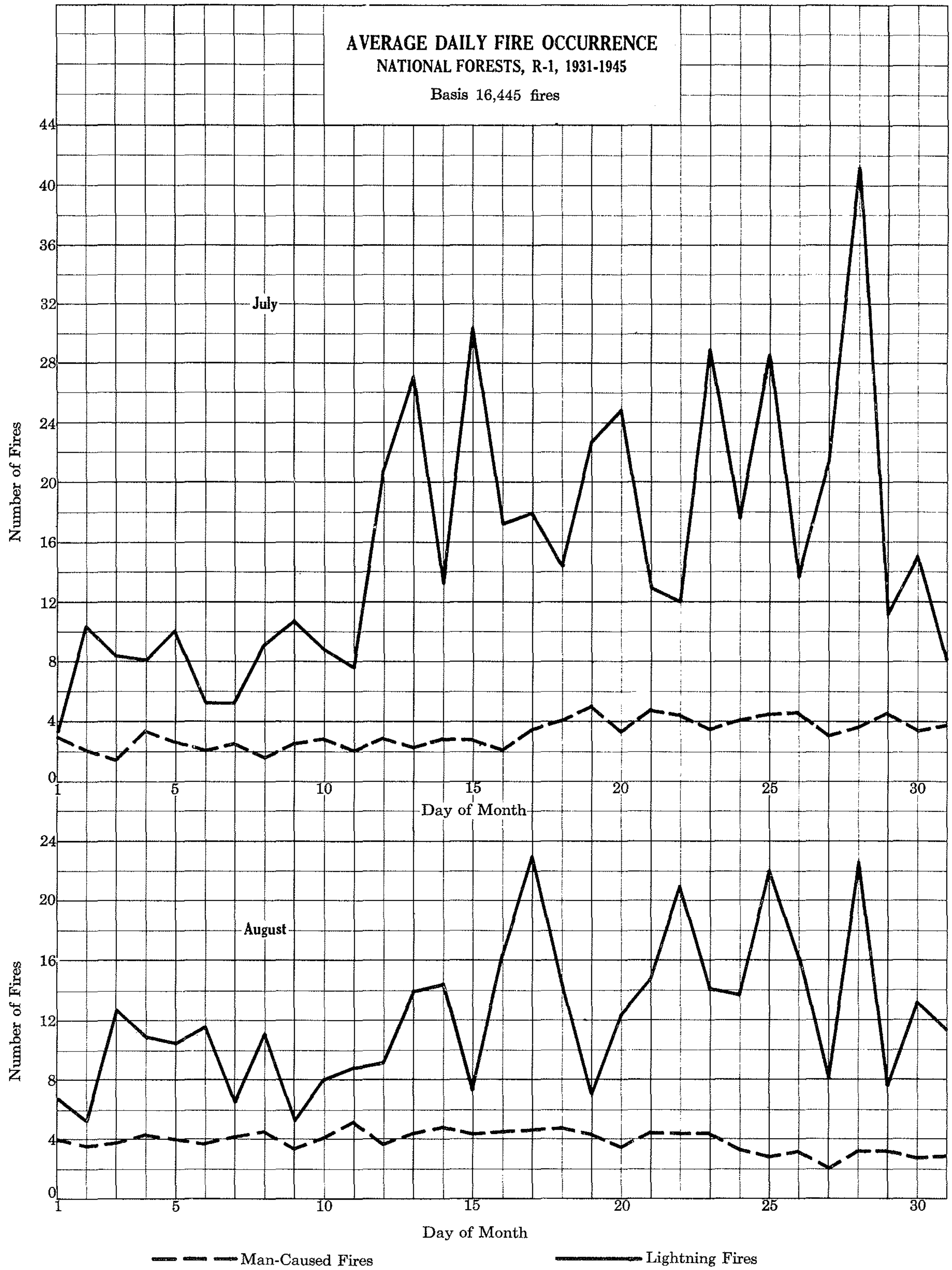

AVERAGE DAILY FIRE OCCURRENCE
NATIONAL FORESTS, R-1, 1931-1945
Basis 16,445 fires
July
August
Number of Fires
Day of Month
Man-Caused Fires
Lightning Fires

Figure 6.

The daily man-caused peak load occurs two weeks after the lightning peak. Over the 15 years studied the average daily peak for lightning fires was July 28, whereas the man-caused peak came on August 11. In addition the average daily occurrence of man-caused fires is greater in August than in July. The reverse is true of lightning fires. The average daily load of man-caused fires exceeds that of lightning fires in the early spring months (March and April) and in the fall (October and November).

Daily regional loads of 50 or more lightning fires occur in every month from May through September. Such loads have occurred 76 times in the 15 years studied (2 times in May, 5 in June, 35 in July, 30 in August, and 4 in September). The all-time peak load for a 24-hour period was 335 fires on July 12, 1940. The average daily load in July is 16 lightning fires. This peak load of 335 fires was 21 times greater than the average. Furthermore, for 10 consecutive days after July 12 lightning fire occurrence remained at a rate of 50 or more per day. A summary of the daily lightning fire occurrence in July 1940 is shown in figure 7. The 15-year average for July shows that 12.01 percent of the lightning fires reach class B size, and 2.57 percent reach class C or larger size.1/ Under the July 1940 peak-load conditions 18.47 percent of the fires reached class B size, and 4.55 reached class C or larger size.

Peak loads of man-caused fires have not occurred. The greatest regional man-caused load for a 24-hour period was 16 fires on July 22, 1931. Regional loads of 15 fires in one day occurred on two occasions. In the 15 years studied regional loads of 10 or more man-caused fires occurred on only 22 days. Critically dry weather or special activities of men, such as recreation and debris burning, have not caused great daily peak loads of man-caused fires. The minor peaks that have occurred are not of major importance when compared to the great loads caused by lightning fires. However, as will be described later, the high percent of area burned by man-caused fires is a significant feature.

Peak daily fire occurrence on individual forests is a critical factor in control action. As illustrated in table 5, there were 354 occasions in 15 years when 10 or more fires occurred in one day on individual forests. On the Coeur d'Alene, Kootenai, Lolo, and Nezperce forests there has been an above-average number of peak-load days prior to July 1. The Bitterroot forest has had an above-average number of peak-load days late in the season. The Clearwater and Nezperce forests had peak daily loads of 10 or more fires in 14 out of 15 years. Likewise, these two forests led the region in the total number of peak-occurrence days.

1/ Size classes of fires are: Class A, one-fourth acre or less; class B, more than one-fourth acre but less than 10 acres; class C, 10 acres or more but less than 100 acres; class D, 100 acres or more but less than 300 acres; and class E, 300 acres or more.

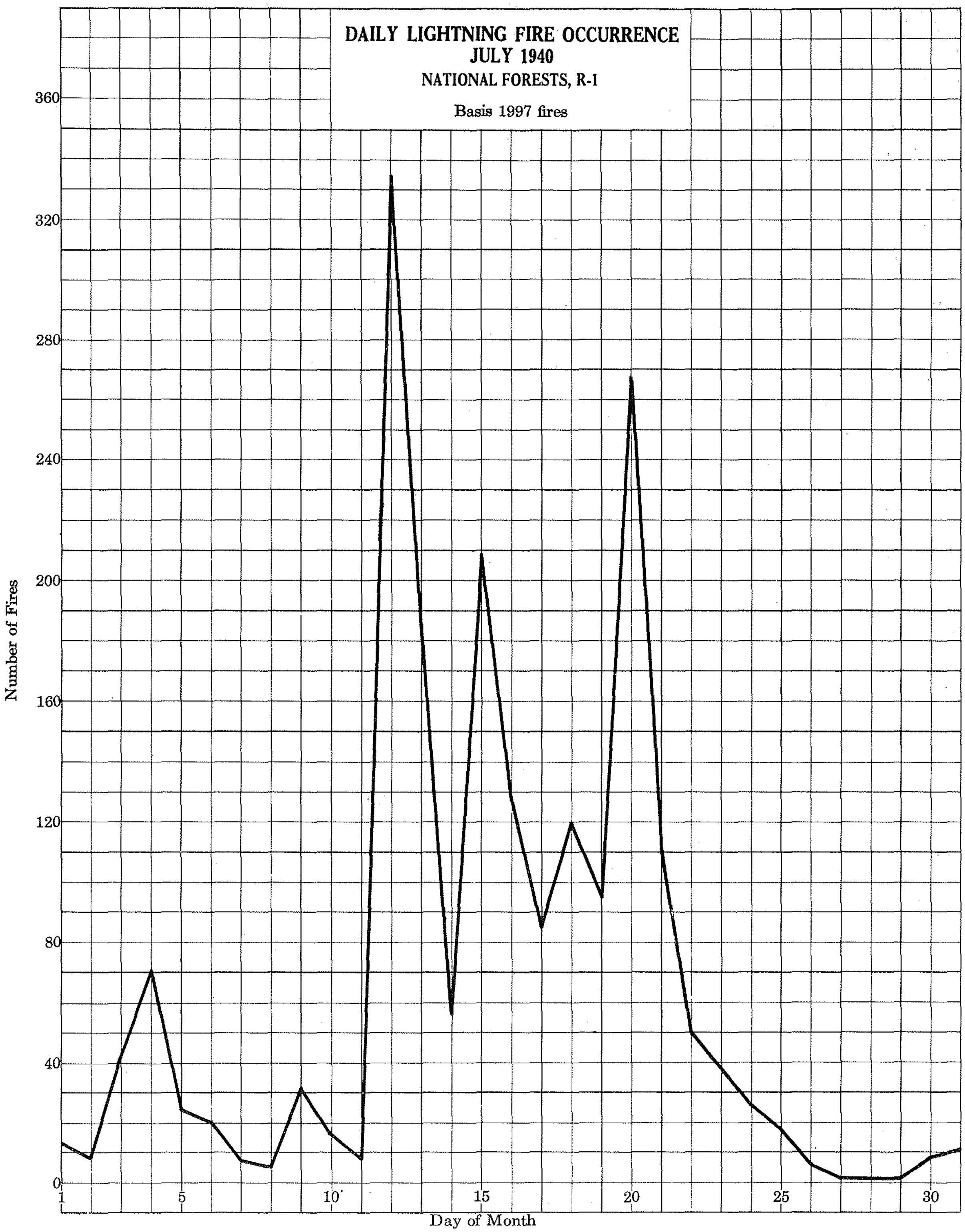

DAILY LIGHTNING FIRE OCCURRENCE
JULY 1940
NATIONAL FORESTS, R-1
Basis 1997 fires
Number of Fires
360
320
280
240
200
160
120
80
40
0
1
5
10
15
20
25
30
Day of Month

Figure 7.

Table 5. Number of Days When Ten or More Fires Have Occurred, National Forests, R-1, 1931-1945

Forest	1/	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	Total	Percent of Peak Load Days
Bitterroot	E										1						1	2
	J		1		1	1	3	1		3	4	2			1		17	40
	A	3			1	1	2			4	2		1			2	16	37
	L					1		2	2				4				9	21
Cabinet	E						1										1	5
	J	1				1	1	2		4	4	1		1			15	75
	A		3												1		4	20
	L																0	0
Clearwater	E				1		2	1									4	8
	J	1			1	2	1	1	2	5	7	2	1		3		26	51
	A	2	1					2	1			5	3			3	17	33
	L			1		1					1		1				4	8
Coeur d'Alene	E						1				1						2	15
	J							1		1	3				1		6	46
	A		2									1			1		4	31
	L								1								1	8
Deerlodge	E																0	0
	J																0	0
	A	1															1	100
	L																0	0
Flathead	E										2						2	6
	J		1			1	2	1		1	7						13	37
	A	1	3		2		1		1	4	2	1			1	1	17	49
	L						1	1	1								3	8
Helena	E																0	0
	J	1						1									2	100
	A																0	0
	L																0	0
Kaniksu	E						1		1								2	7
	J	2			2	1		1	1		5	3	1		1		17	56
	A		2			1	2			2					1	1	9	30
	L								2								2	7
Kootenai	E						2				2						4	13
	J				2	2	1		2		11						18	60
	A					1			3	3							7	24
	L								1								1	3
Lolo	E				1		1	1			2						5	12
	J	1			1	1	2	3		3	5	1				1	18	43
	A	2	4	2			1	1	1	3	1	1	1				17	40
	L					1			1								2	5
Nezperce	E	1			1		2		1		2						7	12
	J	1	1	1	1	2	1	2	2	2	7	3			1	1	25	43
	A	2	2	2	1	2	1	1		3		3	1		1	1	20	35
	L			1				2			2		1				6	10
St. Joe	E				1				1								2	7
	J					2	1	2	1	1	4	1		1	1	1	15	52
	A		4	1		1		2		2						1	11	38
	L			1													1	3
TOTAL	E	1	0	0	4	0	10	2	3	0	10	0	0	0	0	0	30	8
	J	7	3	1	8	13	12	15	8	20	57	13	2	2	8	3	172	49
	A	11	21	5	4	6	7	6	6	21	5	11	6	0	5	9	123	35
	L	0	0	3	0	3	1	5	8	0	3	0	6	0	0	0	29	8

1/ E - Early season fires (before July)
J - July fires
A - August fires
L - Late season fires (after August)

Individual forests must handle loads of over 50 fires per million acres on a single day. As illustrated in table 6, such loads have occurred on four of the western forests. The greatest number of fires in 24 hours was the Kaniksu record of 118 on July 15, 1938. The greatest number of fires per million acres was 59 on the St. Joe forest, July 28, 1937. High fire occurrence may occur for several days in succession. In July 1940 the Kootenai forest had 10 or more fires on 10 days of an 11-day period. More than 50 fires occurred on three of these days.

Daily Period of Origin

The afternoon hours produce the greatest number of fires. The period from noon to 8 p.m. is the time on most forests when the greatest number of lightning and man-caused fires occur. However, as illustrated in figures 8 and 9, there is a considerable difference in the intensity of the forenoon, afternoon, and night loads on the various forests. The St. Joe has more lightning fires at night than in the forenoon or afternoon and is the only forest showing this pattern. All forests have the greatest number of man-caused fires in the afternoon hours. The Helena has more man-caused fires at night than any other forest. On all forests, except the Helena, the forenoon period produces more man-caused fires than the night period.

The greatest number of lightning fires originates between 4 p.m. and 6 p.m. As illustrated in figure 10, this is true in both the eastern and western zones. However, in the western zone a higher percentage of fires occur at night. The great bulk of the fires in the eastern zone start between noon and 10 p.m. The lowest fire occurrence on the east side forests comes between 4 a.m. and 6 a.m. On the western forests the low point occurs between 10 a.m. and noon.

Man-caused fires peak two hours earlier than lightning fires. This peak comes between 2 p.m. and 4 p.m., whereas the lightning peak comes between 4 p.m. and 6 p.m. The build-up of man-caused fires starts early in the morning while lightning occurrence is diminishing. The most dangerous period for man-caused fires is from 10 a.m. to 6 p.m. For lightning fires the worst period is from 2 p.m. to 10 p.m.

Peak loads come at different 2-hour periods on the various forests. Lightning fires are responsible for these peaks. As illustrated in figure 11, there are four different 2-hour periods between 2 p.m. and 10 p.m. when the greatest number of lightning fires have originated on individual forests. On the Kootenai, Nezperce, Deerlodge, and Gallatin forests the peak load has occurred between 2 p.m. and 4 p.m. On the Kaniksu and St. Joe this peak did not occur until the late evening period from 8 p.m. to 10 p.m. Tables 7 and 8 show the distribution of all fires during the 24-hour period.

Table 6. Number of Fires on Peak Occurrence Days, National Forests, Western Zone, R-1, 1931-1945, inclusive 1/

Forest	2/	1931	1932	1933	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945
Bitterroot	N	25	11		18	14	23	19	12	33	33	113	20		18	11
	M	12.0	5.3		8.6	6.7	11.0	9.1	5.7	15.8	15.8	54.0	9.6		8.6	5.3
Cabinet	N	10	21			11	20	28		27	25	16		11	13	
	M	5.8	12.1			6.3	11.5	16.1		15.6	14.4	9.2		6.3	7.5	
Clearwater	N	17	33	27	31	28	30	51	17	36	52	35	24		37	19
	M	15.4	29.9	24.5	28.1	25.4	27.2	46.2	15.4	32.6	47.1	31.7	21.7		33.5	17.2
Coeur d'Alene	N		10				14	17	27	10	62	14			16	
	M		9.3				13.0	15.8	25.1	9.3	57.6	13.0			14.9	
Flathead	N	11	38		64	17	45	34	26	39	60	15			10	18
	M	4.3	15.0		25.2	6.7	17.7	13.4	10.2	15.3	23.6	5.9			3.9	7.1
Kaniksu	N	21	14		16	84	29	21	118	59	45	14	10		16	14
	M	10.0	6.7		7.6	39.9	13.8	10.0	54.1	28.1	21.4	6.7	4.8		7.6	6.7
Kootenai	N				14	29	18		29	70	78					
	M				6.0	12.5	7.8		12.5	30.2	33.7					
Lolo	N	62	26	17	14	18	17	52	15	38	42	13	32			11
	M	25.4	10.7	7.0	5.7	7.4	7.0	21.3	6.2	15.6	17.2	5.3	13.1			4.5
Nezperce	N	20	23	19	26	65	48	39	16	48	42	37	17		26	13
	M	9.3	10.7	8.8	12.1	30.3	22.4	18.2	7.5	22.4	19.6	17.2	7.9		12.1	6.1
St. Joe	N		33	19	17	15	10	88	42	54	16	10		27	18	15
	M		22.3	12.8	11.5	10.1	6.7	59.3	28.3	36.4	10.8	6.7		18.2	12.1	10.1

1/ The day when the greatest number of fires occurred. If less than 10 fires occurred the year is not credited with a peak occurrence day.

2/ N - Number of fires on the peak occurrence day of the year
M - Number per million acres on the peak occurrence day

PERIOD OF ORIGIN OF FIRES IN WESTERN ZONE
NATIONAL FORESTS, R-1

Basis 7349

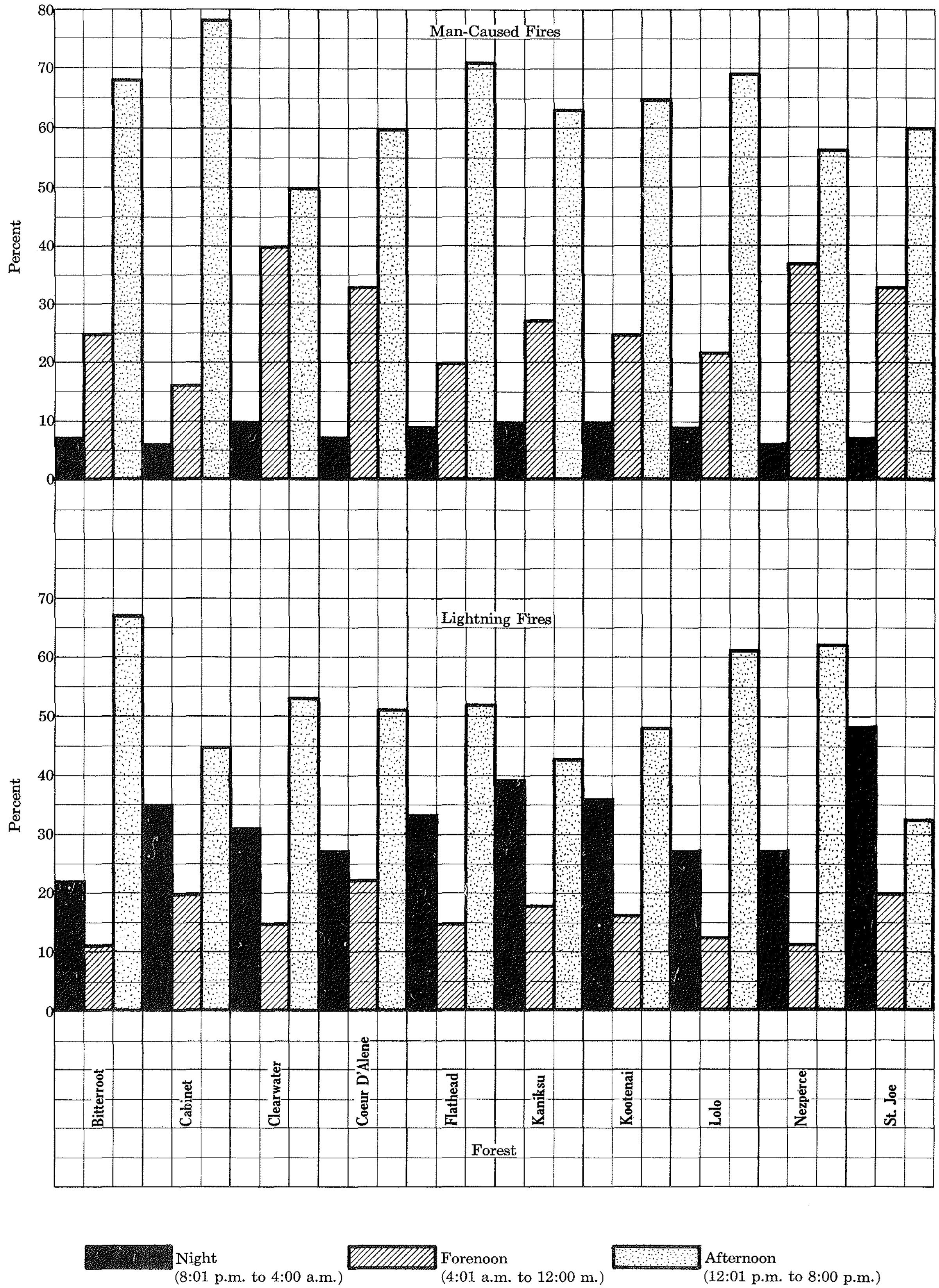


Figure 8.

PERIOD OF ORIGIN OF FIRES IN EASTERN ZONE
NATIONAL FORESTS, R-1

Basis 1837 fires

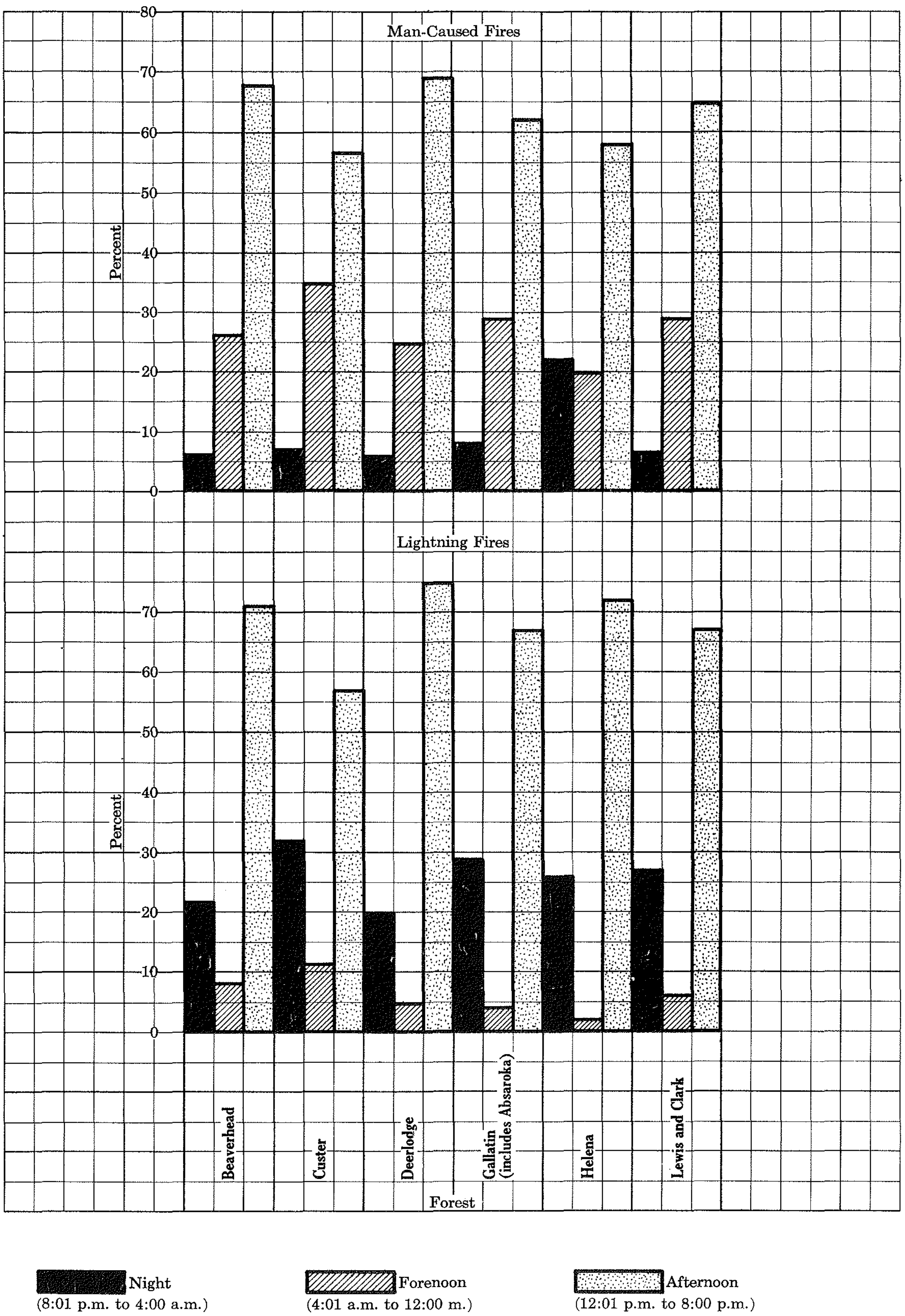


Figure 9.

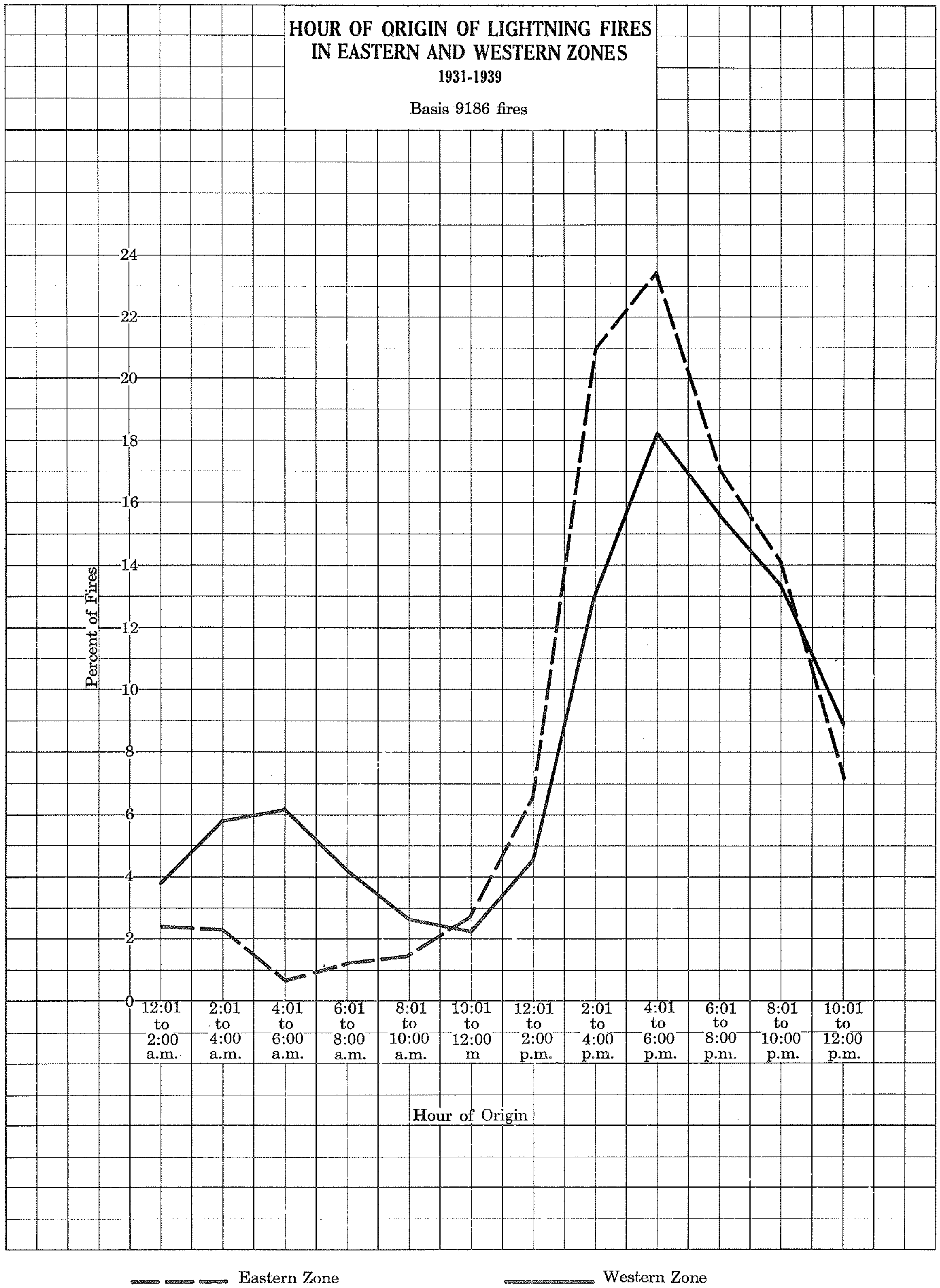

HOUR OF ORIGIN OF LIGHTNING FIRES
IN EASTERN AND WESTERN ZONES
1931-1939
Basis 9186 fires
Percent of Fires
0
2
4
6
8
10
12
14
16
18
20
22
24
12:01 to 2:00 a.m.
2:01 to 4:00 a.m.
4:01 to 6:00 a.m.
6:01 to 8:00 a.m.
8:01 to 10:00 a.m.
10:01 to 12:00 m
12:01 to 2:00 p.m.
2:01 to 4:00 p.m.
4:01 to 6:00 p.m.
6:01 to 8:00 p.m.
8:01 to 10:00 p.m.
10:01 to 12:00 p.m.
Hour of Origin
Eastern Zone
Western Zone

Figure 10.

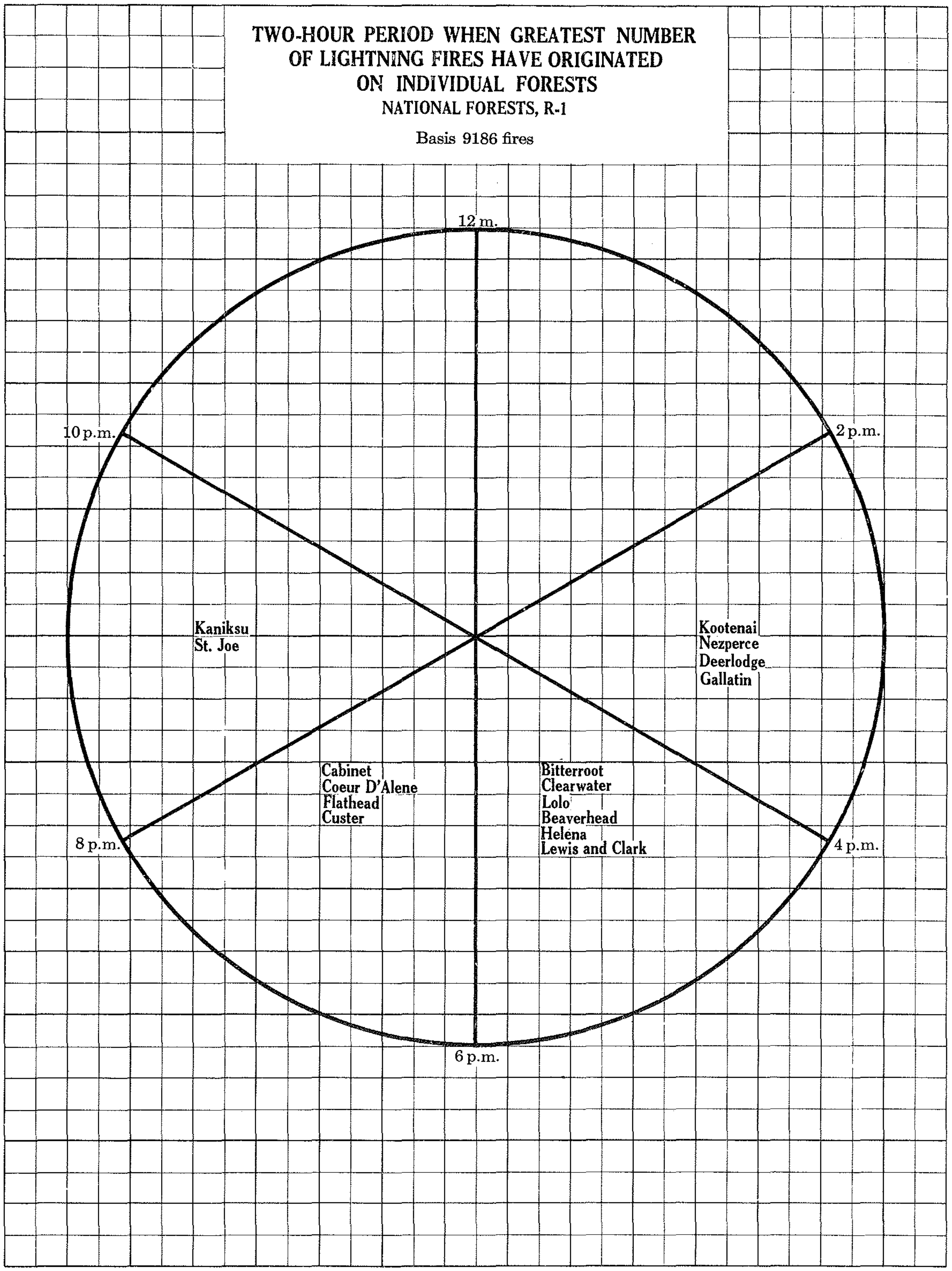

TWO-HOUR PERIOD WHEN GREATEST NUMBER
OF LIGHTNING FIRES HAVE ORIGINATED
ON INDIVIDUAL FORESTS
NATIONAL FORESTS, R-1
Basis 9186 fires
12 m.
2 p.m.
4 p.m.
6 p.m.
8 p.m.
10 p.m.
Kaniksu
St. Joe
Kootenai
Nezperce
Deerlodge
Gallatin
Cabinet
Coeur D'Alene
Flathead
Custer
Bitterroot
Clearwater
Lolo
Beaverhead
Helena
Lewis and Clark

Figure 11.

Table 7. Percent of Fires By Hour of Origin, National Forests, Western Zone, R-1, 1931-1939, inclusive

(Basis 7344 fires)

Forest	Cause 1/	Hour											
		12:01 to 2:00 a.m.	2:01 to 4:00 a.m.	4:01 to 6:00 a.m.	6:01 to 8:00 a.m.	8:01 to 10:00 a.m.	10:01 to 12:00 m.	12:01 to 2:00 p.m.	2:01 to 4:00 p.m.	4:01 to 6:00 p.m.	6:01 to 8:00 p.m.	8:01 to 10:00 p.m.	10:01 to 12:00 p.m.
Bitterroot	L	1.78	3.12	3.45	2.89	2.11	2.45	7.46	18.72	25.41	15.27	12.59	4.90
	M	0.73	0.00	0.73	5.88	4.41	13.97	22.79	22.79	15.44	7.35	5.88	0.00
Cabinet	L	3.61	5.65	9.50	5.88	3.84	1.35	3.39	8.59	11.76	21.04	17.42	7.91
	M	0.80	0.40	1.40	3.01	5.23	6.63	21.93	26.96	20.12	8.45	3.21	1.81
Clearwater	L	4.39	5.96	7.54	3.04	3.37	2.36	3.37	11.71	19.48	18.13	14.18	6.41
	M	0.00	0.00	20.83	2.77	5.55	11.11	13.88	15.27	11.11	9.72	9.72	0.00
Coeur d'Alene	L	3.79	5.86	11.72	2.75	6.20	1.03	7.93	9.65	16.20	17.58	10.34	6.89
	M	0.73	0.36	2.57	2.94	13.23	13.97	18.01	18.75	13.23	9.92	4.04	2.20
Flathead	L	2.48	4.00	3.44	5.65	3.03	2.75	2.48	6.06	17.65	25.65	13.51	13.24
	M	1.97	0.00	0.65	6.57	6.57	5.92	23.68	23.02	13.81	10.52	6.57	0.65
Kaniksu	L	3.04	4.37	6.32	3.52	3.64	4.13	5.35	13.62	13.01	11.55	21.53	9.85
	M	2.23	0.74	1.85	5.20	7.80	11.89	15.24	24.53	14.12	8.92	5.20	2.23
Kootenai	L	7.75	6.55	6.20	4.65	2.06	3.10	3.62	17.24	15.17	12.24	11.72	9.65
	M	1.68	1.01	2.02	4.05	8.10	10.47	17.90	19.93	18.91	8.10	5.06	2.70
Lolo	L	4.22	3.52	4.62	3.92	2.01	1.30	3.11	11.36	30.38	16.29	12.67	6.53
	M	0.53	1.06	1.06	3.97	6.89	9.81	19.09	22.01	18.03	9.81	4.24	3.44
Nezperce	L	3.90	9.23	4.19	4.09	1.23	2.09	8.19	21.23	20.66	11.61	4.19	9.33
	M	0.54	0.54	2.19	7.14	9.34	18.68	16.48	17.58	11.53	10.43	4.16	1.09
St. Joe	L	5.22	9.93	10.95	6.36	1.78	1.14	1.14	5.73	12.10	12.86	18.21	14.52
	M	0.94	0.94	0.31	10.03	7.21	15.36	18.18	20.37	11.91	9.09	3.76	1.88
WESTERN ZONE	L	3.93	5.83	6.19	4.22	2.60	2.22	4.60	13.04	19.22	15.77	13.40	8.91
	M	1.04	0.62	1.98	7.50	5.01	11.27	19.01	22.04	15.82	9.13	4.54	1.98

1/ L - Lightning; M - Man-Caused
Underlined figures show 2-hour period when the greatest number of fires originated.

Table 8. <u>Percent of Fires By Hour of Origin, National Forests, Eastern Zone, R-1, 1931-1939, inclusive</u>

(Basis 1837 fires)

Forest	Cause 1/	Hour: 12:01 to 2:00 a.m.	2:01 to 4:00 a.m.	4:01 to 6:00 a.m.	6:01 to 8:00 a.m.	8:01 to 10:00 a.m.	10:01 to 12:00 m.	12:01 to 2:00 p.m.	2:01 to 4:00 p.m.	4:01 to 6:00 p.m.	6:01 to 8:00 p.m.	8:01 to 10:00 p.m.	10:01 to 12:00 p.m.
Beaverhead	L	2.24	0.75	0.75	0.00	1.49	5.97	11.19	20.15	<u>26.86</u>	11.94	14.92	3.73
	M	2.13	0.00	2.13	0.00	10.64	12.76	17.02	<u>25.53</u>	14.89	10.64	3.19	1.06
Custer	L	1.44	2.87	1.91	1.91	4.31	1.91	4.78	16.27	14.35	<u>22.01</u>	18.18	10.05
	M	0.00	0.00	0.00	1.47	16.18	17.65	19.12	<u>22.06</u>	10.29	5.88	5.88	1.47
Deerlodge	L	3.62	2.26	0.45	0.90	0.45	3.62	9.50	<u>28.05</u>	22.17	14.93	10.86	3.17
	M	0.48	0.00	0.24	2.40	9.86	12.50	22.60	<u>23.80</u>	13.70	9.38	4.33	0.72
Gallatin (includes Absaroka)	L	0.71	4.26	0.00	2.13	0.00	2.13	5.67	<u>21.98</u>	19.86	19.15	14.89	9.22
	M	1.02	0.51	1.02	6.67	6.15	15.38	19.49	<u>20.51</u>	16.41	6.15	4.62	2.05
Helena	L	1.52	2.27	0.00	0.00	0.76	1.52	4.17	24.24	<u>26.14</u>	17.04	13.26	9.09
	M	1.53	1.02	0.00	2.04	4.59	13.26	<u>18.37</u>	16.33	<u>16.33</u>	6.63	16.33	3.57
Lewis and Clark	L	4.74	1.58	0.53	2.10	1.05	2.63	5.79	13.68	<u>31.58</u>	16.32	13.16	6.84
	M	1.59	1.59	6.35	4.76	9.52	7.94	<u>26.98</u>	20.63	11.11	6.35	1.59	1.59
EASTERN ZONE	L	2.42	2.33	0.60	1.12	1.38	2.76	6.56	21.05	<u>23.47</u>	17.08	14.06	7.16
	M	0.97	0.39	0.87	3.00	8.62	13.28	20.74	<u>21.61</u>	14.44	7.94	6.49	1.65

1/ L - Lightning; M - Man-Caused
Underlined figures show 2-hour period when the greatest number of fires originated.

3. AREA BURNED

The Historical Records

The scars of forest fires have long been observed in the northern Rocky Mountains. The Journal of the Lewis and Clark Expedition in 1805 and 1806 describes the results of forest fires in the Bitterroot Mountains (8).2/ J. B. Leiberg's 1898 report to the Geological Survey on his investigations of some of the original forest reserves (now national forests) in Montana and Idaho contains estimates of large forest fires dating back to 1719 (6). Forests in nearly every part of the region contain scars of great fires that have occurred during the last few centuries.

In the 40-year period 1908-1947 12 million acres burned. Over 6 3/4 million acres burned on the national forests. While detailed records for this entire period on other protected lands are not available, it is estimated that the total burn amounts to approximately 5 1/4 million acres.

The 40-year average annual burn is 300,000 acres on 53,000,000 acres of protected lands. On the basis of map studies on the national forests, it is estimated that 14 percent of the total area burned has been swept by fire two or more times in 40 years. Allowing for these reburns, approximately one acre out of five has been burned since 1908. If this rate of burning were continued over a 100-year period, 50 percent of the total area would be swept by fire once, and an additional 3,710,000 acres would be subjected to fire damage two or more times.

On the national forests over 86 percent of the burn occurred in 7 years. In the remaining 33 years the average annual burn of 29,000 acres was less than 1/10 of 1 percent of the area protected. Two years in which very large burns were suffered occurred in each of the first two decades (1910 and 1917 for the 1908-1917 decade; 1919 and 1926 for the 1918-1927 decade). In the decade 1928-1937 there were 3 years when very large burns occurred (1929, 1931, and 1934). As illustrated in figure 12, the area burned has been held below 60,000 acres in every year of the last decade. Furthermore, the annual burn was below 1/10 of 1 percent in 7 years of the last 10.

The area burned has been reduced in each decade since 1908. As shown in table 9, there has been a remarkable decrease over the 40-year period. The average annual area burned in the 10-year period 1938-1947 is only 6 percent of the 1908-1917 average. This great change may be attributed to four factors: (1) More favorable weather conditions, (2) improved fire control measures, (3) deterioration of dangerous fuels created by large single burns of the earlier decades, and (4) a systematic logging slash disposal program. In each of the first three decades there were two or more critically dry years. In the last 10 years there have

2/ Underlined numbers in parentheses refer to Literature Cited listed at the end of this report.

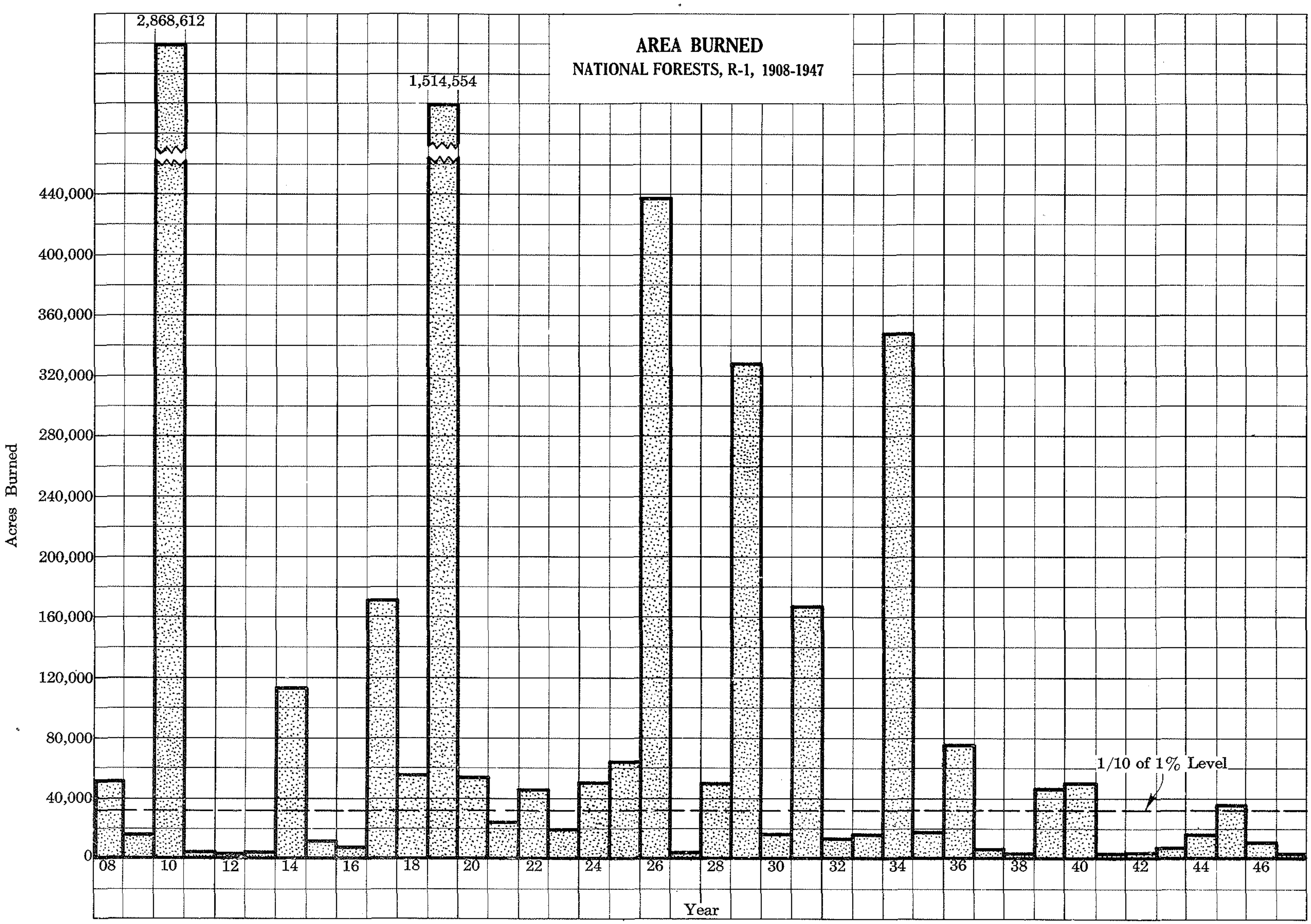

AREA BURNED
NATIONAL FORESTS, R-1, 1908-1947
2,868,612
1,514,554
Acres Burned
440,000
400,000
360,000
320,000
280,000
240,000
200,000
160,000
120,000
80,000
40,000
0
1/10 of 1% Level
08
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
42
44
46
Year

Figure 12.

not been any critically dry years, although 2 years, 1939 and 1940, are border-line cases. As shown in later sections of this report, improved fire control measures have been effective and must be credited with helping to reduce the annual area burned. Changes in fuel conditions have also reduced slightly the areas where explosive fires are highly probable. As shown by Lyman (7), many old single burns, and especially those resulting from fires occurring 30 or more years ago, have deteriorated to less dangerous fuel classifications. However, these factors do not mean that large burns cannot occur again in the future. In every critically dry year since 1908 this region has suffered large fires.

Table 9. Area Burned By Ten-Year Periods, National Forests, R-1, 1908-1947, inclusive

Ten-Year Period	Total Acres Burned	Average Annual Acres Burned	Average Annual Burn, Percent of Area Protected
1908-1947	3,261,074	326,107	0.99
1918-1927	2,291,683	229,168	0.69
1928-1937	1,046,972	102,837	0.31
1938-1947	180,817	18,082	0.05
TOTAL	6,780,546	169,513	0.51

Location of the Burns

The average annual burn in the western zone is 2318 acres per million acres protected. As shown in table 10, three national forests (Clearwater, Kaniksu, and Nezperce), one state forestry department (Washington), and two fire protection associations (Pend d'Oreille and Potlatch) had average annual burns greater than the zone average of 0.23 percent. On 10 of the 23 organized protection units in the zone the average annual burn was held to 1/10 of 1 percent or less.

The average annual burn in the eastern zone is 1518 acres per million acres protected. As shown in table 11, one national forest (Lewis and Clark) and three Indian reservations (Crow-Tongue River, Fort Peck, and Blackfeet) had average annual burns greater than the zone average of 0.15 percent. On 6 of the 11 organized protection units the average annual burn was held to 1/10 of 1 percent or less.

The southwestern part of the western zone has suffered the greatest burns. As shown in table 10, the Clearwater and Nezperce National Forests burned the largest area per million acres protected during the

Table 10. Area Burned in the Western Zone 1931-1945, inclusive

Protection Unit	Total Acres Burned	Average Annual Acres Burned	Average Annual Acres Burned per Million Acres	Average Annual Percent Burned	Years of Record
Bitterroot National Forest	62,173	4,145	1,981	0.20	15
Cabinet National Forest	23,838	1,589	916	0.09	15
Clearwater National Forest	93,909	6,261	5,671	0.57	15
Coeur d'Alene National Forest	26,900	1,794	1,666	0.17	15
Colville National Forest	1,081	360	328	0.03	3
Flathead National Forest	26,100	1,740	685	0.07	15
Kaniksu National Forest	75,582	5,039	2,396	0.24	15
Kootenai National Forest	51,882	3,459	1,494	0.15	15
Lolo National Forest	31,920	2,128	872	0.09	15
Nezperce National Forest	244,162	16,277	7,581	0.76	15
St. Joe National Forest	39,664	2,644	1,783	0.18	15
FOREST SERVICE TOTAL AND AVERAGES	677,221	45,148	2,243	0.22	
Glacier National Park	15,419	1,028	1,015	0.10	15
Flathead Indian Reservation	16,609	1,510	2,024	0.20	14
DEPARTMENT OF INTERIOR TOTAL AND AVERAGES	32,028	2,538	1,443	0.14	
Idaho State Forestry Department	37,407	4,676	1,726	0.17	8
Montana State Forestry Department	1,863	124	670	0.07	15
Washington Division of Forestry	176,768	12,626	5,050	0.50	14
STATE FORESTRY TOTAL AND AVERAGES	216,038	17,426	3,231	0.32	
Blackfoot Forest Prot. Assn.	12,755	981	995	0.10	14
Clearwater Timber Prot. Assn.	4,110	274	541	0.05	15
Northern Montana Forestry Assn.	10,198	780	1,608	0.16	15
Pend d'Oreille Timber Prot. Assn.	21,239	1,931	7,786	0.78	11
Pine Creek Timber Prot. Assn.	117	15	263	0.02	8
Potlatch Timber Prot. Assn.	18,856	1,257	2,709	0.27	15
Priest Lake Timber Prot. Assn.	5,752	383	1,710	0.17	15
ASSOCIATIONS TOTAL AND AVERAGES	73,027	5,621	1,742	0.17	
ZONE TOTAL AND AVERAGES	998,314	70,733	2,318	0.23	

Table 11. Area Burned in the Eastern Zone, 1931-1945, inclusive

Protection Unit	Total Acres Burned	Average Annual Acres Burned	Average Annual Acres Burned per Million Acres	Average Annual Percent Burned	Years of Record
Beaverhead National Forest	5,084	339	115	0.01	15
Custer National Forest	6,310	421	249	0.02	15
Deerlodge National Forest	9,471	631	349	0.03	15
Gallatin National Forest	12,456	830	331	0.03	15
Helena National Forest	8,598	573	330	0.03	15
Lewis and Clark National Forest	67,735	4,516	1,783	0.18	15
FOREST SERVICE TOTAL AND AVERAGES	109,654	7,310	553	0.06	
Yellowstone National Park	49,911	3,327	1,497	0.15	15
Crow-Tongue River Indian Reservation	83,841	7,622	2,795	0.28	14
Fort Belknap-Rocky Boy Indian Reservation	9,349	850	920	0.09	14
Fort Peck Indian Reservation	121,022	11,002	5,254	0.53	14
Blackfeet Indian Reservation	48,079	4,370	2,864	0.29	14
DEPARTMENT OF INTERIOR TOTAL AND AVERAGES	312,202	27,171	2,862	0.29	
ZONE TOTAL AND AVERAGES	421,856	34,481	1,518	0.15	

period 1931-1945. This southwestern corner also was the main trouble spot from 1908 through 1930. For example, the following great burns occurred in the Clearwater-Nezperce area (including the old Selway forest) during critical years:

1910	--	990,000 acres
1919	--	865,979 acres
1929	--	92,854 acres
1931	--	32,749 acres
1934	--	286,569 acres

In the very critical years the Nezperce and Clearwater forests escaped great damage only in 1926. During that year the Kaniksu, with a burn of 165,000 acres, and the Flathead, with 112,000 acres, were the forests contributing the greatest area burned. One of the biggest decreases in area burned occurred on the Flathead forest. During the period 1908-1930 burns of over 100,000 acres occurred on this forest four times. Since 1930 the Flathead's average annual burn of 685 acres per million acres protected is the second lowest rate for any national forest in the western zone.

Very large burns have occurred on range lands in the eastern zone. The 14-year total of over 121,000 acres burned on the Fort Peck Indian Reservation, and, similarly, nearly 84,000 acres on the Crow-Tongue River Reservation reflects the magnitude of the problem on lands where the vegetative cover is grass, sage, and scattered trees. In the more densely timbered areas of the eastern zone large burns occurred during the 1931-1945 period in the Little Rockies area of the Lewis and Clark National Forest and on the high plateaus of Yellowstone National Park. The 15-year burn of nearly 160,000 acres in these two areas accounts for over 74 percent of the area swept by fire in the major forested area of the eastern zone.

Periods When Greatest Burns Occur

The greatest area burned occurs in July and August. As shown in table 12, over 90 percent of the area burned in the national forests occurred in these 2 months. In the pre-season months the total burn amounts to 2.4 percent, while in the post-season months it is 7.2 percent.

In the eastern zone the greatest burn occurs during July. (Figure 13.) During the 1931-1945 period over 58 percent of the total area burned occurred in July. However, this relationship is influenced strongly by the large July burns on the Lewis and Clark National Forest. Three of the six forests in the zone had greater burns in August than in July. The pre- and post-season burn on five of the eastern zone forests was greater than the regional average for these periods.

In the western zone the greatest burn occurs during August. This was true during the 15-year period on 9 of the 11 national forests. Over 75 percent of the burn in the western zone occurred in August, with nearly 62 percent coming in the middle 10-day period of the month. The pre- and post-season burn on the western forests closely follows the regional pattern.

Table 12. Percent of Area Burned by Time of Year on Individual National Forests, R-1, 1931-1945, inclusive

Forest	July and August							Pre- and Post-Season		
	July 1-10	July 11-20	July 21-31	August 1-10	August 11-20	August 21-31	Total	Before July	After Aug.	Total
Bitterroot National Forest	2.4	2.8	2.6	3.6	78.1	7.5	97.0	1.2	1.8	3.0
Cabinet National Forest	1.5	6.8	48.7	6.9	8.9	17.9	90.7	1.8	7.5	9.3
Clearwater National Forest	10.1	0.4	0.1	0.1	78.7	0.1	89.5	5.5	5.0	10.5
Coeur d'Alene National Forest	0.1	0.2	13.0	6.6	70.0	5.0	94.9	1.0	4.1	5.1
Colville National Forest 1/	1.6	1.6	0.1	41.7	2.5	16.7	64.2	34.2	1.6	35.8
Flathead National Forest	0.1	20.6	2.9	12.8	54.3	5.2	95.9	1.6	2.5	4.1
Kaniksu National Forest	0.1	1.0	45.3	24.8	13.8	10.8	95.8	2.9	1.3	4.2
Kootenai National Forest	1.3	17.9	8.4	13.0	31.9	13.6	86.1	5.8	8.1	13.9
Lolo National Forest	10.7	6.8	27.3	6.5	21.7	11.6	84.6	3.4	12.0	15.4
Nezperce National Forest	0.2	0.7	1.2	1.3	84.7	8.0	96.1	0.2	3.7	3.9
St. Joe National Forest	0.1	1.5	0.3	0.2	80.7	0.2	83.0	0.6	16.4	17.0
WESTERN ZONE TOTAL	2.1	2.4	11.4	6.9	61.6	7.3	91.7	1.9	6.4	8.3
Beaverhead National Forest	0.4	0.2	9.4	4.0	49.9	3.3	67.2	11.0	21.8	32.8
Custer National Forest	10.2	2.1	43.8	1.6	4.1	3.8	65.6	19.6	14.8	34.4
Deerlodge National Forest	8.7	2.1	25.6	1.7	14.1	3.0	55.2	2.8	42.0	44.8
Gallatin National Forest	0.1	1.9	4.9	24.4	51.7	2.7	85.7	1.1	13.2	14.3
Helena National Forest	2.6	1.1	22.5	23.7	3.5	4.8	58.2	22.1	19.7	41.8
Lewis and Clark National Forest	6.2	5.2	72.2	0.4	1.4	9.9	95.3	0.2	4.5	4.7
EASTERN ZONE TOTAL	5.2	3.6	49.5	6.8	11.0	7.1	83.2	5.2	11.6	16.8
REGIONAL TOTAL	2.6	2.6	17.2	6.9	53.8	7.3	90.4	2.4	7.2	9.6

1/ Includes 1943-1945 only.

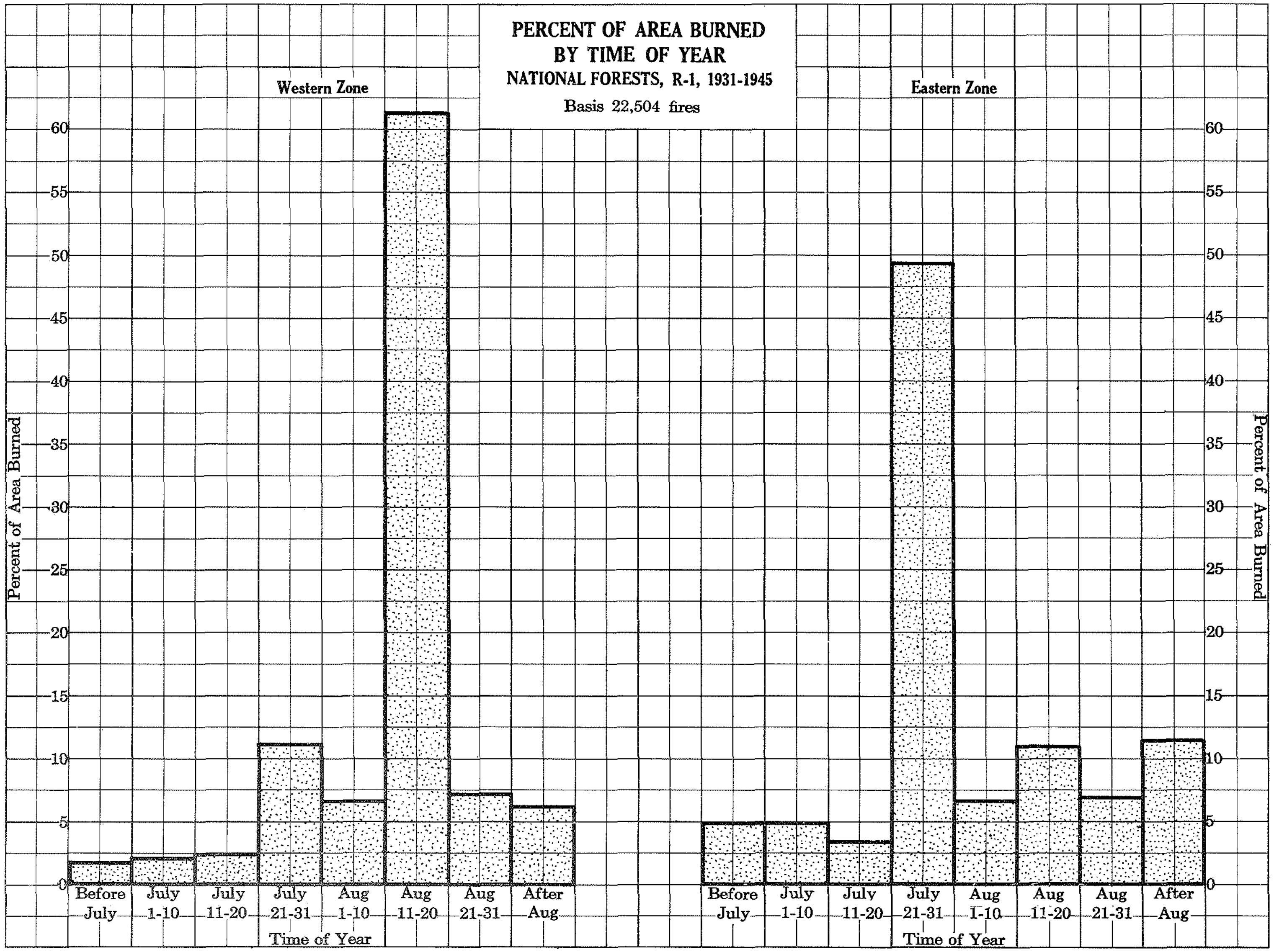

PERCENT OF AREA BURNED
BY TIME OF YEAR
NATIONAL FORESTS, R-1, 1931-1945
Basis 22,504 fires
Western Zone
Eastern Zone
Percent of Area Burned
0
5
10
15
20
25
30
35
40
45
50
55
60
Before July
July 1-10
July 11-20
July 21-31
Aug 1-10
Aug 11-20
Aug 21-31
After Aug
Time of Year

Figure 13.

In both zones there is a slump in area burned during the first 10-day period of August. This mid-season lull in area burned is probably due to the low lightning fire occurrence which has also been observed during this period. Very little area was burned during this part of the month on 13 of the 17 national forests in the region. Less than 7 percent of the total burn was recorded in these 10 days.

Over half the area burned resulted from fires originating in the morning hours. As illustrated in figure 14, over 53 percent of the total burn came from fires occurring between 4 a.m. and noon. The average size of fires originating in the morning hours is 158 acres as compared to 38 acres for night fires and 26 acres for afternoon fires. The morning hours produce more area burned and larger average size because these fires, unless they are controlled quickly, have a long daylight period of relatively severe burning conditions in which to spread.

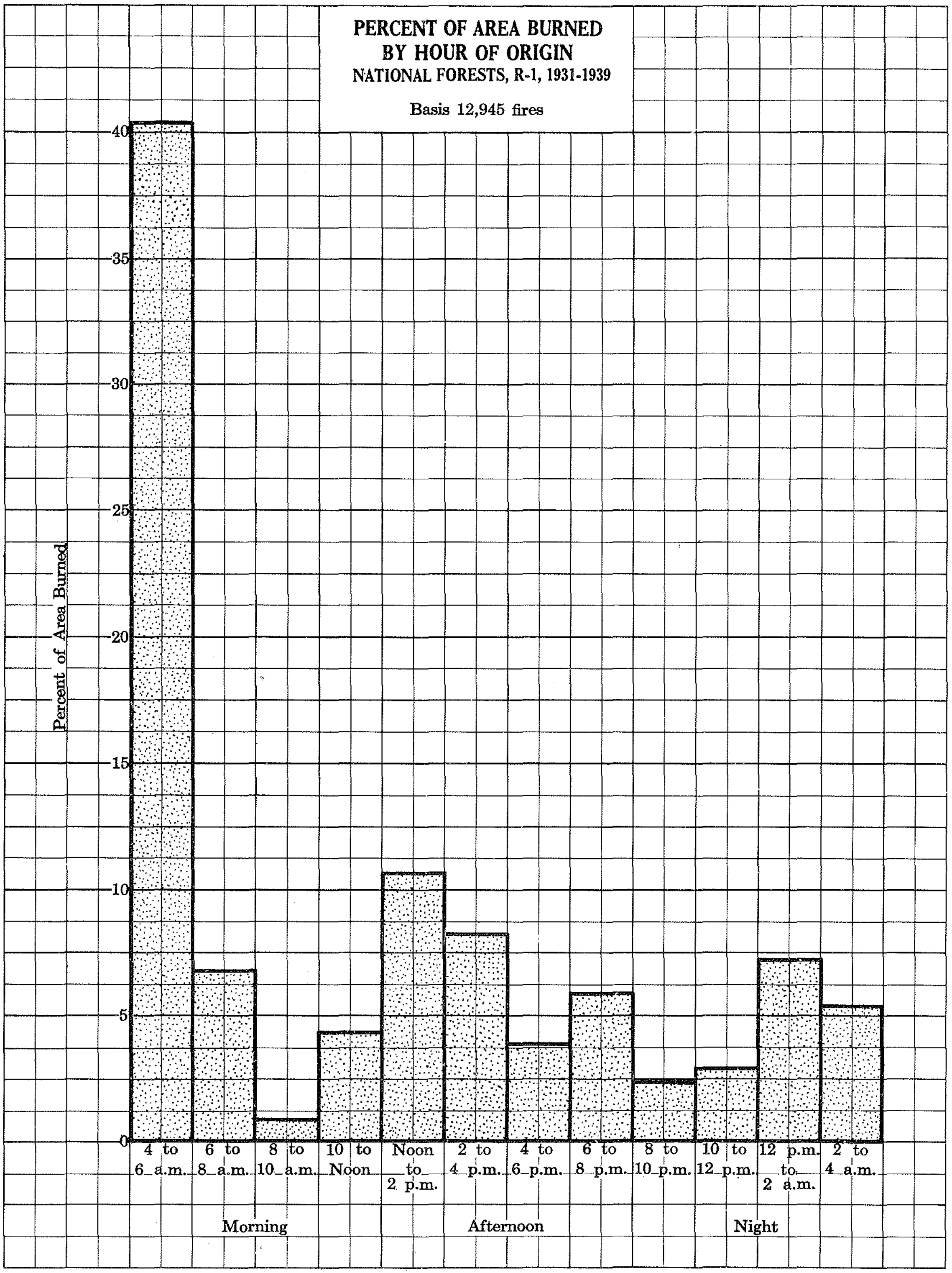

PERCENT OF AREA BURNED
BY HOUR OF ORIGIN
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,945 fires
Percent of Area Burned
40
35
30
25
20
15
10
5
0
4 to 6 a.m.
6 to 8 a.m.
8 to 10 a.m.
10 to Noon
Noon to 2 p.m.
2 to 4 p.m.
4 to 6 p.m.
6 to 8 p.m.
8 to 10 p.m.
10 to 12 p.m.
12 p.m. to 2 a.m.
2 to 4 a.m.
Morning
Afternoon
Night

Figure 14.

4. PROTECTION STANDARDS

Size Class of Fires

Holding the greatest number of fires to the smallest possible size class is an important fire control objective. Protection organizations aim first of all to hold fires to class A size. If a fire escapes control at class A size, the next objective is to hold it to class B size and so on. Each time a fire steps up to a greater size class the odds are better for it to reach the conflagration stage. This relationship is strikingly illustrated by the following summary of fires on the national forests:

1. Of the fires reaching class B or larger size, 24 percent continue on to class C or larger size.

2. Of the fires reaching class C or larger size, 34 percent continue on to class D or larger size.

3. Of the fires reaching class D or larger size, 52 percent will continue on to class E size.

Expressed in the form of betting odds this means:

1. When a fire becomes over 1/4 acre in size, the odds are 1 to 3 that it will burn over 10 acres.

2. When a fire becomes 10 acres in size, the odds are 1 to 2 that it will burn over 100 acres.

3. When a fire becomes 100 acres in size, the odds are better than 1 to 1 that it will burn over 300 acres.

Ninety-five percent of the fires on the national forests are held to class A or B size. These fires contribute an insignificant amount to the total area burned. During the period 1931 through 1945 over 14,000 fires, or 79 percent of the total, were held to class A size. Nearly 3700 fires, or 16 percent, reached class B size. Good suppression action plus breaks in weather and fuels made it possible to hold 95 percent of the fires to these small sizes. However, a 95 percent batting average is not good enough to assure a satisfactory level of protection. The 5 percent of the fires that reach class C or larger size account for over 95 percent of the total area burned.

A higher percentage of man-caused fires reach class C or larger size than lightning fires. As illustrated by figure 15, more man-caused fires reached large size every year from 1931 through 1945. Furthermore, since 1938 there has been a general trend for a greater percentage of man-caused fires to reach the larger size classes. There does not appear to be any correlation between the percent of large size man-caused fires and the character of the season. Some of the highest

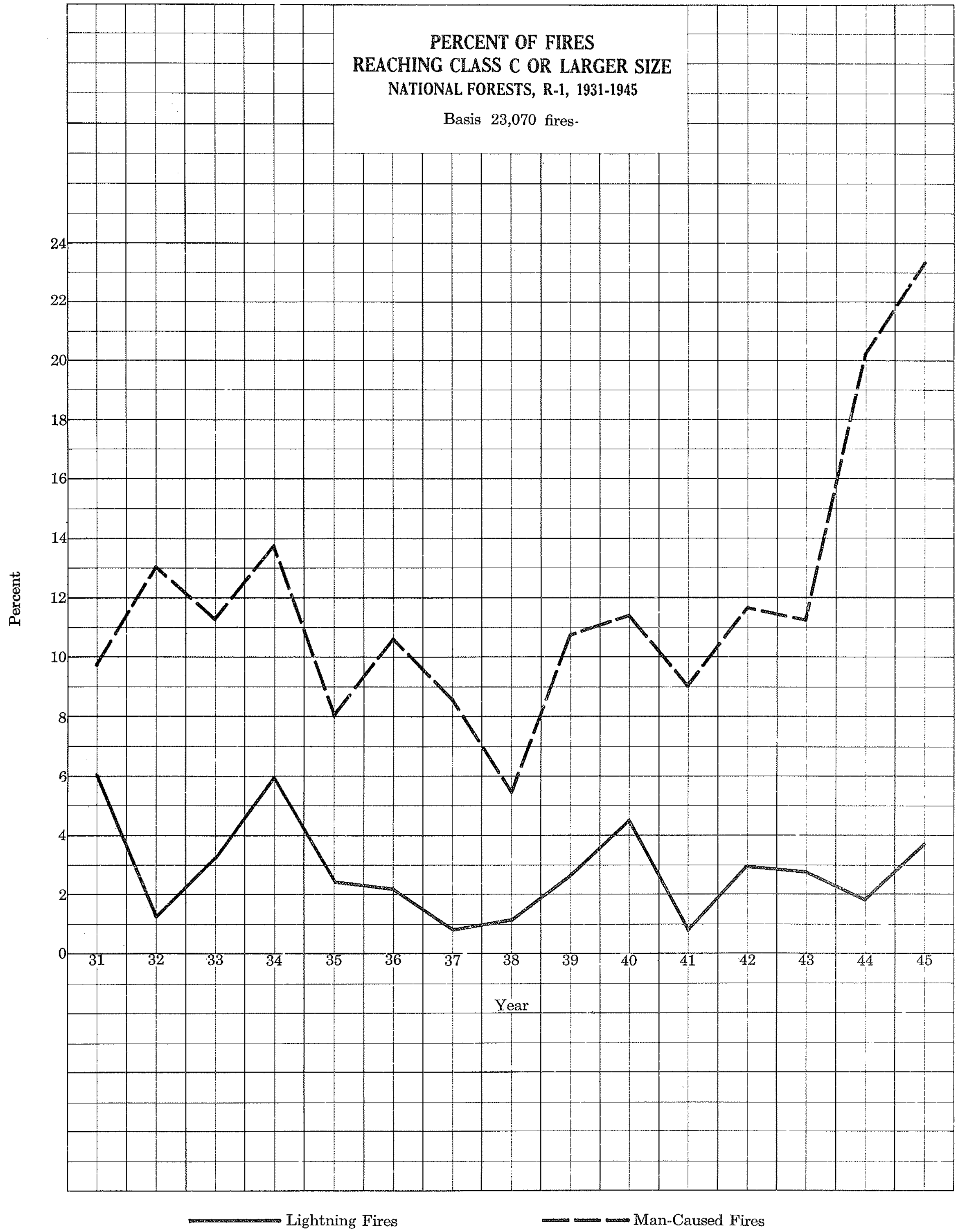

PERCENT OF FIRES
REACHING CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1931-1945
Basis 23,070 fires-
Percent
24
22
20
18
16
14
12
10
8
6
4
2
0
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Year
Lightning Fires
Man-Caused Fires

Figure 15.

percentages shown in figure 15 were reached in easy years. The reverse is true of lightning fires. The critical years of 1931 and 1934 produced the greatest percentages of class C or larger size lightning fires.

Off-season periods produce a high percentage of class C or larger fires. Based upon 15 years of record, one out of every three man-caused fires occurring in the first two decades of April burned more than 10 acres. As shown in figure 16, a high percentage of both lightning and man-caused fires reach large sizes in the spring months. During the regular season the middle 10-day period of August produces a large number of both lightning and man-caused fires over 10 acres in size. During September the percentage of lightning fires reaching class C, D, or E size tapers off sharply from the mid-August peak. However, the percentage of man-caused fires reaching these sizes climbs just as sharply during September.

Forests in the eastern zone have a higher percent of fires reaching class C or larger size. The eastern zone average of nearly 10 percent of the fires in class C, D, or E size is more than double the western zone average of 4 percent. The total number of fires occurring on a forest is inversely related to the number of large size fires. As shown in table 13, the Clearwater forest had only 2 percent class C, D, and E fires, yet this forest leads the region in fire occurrence per million acres. The Beaverhead forest has the greatest percent of large size fires and the lowest fire occurrence in the region.

Percent Burned

Percent of area burned is one measure of protection standards. Many agencies are striving to hold their annual area burned to 1/10 of 1 percent of the area protected. This is a very high standard to achieve when it is applied universally to all lands regardless of the difficulty of the fire control problem. For example, the various protection agencies made the following records during the 1931-1945 period in the two major zones of the region:

Agency	Western Zone	Eastern Zone
National forests	0.22%	0.06%
National parks	0.10%	0.15%
Indian reservations	0.20%	0.32%
State protected lands	0.32%	--
Private associations	0.17%	--

In the national forests of the western zone overburns occurred in 5 out of 15 years. As illustrated in figure 17, more than 1/10 of 1 percent of the area protected was burned in 1931, 1934, 1939, 1940, and 1945. During these 5 years the average annual burn of 122,088 acres is 0.61 percent. During the remaining 10 years the average annual burn of 6685 acres is only 0.03 percent. The great difference between these figures is a dramatic illustration of the need for great flexibility in protection organizations to handle the fire control job in critical years.

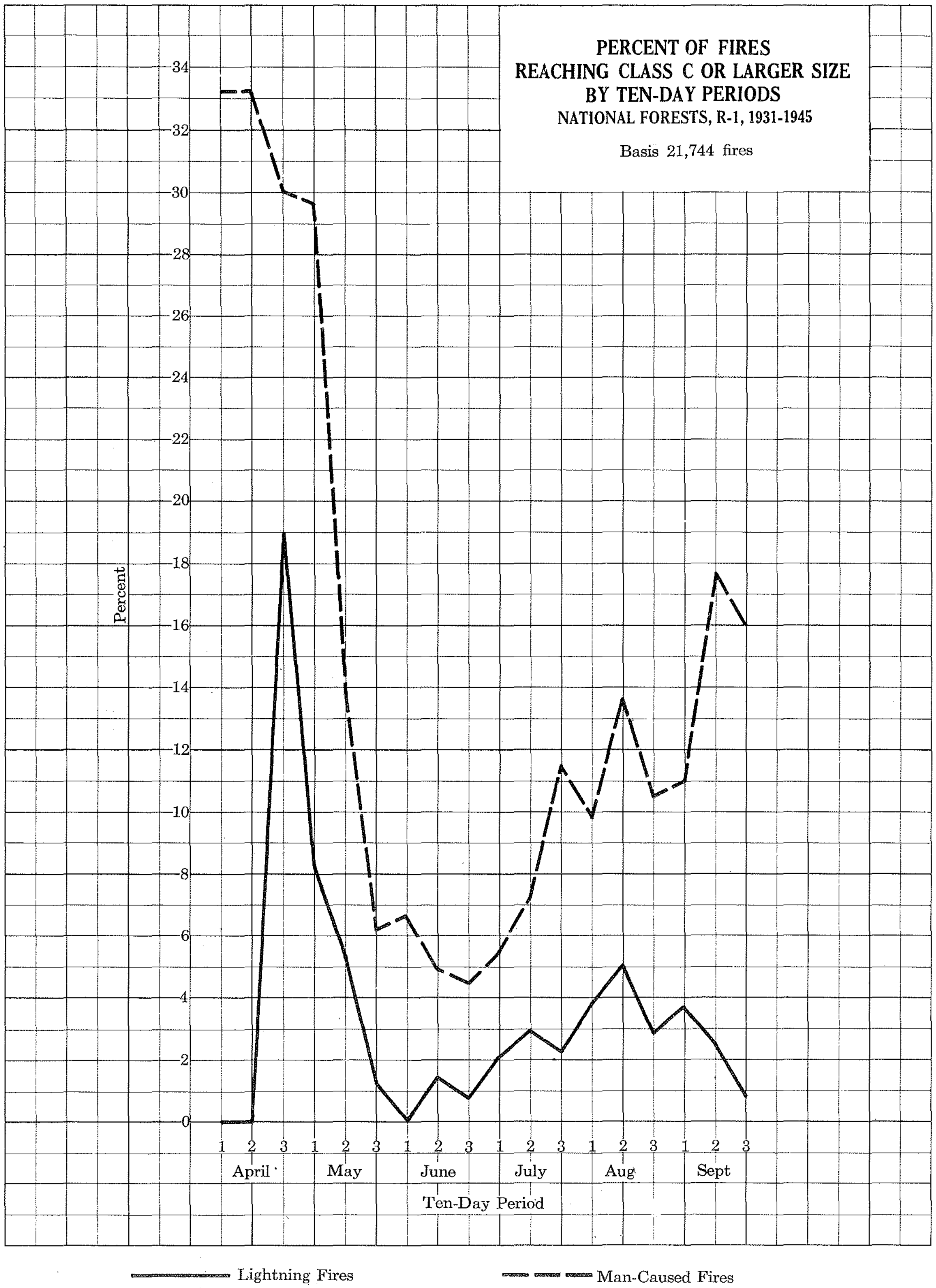

PERCENT OF FIRES
REACHING CLASS C OR LARGER SIZE
BY TEN-DAY PERIODS
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,744 fires
Percent
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1 2 3 1 2 3 1 2 3 1 2 3 1 2 3 1 2 3
April
May
June
July
Aug
Sept
Ten-Day Period
Lightning Fires
Man-Caused Fires

Figure 16.

Table 13. Annual Number and Percent of Fires in Each Size Class, National Forests, R-1, 1931-1945, inclusive

Forest	Class A No.	Class A %	Class B No.	Class B %	Class C No.	Class C %	Class D No.	Class D %	Class E No.	Class E %	Total Classes C,D,E No.	Total Classes C,D,E %
Bitterroot	101.2	78.8	20.5	16.0	4.3	3.3	0.9	0.7	1.5	1.2	6.7	5.2
Cabinet	88.5	74.6	23.5	19.8	4.9	4.1	0.9	0.8	0.8	0.7	6.6	5.6
Clearwater	113.0	88.5	12.2	9.5	1.7	1.3	0.3	0.2	0.6	0.5	2.6	2.0
Coeur d'Alene	61.6	81.4	10.7	14.1	2.6	3.4	0.5	0.7	0.3	0.4	3.4	4.5
Flathead	86.3	83.9	12.4	12.0	3.0	2.9	0.7	0.7	0.5	0.5	4.2	4.1
Kaniksu	105.2	84.6	14.8	11.9	2.7	2.2	0.6	0.5	1.1	0.8	4.4	3.5
Kootenai	87.1	75.6	22.4	19.4	3.7	3.2	0.9	0.8	1.2	1.0	5.8	5.0
Lolo	122.4	76.5	28.5	17.8	6.0	3.7	1.7	1.1	1.5	0.9	9.2	5.7
Nezperce	123.6	85.2	16.2	11.2	2.9	2.0	0.9	0.6	1.5	1.0	5.3	3.6
St. Joe	101.5	87.0	12.3	10.5	2.1	1.8	0.3	0.3	0.5	0.4	2.9	2.5
WESTERN ZONE	990.4	81.5	173.5	14.3	33.9	2.8	7.7	0.6	9.5	0.8	51.1	4.2
Beaverhead	15.5	64.9	5.4	22.6	2.0	8.4	0.7	2.9	0.3	1.2	3.0	12.5
Custer	13.9	48.1	11.5	39.8	3.0	10.4	0.2	0.7	0.3	1.0	3.5	12.1
Deerlodge	38.9	58.3	22.3	33.4	3.8	5.7	1.1	1.7	0.6	0.9	5.5	8.3
Gallatin	23.0	71.4	6.2	19.2	2.0	6.2	0.5	1.6	0.5	1.6	3.0	9.4
Helena	34.4	66.5	12.7	24.6	2.7	5.2	1.0	1.9	0.9	1.8	4.6	8.9
Lewis and Clark	16.2	63.3	6.7	26.2	1.5	5.8	0.4	1.6	0.8	3.1	2.7	10.5
EASTERN ZONE	141.9	62.0	64.8	28.3	15.0	6.6	3.9	1.7	3.4	1.5	22.3	9.7

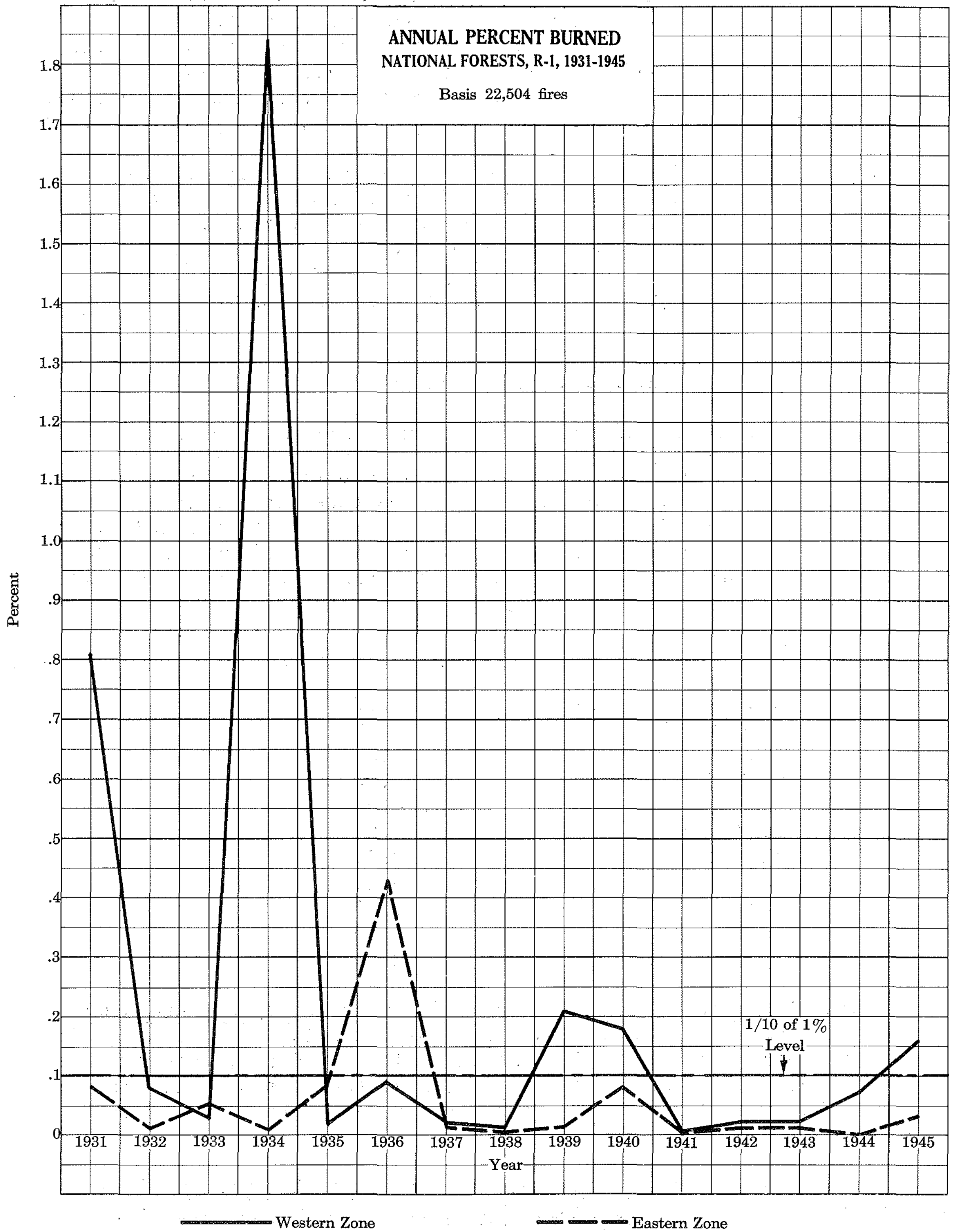

ANNUAL PERCENT BURNED
NATIONAL FORESTS, R-1, 1931-1945
Basis 22,504 fires
Percent
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
Year
1/10 of 1%
Level
Western Zone
Eastern Zone

Figure 17.

In the national forests of the eastern zone an overburn occurred in only one year. (Figure 17.) In 1936 the area burned was 0.43 percent of the area protected. In the remaining 14 years the average annual burn was only 0.02 percent. A characteristic feature of the eastern zone is the occurrence of successive years of easy fire conditions. However, this trend is broken occasionally by a very severe year when greatly increased efforts are necessary to prevent large areas from being swept by fire.

Two separate 10-day periods have produced the greatest burns in the eastern and western zones. As illustrated in figure 18, nearly 50 percent of the area burned in the eastern zone has occurred in the last 10-day period of July. In the western zone over 60 percent of the burn has occurred in the middle 10-day period of August. These two 10-day periods have produced the entire overburn (above 1/10 of 1 percent) in both zones.

Forest Type Standards

Measuring the burn in each forest type is one method of correlating values and protection standards. In 1930 the Forest Service established some guiding standards for tolerable area burned by forest types in each region (9). These standards were based on the best estimates of the value of each major forest type. They were aimed at holding the annual allowable burn in each type to a level commensurate with the values at stake. The following standards were established for northern Rocky Mountain forest types:

Type	Annual % Burn
Western White Pine	0.10
Ponderosa Pine	0.20
Lodgepole Pine	1.00
Larch-Fir	0.25
Douglas-fir	0.30
Grand Fir	0.20
Cedar-Hemlock	0.20
Spruce	0.10
Subalpine	0.50
Brush	2.50
Grass	2.50

In the national forests of the western zone six forest types were overburned during the 1931-1945 period. As illustrated in figure 19, western white pine, ponderosa pine, Douglas-fir, grand fir, Engelmann spruce, and brush were burned at a rate greater than the established standards. The area burned in these six types was 60 percent of the western zone total.

Sizable reductions in burned area were made in several types in 1931-1945 when compared with the 1921-1930 period. As shown in table 14, the average annual burn for all types was less than half that of the 1921-1930 period, and white pine was burned at only one-tenth the former rate. The Douglas-fir, grand fir, brush, and grass types were burned at increased rates. In Engelmann Spruce there was only a slight improvement over the 1921-1930 record.

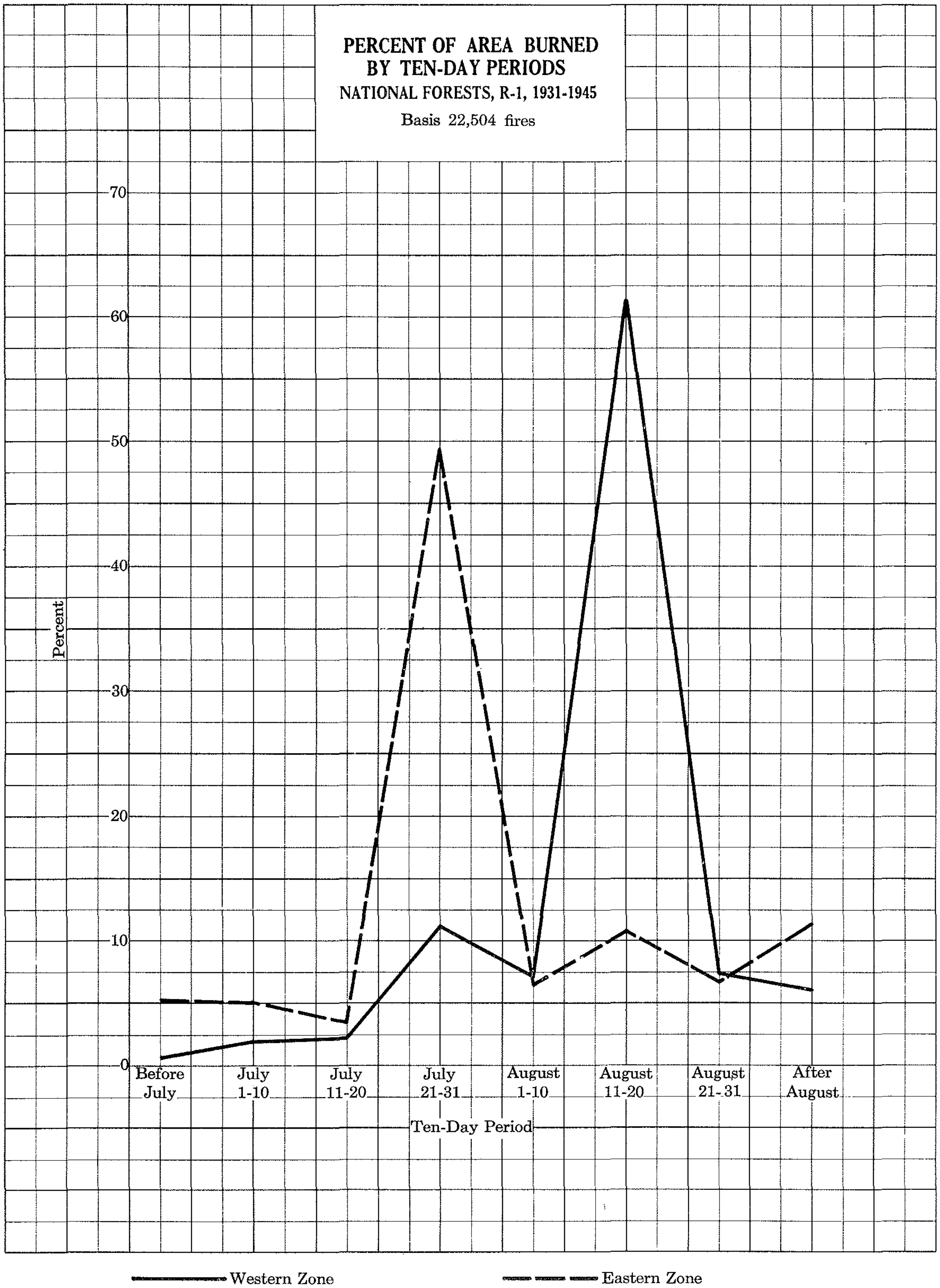
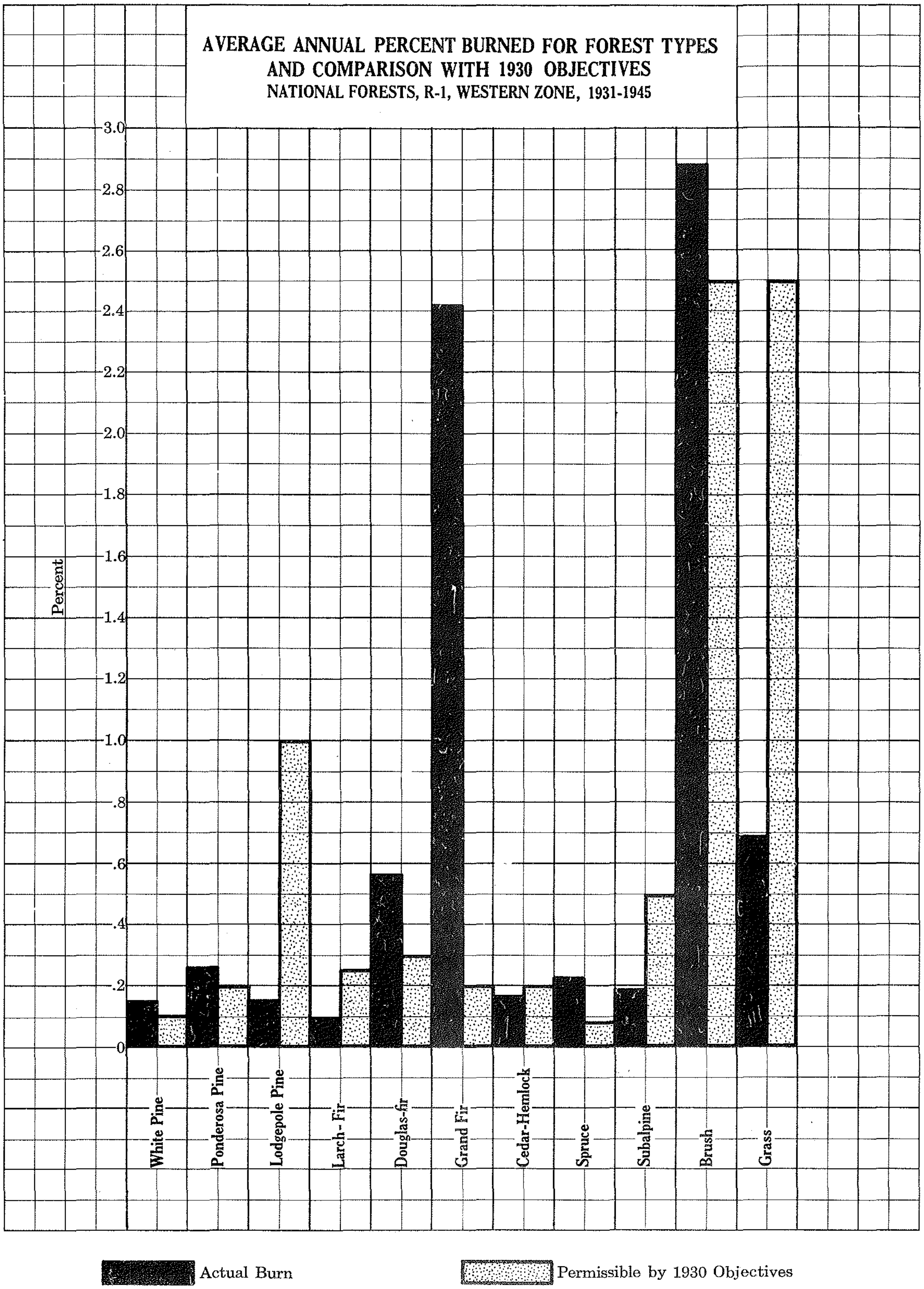

PERCENT OF AREA BURNED
BY TEN-DAY PERIODS
NATIONAL FORESTS, R-1, 1931-1945
Basis 22,504 fires
70
60
50
40
30
20
10
0
Percent
Before July
July 1-10
July 11-20
July 21-31
August 1-10
August 11-20
August 21-31
After August
Ten-Day Period
Western Zone
Eastern Zone

Figure 18.



AVERAGE ANNUAL PERCENT BURNED FOR FOREST TYPES
AND COMPARISON WITH 1930 OBJECTIVES
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1945
Percent
3.0
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
.8
.6
.4
.2
0
White Pine
Ponderosa Pine
Lodgepole Pine
Larch-Fir
Douglas-fir
Grand Fir
Cedar-Hemlock
Spruce
Subalpine
Brush
Grass
Actual Burn
Permissible by 1930 Objectives

Figure 19.

Table 14. Acreage Burned By Timber Types, R-1, National Forests West of Continental Divide, 1921-1930 and 1931-1945, inclusive 1/

Years	Unit	Western White Pine	Ponderosa Pine	Lodgepole Pine	Larch-Fir	Douglas fir	Grand Fir	Cedar-Hemlock	Spruce	Sub-alpine	Brush-Grass	TOTAL
1921 to 1930	Acres	299,748	65,434	131,180	210,905	25,785	55,287	10,969	16,589	141,464	25,438	982,799
	Annual Average Percent	1.416	0.500	0.314	0.680	0.194	1.014	1.294	0.259	0.551	0.763	0.594
1931 to 1945	Acres	61,163	103,676	67,991	61,155	122,838	67,881	7,074	26,969	84,140	62,308	665,195
	Annual Average Percent	0.146	0.267	0.154	0.117	0.571	2.413	0.168	0.234	0.192	3.574	0.235

1/ Excluding Colville National Forest

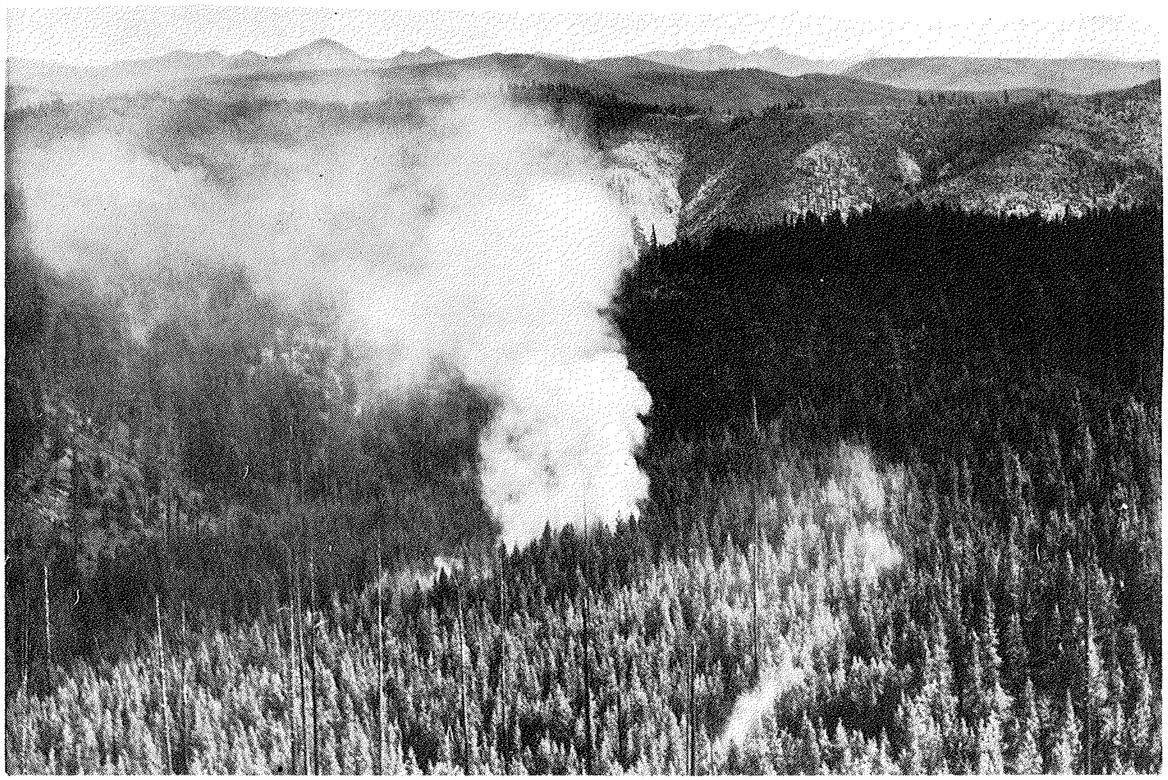
In the national forests of the eastern zone 38 percent of the burn is in lodgepole pine. Because the Forest Survey has not completed a summary of the forest type acreages within the protection boundaries of the eastern zone national forests, it is not known what percent of the lodgepole pine has been burned. However, in view of the intensive stands of lodgepole pine that are known to exist on these forests, this does not appear to be an excessive burn. Ponderosa pine with 16.6 percent of the burn, Douglas-fir with 15.9 percent, and grass with 14.9 percent are the other three types contributing the greatest area burned in this zone.

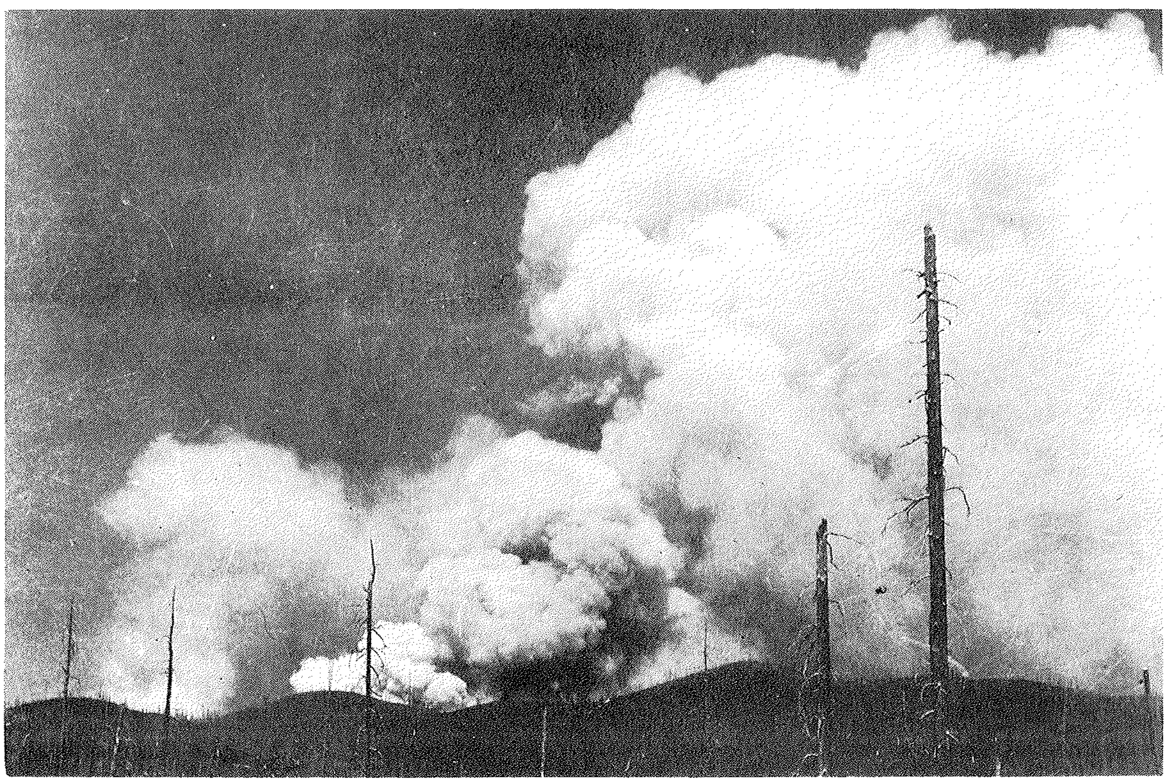
The high percentage of burn in the white pine and ponderosa pine types is a danger signal. These are the two most valuable timber species in the region. In earlier studies Gisborne and Hornby emphasized that these types demanded special attention (5). If the burning rate of the past 25 years were continued, over 62 percent of the white pine and 31 percent of the ponderosa pine would be swept by fire in their average rotation time of 120 years. If the total burn in white pine and ponderosa pine were held to 10 percent in a growing cycle, the protection standard called for would be an average annual burn of 0.08 percent.

Another danger signal is the percent burned in spruce and subalpine types. In many parts of the region these types are associated with the protection of upper watersheds. The growing cycle for these types is 180 years or more. Because of this slow growth fires cause serious and lasting damage. Repetition of the burning rates of the past 25 years would burn 40 percent of the spruce and 56 percent of the subalpine types in the span of a rotation. If a total burn of 15 percent in a rotation were allowed, this would call for an average annual burn of not over 0.08 percent in these types.

The large burn in grand fir reflects the dangerous fuels associated with this type. Grand fir has suffered more from fires than any type in the region -- so much that continuation of past burning rates would cover all of the type in 38 years, exclusive of reburns, or some 60 years prior to the completion of a rotation. The distribution of grand fir is centered in the southwestern corner of the region where, as previously reported, fire conditions are unusually severe. Large numbers of snags are common in grand fir stands, thus contributing measurably to the dangerous fuel conditions and the resultant large burns in this type.

Other measures of values are needed in the establishment of protection standards. From the foregoing analysis it can be seen that some correlation exists between forest types and the standard of protection warranted. However, this is an incomplete story. A full correlation between values and protection standards calls for an evaluation of the effects of forest types and fire damage in those types on all elements of forest worth -- timber production, watershed protection, recreation, wildlife, livestock grazing, and wilderness area preservation.





Forest fire science must continue to uncover the factors which spell the great difference between the small, easily controlled fire and the devastating conflagration.

PART II

FIRE BEHAVIOR

Efficiency, economy, and safety in fire control depend largely upon a thorough understanding of fire behavior. To gain this understanding it is necessary to analyze the separate factors influencing the behavior of fires. Accordingly, in this study the reports of forest fires were analyzed to determine the effects of three major factors -- topography, fuels, and weather. In addition an analysis was made of the combined effects of these factors. In this analysis answers were sought to these basic questions on fire behavior:

1. How is the ignition rate of fires influenced by topography, fuels, and weather?

2. What is the influence of these factors on rate of spread?

3. How may guides to fire behavior be determined for use in designing fire control systems and planning action on going fires?

1. TOPOGRAPHY

Elevation

Major differences in fire behavior occur at various elevation zones. These differences are reflected by distinctive characteristics in the ignition and subsequent rate of spread of fires. They are caused by changes in climate which occur between valley bottoms and mountain summits. These changes are in turn reflected by the character of the vegetative cover and the fuel conditions in which fires may start and spread.

Elevation zones are useful indicators of fire behavior. Many complex factors influence the ignition and rate of spread of fires. Such factors are often difficult to measure and evaluate in the field. However, elevation zones are relatively easy to determine and therefore are useful guides for field personnel in evaluating certain features of fire occurrence and basic rate-of-spread characteristics. In this study elevation zones were determined by 1000-foot intervals ranging from 0-999 feet above sea level to 7000 feet and over. Such broad zones can be readily identified in the various parts of the region.

Over 60 percent of the area in the national forests lies above 5000 feet. As shown in tables 15 and 16, over 43 percent of the western zone and nearly 88 percent of the eastern zone lie above this elevation. In the western zone both the Bitterroot and Flathead National Forests have an average elevation of over 6000 feet. The Colville National Forest has the greatest amount of low country and an average elevation of about 4000 feet. In the eastern zone all forests have an average elevation of over 5000 feet. The Beaverhead and Gallatin National Forests both have an average elevation of approximately 7500 feet. The Custer forest has the lowest average elevation in the eastern zone.

The density of lightning fire occurrence changes sharply in the various elevation zones. On the western forests, as illustrated in figure 20, the greatest density of lightning fires per million acres occurs in the 5000- to 6000-foot elevation zone. On the eastern forests the greatest density is between 3000 and 4000 feet. This 2000-foot difference in lightning fire density is probably due to variations in the fuels available for ignition, the dryness of these fuels during the fire season months, and the character of the lightning storms. More exact determination would require specific research in those fields. However, the fact that the variations in lightning fire density are identifiable in these elevation zones provides a basis for planning appropriate degrees of fire control.

In the northern Idaho forests a belt of very high lightning fire occurrence lies between 5000 and 7000 feet. (Figure 21.) This belt runs through all five national forests from the Canadian border to the Salmon river. Here, on an area of over 2 1/4 million acres lying near the mountain summits, nearly 2400 lightning fires occurred during the 9-year period 1936 through 1944. This is an average annual ignition rate of 116

Table 15. Acreage Within One Thousand-Foot Elevation Zones for the National Forests of Region 1
Western Zone

Forest	Unit	Elevation Zone: 0-999 feet	1000-1999 feet	2000-2999 feet	3000-3999 feet	4000-4999 feet	5000-5999 feet	6000-6999 feet	7000 feet & over	Total
Bitterroot	Acres		1,184	30,388	77,745	217,054	374,911	556,842	833,881	2,092,005
	%		0.06	1.45	3.72	10.38	17.92	26.62	39.85	100.00
Cabinet	Acres			280,340	469,149	476,948	355,453	108,770	43,919	1,734,579
	%			16.16	27.05	27.50	20.49	6.27	2.53	100.00
Clearwater	Acres		10,585	66,535	176,922	373,880	344,393	129,288	2,268	1,103,871
	%		0.96	6.03	16.03	33.87	31.20	11.71	0.20	100.00
Coeur d'Alene	Acres		2,731	282,499	392,923	310,983	86,622	781		1,076,539
	%		0.25	26.24	36.50	28.89	8.05	0.07		100.00
Colville	Acres	3,343	82,090	246,642	424,565	251,099	80,976	7,800		1,096,515
	%	0.31	7.49	22.49	38.72	22.90	7.38	0.71		100.00
Flathead	Acres				325,942	534,840	681,727	682,114	315,091	2,539,714
	%				12.83	21.06	26.84	26.86	12.41	100.00
Kaniksu	Acres		44,845	694,500	533,376	480,197	264,704	85,721		2,103,343
	%		2.13	33.02	25.36	22.83	12.58	4.08		100.00
Kootenai	Acres		20,144	294,802	568,685	616,334	485,784	265,361	64,695	2,315,805
	%		0.87	12.73	24.56	26.61	20.98	11.46	2.79	100.00
Lolo	Acres			72,967	312,771	616,865	752,544	500,513	183,009	2,438,669
	%			2.99	12.82	25.30	30.86	20.52	7.51	100.00
Nezperce	Acres		103,135	165,810	310,200	508,140	521,231	342,727	195,958	2,147,201
	%		4.80	7.72	14.45	23.66	24.27	15.96	9.14	100.00
St. Joe	Acres			158,054	389,477	479,237	408,600	47,222		1,482,590
	%			10.66	26.27	32.32	27.56	3.19		100.00
TOTAL WESTERN ZONE	Acres	3,343	264,714	2,292,537	3,981,755	4,865,577	4,356,945	2,727,139	1,638,821	20,130,831
	%	0.02	1.31	11.39	19.78	24.17	21.64	13.55	8.14	100.00

Table 16. Acreage Within One Thousand-Foot Elevation Zones for the National Forests of Region 1
Eastern Zone

Forest	Unit	Elevation Zone: 0-999 feet	1000-1999 feet	2000-2999 feet	3000-3999 feet	4000-4999 feet	5000-5999 feet	6000-6999 feet	7000 feet and over	Total
Beaverhead	Acres					407	139,166	856,560	1,951,575	2,947,708
	%					0.01	4.72	29.06	66.21	100.00
Custer	Acres			16,837	542,388	466,622	37,683	108,638	517,534	1,689,702
	%			1.02	32.10	27.62	2.22	6.42	30.62	100.00
Deerlodge	Acres					19,800	406,871	662,330	719,014	1,808,015
	%					1.09	22.50	36.63	39.78	100.00
Gallatin	Acres					29,844	266,584	607,780	1,599,505	2,503,713
	%					1.19	10.65	24.28	63.88	100.00
Helena	Acres				25,891	264,167	631,493	570,003	246,772	1,738,326
	%				1.49	15.20	36.33	32.78	14.20	100.00
Lewis and Clark	Acres				19,318	207,369	856,680	900,046	549,964	2,533,377
	%				0.76	8.18	33.82	35.53	21.71	100.00
TOTAL EASTERN ZONE	Acres			16,837	587,597	988,209	2,338,477	3,705,357	5,584,364	13,220,841
	%			0.13	4.44	7.47	17.69	28.03	42.24	100.00
GRAND TOTAL REGION ONE	Acres	3,343	264,714	2,309,374	4,569,352	5,853,786	6,695,422	6,432,496	7,223,185	33,351,672
	%	0.01	0.79	6.92	13.70	17.55	20.08	19.29	21.66	100.00

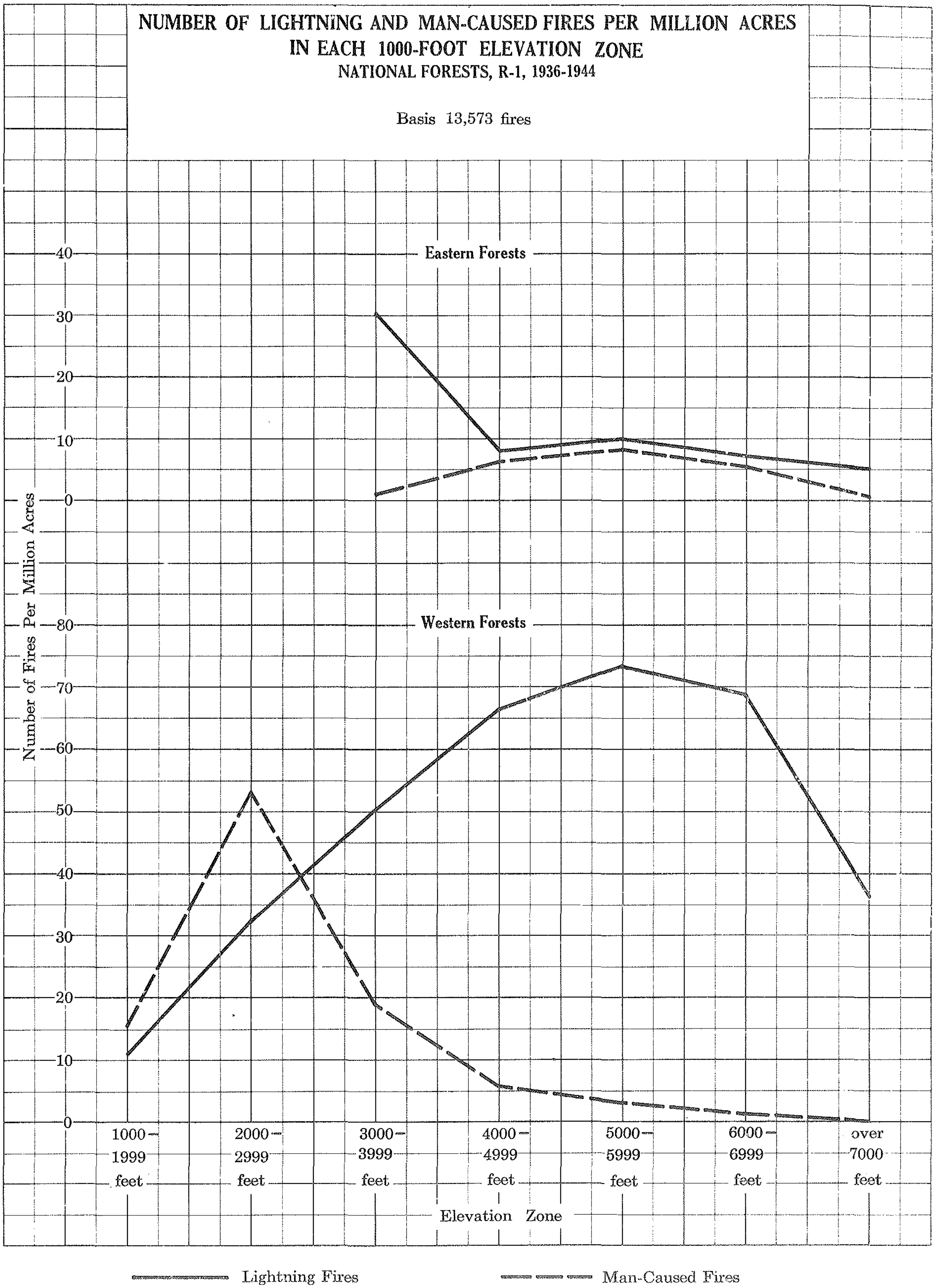

NUMBER OF LIGHTNING AND MAN-CAUSED FIRES PER MILLION ACRES
IN EACH 1000-FOOT ELEVATION ZONE
NATIONAL FORESTS, R-1, 1936-1944
Basis 13,573 fires
Eastern Forests
Western Forests
Number of Fires Per Million Acres
40
30
20
10
0
80
70
60
50
40
30
20
10
0
1000-1999 feet
2000-2999 feet
3000-3999 feet
4000-4999 feet
5000-5999 feet
6000-6999 feet
over 7000 feet
Elevation Zone
Lightning Fires
Man-Caused Fires

Figure 20.

fires per million acres. On the Clearwater forest, as shown in table 17, the annual ignition rate is 177 lightning fires per million acres in both the 5000- to 6000-foot and the 6000- to 7000-foot zones. On the 2200 acres of this forest that lie on the mountain tops just above 7000 feet, the ignition rate reaches the regional high of 440 fires per million acres. In the 6000- to 7000-foot zone the lightning fire ignition rate is 190 on the St. Joe forest, 156 on the Coeur d'Alene, and 123 on the Kaniksu. Similarly, in the 5000- to 6000-foot zone the rate on the Nezperce forest is 110. This distinct and readily identifiable lightning belt obviously calls for intense efforts in fire detection and a sizable force for smokechasing action.

On the eastern forests the highest lightning ignition rate is in the lowest elevation zones. Two forests, the Custer and the Helena, with a total area of 568,279 acres in the 3000- to 4000-foot zone, account for this entire load. During the 1936-1944 period a total of 161 lightning fires occurred in this elevation zone. As shown in table 18, this amounts to an ignition rate of 31 fires per million acres on the Custer forest and 34 on the Helena. As shown in table 16, all eastern forests have relatively high elevation factors. However, the lightning ignition rate in the upper elevation zones is not correspondingly high.

Elevation is not a critical factor in ignition rates of man-caused fires. As shown in tables 17 and 18, the greatest density of man-caused fires normally occurs in the lower elevation zones where Man's activities are most intense. The Cabinet forest's ignition rate of 156 man-caused fires per million acres in the 2000- to 3000-foot zone is the highest in the region.

Most fires are of small size in the higher elevation zones. More fires reach larger sizes in the lower than in the higher elevation zones. As shown in figure 22, this trend has been observed on the eastern and western forests. In the lowest elevation zone for the western forests 69 percent of the fires are held to class A size, whereas in the upper zones over 85 percent are in this size class. In the lowest zone for the eastern forests only 45 percent are held to class A size, while in the highest zone 73 percent are confined to this small size. Thus higher rates of spread are more likely for fires originating in the lower elevation zones. The distribution of over 13,000 fires by size class and elevation zone for all Region 1 national forests is shown in tables 19 and 20.

The perimeter of fires varies according to elevation zones. As illustrated in figure 23, the western forests have an annual rate of over 2600 chains of fire perimeter per million acres in the 1000- to 2000-foot elevation zone. This rate decreases steadily through all elevations to a low of 600 chains per million acres in the zone lying above 7000 feet. The average perimeter per fire likewise varies from 99 chains in the lowest elevation zone to 15 chains in the highest zone. (Figure 24.) On the eastern forests the perimeter per fire is slightly greater in the higher elevation zones than on the western forests.

Table 17. Annual Number of Fires Per Million Acres by Elevation Zones, Western Forests, R-1, 1936-1944, inclusive 1/

(Basis 13,573 fires)

Forest	Cause 2/	Elevation zone: 1000-1999 feet	2000-2999 feet	3000-3999 feet	4000-4999 feet	5000-5999 feet	6000-6999 feet	7000 ft. & over	Total
Bitterroot	L		58.58	35.76	93.66	84.18	54.88	27.05	52.37
	M			27.14	19.44	5.63	1.99	0.26	4.67
	T		58.58	62.90	113.10	89.81	56.87	27.31	57.04
Cabinet	L		30.53	40.97	45.90	47.52	65.37	12.75	42.79
	M		156.56	12.55	6.06	2.19	1.01		31.00
	T		187.09	53.52	51.96	49.71	66.38	12.75	73.79
Clearwater	L		21.64	77.26	136.41	177.12	177.05	440.92	136.79
	M	10.39	10.07	9.44	2.09	8.07	0.85		5.54
	T	10.39	31.71	86.70	138.50	185.19	177.90	440.92	142.33
Coeur d'Alene	L		26.76	49.78	83.96	85.89	156.21		57.49
	M		49.95	19.80	3.57	5.08			21.77
	T		76.71	69.58	87.53	90.97	156.21		79.26
Flathead	L			58.29	41.34	33.58	44.30	33.51	41.34
	M			26.26	4.15	1.79	0.48	0.70	4.95
	T			84.55	45.49	35.37	44.78	34.21	46.29
Kaniksu	L	7.36	29.60	53.11	62.70	87.30	123.19		53.93
	M	9.81	23.67	8.12	1.40	1.25	12.83		10.62
	T	17.17	53.27	61.23	64.10	88.55	136.02		64.55
Kootenai	L	21.84	42.60	63.69	63.46	45.06	27.21	15.46	51.20
	M	49.64	42.20	13.49	21.58	0.68	0.41		9.88
	T	71.48	84.80	77.18	85.04	45.74	27.62	15.46	61.08
Lolo	L		16.72	44.76	51.16	53.59	71.49	53.44	54.40
	M		89.90	58.60	12.26	1.77	1.12	0.60	14.12
	T		106.62	103.36	83.42	55.36	72.61	54.04	68.52
Nezperce	L	10.76	26.78	39.75	74.57	109.78	98.56	66.90	74.46
	M	8.63	10.74	8.96	5.04	5.76	5.19	1.68	6.10
	T	19.39	37.52	48.71	79.61	115.54	103.75	68.58	80.56
St. Joe	L		52.01	39.95	60.51	80.49	190.59		63.93
	M		86.49	22.54	4.17	2.18	9.32		17.54
	T		138.50	62.49	64.68	82.67	199.91		81.47
TOTAL WESTERN ZONE	L	10.95	32.53	50.79	66.99	73.72	69.26	36.00	58.89
	M	15.22	53.55	19.08	5.49	3.09	1.72	0.54	11.78
	T	26.17	86.08	69.87	72.48	76.81	70.98	36.54	70.67

1/ Excluding Colville

2/ L - Lightning; M - Man-Caused; T - Total

Table 18. Annual Number of Fires Per Million Acres by Elevation Zones, Eastern Forests, R-1, 1936-1944, inclusive

(Basis 3220 fires)

Forest	Cause 2/	Elevation Zone 3000-3999 feet	4000-4999 feet	5000-5999 feet	6000-6999 feet	7000 ft. & over	Total
Beaverhead	L				4.16	4.50	4.18
	M			4.81	3.24	1.25	2.00
	T			4.81	7.40	5.75	6.18
Custer	L	31.34	1.91	11.68	9.20	2.14	12.10
	M	1.64	0.24	5.84	1.01	1.51	1.25
	T	32.98	2.15	17.52	10.21	3.65	13.35
Deerlodge	L		16.67	14.48	11.41	12.21	12.48
	M		28.28	25.12	14.25	3.24	12.48
	T		44.95	39.60	25.66	15.45	24.96
Gallatin 1/	L		7.38	4.99	6.76	3.40	4.43
	M		14.74	9.60	8.95	0.83	3.91
	T		22.12	14.59	15.71	4.23	8.34
Helena	L	34.37	23.13	19.89	7.21	9.89	15.02
	M		18.09	7.92	2.74	1.34	6.71
	T	34.37	41.22	27.81	9.95	11.23	21.73
Lewis and Clark	L		2.12	4.02	6.04	7.87	5.40
	M		2.12	2.85	1.36		1.62
	T		4.24	6.87	7.40	7.87	7.02
TOTAL EASTERN ZONE	L	30.45	8.10	10.12	6.96	5.53	8.03
	M	1.51	6.40	9.03	5.55	1.29	4.24
	T	31.96	14.50	19.15	12.51	6.82	12.27

1/ Including Absaroka

2/ L - Lightning; M - Man-Caused; T - Total

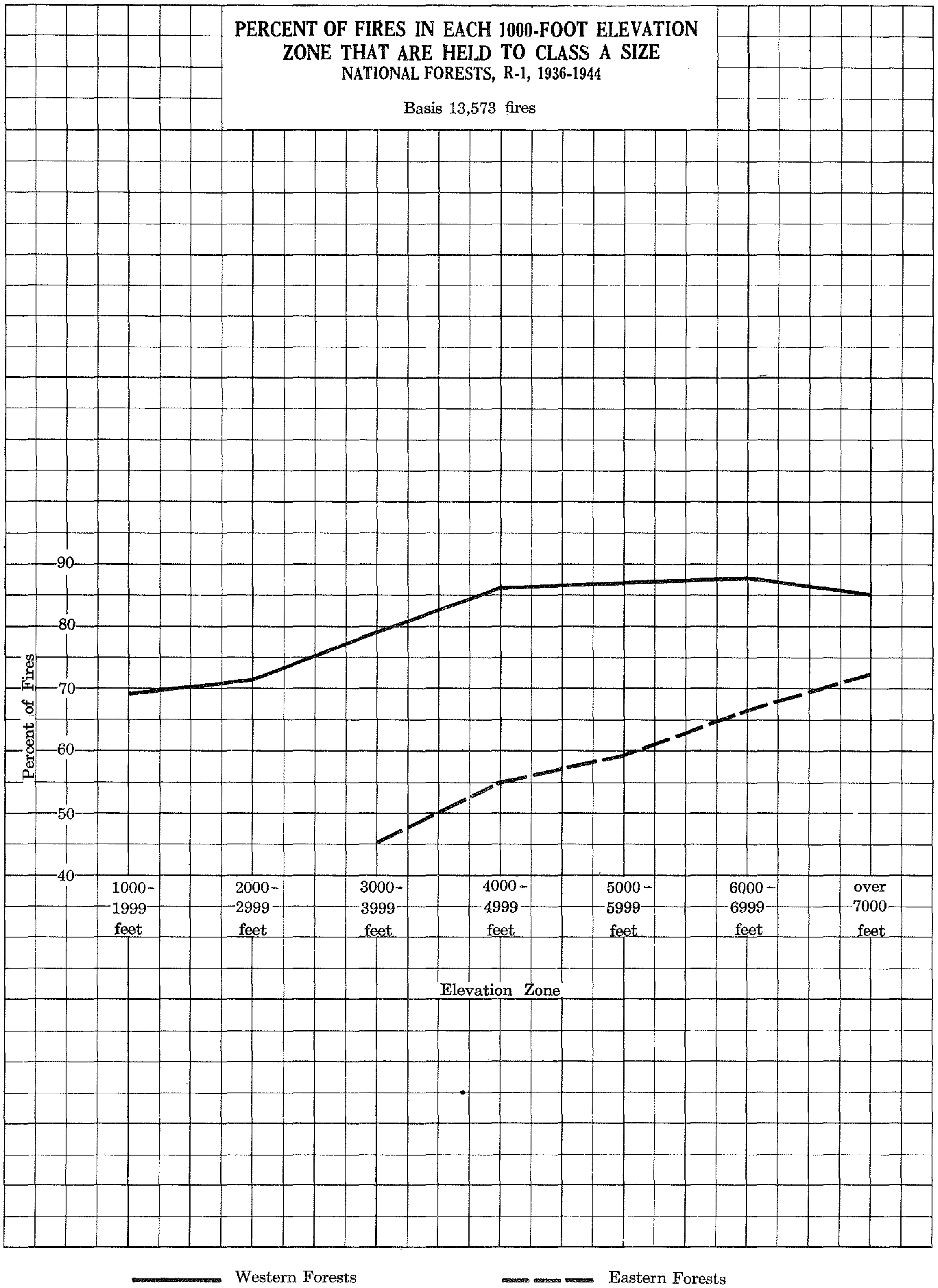

PERCENT OF FIRES IN EACH 1000-FOOT ELEVATION
ZONE THAT ARE HELD TO CLASS A SIZE
NATIONAL FORESTS, R-1, 1936-1944
Basis 13,573 fires
90
80
70
60
50
40
Percent of Fires
1000-
1999
feet
2000-
2999
feet
3000-
3999
feet
4000-
4999
feet
5000-
5999
feet
6000-
6999
feet
over
7000
feet
Elevation Zone
Western Forests
Eastern Forests

Figure 22.

Table 19. Number and Percent of Fires by 1000-Foot Elevation Zones and Size Classes, Western Zone, National Forests, R-1, 1936-1944, inclusive

(Basis 12,107 fires)

Forest	Zone and Size Class																																		
	1000-1999 feet					2000-2999 feet					3000-3999 feet					4000-4999 feet					5000-5999 feet					6000-6999 feet					7000 feet & over				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Bitterroot						16					28	13	2		1	181	26	11		3	250	46	4	1	2	231	33	14	4	3	151	41	10	2	1
Cabinet	1					305	136	27	1	3	188	31	6		1	190	29	2	2		134	24	1			57	8				5				
Clearwater	1					16	1	1		1	114	19	4	1		417	42	6		1	520	48	5	1		184	20	3			9				
Coeur d'Alene						129	54	11	1		200	41	3	1	1	228	13	2		2	65	5	1			11									
Flathead						2					212	26	6	4		182	27	5	3	2	162	40	12	1	2	236	32	7			91	4	2		
Kaniksu	4	2			1	257	57	12	4	3	248	37	4	1	4	253	22	2			187	20	3	1		90	5	1			3	1			
Kootenai	10	3				166	47	7	3	2	296	82	12	3	2	273	71	15	2	3	155	39	1	2	3	59	4	3			9				
Lolo						55	13	1	1		189	68	24	8	2	287	55	8		2	308	59	7		1	281	39	6	1		83	6			
Nezperce	12	3			3	38	13	1	2	2	109	17	6	3	1	319	35	7	3		492	46	2		2	295	22	2		1	109	10	2		
St. Joe	2	1				152	32	11	1	1	185	30	4			261	16	1		1	290	12	2			81	3	1							
GRAND TOTAL WESTERN ZONE	30	9			4	1136	353	71	13	12	1769	364	71	21	12	2591	336	59	10	14	2563	339	38	6	10	1525	166	37	5	4	460	62	14	2	1
ZONE PERCENTAGE	69.8	20.9			9.3	71.7	22.3	4.5	0.8	0.7	79.1	16.3	3.2	0.9	0.5	86.1	11.2	2.0	0.3	0.4	86.7	11.5	1.3	0.2	0.3	87.8	9.6	2.1	0.3	0.2	85.3	11.5	2.6	0.4	0.2

Table 20. Number and Percent of Fires by 1000-Foot Elevation Zones and Size Classes, Eastern Zone, National Forests, R-1, 1936-1944, inclusive

(Basis 1,461 fires)

Forest	Zone and Size Class																								
	3000-3999 feet					4000-4999 feet					5000-5999 feet					6000-6999 feet					7000 feet & over				
	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Beaverhead											3	3				39	10	5	2	1	68	24	5	4	
Custer	69	74	16	2		2	6	1			3	3				4	5	1			13	3	1		
Deerlodge						2	3	3			71	51	14	7	2	88	57	5	1	2	67	28	4	1	
Gallatin 1/						2	2	1	1		21	8	4	1	1	68	13	4		1	49	9	3		
Helena	7		1			62	23	9	3	1	105	35	13	3	2	35	13	1	2		21	3	1		
Lewis and Clark						3	5				35	13	3		2	44	9	5	1	1	31	6	2		
GRAND TOTAL EASTERN ZONE	76	74	17	2		71	39	14	4	1	238	113	34	11	7	278	107	21	6	5	249	73	16	5	
ZONE PERCENTAGE	45.0	43.8	10.0	1.2		55.0	30.2	10.9	3.1	0.8	59.1	28.0	8.4	2.7	1.8	66.7	25.7	5.0	1.4	1.2	72.6	21.3	4.7	1.4	

1/ Includes Absaroka

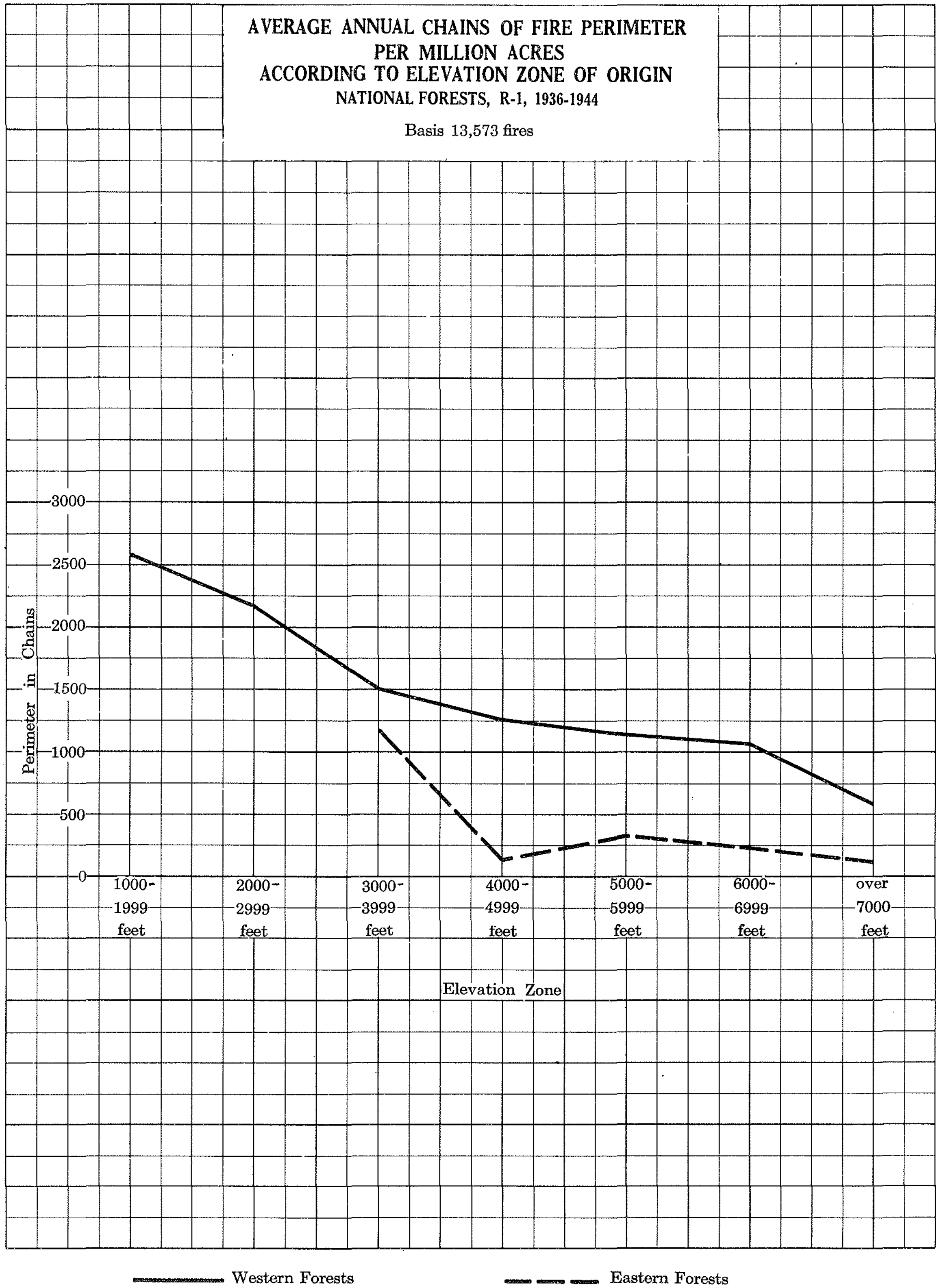

AVERAGE ANNUAL CHAINS OF FIRE PERIMETER
PER MILLION ACRES
ACCORDING TO ELEVATION ZONE OF ORIGIN
NATIONAL FORESTS, R-1, 1936-1944
Basis 13,573 fires
Perimeter in Chains
3000
2500
2000
1500
1000
500
0
1000-1999 feet
2000-2999 feet
3000-3999 feet
4000-4999 feet
5000-5999 feet
6000-6999 feet
over 7000 feet
Elevation Zone
Western Forests
Eastern Forests

Figure 23.

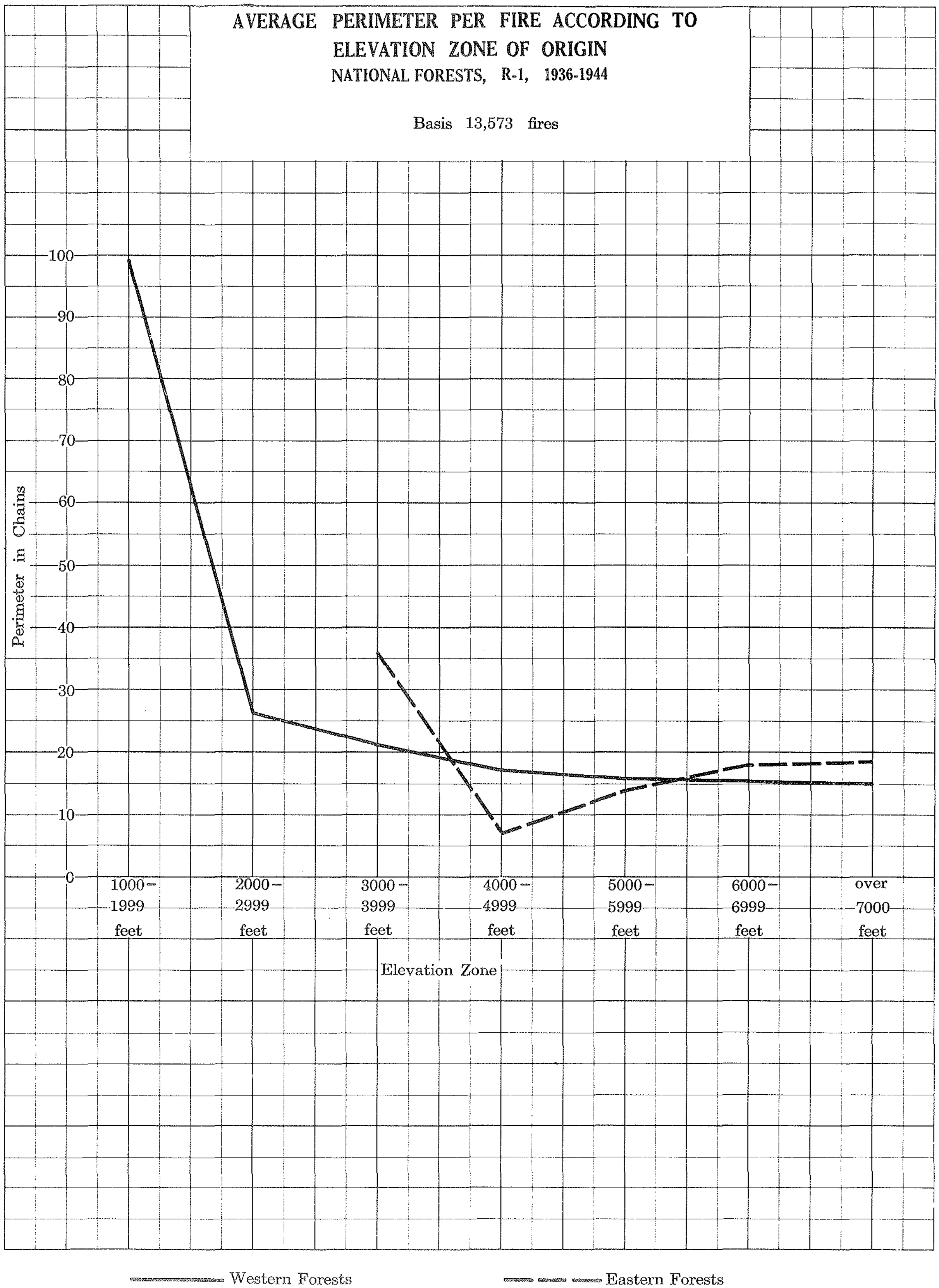

AVERAGE PERIMETER PER FIRE ACCORDING TO
ELEVATION ZONE OF ORIGIN
NATIONAL FORESTS, R-1, 1936-1944
Basis 13,573 fires
Perimeter in Chains
100
90
80
70
60
50
40
30
20
10
0
1000—1999 feet
2000—2999 feet
3000—3999 feet
4000—4999 feet
5000—5999 feet
6000—6999 feet
over 7000 feet
Elevation Zone
Western Forests
Eastern Forests

Figure 24.

The greatest amount of fire business is in the middle elevation zones. The total annual perimeter of fires on the national forests averages over 32,000 chains or 400 miles. As illustrated in figure 25, the greatest part of this perimeter results from fires occurring in the middle elevation zones of the two sections of the region. On the western forests fires originating between 3000 and 5000 feet spread to an average annual total of 12,000 chains. On the eastern forests in the zone between 5000 and 7000 feet this average annual perimeter is 3400 chains. This fire load is a result of the area in these zones, the number of fires occurring, and the existing combination of fuel and weather conditions.

Aspect

The greatest number of fires occur on slopes facing south. The ignition rate of fires increases steadily around the compass from north to south. As shown in figure 26, nearly 15 percent of the fires originate on south slopes; and over 41 percent originate on southeast, south, and southwest slopes. Fire occurrence is lowest on northwest, north, and northeast slopes. Only 7 percent of the fires occur on level ground because the country is so mountainous.

Southwest slopes produce the greatest number of large size fires. As illustrated in figure 27, over 7 percent of the fires originating on southwest slopes spread to class C or larger size, as compared to less than 3 percent on north slopes. In the national forests of Region 1 a total of 98 fires over 300 acres in size occurred on southeast, south, and southwest slopes during the period 1931 through 1944. As shown in table 21, this is 54 percent of the class E fires that occurred during the 14-year period.

Aspect is an important indicator of fire behavior. From the discussion in the foregoing paragraphs it is evident that aspect is an important factor in determining both the ignition rate and the final size of fires. The ignition rate is 1.7 times greater on south than on northwest slopes. The potential for large size fires is 2.7 times greater on southwest slopes than on north slopes. The ignition rate and large fire potential for all slopes is as follows:

Slope	Ignition Rate	Large Fire Potential
North	1.112	1.000
Northeast	1.233	1.253
East	1.315	1.404
Southeast	1.341	1.895
South	1.704	2.494
Southwest	1.586	2.654
West	1.318	1.686
Northwest	1.000	1.331

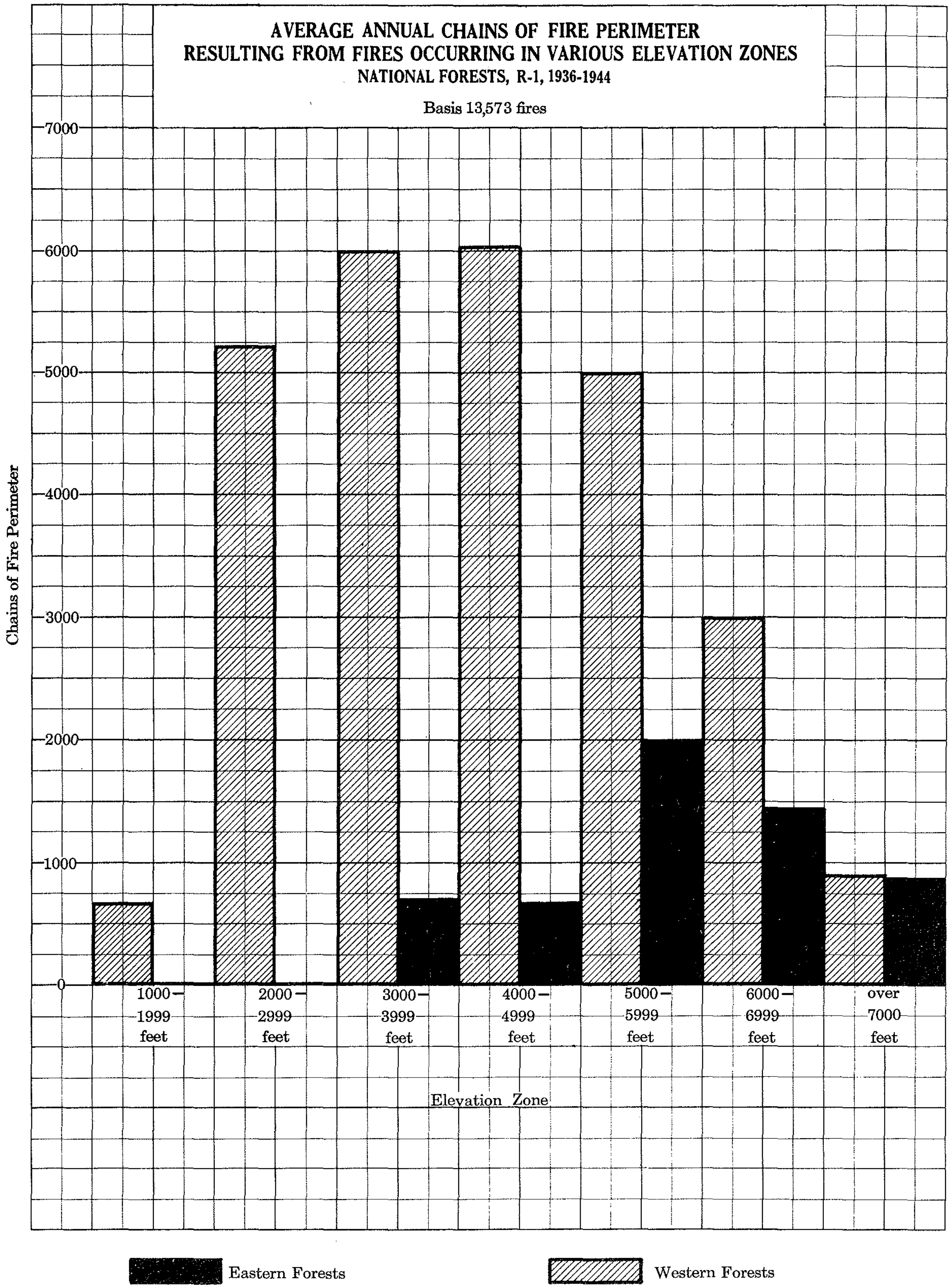

AVERAGE ANNUAL CHAINS OF FIRE PERIMETER
RESULTING FROM FIRES OCCURRING IN VARIOUS ELEVATION ZONES
NATIONAL FORESTS, R-1, 1936-1944
Basis 13,573 fires
Chains of Fire Perimeter
7000
6000
5000
4000
3000
2000
1000
0
1000-1999 feet
2000-2999 feet
3000-3999 feet
4000-4999 feet
5000-5999 feet
6000-6999 feet
over 7000 feet
Elevation Zone
Eastern Forests
Western Forests

Figure 25.

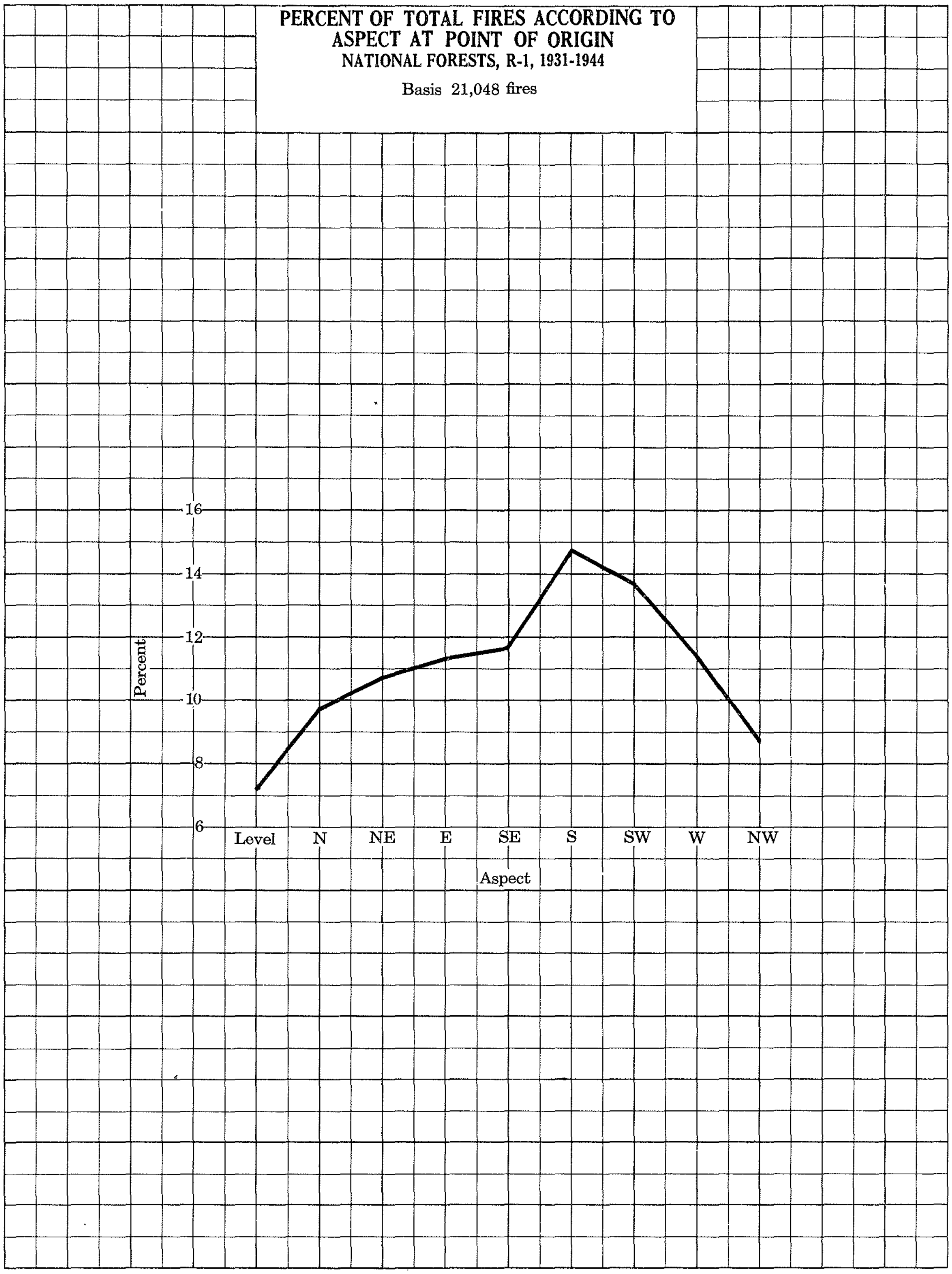

PERCENT OF TOTAL FIRES ACCORDING TO
ASPECT AT POINT OF ORIGIN
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,048 fires
Percent
16
14
12
10
8
6
Level
N
NE
E
SE
S
SW
W
NW
Aspect

Figure 26.

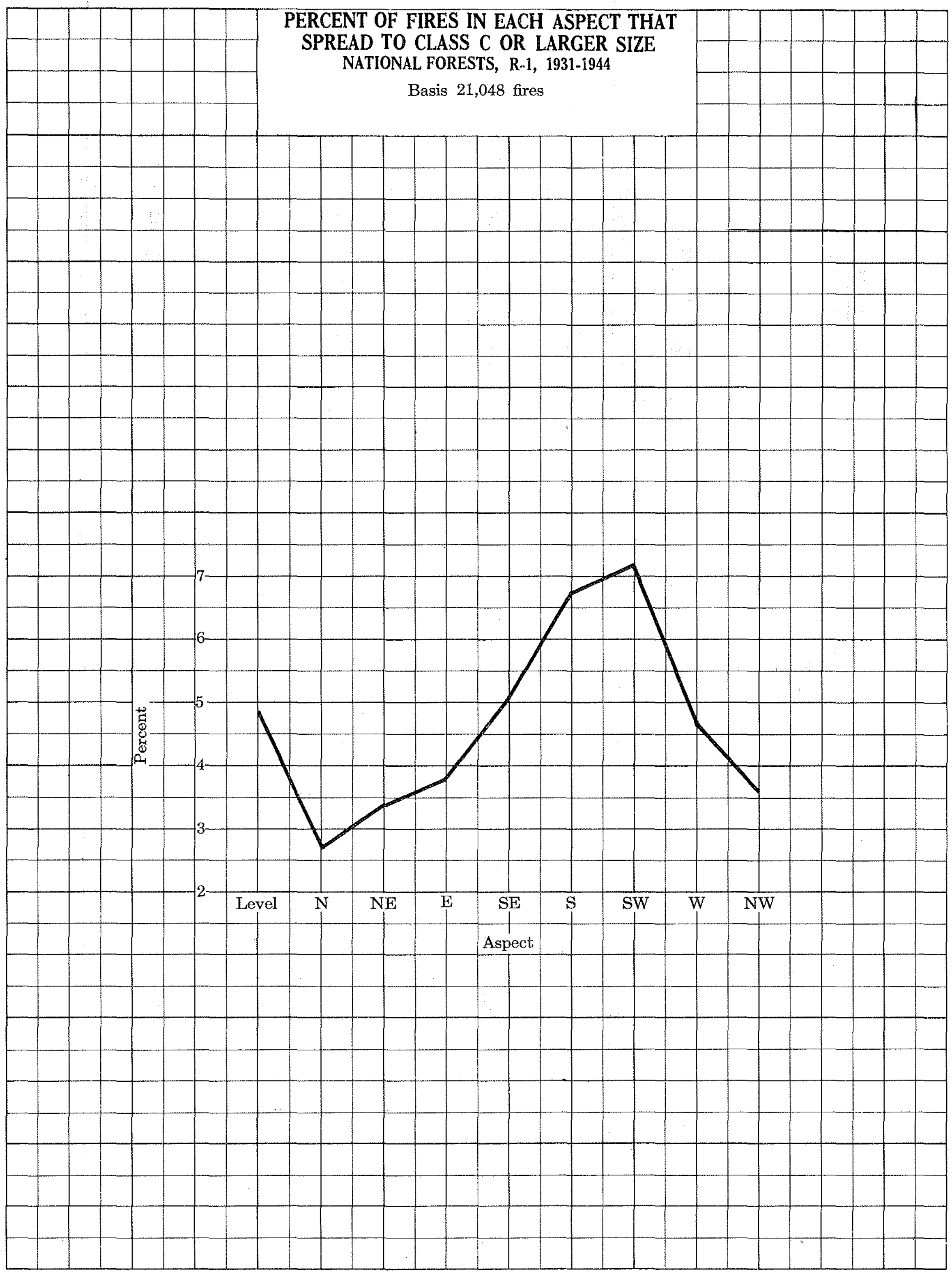

PERCENT OF FIRES IN EACH ASPECT THAT
SPREAD TO CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,048 fires
Percent
7
6
5
4
3
2
Level
N
NE
E
SE
S
SW
W
NW
Aspect

Figure 27.

Table 21. Total Number and Percent of Fires According to Exposure at Point of Origin and Final Size Class, National Forests, R-1, 1931-1944, inclusive

(Basis 21,048 fires)

Size Class	Level or Ridgetop		North		Northeast		East		Southeast		South		Southwest		West		Northwest		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A	1,184	7	1,747	11	1,886	11	1,970	12	1,886	11	2,332	14	2,153	13	1,976	12	1,526	9	16,660	100
B	253	7	245	7	306	9	359	11	456	14	591	18	556	17	340	10	248	7	3,354	100
C	49	7	34	5	50	7	60	9	88	13	143	21	137	20	73	11	44	7	678	100
D	12	7	13	7	12	7	19	11	21	12	37	21	30	17	19	11	12	7	175	100
E	13	7	9	5	16	9	14	8	19	10	34	19	45	25	20	11	11	6	181	100
TOTAL	1,511	7	2,048	10	2,270	10	2,422	11	2,470	12	3,137	15	2,921	14	2,428	12	1,841	9	21,048	100

Topography at Point of Origin

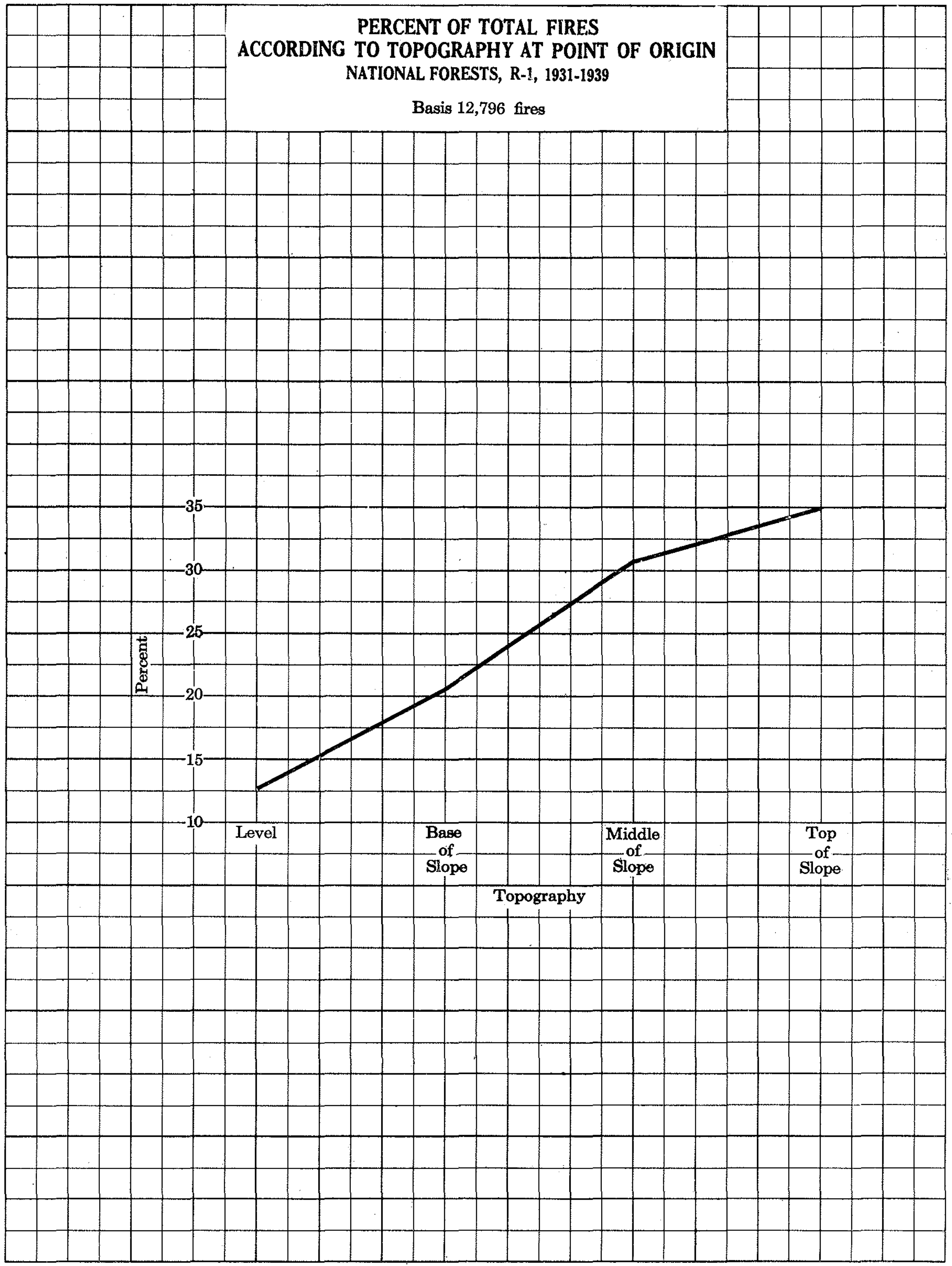
The greatest number of fires occur near the top of a slope. The fact that the ignition rate is higher near the top of a slope is a further result of the intense lightning fire occurrence at the upper elevations. As illustrated in figure 28, the ignition rate increases from the base of a slope to the top. Over 35 percent of the fires occur at the top of a slope and 31 percent in the middle of a slope. This study, which was based on 12,796 fires occurring during the 1931-1939 period, shows a somewhat higher percentage of fires occurring on level ground than did the aspect study which included the entire period 1931 through 1944. This slight variance is due to the different number of fires in the sample and the fact that some fires listed for an aspect other than level were on such gentle slopes as to be included in the level category in the topographic position study. In each study the number of fires occurring in level areas was less than on any slope.

The greatest number of large fires originate at the base of a slope. As illustrated in figure 29, nearly 11 percent of the fires originating in this topographic position spread to class C or larger size, while less than 2 percent of the fires at the top of a slope reach such size. During the 1931-1939 period 60 out of a total of 131 class E fires started at the base of a slope. This does not necessarily mean that rate of spread is consistently greater at the base of a slope. However, it does indicate that greater fuel bodies are available from the bottom of a slope. Hayes has shown that the rate-of-spread potential is greater in the thermal belt which is most often in the middle of the slope (3). The average annual number of fires by size class and topography is shown in table 22.

Steepness of Slope

The greatest number of fires occur on gentle slopes. In a study of 21,158 fires it was found that over 35 percent originated on slopes ranging from 0 to 20 percent. As illustrated in figure 30, when the steepness of the slope increases, the number of fires decreases. This decrease in occurrence on the steeper slopes is a result of the character of the topography. Greater areas of gentle slopes occupied by combustible fuels are available as places for fires to start.

A higher percentage of fires spread to large size on steep slopes. During the 1931-1944 period 141 fires originating on slopes of over 60 percent reached class C or larger size. As shown in figure 31, this was over 7 percent of the number of fires occurring on these steep slopes. In the 0 to 20 percent class less than 4 percent of the fires spread to sizes greater than 10 acres. This study shows that the large fire potential is 1.8 times greater on steep than on gentle slopes. The distribution of over 21,000 fires by size and slope class is shown in table 23.



PERCENT OF TOTAL FIRES
ACCORDING TO TOPOGRAPHY AT POINT OF ORIGIN
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,796 fires
Percent
35
30
25
20
15
10
Level
Base of Slope
Middle of Slope
Top of Slope
Topography

Figure 28

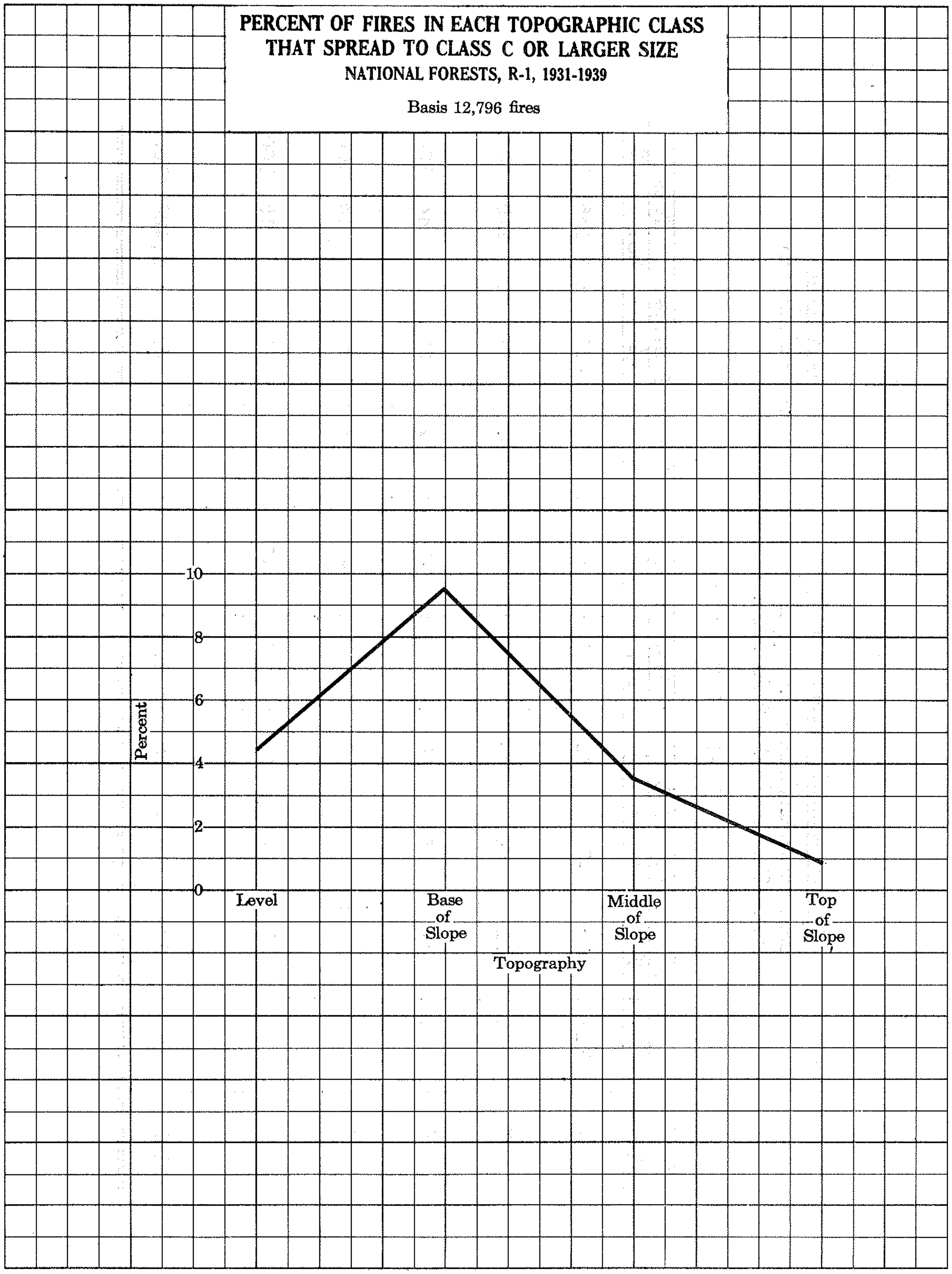

PERCENT OF FIRES IN EACH TOPOGRAPHIC CLASS
THAT SPREAD TO CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,796 fires
Percent
10
8
6
4
2
0
Level
Base of Slope
Middle of Slope
Top of Slope
Topography

Figure 29.

Table 22. Average Annual Number and Percent of Fires According to Topography at Point of Origin and Final Size Class, National Forests, R-1, 1931-1939, inclusive

(Basis 12,796 fires)

Size Class	Level		Top of Slope		Base of Slope		Middle of Slope		Total	
	No.	%	No.	%	No.	%	No.	%	No.	%
A	147	13	436	39	197	17	355	31	1,135	100
B	24	11	56	26	66	31	69	32	215	100
C	6	14	7	16	19	43	12	27	44	100
D	2	15	1	8	6	46	4	31	13	100
E	2	13	2	13	7	47	4	27	15	100
TOTAL	181	13	502	35	295	21	444	31	1,422	100

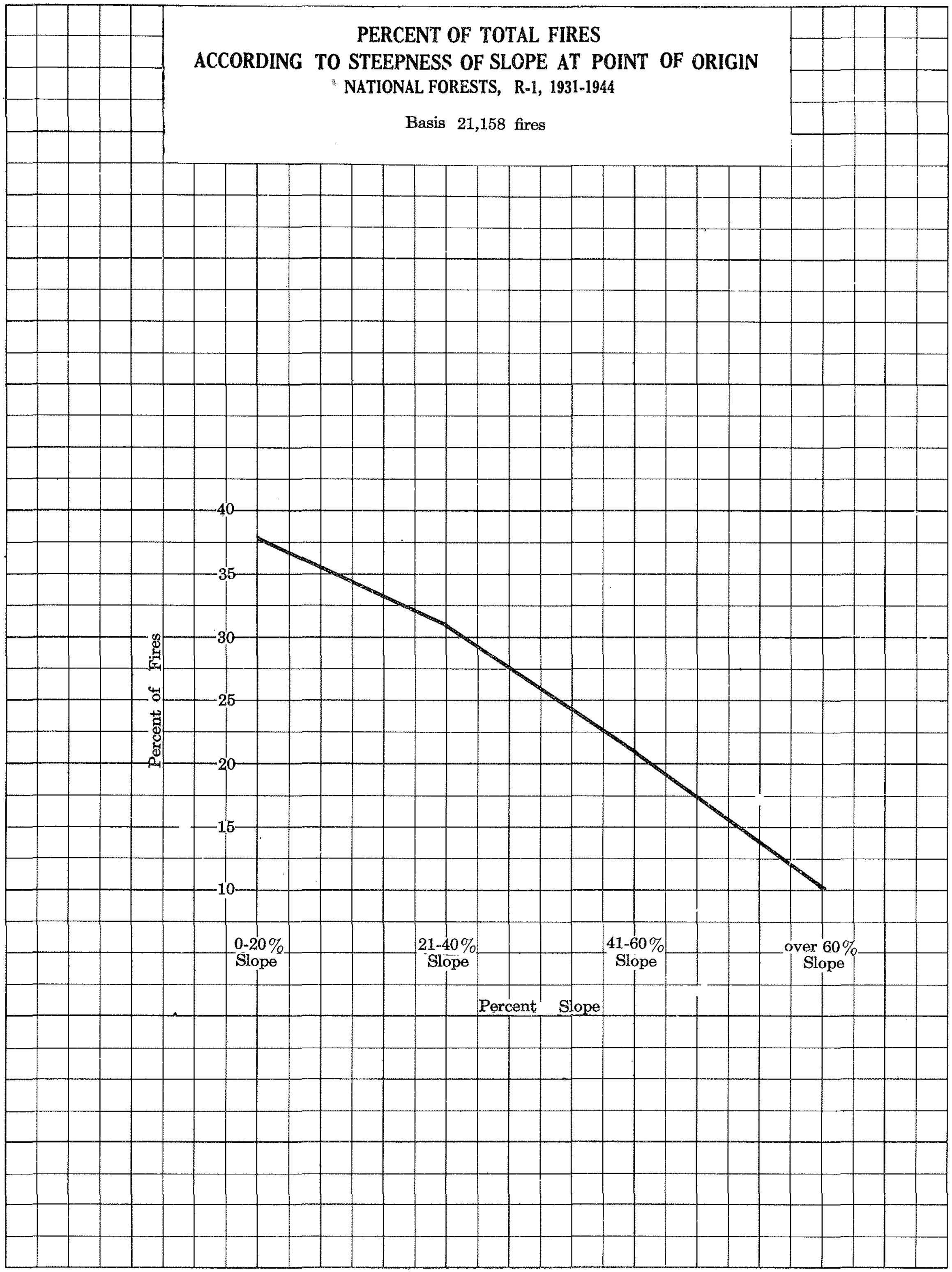

PERCENT OF TOTAL FIRES
ACCORDING TO STEEPNESS OF SLOPE AT POINT OF ORIGIN
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,158 fires
40
35
30
25
20
15
10
Percent of Fires
0-20% Slope
21-40% Slope
41-60% Slope
over 60% Slope
Percent Slope

Figure 30.

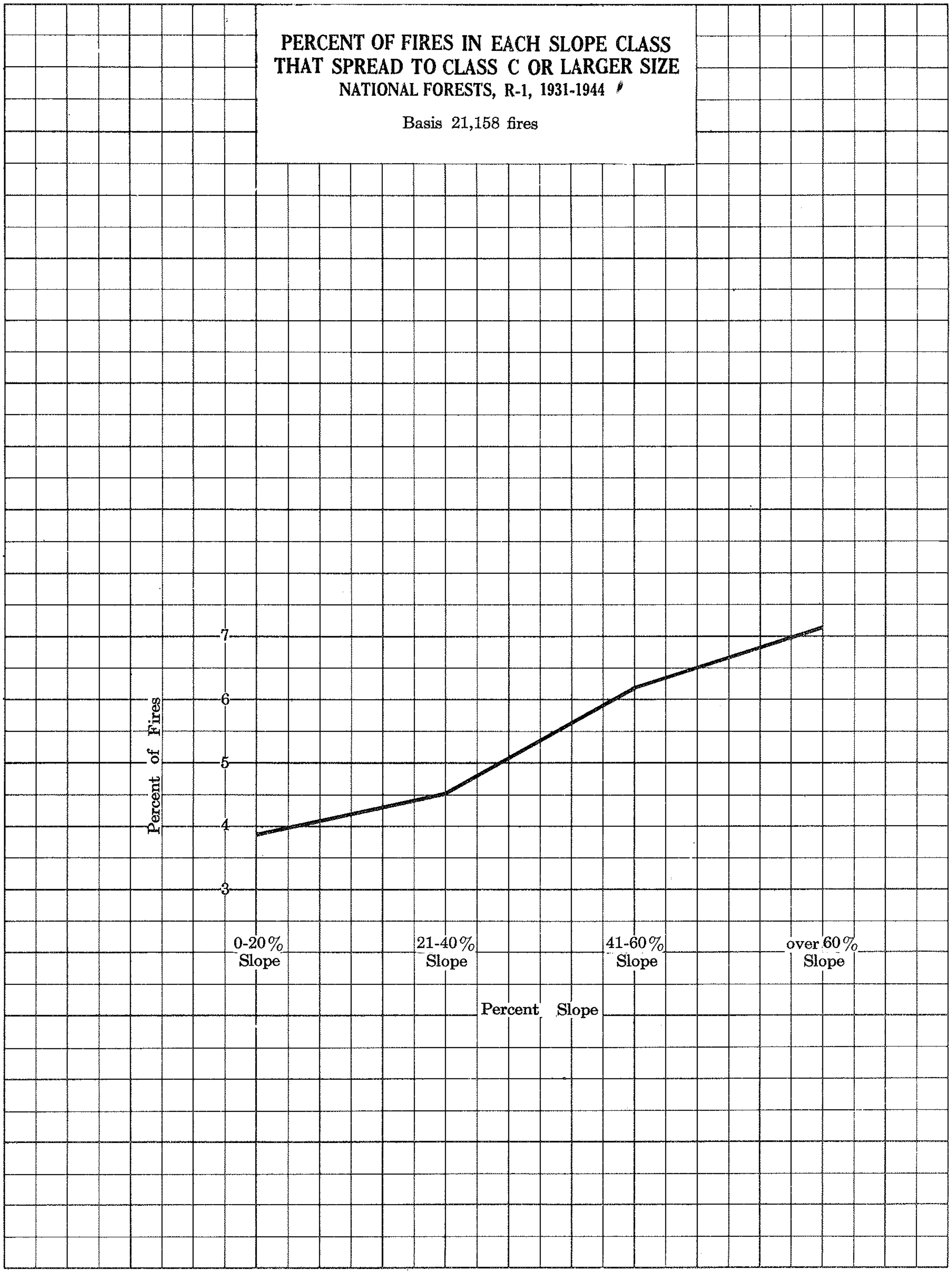

PERCENT OF FIRES IN EACH SLOPE CLASS
THAT SPREAD TO CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,158 fires
Percent of Fires
7
6
5
4
3
0-20% Slope
21-40% Slope
41-60% Slope
over 60% Slope
Percent Slope

Figure 31.

Table 23. Average Annual Number and Percent of Fires According to Steepness of Slope at Point of Origin and Final Size Class, National Forests, R-1, 1931-1944, inclusive

(Basis 21,158 fires)

Size	0-5% Slope		6-20% Slope		21-40% Slope		41-60% Slope		Over 60% Slope		Total	
Class	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
A	193	16.0	275	23.0	376	31.0	238	20.0	114	10.0	1,196	100.0
B	35	15.0	51	21.0	74	31.0	50	21.0	29	12.0	239	100.0
C	8	16.0	7	14.0	14	29.0	13	27.0	7	14.0	49	100.0
D	2	15.3	2	15.3	4	31.0	3	23.0	2	15.3	13	100.0
E	2	15.3	2	15.3	4	31.0	3	23.0	2	15.3	13	100.0
TOTAL	240	16.0	337	22.0	472	31.0	307	21.0	154	10.0	1,510	100.0

2. FUELS

The general character, volume, and arrangement of fuels are important factors influencing fire behavior. In studying these factors it is necessary to consider various fuels according to their ease of ignition as well as their effect on rate of spread of fires. Other measures of fire behavior, such as tendency to burn into the crowns of trees and to spot ahead of the main burn, are likewise important considerations. To gain a full appreciation of the effect of fuels on fire behavior, it is necessary to evaluate them by commonly used field observations such as character of vegetation, species, and forest condition. In addition a major objective in this study is to analyze the fuel classification system designed specifically for fire control purposes in the northern Rocky Mountains (4, 10).

Timber and Grass Fuels

Over 90 percent of the fires on the national forests occur in timber fuels. As shown in table 24, only 6 percent of the fires in the western zone originate in grass fuels, while in the eastern zone 16 percent are in grass. Four forests, the Deerlodge, Cabinet, Lolo, and Custer, handle relatively heavy loads in grass fuels. The Flathead, Kootenai, and Lewis and Clark forests handle the fewest fires in grass.

The ignition rate is higher in grass than in timber fuels. In a study of 17,909 fires that occurred in the western zone it was found that the ignition rate in grass fuels was 207 fires per million acres as compared to only 68 in timber fuels. This is a remarkably high occurrence rate in view of the fact that grass is normally not in an ignitable condition during a part of the fire season. Grass fires usually will start only in the spring prior to the period when the vegetation becomes green, and in the late summer and fall when vegetation is cured. Normally, during May, June, and the forepart of July the ignition rate will be very low in grass. Therefore, during the period when grass is cured it is a highly ignitable fuel. In the western zone grass was found to be 3 times as ignitable as timber fuels. Similar studies could not be made in the eastern zone because the required Forest Survey statistics on vegetative types were not available.

More fires in grass have high initial rates of spread than in timber fuels. A study of 2813 fires during the 1936-1948 period shows that a large number of grass fires have high rates of spread between discovery and first attack. Only those fires with an elapsed discovery time of 1 hour or less were analyzed. The results, as illustrated in figure 32, show that 16 percent of the fires in grass have a rate of spread above 40 chains per hour perimeter increase. In timber fuels only 2 percent of the fires spread faster than 40 chains per hour. Likewise it was found that only 21 percent of the grass fires have an initial rate of spread of one or less chains per hour, while 58 percent of the timber fires spread at this low rate.

Table 24. Number and Percent of Fires Occurring in Timber and Grass Fuels, National Forests, R-1, 1931-1945, inclusive

(Basis 21,547 fires)

Forest	Timber Fuels			Grass Fuels		
	No. Fires	% on Forest	% in Zone	No. Fires	% on Forest	% in Zone
Bitterroot	1,738	94.51	10.17	101	5.49	8.71
Cabinet	1,358	78.77	7.95	366	21.23	31.55
Clearwater	1,670	91.40	9.77	157	8.60	13.53
Coeur d'Alene	1,024	92.92	5.99	78	7.08	6.72
Flathead	1,561	98.55	9.13	23	1.45	1.98
Kaniksu	1,912	97.10	11.19	57	2.90	4.91
Kootenai	1,643	97.62	9.61	40	2.38	3.45
Lolo	2,078	91.06	12.16	204	8.94	17.59
Nezperce	2,536	97.16	14.67	74	2.84	6.38
St. Joe	1,600	96.38	9.36	60	3.62	5.18
WESTERN ZONE	17,090	93.64	100.00	1,160	6.36	100.00
Beaverhead	286	81.71	10.29	64	18.29	12.38
Custer	336	78.14	12.09	94	21.86	18.18
Deerlodge	792	81.31	28.49	182	18.69	35.20
Gallatin	351	82.39	12.62	75	17.61	14.51
Helena	664	90.22	23.88	72	9.78	13.93
Lewis and Clark	351	92.12	12.62	30	7.88	5.80
EASTERN ZONE	2,780	84.32	100.00	517	15.68	100.00
TOTAL REGION ONE	19,870	92.22		1,677	7.78	

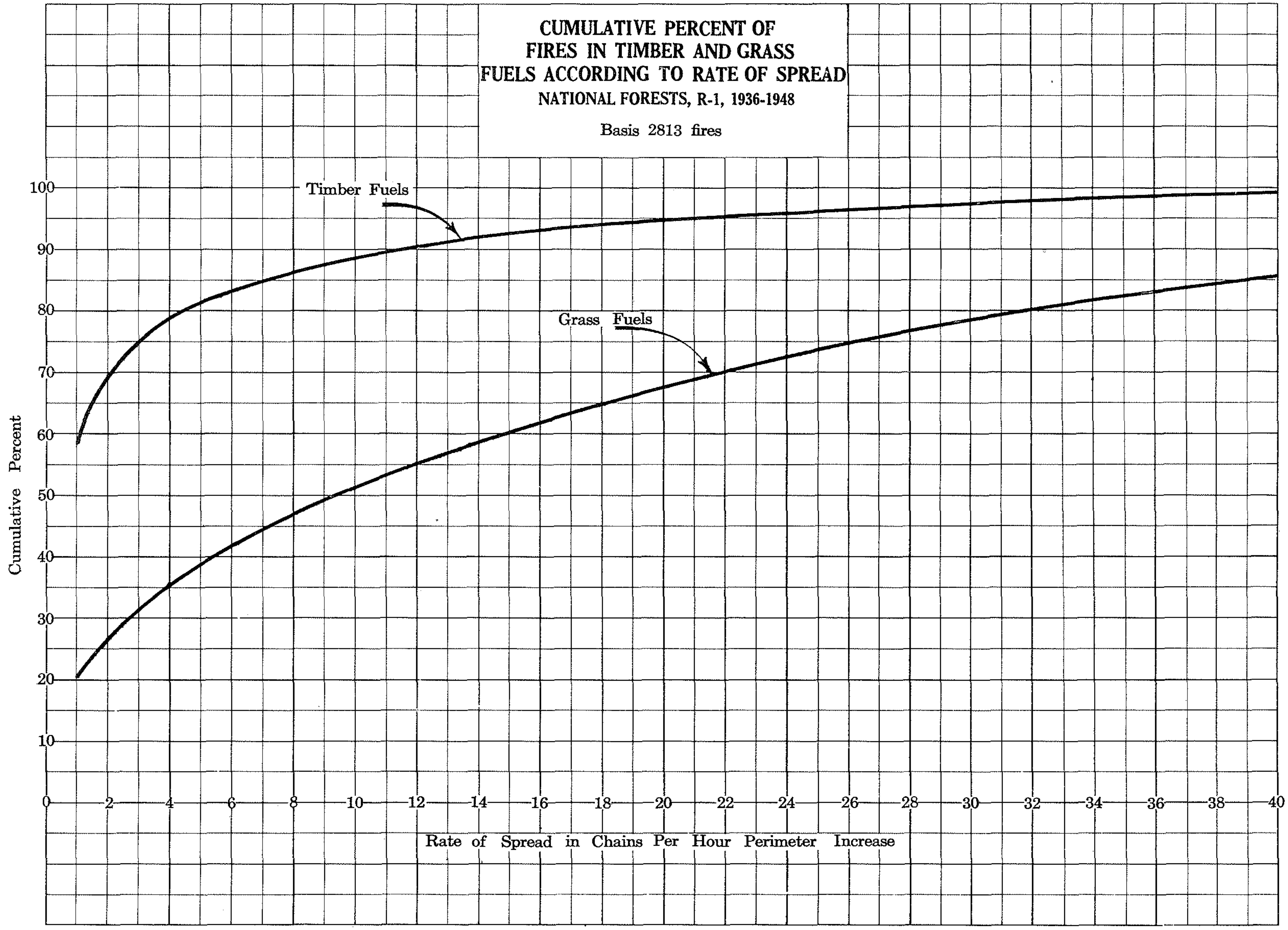

CUMULATIVE PERCENT OF
FIRES IN TIMBER AND GRASS
FUELS ACCORDING TO RATE OF SPREAD
NATIONAL FORESTS, R-1, 1936-1948
Basis 2813 fires
Timber Fuels
Grass Fuels
Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Rate of Spread in Chains Per Hour Perimeter Increase

Figure 32.

The combination of high rates of ignition and spread in grass fuels is significant. As previously explained, fires ignite easily in grass during that period of the year when vegetation is cured. Because of the dry condition of the grass the period of high occurrence is also the period when high rates of spread are to be expected. Over half of the fires starting in grass will spread faster than 10 chains per hour. Thus when a grass fire is reported, high rates of spread are probable. These same relationships do not hold true in timber fuels. Fires in timber may ignite under relatively moist conditions and in some cases hang over for several days before gaining any sizable increase in perimeter.

Forest Condition

The ignition rate is high in cut-over forests. An analysis of nearly 10,000 fires that occurred in cut-over, previously burned, and green forests in the western zone shows that cut-over forests have an ignition rate of 497 fires per million acres. As illustrated in figure 33, the cut-over forests' ignition rate is 2.5 times greater than in burned forests, and 10 times greater than in green forests.

A high percent of the fires originating on cut-over lands reach class C or larger size. A study of 1121 fires originating in cut-over forests revealed that 8.66 percent spread to sizes of 10 acres or more. As illustrated in figure 34, this is over twice the percent of class C or larger fires that occur in burned or green forests. The distribution of over 11,000 fires in green, burned, and cut-over forests is shown in table 25.

Table 25. Number and Percent of Fires by Size Class in Green, Burned, and Cut-Over Forests, National Forests, R-1, 1931-1939, inclusive

(Basis 11,656 fires)

Size	Green Forests		Burned Forests		Cut-Over Forests	
Class	No.	%	No.	%	No.	%
A	6653	82.67	2103	84.56	752	67.08
B	1109	13.78	282	11.34	272	24.26
C	166	2.06	61	2.45	63	5.62
D	57	0.71	19	0.76	15	1.34
E	63	0.78	22	0.89	19	1.70
TOTAL	8048	100.00	2487	100.00	1121	100.00

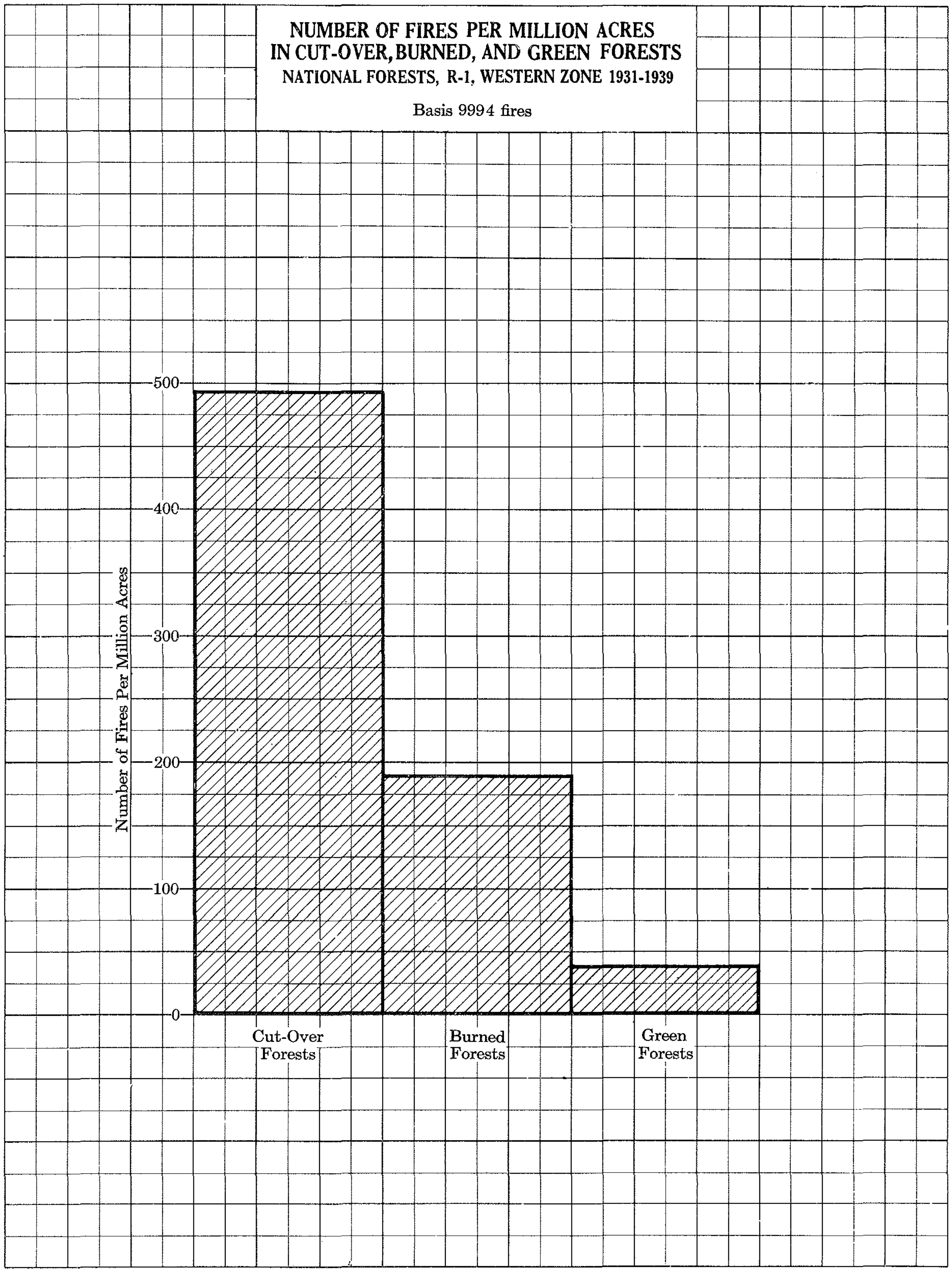

NUMBER OF FIRES PER MILLION ACRES
IN CUT-OVER, BURNED, AND GREEN FORESTS
NATIONAL FORESTS, R-1, WESTERN ZONE 1931-1939
Basis 9994 fires
Number of Fires Per Million Acres
500
400
300
200
100
0
Cut-Over Forests
Burned Forests
Green Forests

Figure 33.

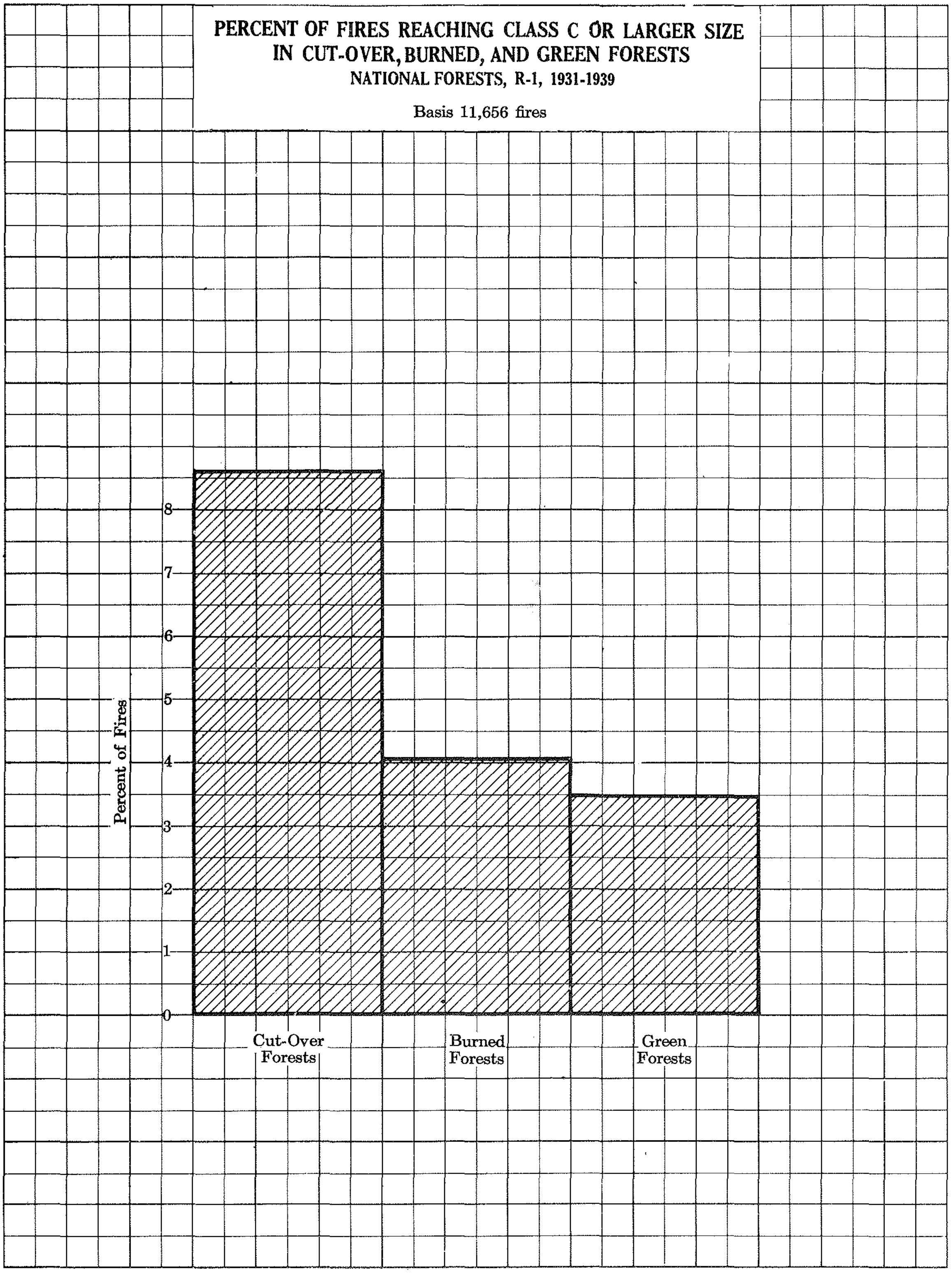

PERCENT OF FIRES REACHING CLASS C OR LARGER SIZE
IN CUT-OVER, BURNED, AND GREEN FORESTS
NATIONAL FORESTS, R-1, 1931-1939
Basis 11,656 fires
Percent of Fires
0
1
2
3
4
5
6
7
8
Cut-Over Forests
Burned Forests
Green Forests

Figure 34.

Fires in previously burned forests have the largest average size. On nearly 2500 fires originating in burned forests the average size was 84 acres. As illustrated in figure 35, fires in old burns averaged over twice as big as fires in green forests and cut-over lands. The large size is a result of the extensive areas of dangerous fuels created by single burns in the period prior to 1931.

Large areas have been burned per million acres protected in both cut-over and previously burned forests. As illustrated in figure 36, the area burned per million is 22,000 acres in cut-over forests and 16,000 in burned forests, as compared to only 2000 in green forests. This study was made of nearly 10,000 fires that occurred during the 1931-1939 period on over 19,000,000 acres of forest land in the western zone. Forest Survey statistics used in subdividing the area by type showed 91.5 percent of the area as green forests, 7.3 percent as burned forests, and 1.2 percent as cut-over forests. Obviously these figures will vary somewhat from year to year as new areas are cut-over or burned. However, these fluctuations will not be great enough to alter the results materially. The significant feature of the study is that the fuel conditions created in burned and cut-over forests present more difficult fire control problems than are experienced in green forests.

Forest Type

Ignition rates vary widely by forest type. As illustrated in figure 37, the number of fires per million acres in the western zone varies from 410 in grand fir to 40 in fir-larch. These variations are influenced by lightning occurrence within the range of the type and the character of the fuel normally inherent in each type. The very high ignition rate in grand fir is influenced by the location of large areas of this type in the intense lightning occurrence belt of the Nezperce and Clearwater National Forests. Both the grand fir and cedar-hemlock types have large numbers of snags and dead material on the forest floor which are easily ignitable. High ignition rates in ponderosa pine and grass reflect the dry conditions associated with these types.

Exclusive of the grass type ponderosa pine has the highest initial rate of spread. In a study of 3872 fires in ponderosa pine the average rate of spread was 4.03 chains per hour perimeter increase from origin to first attack. This includes all fires regardless of time, date of origin, or burning index. Similar studies in other forest types illustrated in figure 38, show that Douglas-fir, western white pine, and lodgepole pine have average rates of spread above 2 chains per hour. Fires in all other forest types spread at average rates of less than 2 chains per hour. All of these rate-of-spread figures show the perimeter increase per hour only during the early stages of a fire. Rates of spread on large fires will be much higher. As will be explained later, the initial rates of spread also will be much higher for fires occurring under mid- and late-season burning conditions.

Exclusive of the grass type ponderosa pine has the highest percent of fires spreading to class C or larger size. During the 1931-1939 period 143 fires in ponderosa pine, or 6.28 percent of the total in that type, reached class C or larger size. As illustrated in figure 39, three other

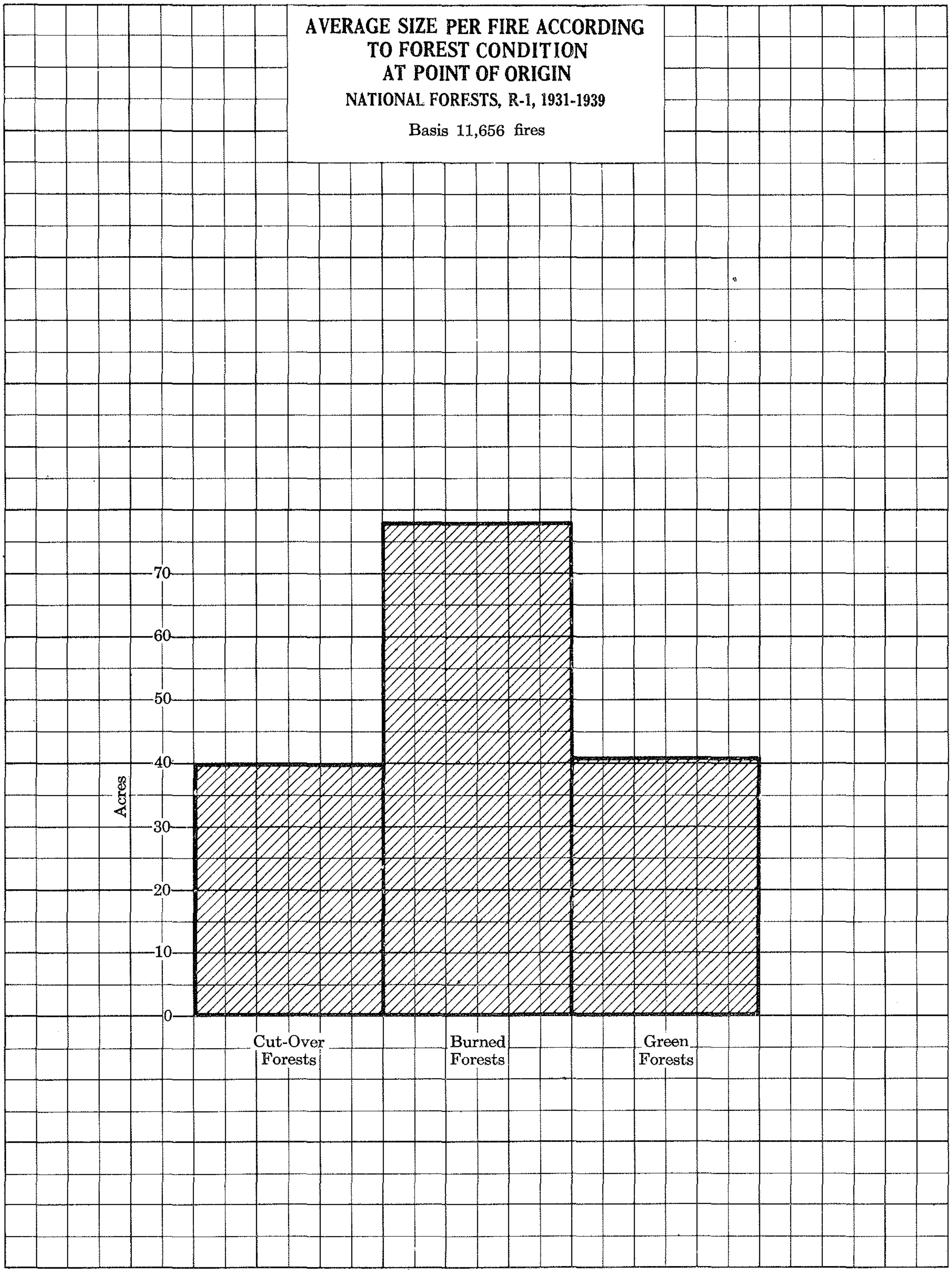

AVERAGE SIZE PER FIRE ACCORDING
TO FOREST CONDITION
AT POINT OF ORIGIN
NATIONAL FORESTS, R-1, 1931-1939
Basis 11,656 fires
Acres
70
60
50
40
30
20
10
0
Cut-Over Forests
Burned Forests
Green Forests

Figure 35.

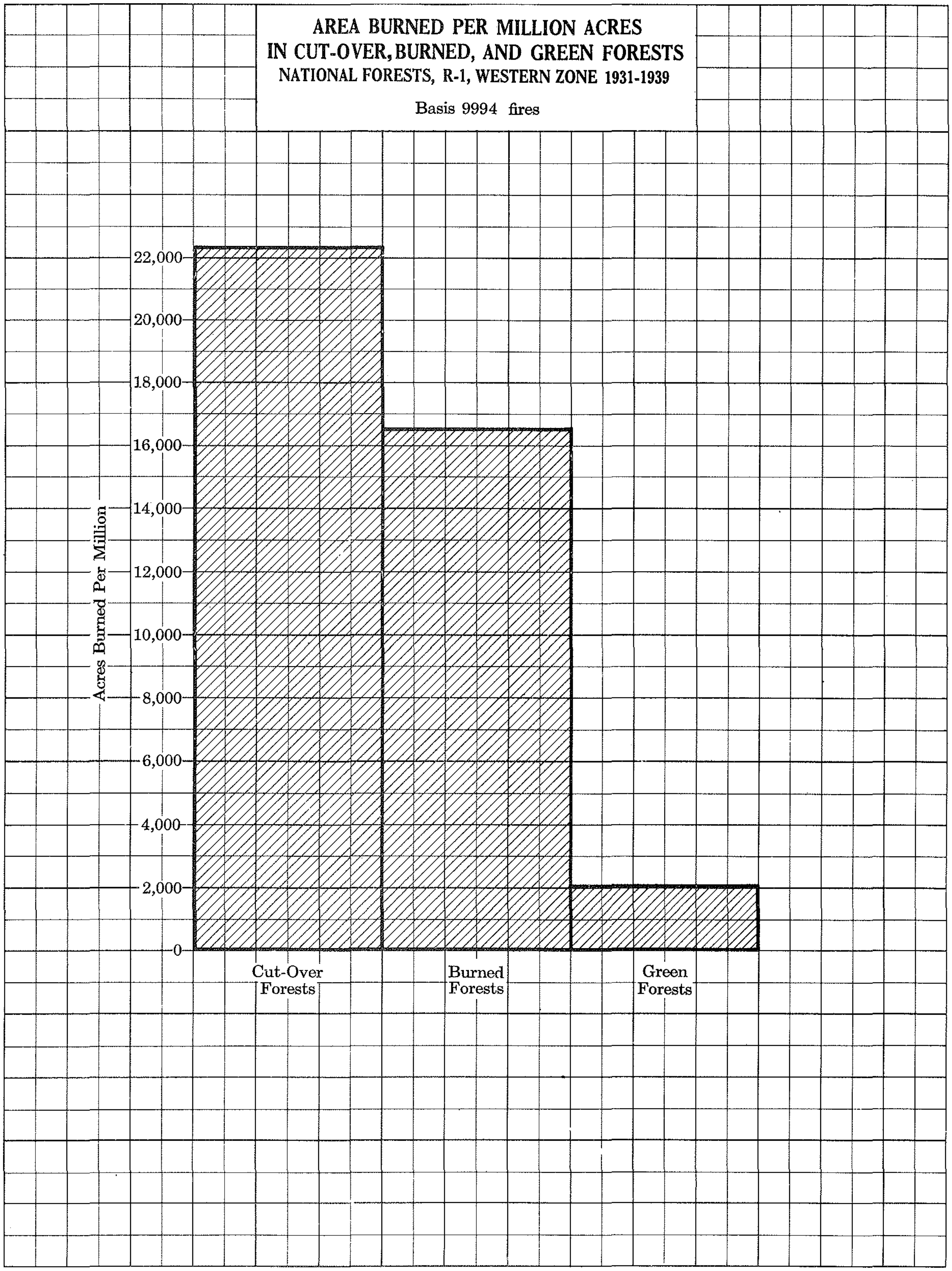
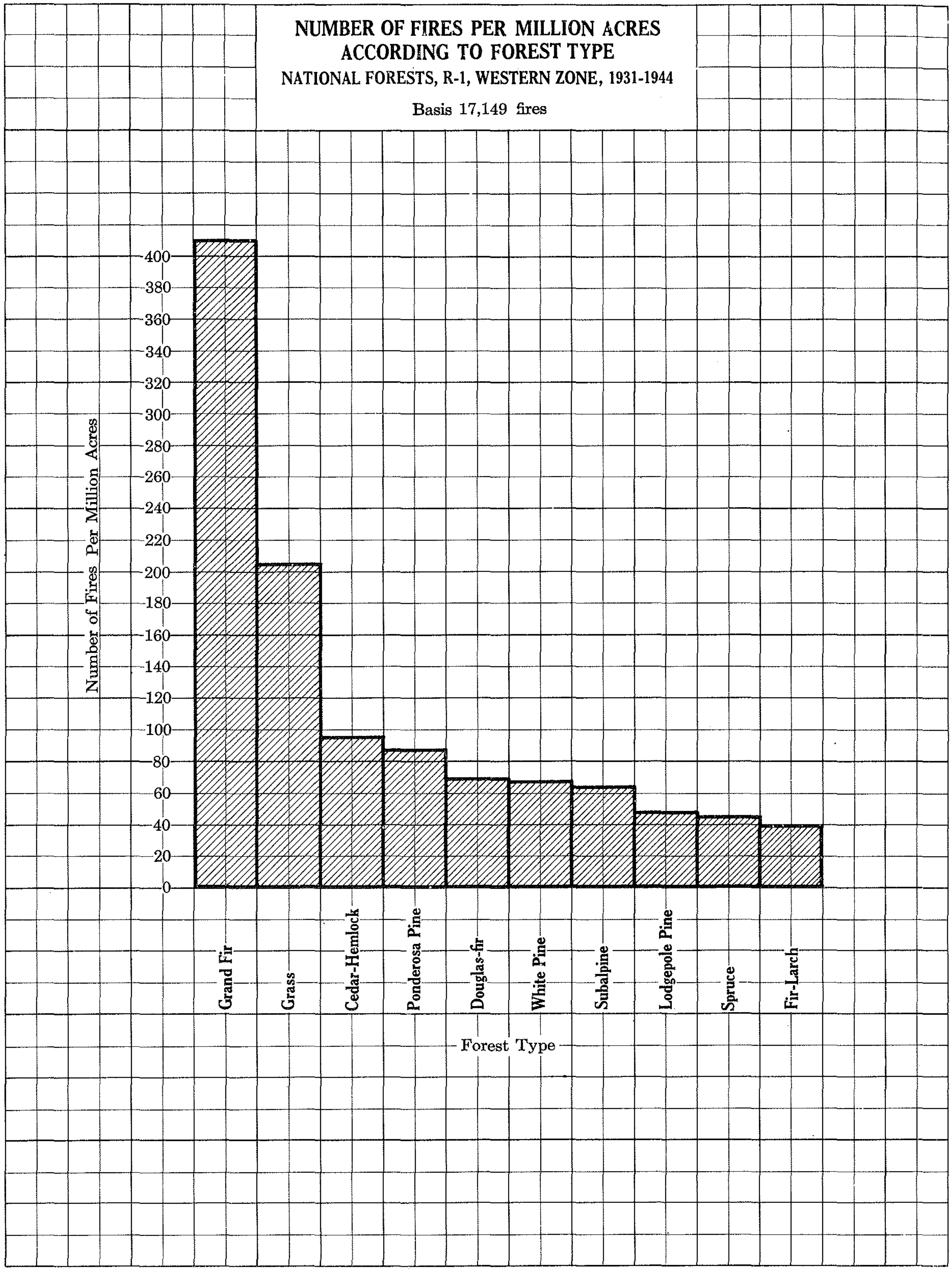
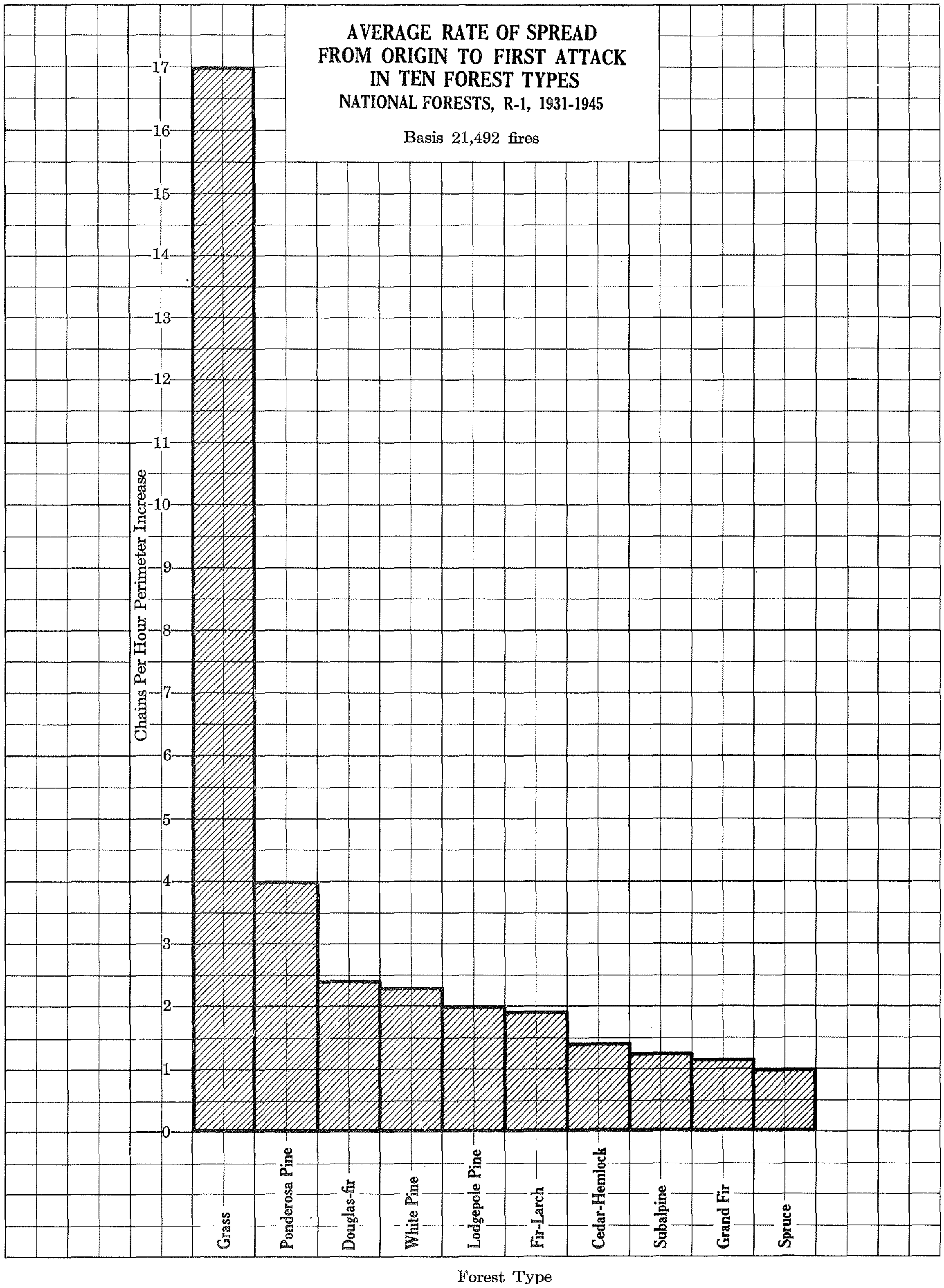

AREA BURNED PER MILLION ACRES
IN CUT-OVER, BURNED, AND GREEN FORESTS
NATIONAL FORESTS, R-1, WESTERN ZONE 1931-1939
Basis 9994 fires
Acres Burned Per Million
22,000
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Cut-Over Forests
Burned Forests
Green Forests

Figure 36.



NUMBER OF FIRES PER MILLION ACRES
ACCORDING TO FOREST TYPE
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1944
Basis 17,149 fires
Number of Fires Per Million Acres
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Grand Fir
Grass
Cedar-Hemlock
Ponderosa Pine
Douglas-fir
White Pine
Subalpine
Lodgepole Pine
Spruce
Fir-Larch
Forest Type

Figure 37.


AVERAGE RATE OF SPREAD
FROM ORIGIN TO FIRST ATTACK
IN TEN FOREST TYPES
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,492 fires
Chains Per Hour Perimeter Increase
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
Grass
Ponderosa Pine
Douglas-fir
White Pine
Lodgepole Pine
Fir-Larch
Cedar-Hemlock
Subalpine
Grand Fir
Spruce
Forest Type

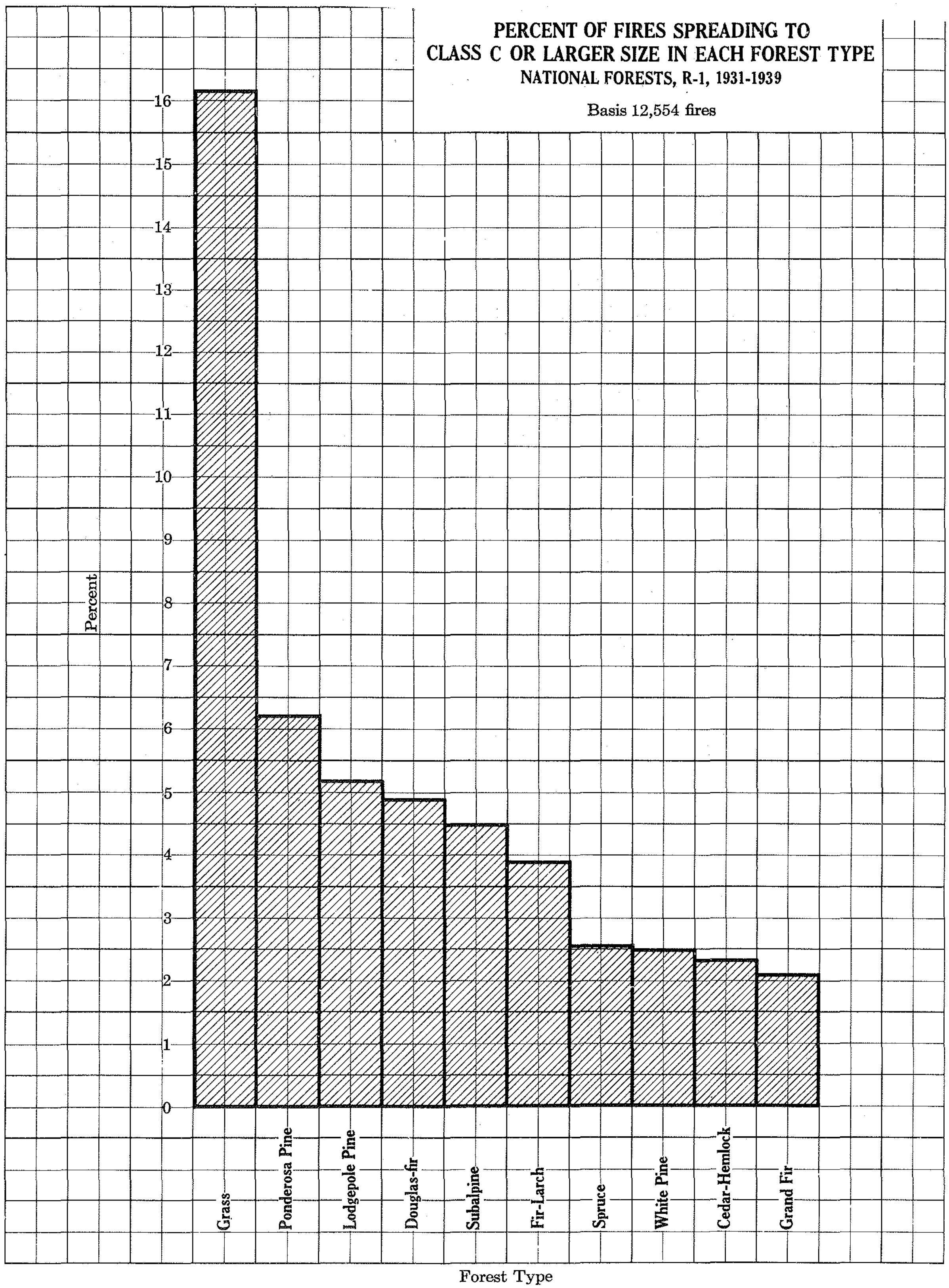

PERCENT OF FIRES SPREADING TO
CLASS C OR LARGER SIZE IN EACH FOREST TYPE
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,554 fires
Percent
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Grass
Ponderosa Pine
Lodgepole Pine
Douglas-fir
Subalpine
Fir-Larch
Spruce
White Pine
Cedar-Hemlock
Grand Fir
Forest Type

Figure 39.

types, lodgepole pine, Douglas-fir, and subalpine, had a relatively high percentage of fires in the larger size classes. In all other types less than 4 percent of the fires spread to sizes greater than 10 acres. The distribution of fires by size class in all types is shown in table 26.

A dead snag is the material first ignited in most fires. As shown in table 27, a high percentage of fires in all forest types start in snags. Over 34 percent of nearly 12,000 fires showed a dead snag as the material first ignited. The grand fir type, as illustrated in figure 40, has the highest percent of fires starting in snags. White pine and subalpine also show a large number of fires in snags with both types averaging over 40 percent of their fires in this material. The next most common materials ignited are duff, with nearly 30 percent of the fires, and wood on the ground with 11 percent.

Slash is the material causing the highest percentage of class C or larger fires. As illustrated in figure 41, nearly 20 percent of the fires where slash was the material first ignited spread to sizes greater than 10 acres. Over 17 percent of the fires where grass was the material first ignited spread to this size. In all other materials less than 10 percent of the fires spread to class C or larger size. An interesting feature of this study was the fact that only 2 percent of the fires originating in snags spread to the larger size classes. Thus while snags have a high ignition rate as explained above, very few fires in this material spread to sizes greater than 10 acres. Only fires originating in green tree tops show a smaller percent of class C, D, or E fires.

Fuel Classification

Fuel classification as used in Region 1 is an important index of fire behavior. The classification system originally designed by Hornby divides various fuels into four rate-of-spread classes known as low, medium, high, and extreme, and also into four resistance-to-control classes likewise rated low, medium, high, and extreme (10). Thus a fuel rated high-medium has a high rate of spread and a medium resistance to control. In this study the major emphasis has been on the rate-of-spread classification because that factor is most important to fire behavior. The results show that the rate-of-spread classifications provide effective means of evaluating fire behavior. The results also show that a further improvement in evaluating fire behavior may be accomplished by a revision of the present fuel classification system.

Fuel types vary greatly in the western and eastern zones. In the national forests of the eastern zone nearly 71 percent of the vegetated area is classified in the low rate-of-spread type, while in the western zone only 31 percent is in this type. As shown in table 28, the western forests have a large percent of their area in the medium and high rate-of-spread fuel types. On the Nezperce forest over 25 percent of the area is classified as high rate of spread. The Coeur d'Alene, Kaniksu, and Kootenai forests all have over 20 percent of their area in the high rate-of-spread type. In the eastern zone only the Helena forest has more than 10 percent of its area in this type.

Table 26. Number and Percent of Fires in Each Forest Type by Size Class, National Forests, R-1, 1931-1939, inclusive

(Basis 12,554 fires)

Forest Type	Size Class A		B		C		D		E		Total
	No.	%	No.	%	No.	%	No.	%	No.	%	No.
White Pine	1549	88.87	150	8.61	21	1.20	3	0.17	20	1.15	1743
Ponderosa Pine	1637	71.89	497	21.83	98	4.30	27	1.19	18	0.79	2277
Lodgepole Pine	1524	75.60	387	19.20	68	3.37	20	0.99	17	0.84	2016
Douglas-fir	1043	78.42	222	16.70	35	2.63	18	1.35	12	0.90	1330
Fir-Larch	1037	84.31	145	11.78	31	2.52	11	0.90	6	0.49	1230
Grand Fir	612	90.00	54	7.94	3	0.44	4	0.59	7	1.03	680
Cedar-Hemlock	188	87.85	21	9.81	2	0.94	1	0.47	2	0.94	214
Spruce	304	88.12	32	9.28	4	1.16			5	1.44	345
Subalpine	1660	84.65	213	10.86	53	2.70	18	0.92	17	0.87	1961
Grass	462	60.95	173	22.82	81	10.69	19	2.51	23	3.03	758

Table 27. Number and Percent of Fires in Each Forest Type According to Material First Ignited, National Forests, R-1, 1931-1939, inclusive

(Basis 11,835 fires)

Material	Unit	Forest Type: White Pine	Ponderosa Pine	Lodgepole Pine	Fir-Larch	Douglas fir	Grand Fir	Cedar Hemlock	Spruce	Sub-alpine	Total
Duff on Ground	No.	437	712	740	386	460	113	55	122	499	3524
	%	25.05	31.52	36.28	31.28	34.41	16.61	25.82	34.96	25.21	29.78
Slash	No.	71	55	52	59	38	9	13	3		300
	%	4.07	2.43	2.55	4.78	2.84	1.32	6.10	0.86		2.53
Green Tree Top	No.	157	261	94	106	137	104	29	28	239	1155
	%	9.00	11.55	4.60	8.59	10.25	15.30	13.62	8.02	12.08	9.76
Moss on Tree	No.	39	20	42	38	25	18	10	25	182	399
	%	2.23	0.89	2.06	3.08	1.87	2.65	4.69	7.16	9.20	3.37
Brush	No.	12	12	6	17	11	34	4	3	3	102
	%	0.68	0.53	0.29	1.38	0.82	5.00	1.88	0.86	0.15	0.86
Snag	No.	735	598	621	383	402	322	75	117	821	4074
	%	42.14	26.47	30.44	31.04	30.07	47.36	35.21	33.52	41.49	34.42
Grass	No.	61	377	203	82	98	9	4	8	69	911
	%	3.49	16.69	9.95	6.64	7.33	1.32	1.88	2.29	3.48	7.70
Weeds	No.	2	2		1		4				9
	%	0.15	0.09		0.08		0.59				0.08
Wood on Ground	No.	230	222	282	162	166	67	23	43	166	1361
	%	13.19	9.83	13.83	13.13	12.41	9.85	10.80	12.32	8.39	11.50
TOTAL	No.	1744	2259	2040	1234	1337	680	213	349	1979	11,835
	%	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

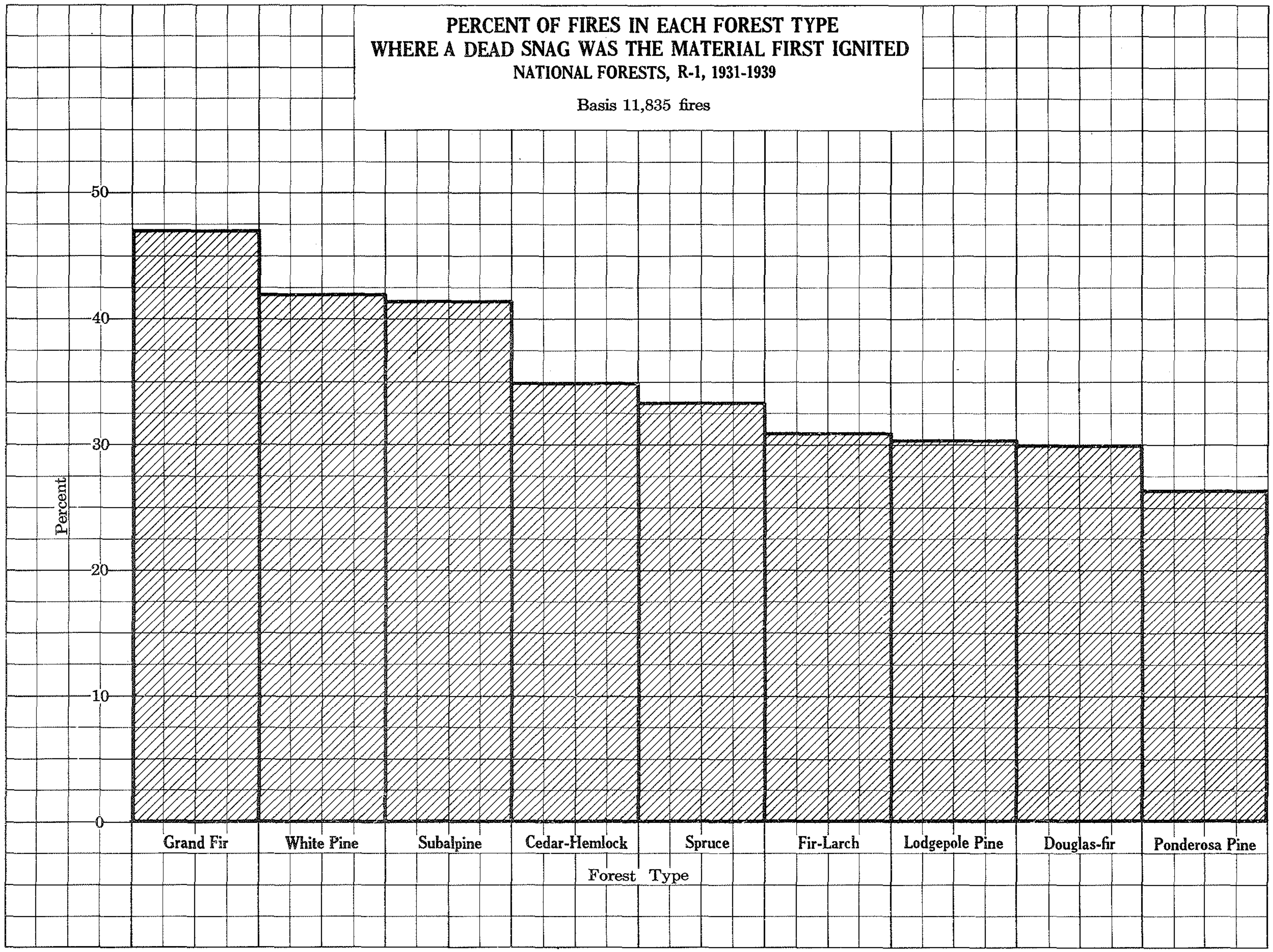

PERCENT OF FIRES IN EACH FOREST TYPE
WHERE A DEAD SNAG WAS THE MATERIAL FIRST IGNITED
NATIONAL FORESTS, R-1, 1931-1939
Basis 11,835 fires
Percent
50
40
30
20
10
0
Grand Fir
White Pine
Subalpine
Cedar-Hemlock
Spruce
Fir-Larch
Lodgepole Pine
Douglas-fir
Ponderosa Pine
Forest Type

Figure 40.

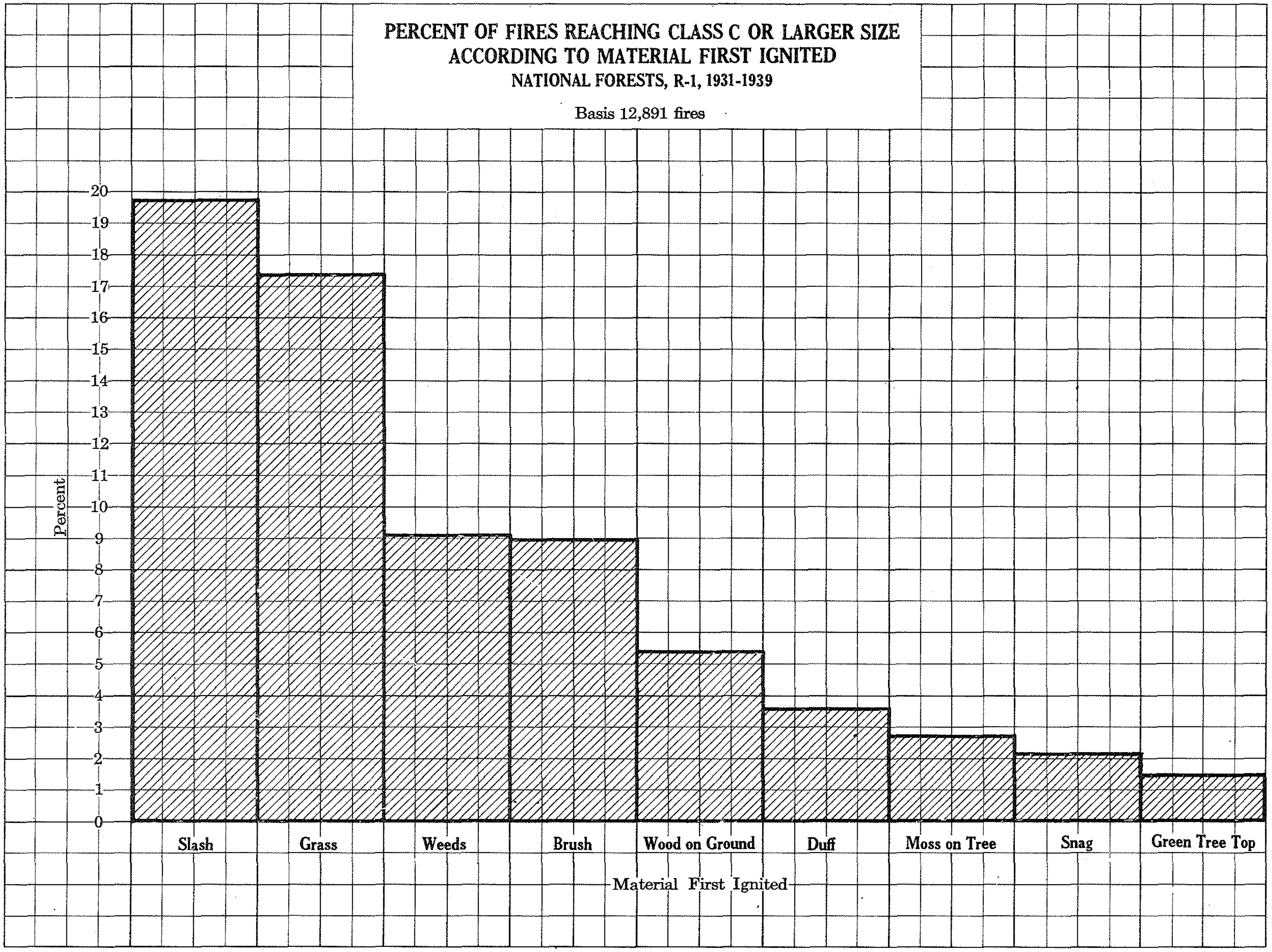

PERCENT OF FIRES REACHING CLASS C OR LARGER SIZE
ACCORDING TO MATERIAL FIRST IGNITED
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,891 fires
Percent
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Slash
Grass
Weeds
Brush
Wood on Ground
Duff
Moss on Tree
Snag
Green Tree Top
Material First Ignited

Figure 41.

Table 28. Area and Percent in Each Fuel Type According to Rate-of-Spread Classification, National Forests, R-1

Forest	Rate-of-Spread Classification							
	Low		Medium		High		Extreme	
	Acres	%	Acres	%	Acres	%	Acres	%
Bitterroot	870,819	43.61	828,686	41.50	297,328	14.89		
Cabinet	374,144	27.78	746,753	55.45	225,910	16.77		
Clearwater	577,347	50.48	458,860	40.12	107,509	9.40		
Coeur d'Alene	185,371	21.05	474,127	53.84	218,351	24.80	2,773	0.31
Flathead	1,015,043	39.75	1,029,598	40.32	507,905	19.89	1,022	0.04
Kaniksu	443,517	19.25	1,319,724	57.28	525,642	22.81	15,103	0.66
Kootenai	420,204	20.06	1,151,057	54.95	520,960	24.87	2,514	0.12
Lolo	956,301	42.92	915,527	41.09	354,713	15.92	1,560	0.07
Nezperce	508,239	25.72	948,897	48.02	505,669	25.59	13,240	0.67
St. Joe	337,635	19.69	1,066,409	62.19	309,515	18.05	1,200	0.07
WESTERN ZONE	5,688,620	31.19	8,939,638	49.01	3,573,502	19.59	37,412	0.21
Absaroka	1,115,871	91.69	84,460	6.94	16,551	1.36	122	0.01
Beaverhead	1,009,724	50.55	933,422	46.73	54,331	2.72		
Custer	793,123	63.58	348,410	27.93	104,910	8.41	998	0.08
Deerlodge	977,833	73.53	343,896	25.86	8,112	0.61		
Gallatin	902,474	79.89	203,901	18.05	23,270	2.06		
Helena	787,202	71.60	184,816	16.81	127,426	11.59		
Lewis and Clark	1,493,958	76.17	457,974	23.35	9,415	0.48		
EASTERN ZONE	7,080,185	70.93	2,556,879	25.61	344,015	3.45	1,120	0.01
TOTAL REGION ONE	12,768,805	45.25	11,496,517	40.73	3,917,517	13.88	38,532	0.14

The greatest number of fires per million acres occur in fuels classified high in rate of spread. In the western zone the ignition rate is 96.82 and in the eastern zone 92.25 fires per million acres. Topographic factors will cause some variations in the ignition rates in various fuel types. On the Clearwater forest, as shown in table 29, a large number of fires per million acres occur in the low and medium fuel types. The high ignition rate in these fuels on the Clearwater is caused by the intense lightning occurrence in the upper elevation zones which are also areas dominated by low and medium fuels. When viewed on a broad regional basis, high rate-of-spread fuels, as illustrated in figure 42, clearly have the highest ignition rate.

Table 29. Average Annual Number of Fires Per Million Acres in Each Fuel Rate-of-Spread Classification, National Forests, R-1, 1940-1944, inclusive

(Basis 8,162 fires)

Forest	Low	Medium	High	Extreme
Bitterroot	48.92	92.43	108.97	
Cabinet	81.25	91.33	215.13	
Clearwater	117.09	200.07	107.90	
Coeur d'Alene	72.29	109.67	182.27	216.37
Flathead	46.89	46.81	36.23	
Kaniksu	50.96	57.44	60.50	13.24
Kootenai	45.22	75.06	96.36	238.66
Lolo	48.10	85.20	123.48	
Nezperce	83.42	84.10	96.90	
St. Joe	58.05	61.89	65.91	166.67
WESTERN ZONE	61.74	80.85	96.82	85.53
Absaroka	6.09	14.21		
Beaverhead	11.49	10.93	18.40	
Custer	12.10	35.59	51.47	
Deerlodge	51.75	28.50	147.93	
Gallatin	12.85	18.64	60.16	
Helena	31.50	102.80	42.38	
Lewis and Clark	10.04	15.72	106.21	
EASTERN ZONE	18.36	30.11	44.76	
TOTAL REGION ONE	37.68	68.40	92.25	85.53

Fires in extreme fuels spread over 5 times faster than those in low fuels. As illustrated in figure 43, the average rate of spread from origin to attack varies from 2.8 chains per hour in low fuels to 15 chains in extreme fuels. Fires in medium fuels spread only 0.2 chain faster than low fuels. In high fuels the average rate of spread is 9.8 chains per hour. These average initial rates of spread are significant only in that they show the relationships between fuel types. Average rate-of-spread figures are not useful for planning purposes because large numbers of fires will spread at much faster rates when burning conditions are severe.

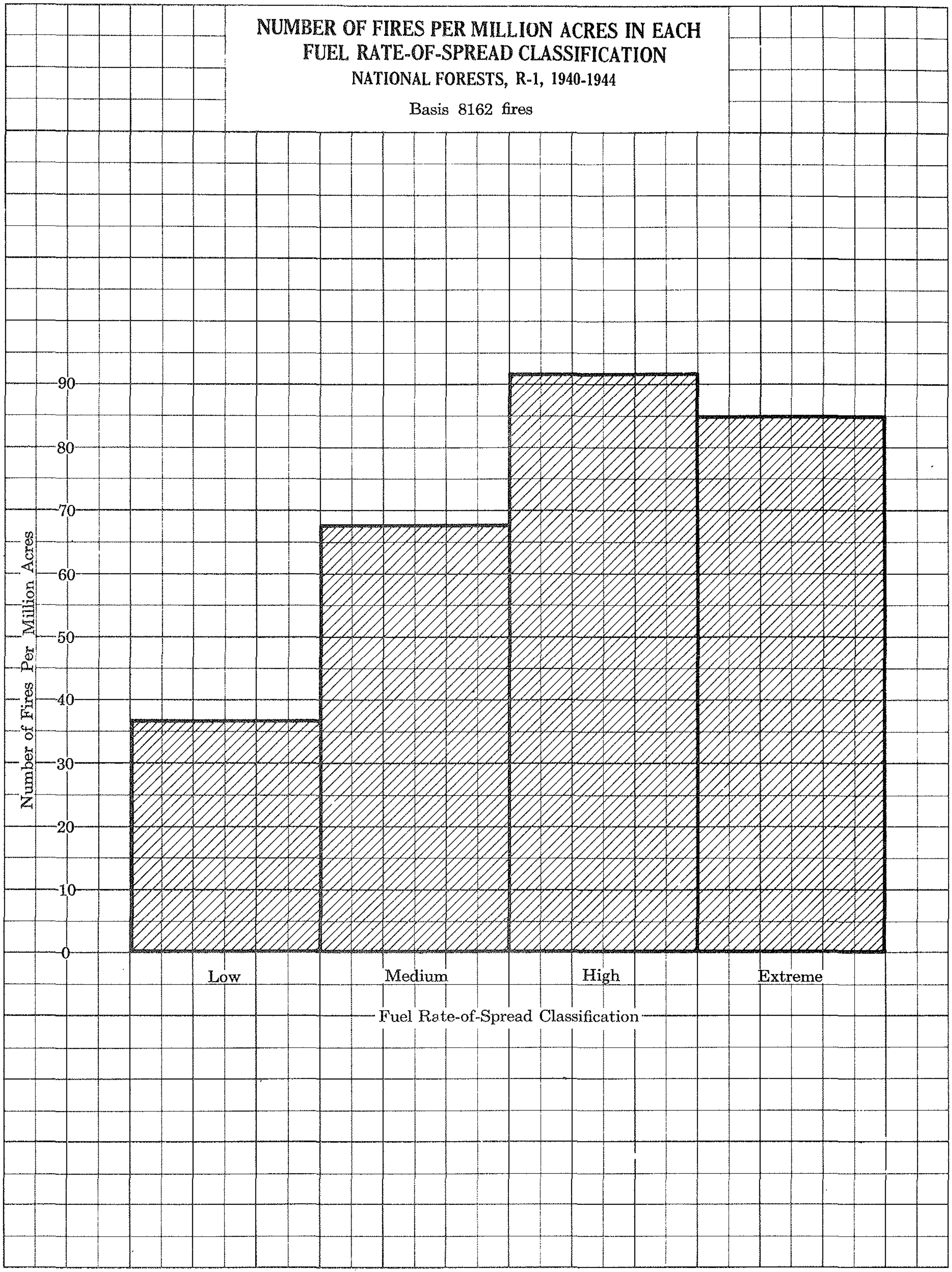

NUMBER OF FIRES PER MILLION ACRES IN EACH
FUEL RATE-OF-SPREAD CLASSIFICATION
NATIONAL FORESTS, R-1, 1940-1944
Basis 8162 fires
Number of Fires Per Million Acres
90
80
70
60
50
40
30
20
10
0
Low
Medium
High
Extreme
Fuel Rate-of-Spread Classification

Figure 42.

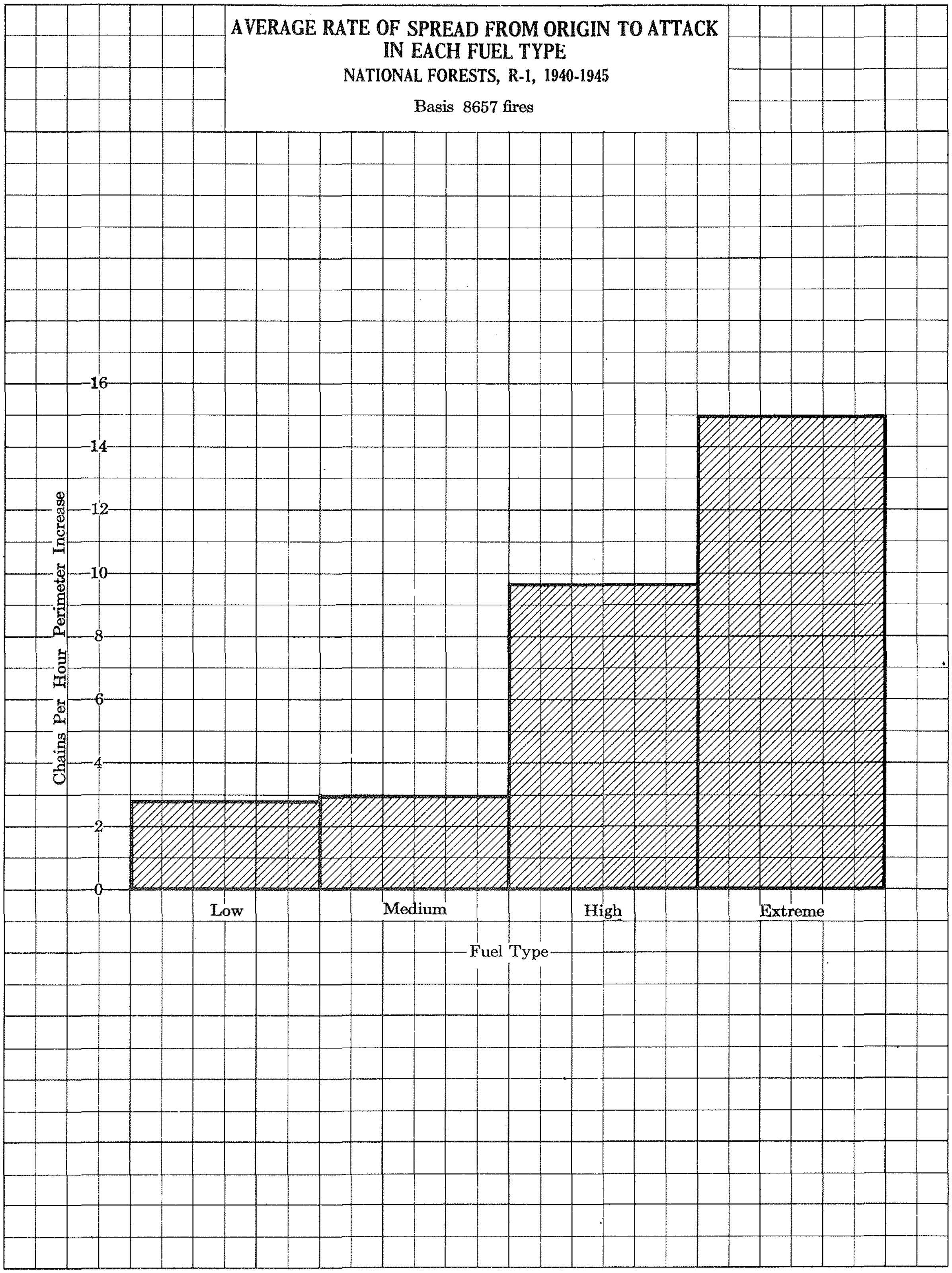

AVERAGE RATE OF SPREAD FROM ORIGIN TO ATTACK
IN EACH FUEL TYPE
NATIONAL FORESTS, R-1, 1940-1945
Basis 8657 fires
Chains Per Hour Perimeter Increase
0
2
4
6
8
10
12
14
16
Low
Medium
High
Extreme
Fuel Type

Figure 43.

Fuel classification is a good indicator of the probable behavior of fires. In studying fire behavior over 8000 fires were classified according to their character on arrival as follows:

Smoldering -- making linear forward spread less than 2 feet per hour.

Creeping -- making linear forward spread 2 feet to 10 chains per hour, without spotting or crowning.

Running -- making linear forward spread over 10 chains per hour, without spotting or crowning.

Spotting -- throwing wind-borne, fire-starting sparks or embers ahead, regardless of rate of spread.

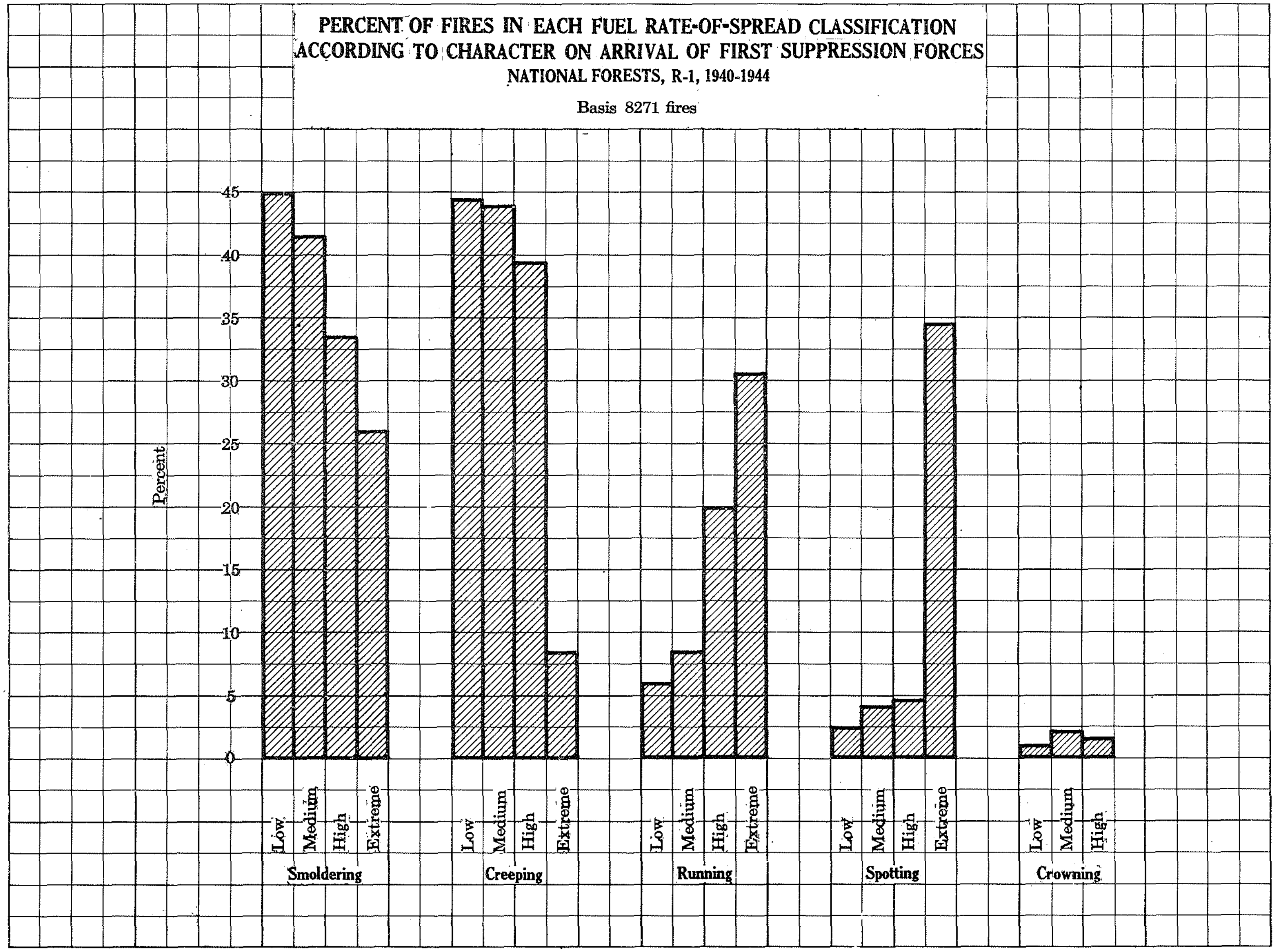
Crowning -- fire advancing primarily from crown to crown in brush or trees.

The results, as illustrated in figure 44 and as explained below, show that fuel classification provides a good indicator of the probable character of a fire.

The greatest number of fires in low and medium fuels are characterized by smoldering or creeping. Over 89 percent of the fires in low fuels and 85 percent in medium fuels were in these two behavior classes. Also, as illustrated in figure 44, a small percent of the fires in these fuels were running or spotting on arrival of the first suppression forces.

Medium fuels have a relatively high crowning factor. Only 151 fires out of a total of 8271 in all fuels were observed to be crowning on arrival. In medium fuels 2 percent of the fires were crowning, as against only 1.7 percent in high fuels and 1.6 percent in low fuels. Medium fuels are more likely to cause crown fires because they are located in green forests with sufficient volumes of ground fuels to build up the necessary heat. Low fuels have less of this type material on the forest floor. Crowning in high fuels will be infrequent because this type is often in single burns or old cut-over forests where the crowns are lacking. Crowning is totally absent in extreme fuels because this type is confined to slash and the worst single burns where green trees are not present in any great numbers.

High and extreme fuels have large numbers of fires characterized as running. Nearly 20 percent of the fires in high fuels and over 30 percent in extreme fuels were running when the first suppression forces arrived. These are the potentially dangerous fires which will have high initial rates of spread and which may in turn burn large areas. The fact that one fire out of five in high fuels and nearly one out of three in extreme fuels were in this category is a vivid illustration of how fuel classification may give advance warning of probable fire behavior.



PERCENT OF FIRES IN EACH FUEL RATE-OF-SPREAD CLASSIFICATION
ACCORDING TO CHARACTER ON ARRIVAL OF FIRST SUPPRESSION FORCES
NATIONAL FORESTS, R-1, 1940-1944
Basis 8271 fires
Percent
45
40
35
30
25
20
15
10
5
0
Low
Medium
High
Extreme
Smoldering
Low
Medium
High
Extreme
Creeping
Low
Medium
High
Extreme
Running
Low
Medium
High
Extreme
Spotting
Low
Medium
High
Crowning

Figure 44.

Spotting is a characteristic of extreme fuels. Nearly 35 percent of the fires in extreme fuels were spotting on arrival. In all other fuels less than 5 percent of the fires were spotting. In extreme fuels spotting was observed more frequently than any of the five characteristics used in evaluating fire behavior. The tendency of this fuel to cause spot fires is an indication of the high inflammability of undisposed slash which makes up the greatest portion of this type in the region.

Fires which are running, spotting, or crowning are most apt to spread to large size. Over 79 percent of all class C, D, and E fires had these fire behavior characteristics upon the arrival of the first suppression forces. As illustrated in figure 45, over 34 percent of the fires which were crowning spread to sizes of 10 acres or more. Similarly, over 20 percent of the fires that were running or spotting became class C or larger fires. Only 4 out of 3375 fires that were smoldering reached class C or D size, and none spread to class E size. Over 90 percent of the class E fires were running, spotting, or crowning when first suppression forces arrived.

Effective fuel classification requires clear identification of flashy fuels. All studies of rate of spread indicated the need to identify grass as a fuel type separate from the low, medium, high, and extreme classifications as now rated. Under the original classification system grass was included in all of the rate-of-spread types. To provide a test of a fuel classification system in which grass is rated separately from timber fuels, nearly 3000 fires were selected for initial rate-of-spread determinations. The results, as shown in figure 46, lead to these conclusions:

1. The five rate-of-spread types -- low, medium, high, extreme, and grass -- provide an effective means of identifying fast-traveling fires. For example, 16 percent of the fires in grass spread at more than 40 chains per hour. In extreme fuels 9 percent of the fires spread at this rate, in high fuels 5 percent, and in low and medium fuels only 1 percent.

2. There is little difference in rate of spread between the low and medium types. As illustrated in figure 46, the initial rate of spread is about the same in these two types. However, as explained previously, later rates of spread will be higher in medium fuels because of the greater tendency of fires in this type to crown.

3. Significant differences in rate of spread exist between the medium, high, extreme, and grass types. As shown in figure 46, less than 10 percent of the fires in medium fuels will spread faster than 10 chains per hour. In high fuels over 20 percent of the fires will spread at this rate, in extreme fuels 30 percent, and in grass fuels 50 percent.

Classification of grass as a separate fuel type will foster more effective fire control planning. For use in planning activities fuels have been classified according to the maximum rate at which 85 percent of the fires will spread in each type (10). Adoption of this classification system enabled fire control planners to design presuppression organizations to handle 85 percent of the fires. Only 15 percent of the fires

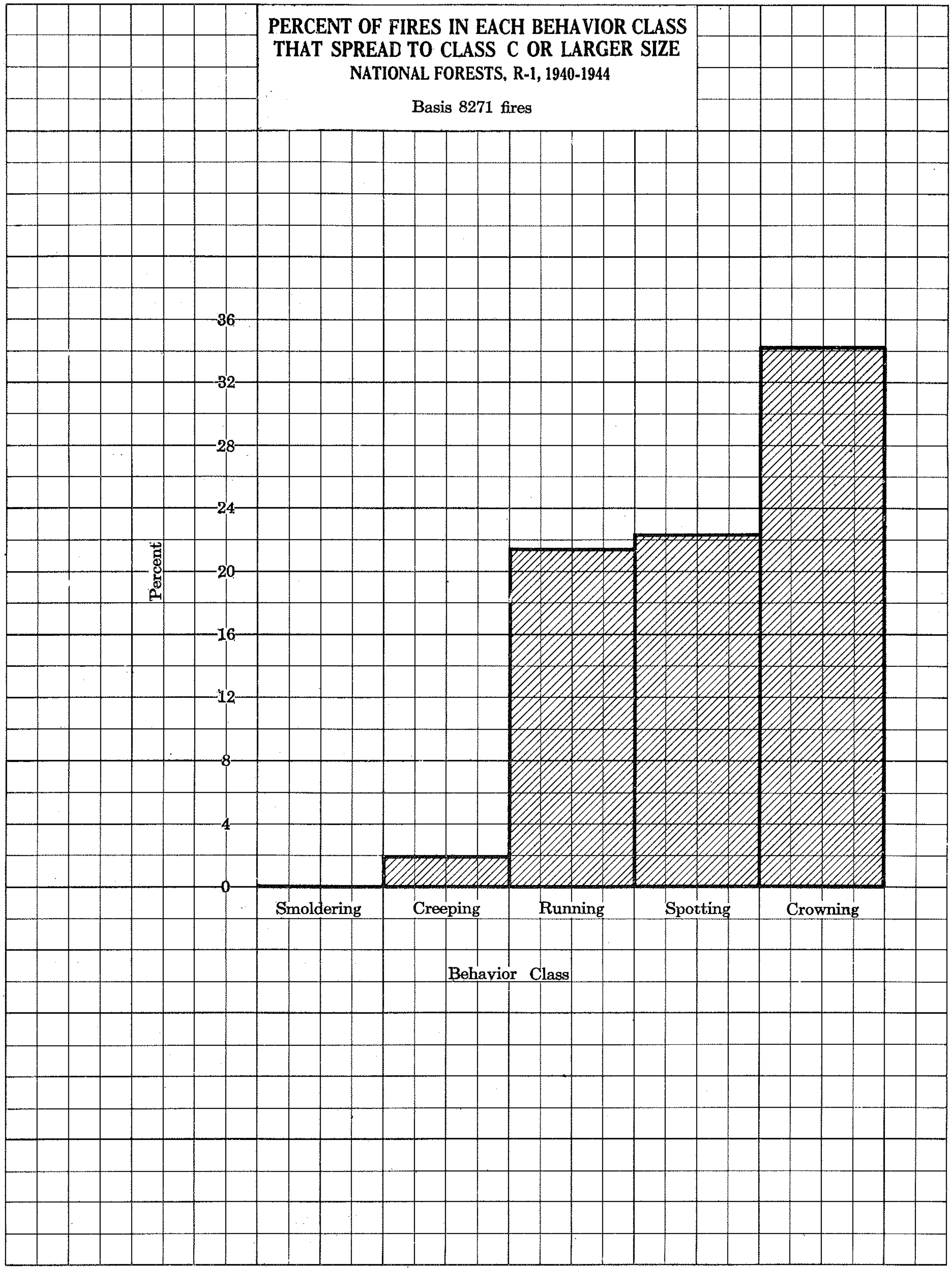

PERCENT OF FIRES IN EACH BEHAVIOR CLASS
THAT SPREAD TO CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1940-1944
Basis 8271 fires
Percent
36
32
28
24
20
16
12
8
4
0
Smoldering
Creeping
Running
Spotting
Crowning
Behavior Class

Figure 45.

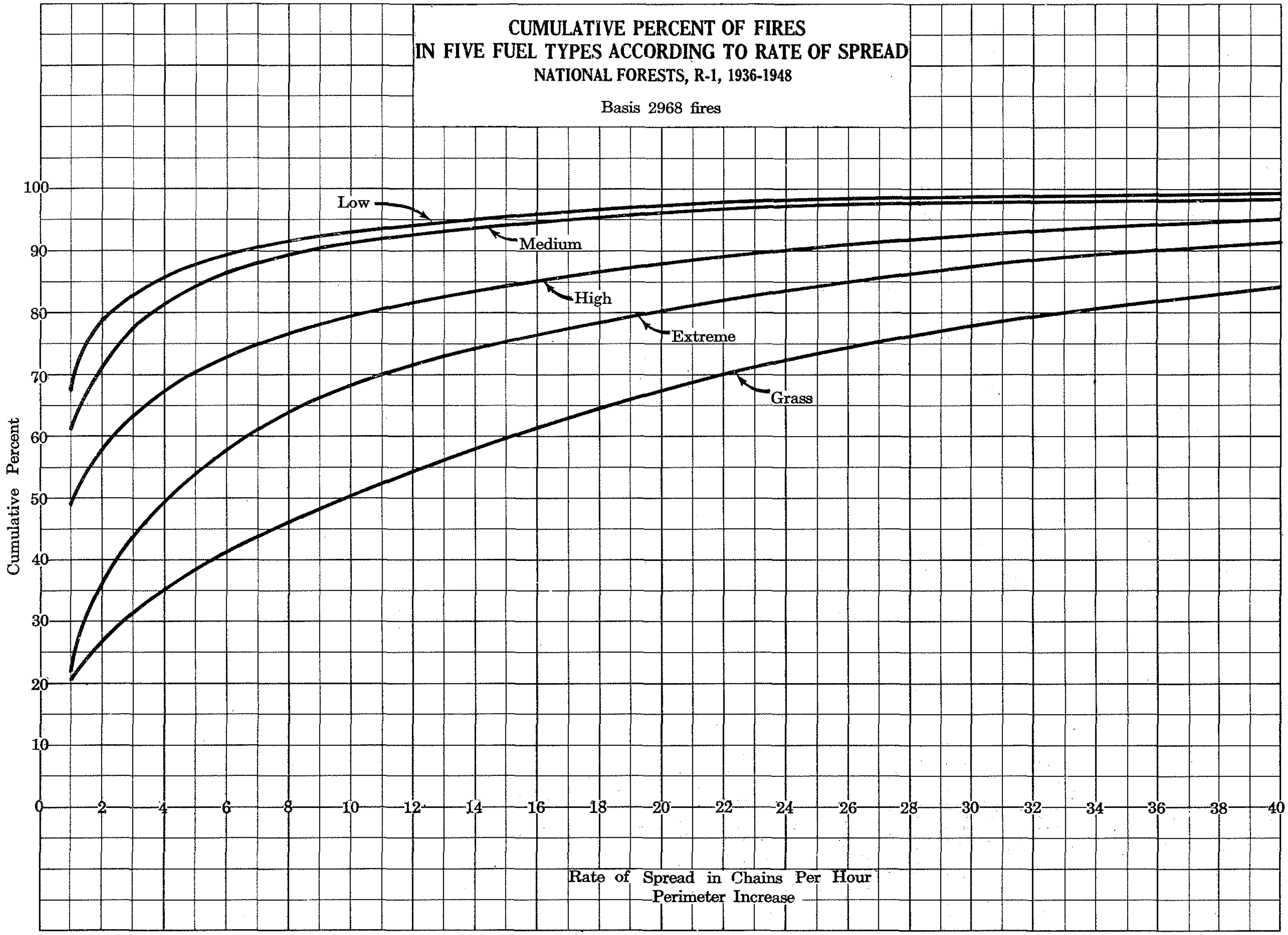
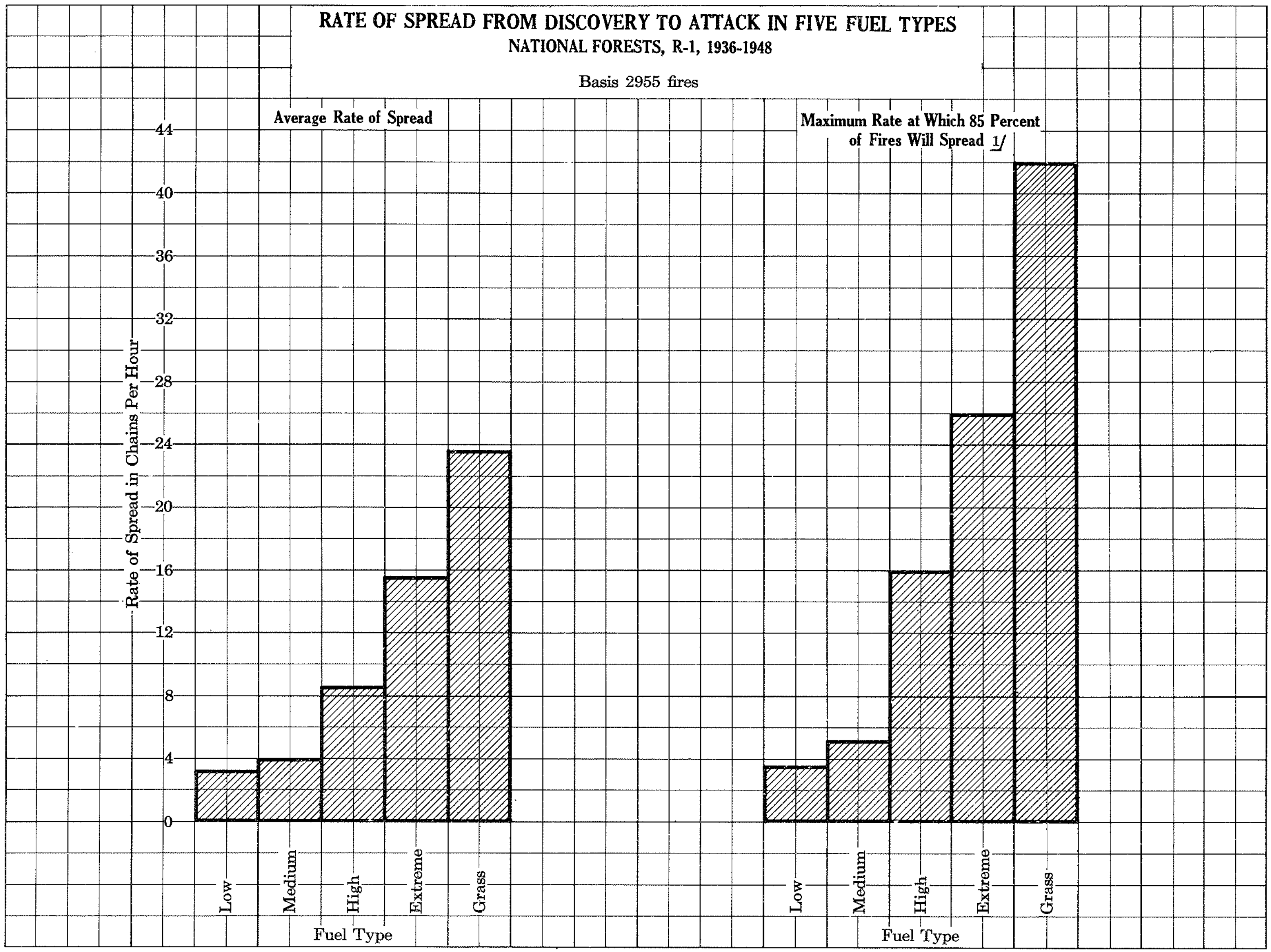

CUMULATIVE PERCENT OF FIRES
IN FIVE FUEL TYPES ACCORDING TO RATE OF SPREAD
NATIONAL FORESTS, R-1, 1936-1948
Basis 2968 fires
Cumulative Percent
100
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
20
22
24
26
28
30
32
34
36
38
40
Low
Medium
High
Extreme
Grass
Rate of Spread in Chains Per Hour
Perimeter Increase

Figure 46.

in each fuel type would be expected to spread faster than the classified rates and thus require action over and above that provided by the planned presuppression organization. Hornby has shown the effectiveness and economy of this principle of fuel classification (4). Separate identification of grass fuels will enable further improvements to be made in fire control planning. As shown in figure 47, the maximum rates at which 85 percent of the fires will spread are higher than the average rates in all fuel types, and grass fires in both cases have the highest rates.

Measurement of final perimeters of fires shows the effectiveness of fuel classification into five rate-of-spread types. This system of fuel classification provides an indicator of final size as well as initial rate of spread of fires. As illustrated in figure 48, final size steps up in proportion to rate of spread except in the case of grass fires. Fires in extreme fuels, although having slightly lower initial rates of spread than grass fires, have a greater final size. Likewise, as illustrated in figure 49, a higher percentage of western zone fires in extreme fuels reach class C or larger size. These differences are probably due to the large volume of inflammable material associated with extreme fuels which in turn cause a much more difficult control job. Fires in all fuels in the eastern zone have a larger average size than those in the western zone. This is apparently due to the more intensive fire protection organization in the western zone.

Fuel classification shows the amount of fire business to be expected. The average annual chains of fire perimeter per million acres reflects the amount of fire business caused by fire occurrence and rate of spread in each fuel type. As illustrated in figure 50, the annual control job in the western zone varies from 700 chains per million acres in low fuels to nearly 6000 chains in extreme fuels. This great variation in fire business illustrates the importance of identifying the problem areas through fuel classification.



1/ 15% of fires will spread faster

Figure 47.

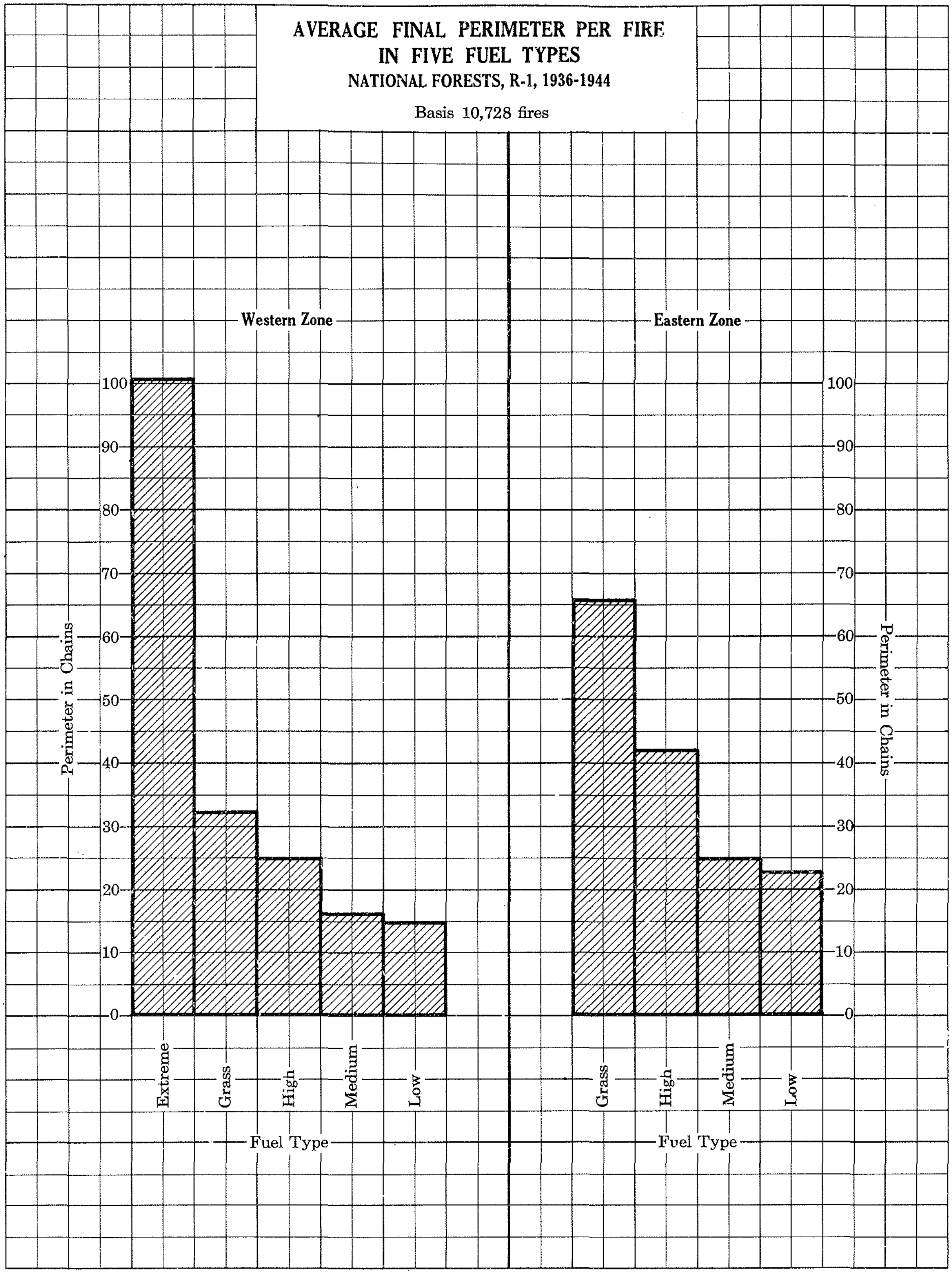

AVERAGE FINAL PERIMETER PER FIRE
IN FIVE FUEL TYPES
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,728 fires
Western Zone
Eastern Zone
Perimeter in Chains
100
90
80
70
60
50
40
30
20
10
0
Extreme
Grass
High
Medium
Low
Fuel Type

Figure 48.

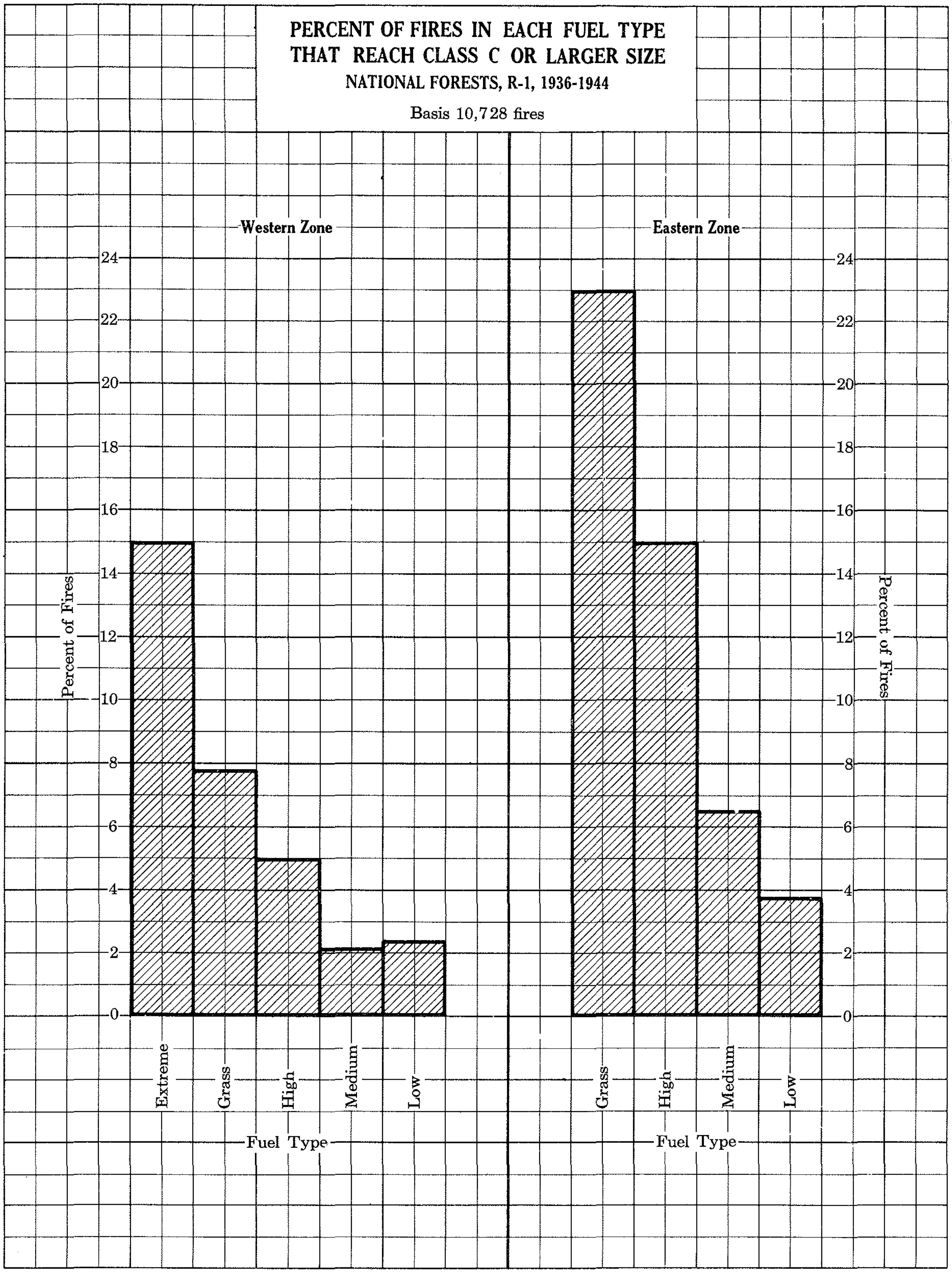

PERCENT OF FIRES IN EACH FUEL TYPE
THAT REACH CLASS C OR LARGER SIZE
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,728 fires
Western Zone
Eastern Zone
Percent of Fires
24
22
20
18
16
14
12
10
8
6
4
2
0
Extreme
Grass
High
Medium
Low
Fuel Type

Figure 49.

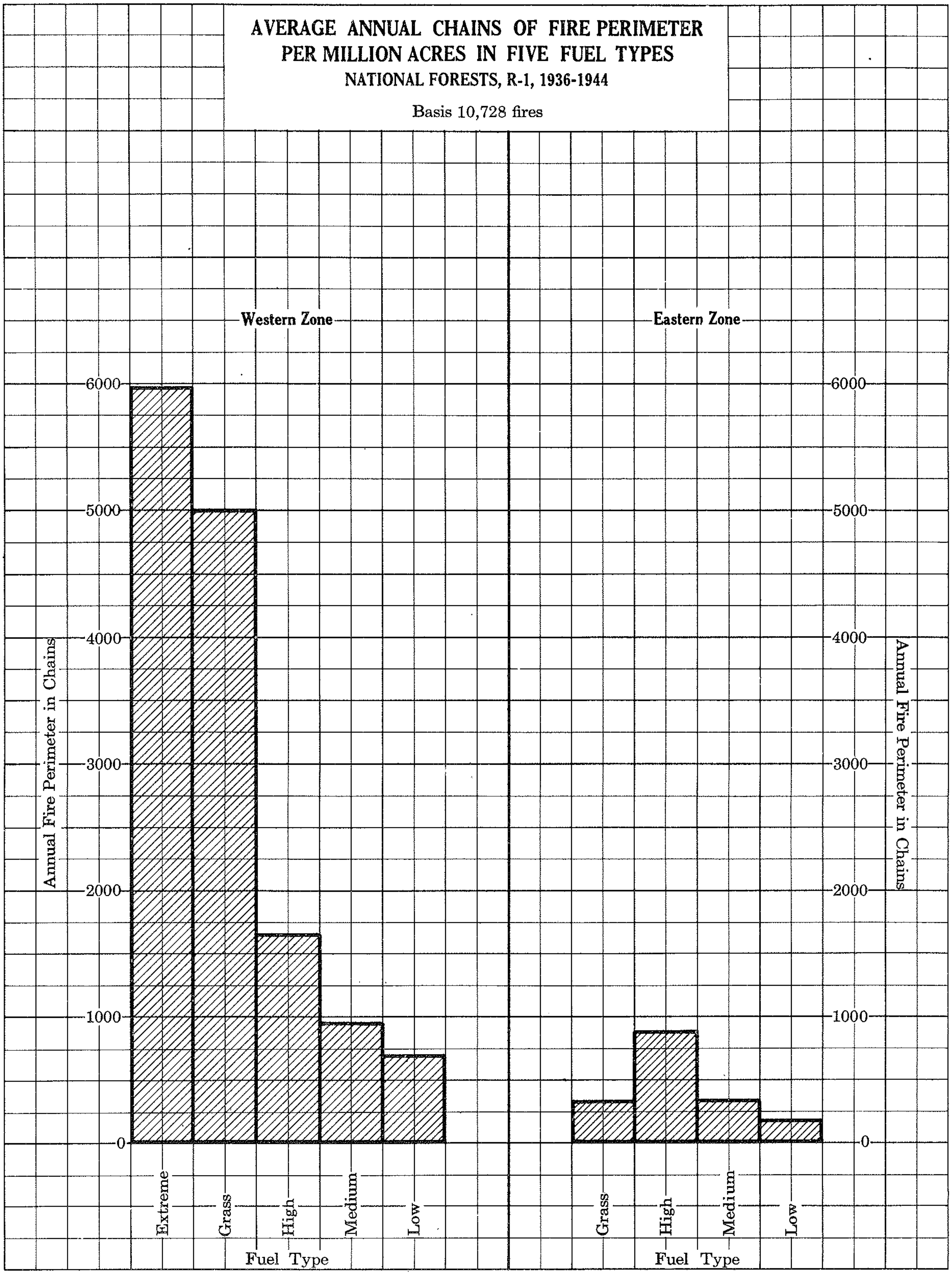

AVERAGE ANNUAL CHAINS OF FIRE PERIMETER
PER MILLION ACRES IN FIVE FUEL TYPES
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,728 fires
Western Zone
Eastern Zone
Annual Fire Perimeter in Chains
6000
5000
4000
3000
2000
1000
0
Extreme
Grass
High
Medium
Low
Fuel Type
Grass
High
Medium
Low
Fuel Type
Annual Fire Perimeter in Chains

Figure 50.

3. WEATHER

Weather conditions are of major importance in determining the probable behavior of fires. The time of occurrence and amount of precipitation, wind velocity and direction, temperature, relative humidity, and the frequency and character of lightning storms are all important factors influencing the ignition and subsequent rate of spread of fires. No attempt has been made in this study to make an exhaustive analysis of all of these factors. Gisborne, Hayes, and others have performed extensive research in this field (1, 3). The study reported here has been confined to those weather factors which could be analyzed in connection with the available data contained in individual fire reports. The specific objective was to study fire behavior as influenced by precipitation, wind, and burning index.

Precipitation

Precipitation is one measure of the difference in fire conditions in the eastern and western zones of the region. Measurements made at 14 representative stations show that average annual precipitation is 6.17 inches greater in the western than in the eastern zone. As shown in table 30, the western zone average annual precipitation at nine Weather Bureau stations situated in cities and towns near forest areas is 19.13 inches. In the eastern zone the average at five stations, likewise situated near forest areas, is 12.96 inches. The greater moisture in the western zone is one of the factors accounting for the heavier forest growth. This in turn is reflected in heavy fuels which often are a major factor in determining the severity of the forest fire problem.

July and August precipitation is lower in the western zone. This is in direct contrast to the annual precipitation which, as described above, is higher in the western zone. As shown in table 30, the July and August precipitation was lower in the western zone in 14 of 15 years. In 5 of 15 years the precipitation in these 2 months averaged less than 1 inch in the western zone and was less than 2 inches in 14 years. On the other hand, in the eastern zone the lowest July and August precipitation was 1.35 inches and was above 2 inches in 5 of 15 years. The very low precipitation in the western zone during July and August is one of the factors accounting for the severe fire conditions. The dry summer months make even heavy forest fuels become highly inflammable.

A deficiency in annual precipitation is not necessarily an indication of severe burning conditions. Little correlation was found in a comparison of annual precipitation and annual area burned. Part of this lack of correlation may be due to the lack of adequate yearlong precipitation records within the forest areas. In this study it was necessary to use precipitation measurements at Weather Bureau stations in towns near national forests. In many instances such measurements may not be representative of the conditions in the forests. Likewise, area burned is not necessarily a true indicator of burning conditions because even under severe situations skill in control activities may hold the burn to small areas. However, there is an obvious relationship between these two factors because fuels must be relatively dry to permit very

Table 30. Average Annual and July-August Precipitation in the Western and Eastern Zones, 1930-1945, inclusive

Year	Western Zone 1/ Annual Average	Western Zone 1/ July and August Average	Eastern Zone 2/ Annual Average	Eastern Zone 2/ July and August Average
1930-1931	14.51	0.61	9.80	1.66
1931-1932	19.91	1.34	14.59	3.57
1932-1933	20.65	1.16	14.09	4.12
1933-1934	22.47	0.28	10.79	1.35
1934-1935	18.47	1.24	10.43	1.54
1935-1936	17.92	0.95	10.49	1.63
1936-1937	15.98	1.47	10.51	1.57
1937-1938	22.01	1.76	15.85	2.89
1938-1939	15.98	0.68	12.73	1.43
1939-1940	19.62	1.29	13.68	1.41
1940-1941	21.05	2.03	17.69	2.70
1941-1942	21.68	1.74	13.85	1.52
1942-1943	22.99	1.42	12.53	1.46
1943-1944	15.71	1.35	15.64	2.42
1944-1945	18.02	0.55	11.69	1.95
15-year average	19.13	1.17	12.96	2.08

1/ Average annual western zone precipitation is that recorded from October 1 through September 30 at the following stations:

Orofino, Idaho	Elevation	1027	feet
Priest River, Idaho	"	2380	"
St. Maries, Idaho	"	2155	"
Grangeville, Idaho	"	3323	"
Kalispell, Montana	"	2973	"
Libby, Montana	"	2075	"
Thompson Falls, Montana	"	2439	"
Hamilton, Montana	"	3529	"
Missoula, Montana	"	3225	"

2/ Average annual eastern zone precipitation is that recorded from October 1 through September 30 at the following stations:

Billings, Montana	Elevation	3115	feet
Big Timber, Montana	"	4100	"
Helena, Montana	"	4110	"
Great Falls, Montana	"	3360	"
Dillon, Montana	"	5143	"

large burns. To provide the best test of the effect of annual precipitation, the yearly moisture totals from 14 representative stations were computed from October 1 of the year preceding the fire season through September 30 of the year in which area burned was measured. A summary of the results of this study for the eastern and western zones is shown in figures 51 and 52. The lack of correlation between annual precipitation and area burned is highlighted by the fact that in the western zone 1934 was a relatively wet year, yet nearly 350,000 acres were burned.

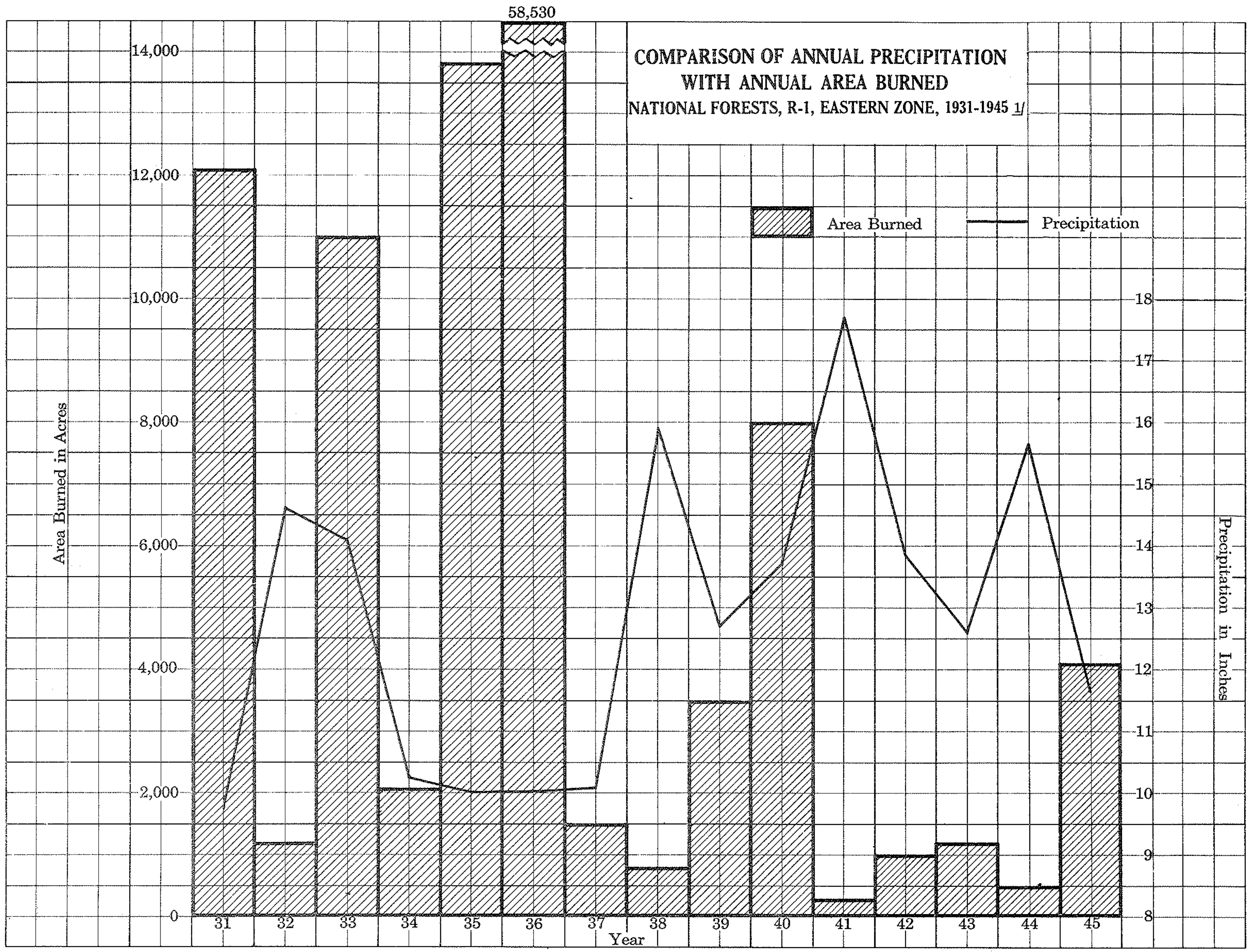
In the western zone July and August precipitation shows good correlation with area burned. As illustrated in figure 53, the six driest periods in July and August also were the periods when the greatest burns occurred. This comparison illustrates the fact that date of precipitation is an important element in determining the severity of burning conditions. For example, in 1934 annual precipitation was high, but drouth conditions in July and August made this one of the most critical fire seasons in recent years. In the eastern zone, as illustrated in figure 54, a close correlation between July and August precipitation and area burned was not found. The light yet flashy fuels of the eastern zone will dry out rather rapidly after summer rains, and for this reason precipitation is not a complete indicator of burning conditions.

Wind Velocity

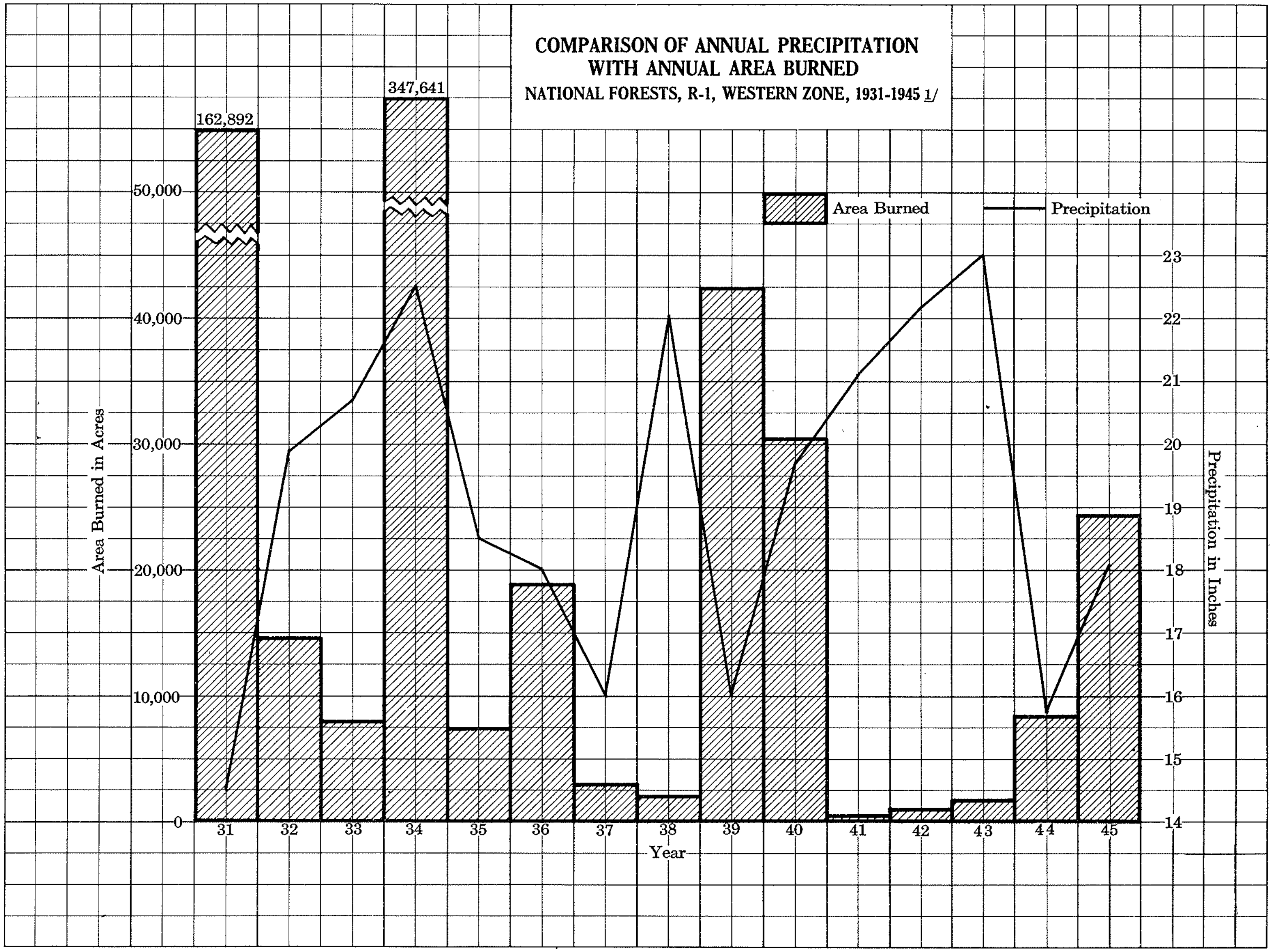
On over 50 percent of the fires wind velocity is light at the time of initial attack. As illustrated in figure 55, very high wind velocities are not common in this region. In a study of over 12,000 fires the wind velocities at the time of first attack were less than 19 miles per hour in 91 percent of the cases, and gale velocities of 39 to 54 miles per hour were observed on only 27 fires, or 0.2 percent of the cases. As will be shown later, high wind velocities have a very important effect on fire behavior, and such velocities on even a few fires may produce disastrous consequences. However, this region is fortunate in that it is not subjected to frequent high winds accompanied by very low humidities such as the so-called Santa Ana winds experienced in southern California.

High wind velocities are more common in the eastern zone. As shown in table 31, higher wind velocities were observed on all of the eastern forests than on any of the western forests. In the eastern zone over 20 percent of the fires had wind velocities of 19 or more miles per hour at first attack as compared to only 7 percent in the western zone. The Lewis and Clark and Beaverhead National Forests reported nearly one-fourth of their fires with wind velocities of 19 or more miles per hour.

Gale wind velocities were reported on more than one national forest in only 2 years out of 9. In 1931 the wind velocity at first attack was reported as gale strength (39-54 miles per hour) on 12 fires on 8 separate national forests. In 1932 there were 7 fires on 4 national forests in which these high velocities were reported. In all other years studied (1931-1939) not more than one national forest per year reported winds of this strength.

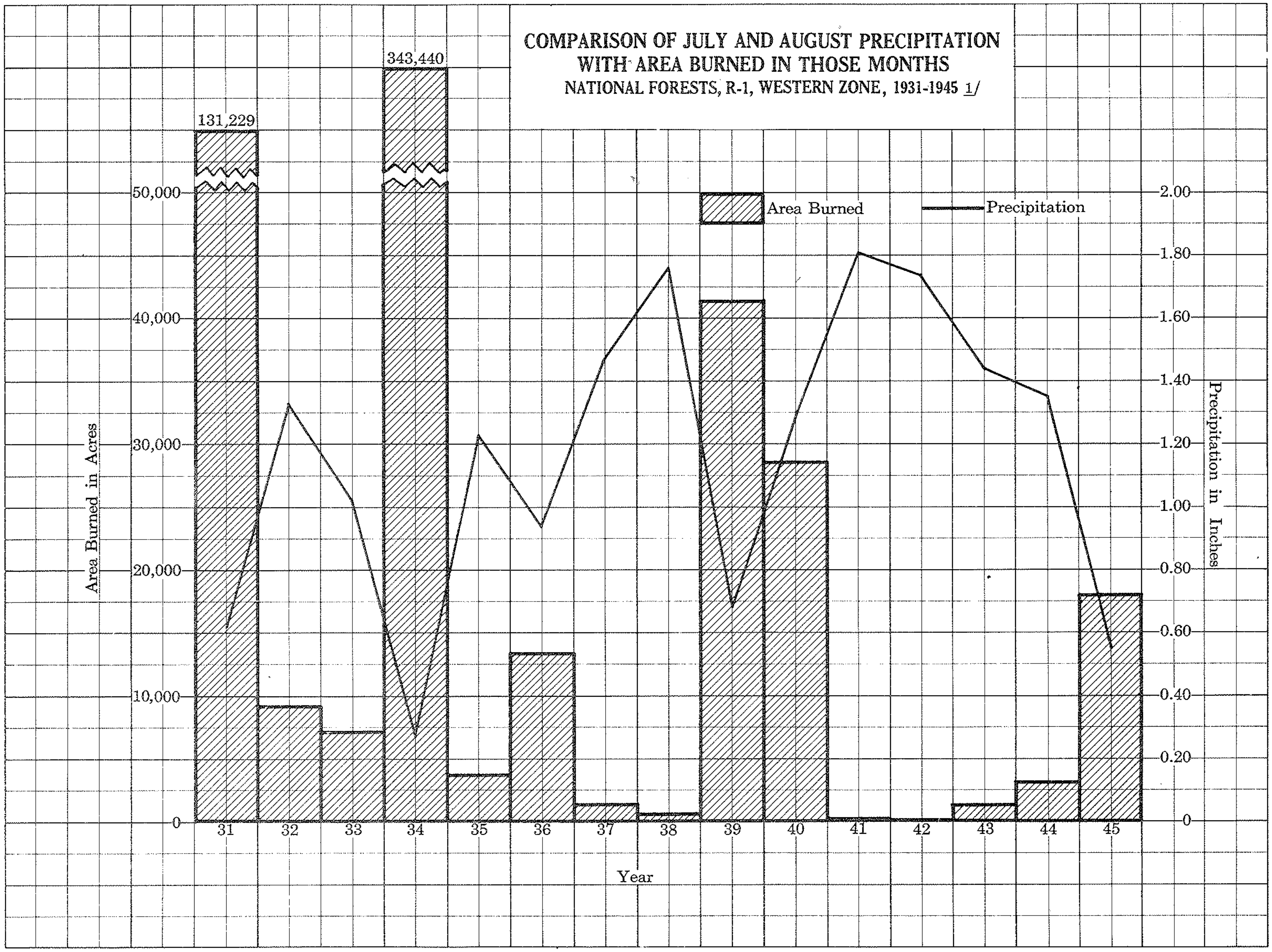


1/ Precipitation shown is 12 months' average from October 1 of year preceding fire season through September 30 as recorded at Billings, Big Timber, Helena, Great Falls, and Dillon, all in Montana.



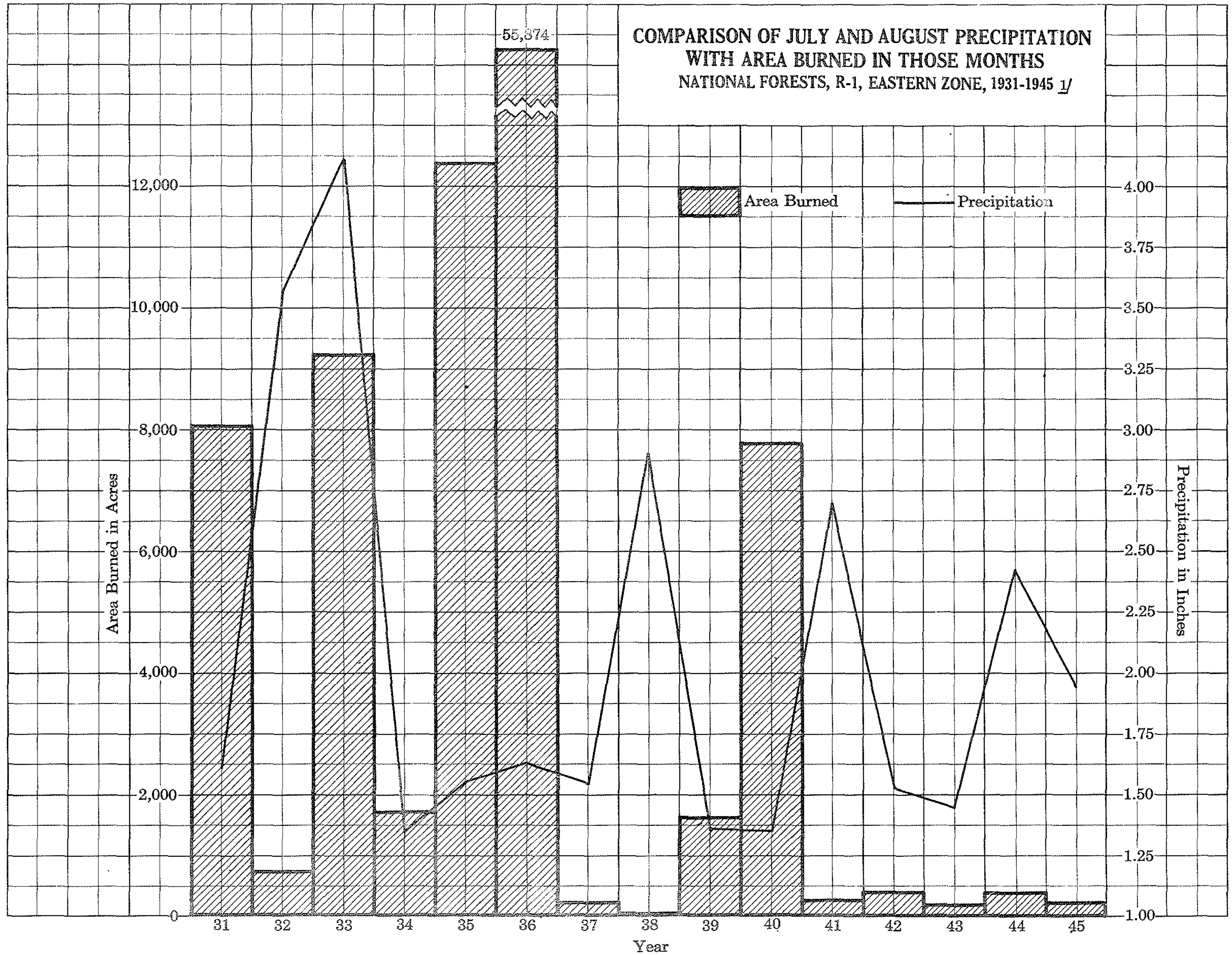
1/ Precipitation shown is 12 months' average from October 1 of year preceding fire season through September 30 as recorded at Orofino, Priest River, St. Maries, and Grangeville, Idaho; Kalispell, Libby, Thompson Falls, Hamilton, and Missoula, Montana.

Figure 52.



COMPARISON OF JULY AND AUGUST PRECIPITATION WITH AREA BURNED IN THOSE MONTHS
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1945 1/

1/ Precipitation shown is July and August average at Orofino, Priest River, St. Maries, and Grangeville, Idaho; Kalispell, Libby, Thompson Falls, Hamilton, and Missoula, Montana.



1/ Precipitation shown is July and August average at Billings, Big Timber, Helena, Great Falls, and Dillon, all in Montana.

Figure 54.

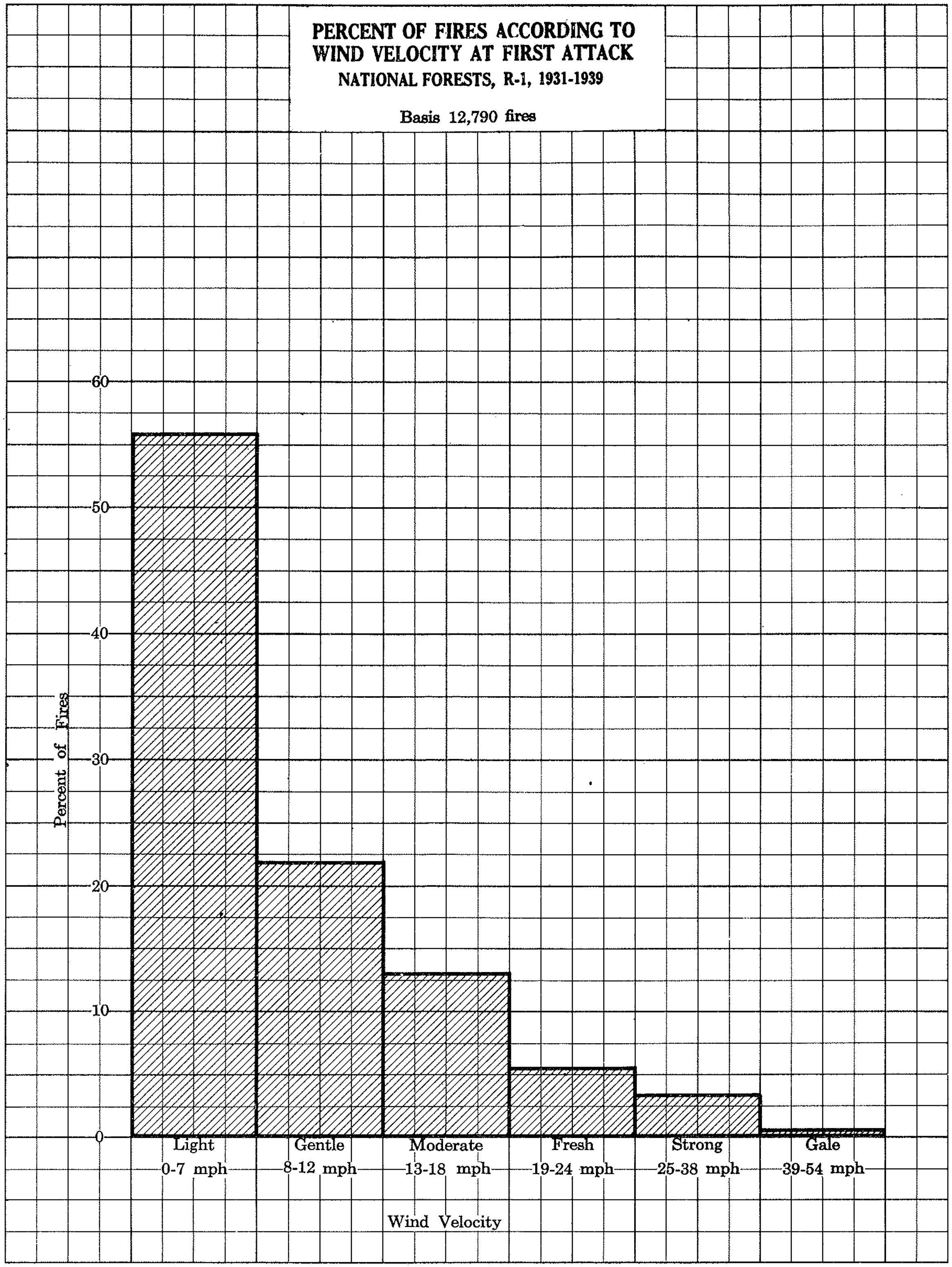

PERCENT OF FIRES ACCORDING TO
WIND VELOCITY AT FIRST ATTACK
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,790 fires
Percent of Fires
60
50
40
30
20
10
0
Light
0-7 mph
Gentle
8-12 mph
Moderate
13-18 mph
Fresh
19-24 mph
Strong
25-38 mph
Gale
39-54 mph
Wind Velocity

Figure 55.

Table 31. Percent of Fires According to Wind Velocity at First Attack, National Forests, R-1, 1931-1939, inclusive

Forest	Light 0-7 mph		Gentle 8-12 mph		Moderate 13-18 mph		Fresh 19-24 mph		Strong 25-38 mph		Gale 39-54 mph		Total No.
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	
Bitterroot	658	64.45	191	18.71	127	12.44	32	3.13	13	1.27			1,021
Cabinet	495	53.40	228	24.60	128	13.80	37	3.99	37	3.99	2	0.22	927
Clearwater	602	63.37	192	20.21	95	10.00	46	4.84	15	1.58			950
Coeur d'Alene	314	55.97	127	22.64	71	12.65	29	5.17	18	3.21	2	0.36	561
Flathead	564	58.15	234	24.12	107	11.03	49	5.05	16	1.65			970
Kaniksu	803	63.33	246	19.40	139	10.96	60	4.73	16	1.26	4	0.32	1,268
Kootenai	479	54.74	183	20.91	145	16.57	39	4.46	25	2.86	4	0.46	875
Lolo	790	58.05	311	22.85	167	12.27	75	5.51	15	1.10	3	0.22	1,361
Nezperce	1026	62.29	359	21.79	139	8.44	81	4.92	41	2.49	1	0.06	1,647
St. Joe	631	58.27	267	24.65	124	11.45	44	4.06	17	1.57			1,083
WESTERN ZONE	6362	59.66	2338	21.93	1242	11.65	492	4.61	213	2.00	16	0.15	10,663
Beaverhead	69	30.80	53	23.66	45	20.09	22	9.82	32	14.29	3	1.34	224
Custer	102	37.64	54	19.93	54	19.93	23	8.49	35	12.91	3	1.10	271
Deerlodge	249	40.61	144	23.49	115	18.77	61	9.95	44	7.18			613
Gallatin	153	47.52	52	16.15	50	15.53	36	11.18	30	9.31	1	0.31	322
Helena	164	35.96	114	25.00	93	20.39	40	8.78	43	9.43	2	0.44	456
Lewis and Clark	77	31.95	52	21.58	53	21.99	30	12.45	27	11.20	2	0.83	241
EASTERN ZONE	814	38.27	469	22.04	410	19.28	212	9.96	211	9.93	11	0.52	2,127
TOTAL REGION ONE	7176	56.10	2807	22.00	1652	12.90	704	5.50	424	3.30	27	0.20	12,790

The final size of fires increases as wind velocity at first attack increases. In a study of over 12,000 fires a remarkable correlation was found between the wind velocity at the time of first attack and final size. This increase in size of fires is illustrated in figure 56. As a result of this test there can be little doubt that high winds are breeders of trouble for the fire control organizations. More aggressive fire suppression measures are clearly called for as wind velocities increase.

Fire Danger Rating

Fire danger rating provides an effective method for evaluating the severity of a fire season. The fire danger rating system developed by Gisborne provides a sound basis for determining the effect of weather conditions (1). This system is superior because it integrates all major weather factors into one numerical rating. Four factors -- calendar date, relative humidity, wind velocity, and fuel moisture -- are combined to form a burning index rating. Two other factors -- lightning occurrence and visibility -- are added to burning index to obtain fire danger rating. As explained in the following paragraphs, the ratings obtained from measurement of these factors show a remarkable correlation with the severity of fire conditions which actually existed on the national forests.

Annual summaries of fire danger rating show that major variations have occurred in the character of fire seasons. Gisborne developed a method of analyzing fire danger measurements which enabled an entire season to be rated according to three categories -- easy, average, and critical. His studies indicated that the worst probable fire danger on any forest in the western zone would not average above 76.02 during July and August. Likewise, he found that the least probable danger rating during these months would not fall below 21.48. A forest with 0 to 32 percent of worst probable fire danger would have its season rated easy, while 33 to 67 percent calls for an average rating, and 68 percent or over a critical rating. As shown in table 32, variations in these ratings from a low of 10 percent of worst probable to a high of 93 percent have occurred on the national forests in the western zone.

The western zone has experienced cycles of high and low burning index. This fact is vividly illustrated in figure 57. During the 7-year period 1934 through 1940 ratings of 65 percent of worst probable fire danger or higher occurred on one or more forests each year. During the 8-year period 1941 through 1948 average fire danger in the western zone during these months did not climb to this level on a single occasion. During the entire period covered by this study the effect of the higher fire danger in the earlier period has been observed. For example, in 1934 when every forest in the western zone had a critical fire danger rating, over 9 percent of the fires reached class C or larger size. This was the highest percent of large size fires of any year in which danger rating was evaluated.

Fire danger rating shows good correlation with area burned. Over 90 percent of the area burned from 1934 through 1948 occurred in the earlier 7-year period of higher fire danger. Specific studies of area

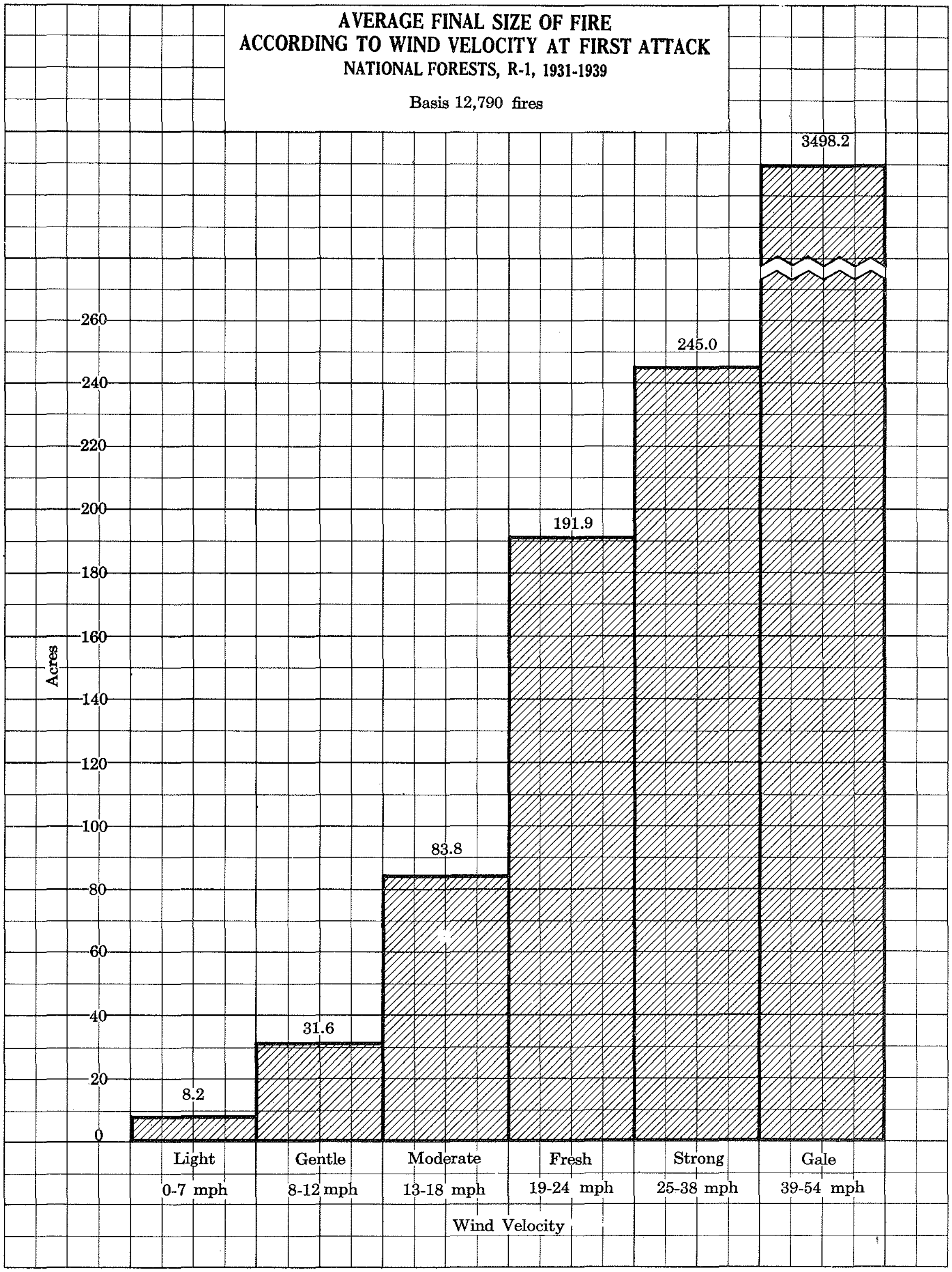

AVERAGE FINAL SIZE OF FIRE
ACCORDING TO WIND VELOCITY AT FIRST ATTACK
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,790 fires
Acres
0
20
40
60
80
100
120
140
160
180
200
220
240
260
8.2
31.6
83.8
191.9
245.0
3498.2
Light
0-7 mph
Gentle
8-12 mph
Moderate
13-18 mph
Fresh
19-24 mph
Strong
25-38 mph
Gale
39-54 mph
Wind Velocity

Figure 56.

Table 32. Percentage of Worst Probable Fire Danger, National Forests, R-1, Western Zone, 1934-1948, inclusive

Statistical analysis of the July-August (62-day average) danger class for each of the 10 western forests (Colville excluded) for the years 1934 through 1948 shows that at least 99% of such averages can be expected to fall between a maximum of class 76.02 and a minimum of class 21.48. These limits are therefore assumed as Worst Probable and Least Probable danger classes. By this scale a forest averaging class 76.02 would be rated as 100% of Worst Probable. If its average were 21.48 it would rate 0%. Class 48.75 rates 50% of Worst Probable.

In the cases listed below percentages of 68% or more are considered critical and are underlined. Percentages of 32% or less are called easy. Intermediate percentages indicate average July-August fire danger.

Percentage of Worst Probable

Forest	Year														
	1934	1935	1936	1937	1938	1939	1940	1941	1942	1943	1944	1945	1946	1947	1948
Bitterroot	71	71	58	73	52	65	76	36	60	51	34	49	32	36	18
Cabinet	84	61	80	65	65	71	80	46	52	45	34	45	40	36	17
Clearwater	87	65	63	65	52	58	58	34	43	43	23	34	18	23	12
Coeur d'Alene	75	61	65	49	61	71	71	40	43	40	29	38	30	23	10
Colville										52	36	51	36	29	18
Flathead	93	65	78	71	61	67	67	47	43	52	27	40	25	27	16
Kaniksu	71	45	67	52	61	75	67	43	45	45	32	47	30	25	12
Kootenai	78	58	87	61	65	71	71	43	38	45	27	43	29	23	10
Lolo	85	71	85	71	58	71	78	43	55	52	34	52	38	41	30
Nezperce	89	80	67	67	52	58	61	34	49	43	34	43	25	38	18
St. Joe	75	71	61	55	55	67	61	38	45	36	32	36	29	32	16

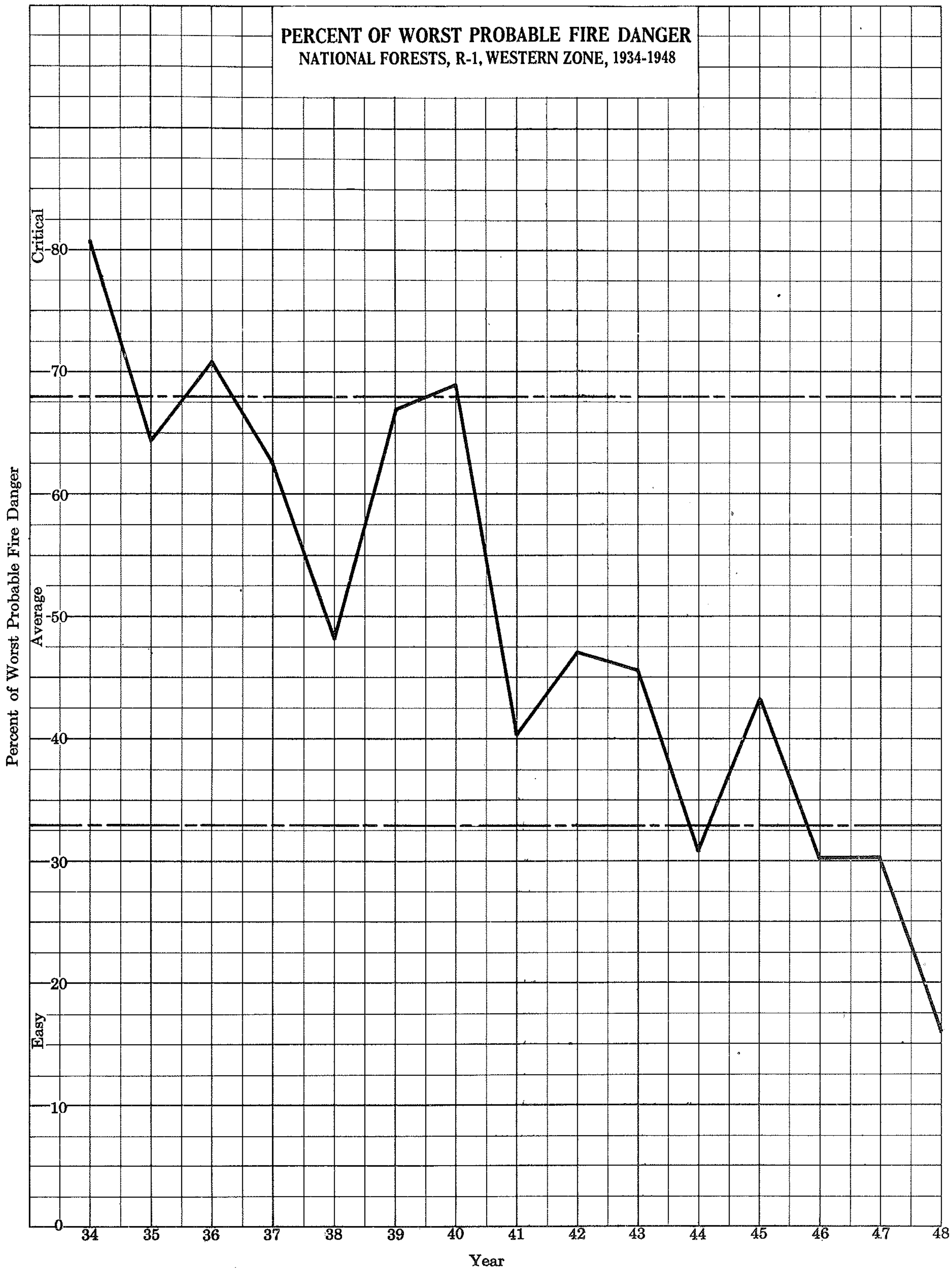

PERCENT OF WORST PROBABLE FIRE DANGER
NATIONAL FORESTS, R-1, WESTERN ZONE, 1934-1948
Percent of Worst Probable Fire Danger
Critical
Average
Easy
80
70
60
50
40
30
20
10
0
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
Year

Figure 57.

burned and fire danger in July and August show that most of the large burns have occurred where fire danger is high. As illustrated in figure 58, the July and August average fire danger reached very high ratings in 1934, 1936, 1939, and 1940. These were also periods when relatively large areas were burned. Only the fire season of 1945 shows a relatively large burn when fire danger was below 67 percent of worst probable. In all other years when average or easy conditions prevailed the area burned was less than 5000 acres during July and August in the western zone.

A fire danger rating of 45 to 62 is most common during July and August. As illustrated in figure 59, fire danger averages between 45 and 62 on over 42 percent of the days during July and August. During the 1934-1945 period nearly 90 percent of the daily danger ratings were between 28 and 78. Only 6 percent of the fire danger ratings in July and August were found to be less than 28 and 4 percent above 78.

Burning Index

Burning index is an effective indicator of fire behavior. When properly applied in conjunction with other variables, burning index is a dependable measurement for evaluating probable rate of spread, size class of fires, and final perimeter. As explained in the following paragraphs and in the succeeding chapter on FIRE BEHAVIOR RATING, burning index provides a useful guide for evaluating weather factors when designing fire control systems or planning action on going fires.

More fires will spread faster as burning index increases. This fact was clearly demonstrated by a study of nearly 3000 fires for which burning index and other factors governing rate of spread could be more or less precisely measured. The burning index for these fires was divided into classes as follows:

B. I. Class	B.I. Rating on Model 4 Meter Used 1936-37	B.I. Rating on Model 5 Meter Used 1938-43	B.I. Rating on Model 6 Meter Used 1944-48
1	1	1.0 - 1.4	1 - 10
2	2	1.6 - 2.4	11 - 27
3	3	2.6 - 3.4	28 - 44
4	4	3.6 - 4.4	45 - 62
5	5	4.6 - 5.4	63 - 78
6	6	5.6 - 6.4	79 - 95
7 ⊕	7	6.6 - 7.4	96 - 100

⊕ Class 7 not used because of a lack of observations.

A distribution of the fires in this study according to rate of spread and burning index class is shown in figure 60. Only 1 percent of the fires in B.I. class 1 spread at rates greater than 40 chains perimeter increase per hour. Over 76 percent of the fires in this class did not spread faster than 1 chain per hour. On the other hand, in B.I. class 6 nearly 14 percent of the fires spread faster than 40 chains per hour, and only 25 percent spread as slowly as 1 chain per hour.

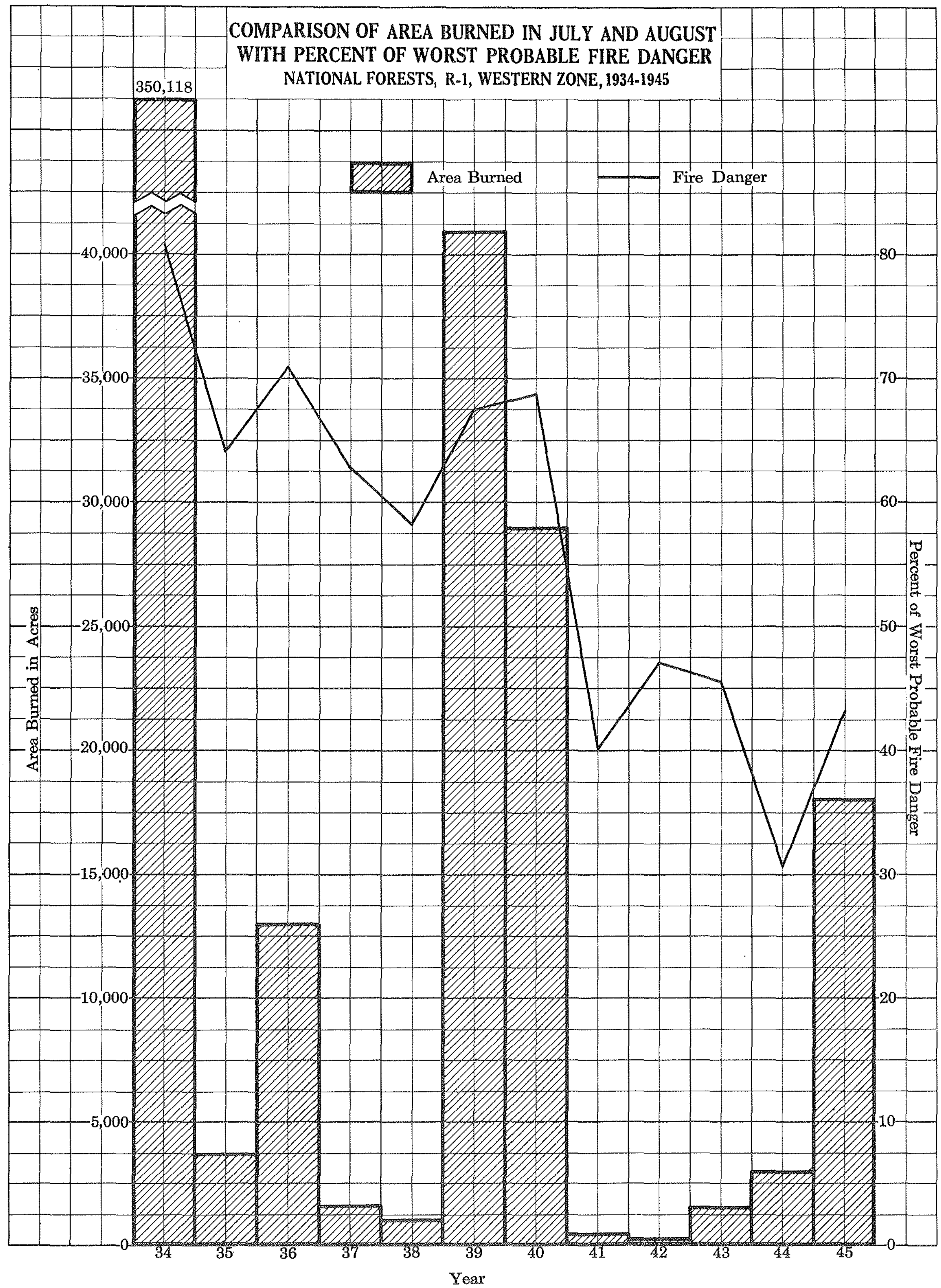

COMPARISON OF AREA BURNED IN JULY AND AUGUST
WITH PERCENT OF WORST PROBABLE FIRE DANGER
NATIONAL FORESTS, R-1, WESTERN ZONE, 1934-1945
350,118
Area Burned
Fire Danger
Area Burned in Acres
40,000
35,000
30,000
25,000
20,000
15,000
10,000
5,000
0
Percent of Worst Probable Fire Danger
80
70
60
50
40
30
20
10
0
34
35
36
37
38
39
40
41
42
43
44
45
Year

Figure 58.

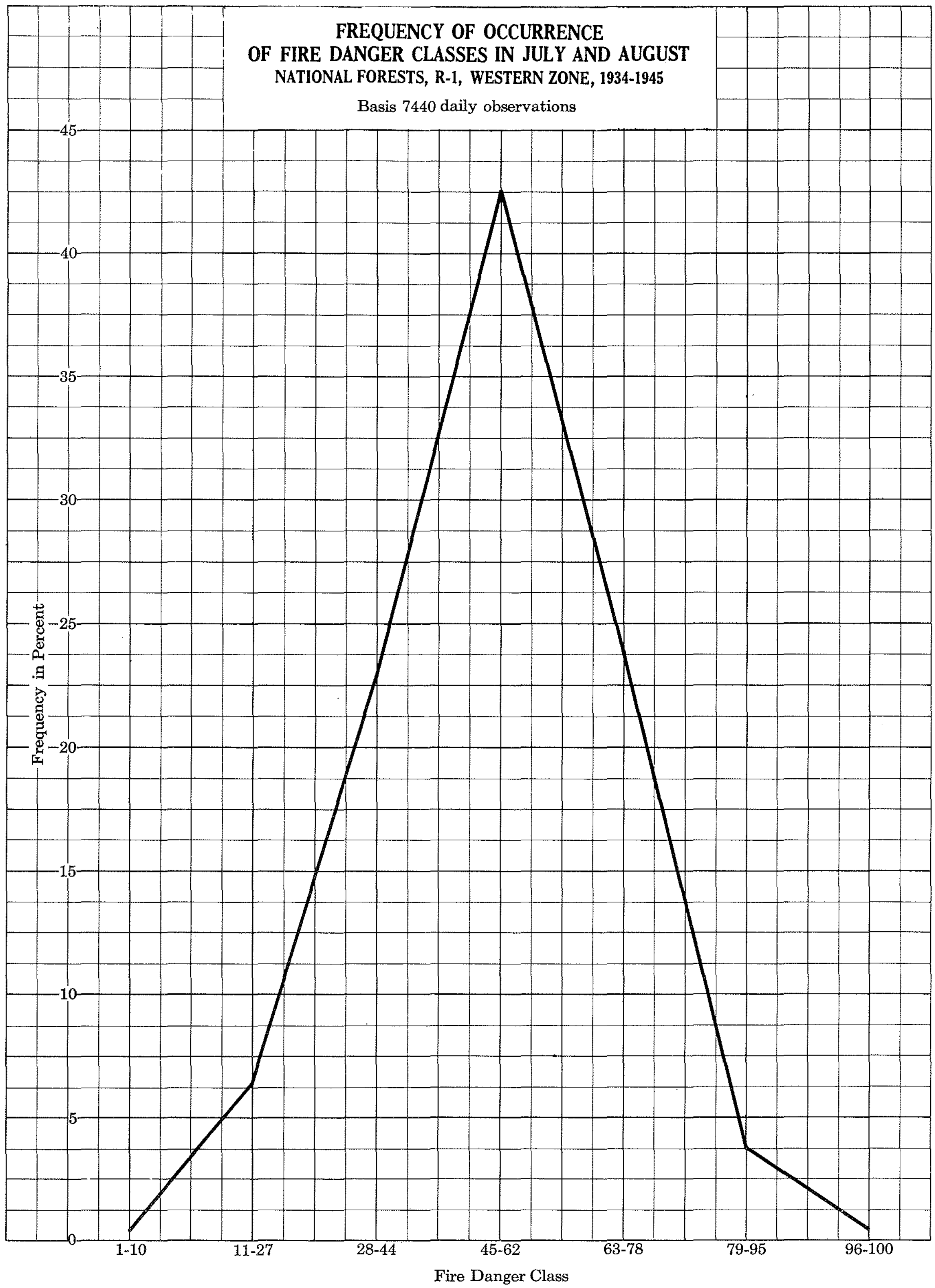
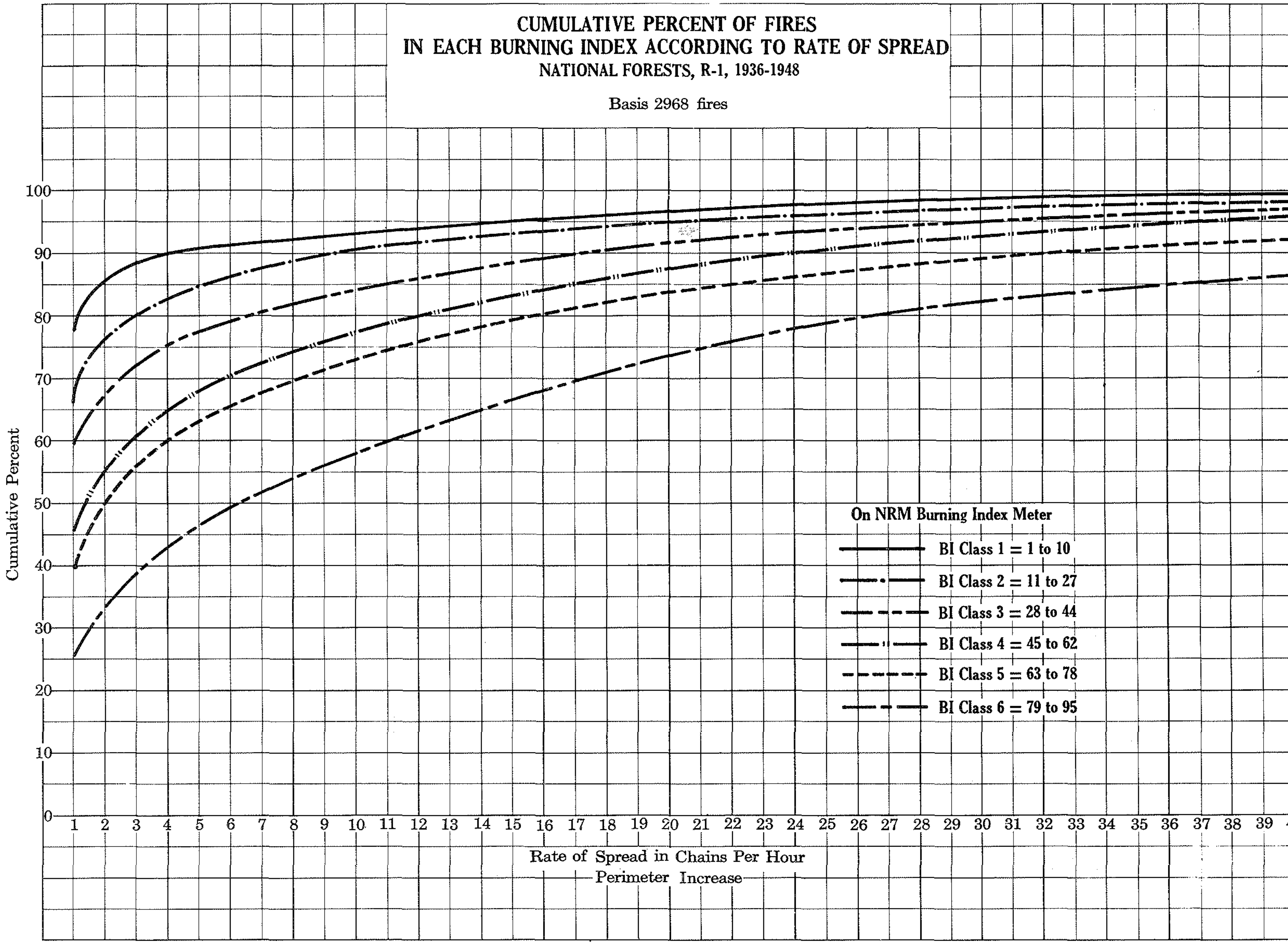

FREQUENCY OF OCCURRENCE
OF FIRE DANGER CLASSES IN JULY AND AUGUST
NATIONAL FORESTS, R-1, WESTERN ZONE, 1934-1945
Basis 7440 daily observations
Frequency in Percent
45
40
35
30
25
20
15
10
5
0
1-10
11-27
28-44
45-62
63-78
79-95
96-100
Fire Danger Class

Figure 59.



CUMULATIVE PERCENT OF FIRES
IN EACH BURNING INDEX ACCORDING TO RATE OF SPREAD
NATIONAL FORESTS, R-1, 1936-1948
Basis 2968 fires
Cumulative Percent
0
10
20
30
40
50
60
70
80
90
100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
Rate of Spread in Chains Per Hour
Perimeter Increase
On NRM Burning Index Meter
BI Class 1 = 1 to 10
BI Class 2 = 11 to 27
BI Class 3 = 28 to 44
BI Class 4 = 45 to 62
BI Class 5 = 63 to 78
BI Class 6 = 79 to 95

Figure 60.

The average danger point in rate of spread is a burning index of approximately 50. As will be explained in the next chapter, some fuels reach a dangerous rate of spread at less than B.I. 50 and others at much more than 50. However, when an average of all fires is considered, regardless of fuel type, the rate of spread is high enough at B.I. 50 that class A size may be exceeded within 1 hour after discovery. As illustrated in figure 61, a study of nearly 3000 fires revealed that average rate of spread varies from 3 chains per hour at a B.I. of 10 to 21 chains per hour at a B.I. of 80. This striking correlation between rate of spread and burning index demonstrates the value of B.I. measurements in planning the required flexibility in fire control systems and in making more aggressive attacks on going fires as B.I. increases. However, it must also be borne in mind that the rates of spread shown in figure 61 are averages and are subject to wide fluctuations caused by variations in fuels and topography.

The percent of fires reaching large size increases as burning index increases. As illustrated in figure 62, less than 1 percent of the fires reach class C size at a B.I. of 10. However, at a B.I. of 80 over 12 percent of the fires spread to this size. Figure 62 also illustrates that a B.I. of 50 is the point where a sharp increase in large size fires becomes apparent. This study was based on nearly 11,000 fires and includes all fires for which burning index was recorded during the 9-year period 1936 through 1944.

The average final perimeter per fire increases as burning index increases. In a study of nearly 11,000 fires it was found that burning index gives a good indication of the magnitude of the suppression job. When burning index was less than 20, fires did not average above 10 chains in final perimeter. When B.I. was from 20 to 50, fires did not average more than 17 chains in perimeter. However, above a B.I. of 50 a sharp increase again was observed. As illustrated in figure 63, the average final perimeter per fire was 23 chains at B.I. 60, 34 chains at B.I. 70, and 54 chains at B.I. 80. This relationship probably illustrates the meaning of burning index in more positive terms than in any of the studies made. Burning index measurements were clearly demonstrated to be guides showing major variations in fire behavior and in turn calling for different degrees of action by the fire control forces.

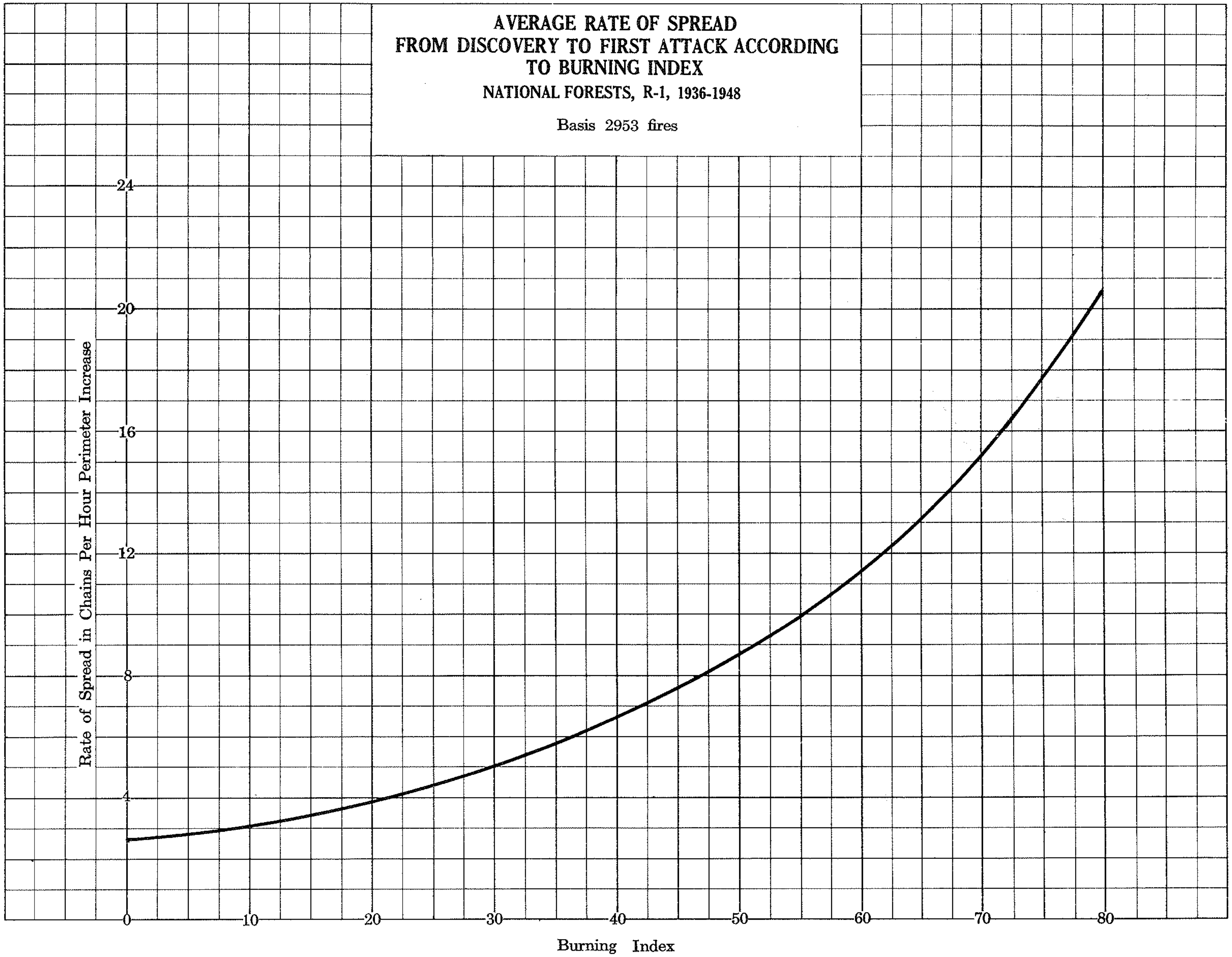

AVERAGE RATE OF SPREAD
FROM DISCOVERY TO FIRST ATTACK ACCORDING
TO BURNING INDEX
NATIONAL FORESTS, R-1, 1936-1948
Basis 2953 fires
Rate of Spread in Chains Per Hour Perimeter Increase
0
4
8
12
16
20
24
10
20
30
40
50
60
70
80
Burning Index

Figure 61.

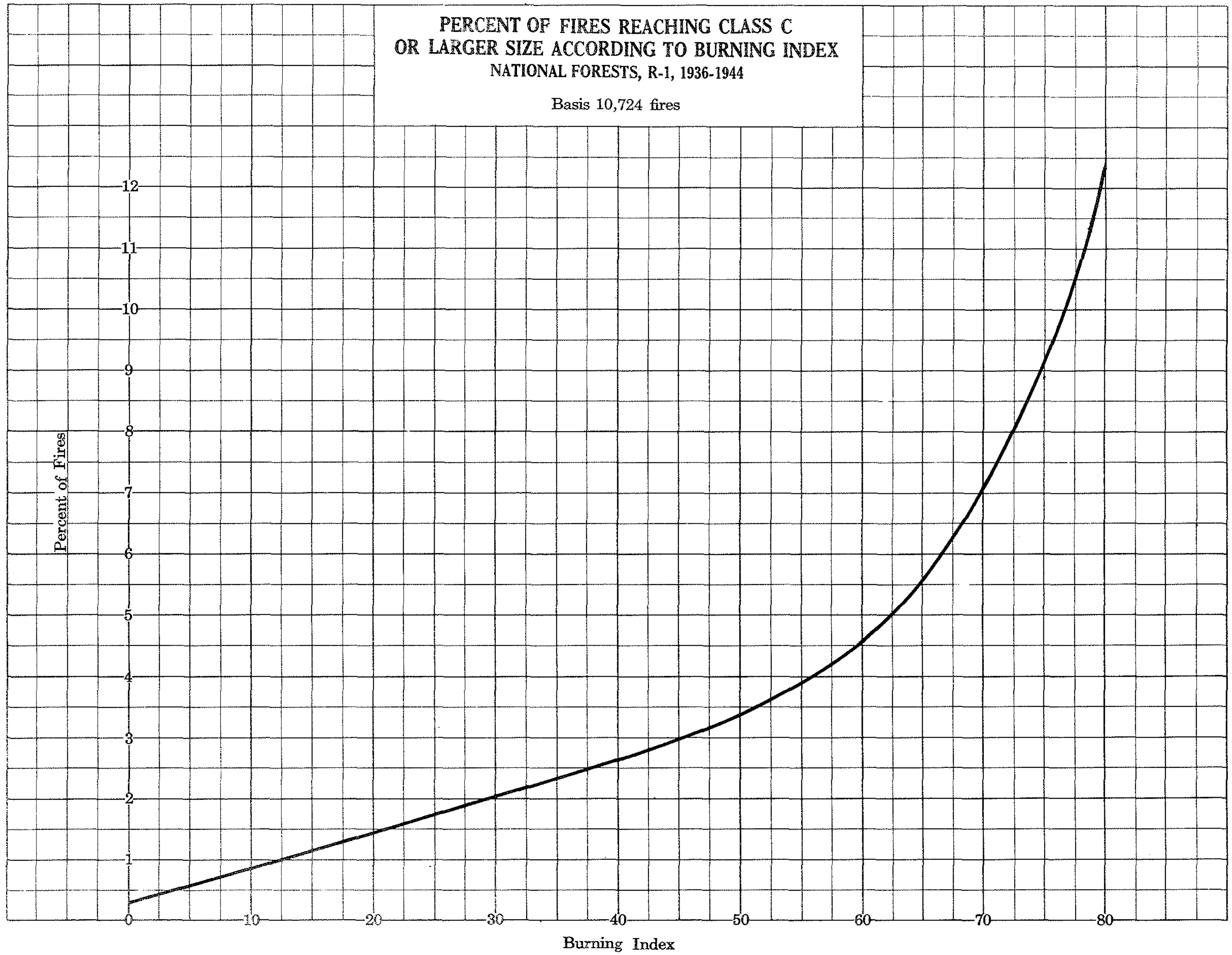

PERCENT OF FIRES REACHING CLASS C
OR LARGER SIZE ACCORDING TO BURNING INDEX
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,724 fires
Percent of Fires
0
1
2
3
4
5
6
7
8
9
10
11
12
10
20
30
40
50
60
70
80
Burning Index

Figure 62.

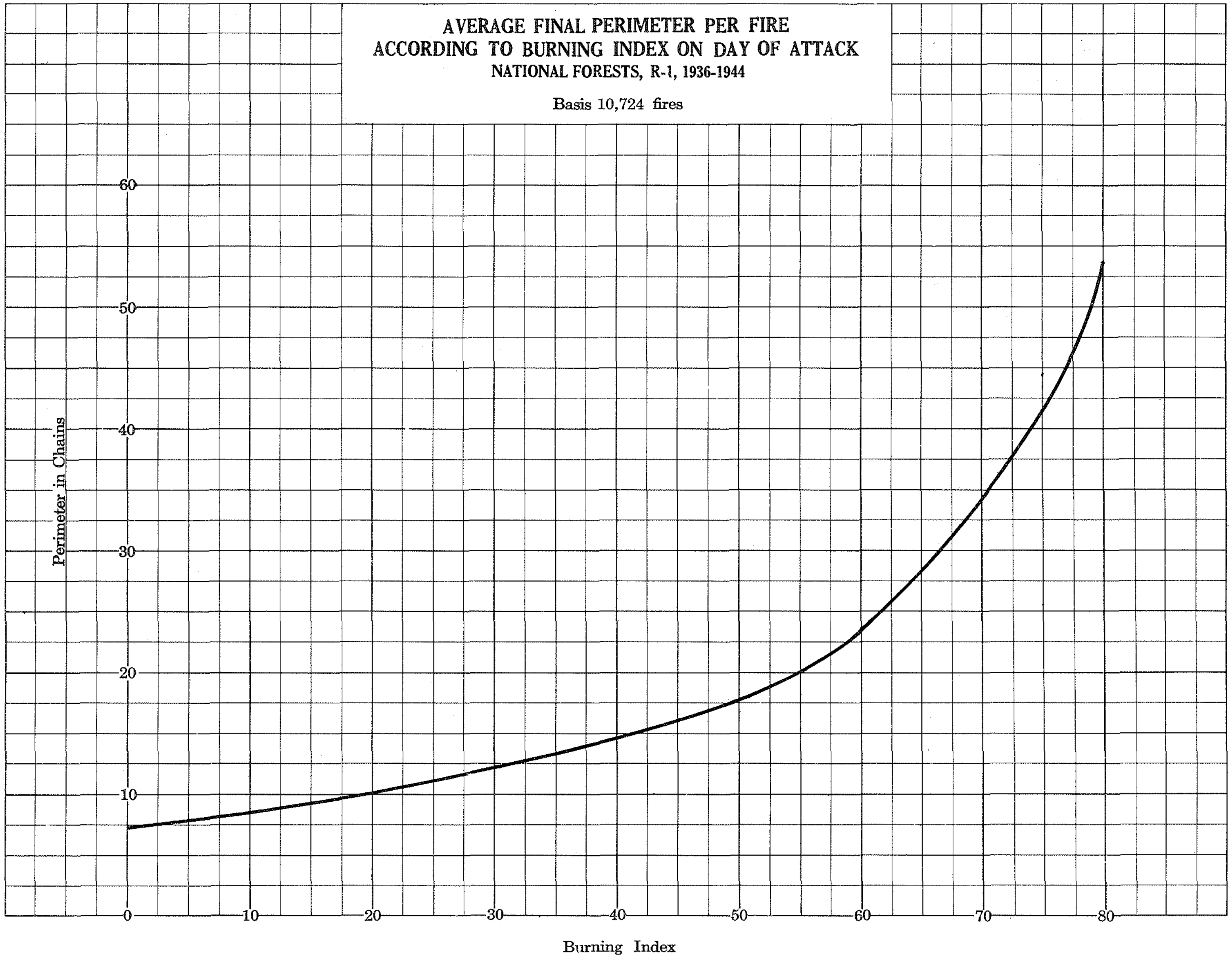

AVERAGE FINAL PERIMETER PER FIRE
ACCORDING TO BURNING INDEX ON DAY OF ATTACK
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,724 fires
Perimeter in Chains
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
Burning Index

Figure 63.

4. FIRE BEHAVIOR RATING

The foregoing three chapters reported on the results of analyses of three basic factors influencing fire behavior -- topography, fuels, and weather. In the design of fire control systems and in planning action on going fires it is necessary to evaluate the combined effects of these factors. The objective in this type of evaluation is to provide a general guide for probable fire behavior. Studies of the combined effects of topography, fuels, and weather led to the conclusion that fire behavior may be rated with reasonable accuracy through the following process:

1. Probable ignition rates on each fire control unit may be determined in accordance with topography and fuel characteristics as outlined in the foregoing chapters on those factors.

2. Probable rate of spread may be calculated through application of fuel classification and burning index rating as described in the following paragraphs.

3. In planning action on a going fire the topographic characteristics at the site of the fire must be known and used to adjust the calculation of rate of spread according to fuel type and burning index.

Influence of Rate of Spread on the Design of Fire Control Systems

Rate-of-spread classifications serve as warning signals for dangerous fire behavior. In earlier studies Hornby established the importance of planning the type, strength, and location of fire control forces in accordance with the probable rate that fires will gain perimeter (4). His objective was to evaluate basic behavior factors so as to plan fire control forces which could build fire line faster than the fire makes perimeter (2). This principle of rating fire behavior has long been recognized in fire control planning in Region 1 of the Forest Service. The present study clearly shows the value of determining rate of spread according to variations in fuel classification and burning index. Determining rate of spread in this manner enables identification of the areas and periods of greatest danger.

Rate-of-spread classifications are higher than the previously established standards. As explained in chapter 2, fuels are classified for fire control planning purposes in Region 1 so as to show the maximum rate of spread for 85 percent of the fires (10). The R-1 Fuel Type Handbook describes rate of spread for each fuel type at a burning index of 70 as follows:

Low -- On a class 5 day (B.I. 70) about 15 percent of the fires in this fuel type will make more than 6 chains perimeter per hour average for the first 3 or 4 hours. About 85 percent will spread slower.

Medium -- On a class 5 day (B.I. 70) about 15 percent of the fires in this fuel type will make more than 8 chains perimeter per hour average for the first 3 or 4 hours. About 85 percent will spread slower.

High -- On a class 5 day (B.I.70) about 15 percent of the fires in this fuel type will make more than 10 chains perimeter per hour average for the first 3 or 4 hours. About 85 percent will spread slower.

Extreme -- On a class 5 day (B.I. 70) about 15 percent of the fires in this fuel type will make more than 20 chains perimeter per hour average for the first 3 or 4 hours. About 85 percent will spread slower.

Grass -- Not classified separately under previous standards.

As illustrated in figure 64, this study shows higher rates of spread at B.I. 70 than the above standards. The comparison is as follows:

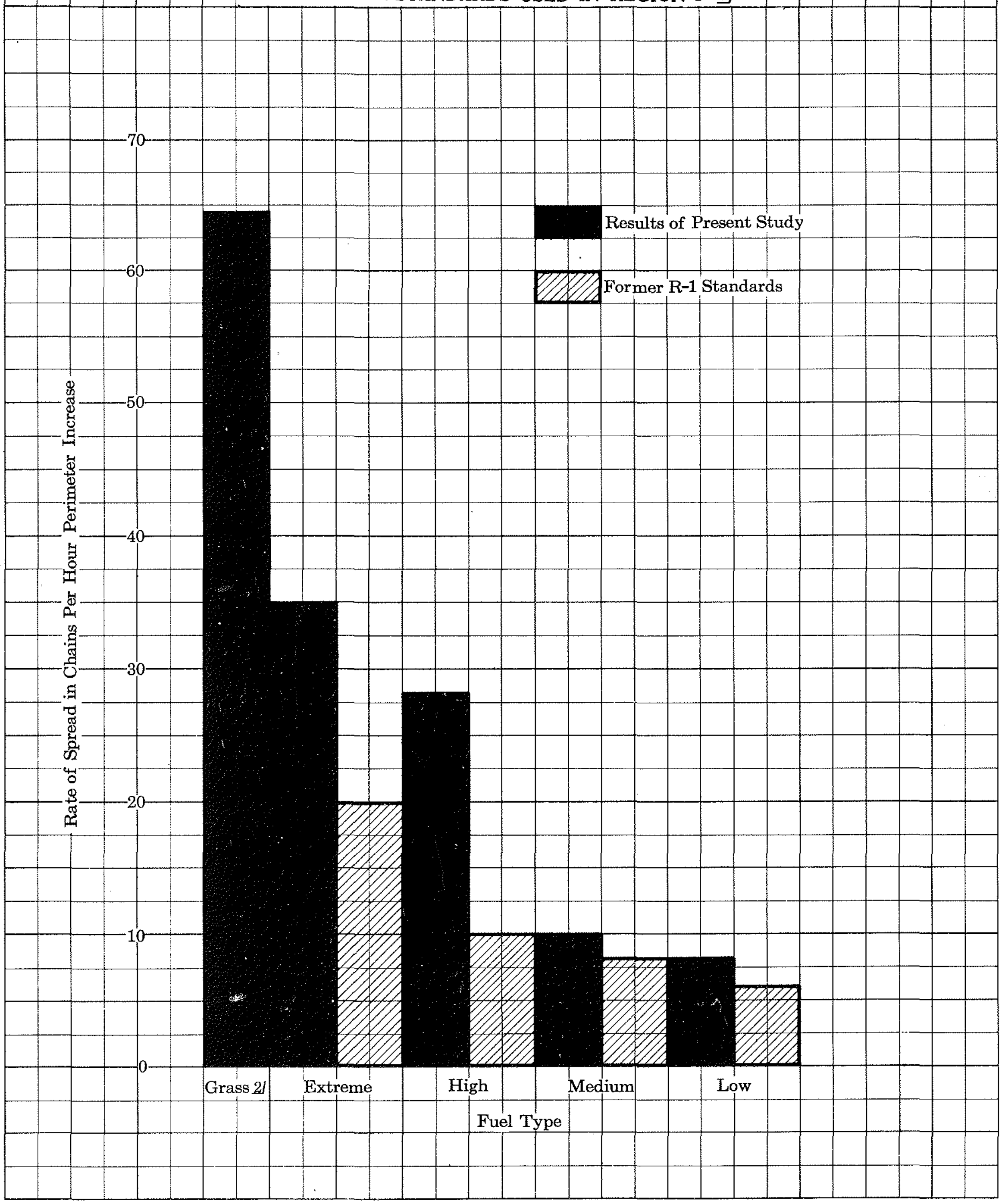
Fuel Type	Old Standard	Study Results
Low	6 c.p.h.	8 c.p.h.
Medium	8 c.p.h.	10 c.p.h.
High	10 c.p.h.	28 c.p.h.
Extreme	20 c.p.h.	35 c.p.h.
Grass	Not rated	65 c.p.h.

High rates of spread are reached in each fuel type at different burning index ratings. In testing this feature separate groups of curves were constructed to show average rate of spread and the maximum rate of spread for 85 percent of the fires. The results, as illustrated in figures 65 and 66, show that as fuel classification decreases, burning index must increase to permit high rates of spread. For example, the average rate of spread in grass is nearly 20 chains per hour at a B.I. of 20, while in low and medium fuels this average rate of spread is not reached at a B.I. of 80.

Rate of spread cannot be measured precisely through application of burning index and fuel classification exclusive of other factors. This fact is vividly demonstrated by comparing average rate of spread with maximum rate of spread for 85 percent of the fires, as shown in figures 65 and 66. Even at high burning index ratings a few fires in the worst fuels will only creep. Likewise, at relatively low burning index ratings a few fires in low or medium fuels may spread rapidly. These differences in some cases are caused by lack of precision in fuel classification or in lack of burning index ratings that are fully representative of the actual conditions at the site of a fire. Other factors, such as aspect, steepness of slope, and natural barriers, also will affect rate of spread. However, the trends shown in figures 65 and 66 may be applied with reasonable accuracy if these influencing factors are carefully evaluated in the field.

Maximum rates of spread for 85 percent of the fires must be considered in fire control planning. A fire control organization planned to meet only average rates of spread would fall short of meeting the problems presented by many fast-spreading fires. For this reason fire control planners must consider the rate-of-spread factors shown in figure 66. With these factors as a guide, only 15 percent of the fires may be expected to spread faster than the rates shown. This has the effect of giving the fire control organization odds of approximately 5.6 to 1 that

COMPARISON OF MAXIMUM RATE OF SPREAD FROM DISCOVERY TO FIRST ATTACK FOR 85 PERCENT OF THE FIRES IN EACH FUEL TYPE AT A BURNING INDEX OF 70 WITH FORMER STANDARDS USED IN REGION 1 1/



1/15% of the fires will spread faster than the rates shown

2/Grass was not classified separately under former fuel standards in R-1

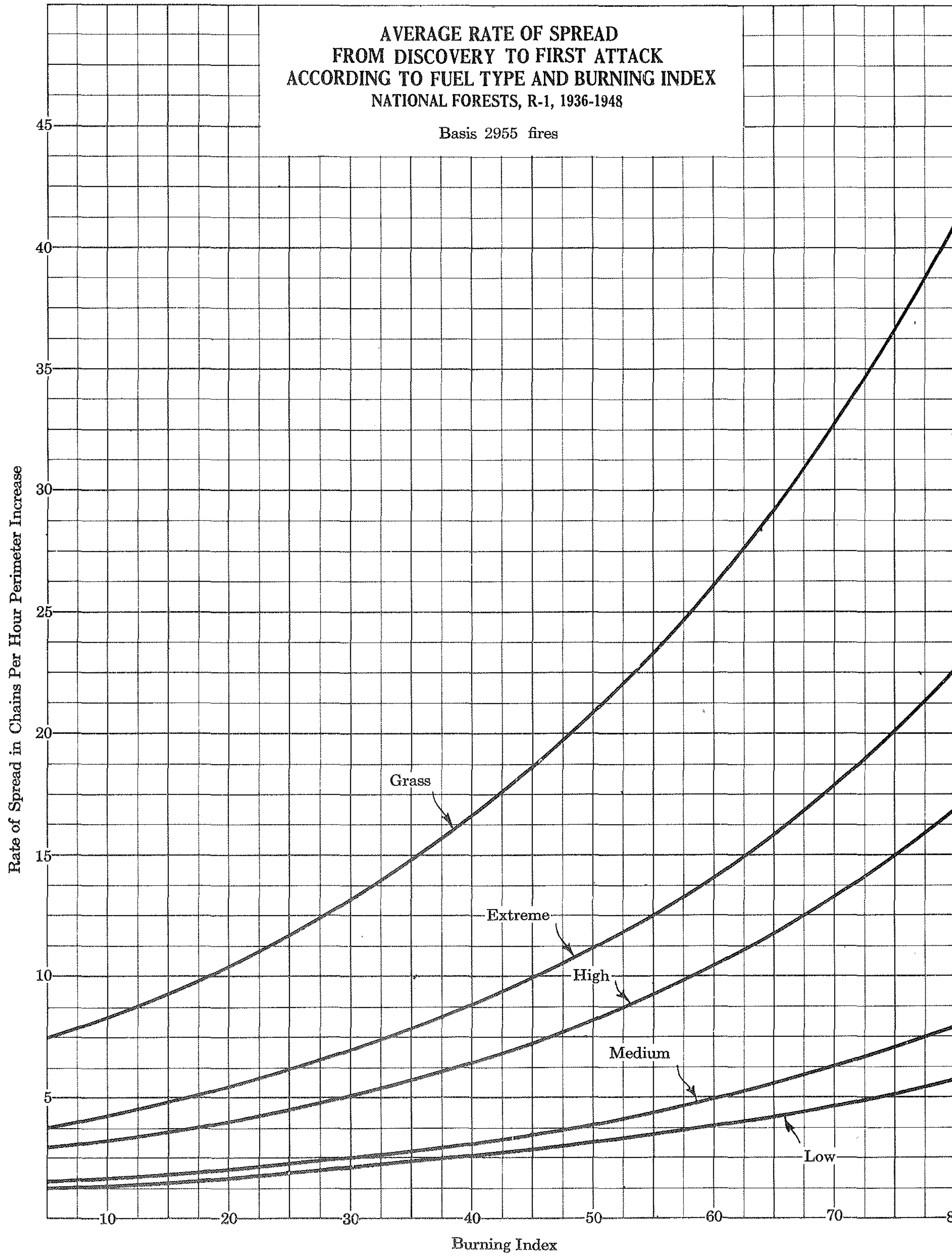
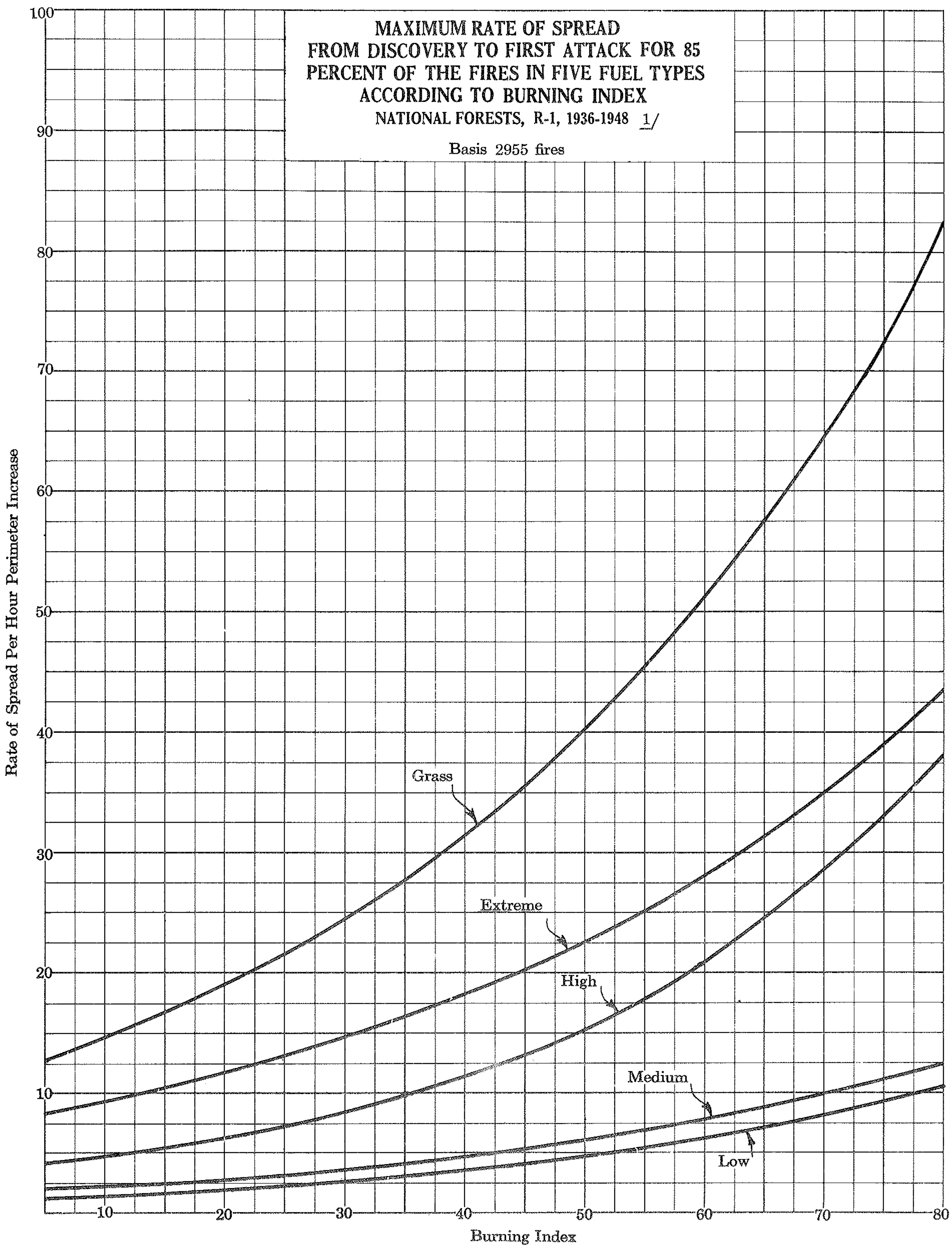

AVERAGE RATE OF SPREAD
FROM DISCOVERY TO FIRST ATTACK
ACCORDING TO FUEL TYPE AND BURNING INDEX
NATIONAL FORESTS, R-1, 1936-1948
Basis 2955 fires
Rate of Spread in Chains Per Hour Perimeter Increase
45
40
35
30
25
20
15
10
5
Grass
Extreme
High
Medium
Low
10
20
30
40
50
60
70
80
Burning Index

Figure 65.



1/ 15% of the fires will spread faster than the rates shown

Figure 66.

fires will not spread faster than the anticipated rate. Use of the maximum rate of spread for 85 percent of the fires in each fuel type also indicates the number of fires that can be handled by the initial attack forces. In general application a fire organization planned on this level may expect to require reinforcements on only 15 percent of the fires.

Determining Rate of Spread on Going Fires

Rate of spread varies widely according to conditions at the site of a fire. In a study of over 12,000 fires it was found that rate of spread from discovery to initial attack ranged from 0 to over 500 chains per hour in perimeter increase. On large fires much higher rates of spread will occur. Tests of large fires were not attempted in this study because fire report statistics are inadequate for that purpose. The objective was to determine the basic factors influencing initial rates of spread and to determine if fire report statistics can provide some basic guides for dispatchers and initial attack forces. In spite of the great variations in initial rate of spread, it was found that careful evaluation of topography, fuels, and weather enables the range to be narrowed down to limits which should foster better action planning on the going fire.

The effect of burning index on rate of spread must be evaluated separately in each fuel type. For example, an average rate of spread of 10 chains per hour is reached in the various fuels at the following burning index ratings:

Fuel Rate-of-Spread Classification	Burning Index
Low	Over 80
Medium	Over 80
High	58
Extreme	45
Grass	18

Because of these great differences it is essential for dispatchers and firegoers to be fully cognizant of both burning index and fuel classification. A relatively low burning index does not mean that high rates of spread will not occur. In grass and extreme fuels fires may be expected to exceed class A size in one hour or less at burning index ratings below 40.

Average rate of spread according to fuel type and burning index provides a general guide for planning action on going fires. As explained previously, in the over-all design of fire control systems the planner considers the maximum rate of spread for 85 percent of the fires. However, all fires would obviously not be expected by the dispatcher to spread at the maximum rate of the 85 percent level. If a fire organization dispatched forces on this principle, the result would be gross overmanning and unnecessary expenditure of funds. The average rate-of-spread factors shown for each fuel type in figures 67 through 71 are more appropriate guides for this purpose. During studies of nearly 3000 fires it was found that two-thirds of the fires in each fuel type spread within the following deviations of the rates shown:

Rate-of-Spread Classification	Deviations
Low	plus or minus 2 c.p.h.
Medium	plus or minus 3 c.p.h.
High	plus or minus 7 c.p.h.
Extreme	plus or minus 9 c.p.h.
Grass	plus or minus 17 c.p.h.

Factors at the site of a fire will determine whether to plan on above- or below-average rate of spread. The average rates of spread shown for each fuel type in figures 67 through 71 indicate the general upward trend as burning index increases and provide a basis for estimating the perimeter increase per hour. However, an evaluation of other factors influencing rate of spread must be made on each fire to take care of the deviations shown in each fuel type. The fire behavior studies have indicated the following guide lines for each fuel type:

1. In all fuels -- lower rates of spread may be expected when natural barriers break up the fuel body. Higher rates of spread may be expected on areas fully exposed to wind, in topographic formations making natural chimneys, on south-facing slopes, on steep slopes, and during periods when herbaceous vegetation is fully cured.

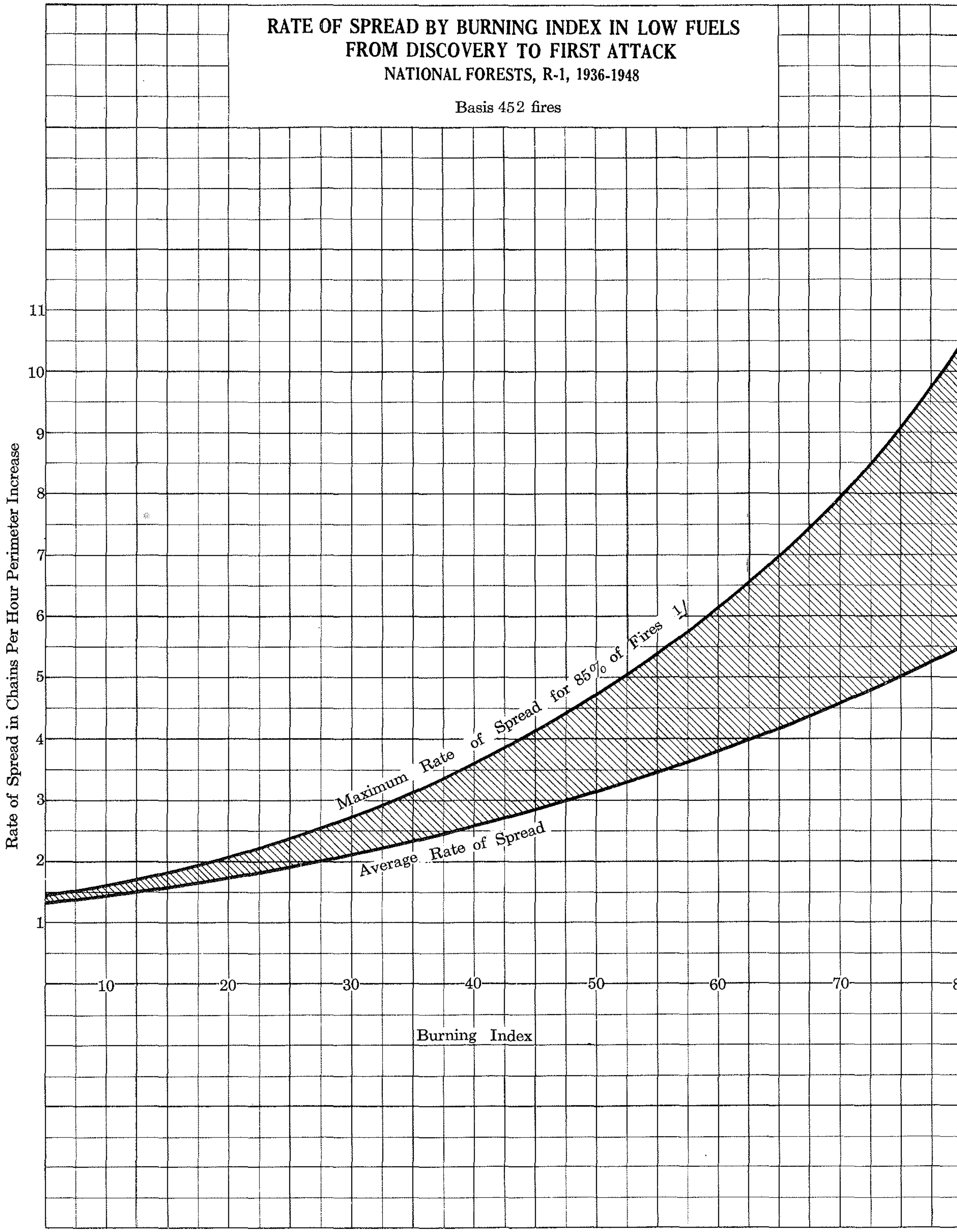
2. In low fuels -- while the tendency of fires to crown is low, high rates of spread may be expected when crowning does occur.

3. In medium fuels -- crowning is more probable than in either low or high fuels.

4. In high fuels -- if fire is spotting ahead, above-average rate of spread may be expected.

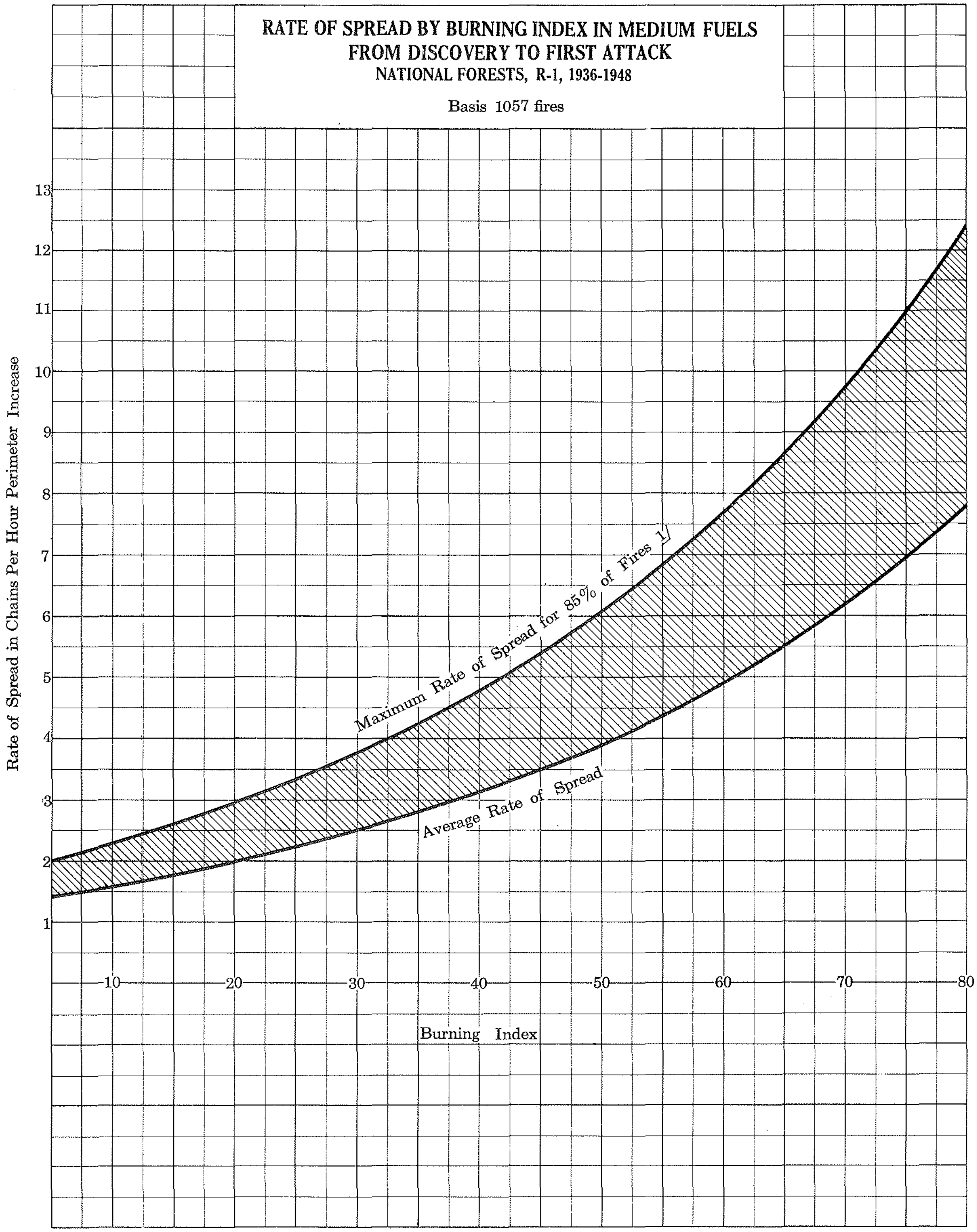
5. In extreme fuels -- spotting is highly probable in this fuel type, and if this occurs in the initial stages of a fire, very high rates of spread may be expected.

6. In grass fuels -- rate of spread will vary widely according to the state of curing of the vegetation.



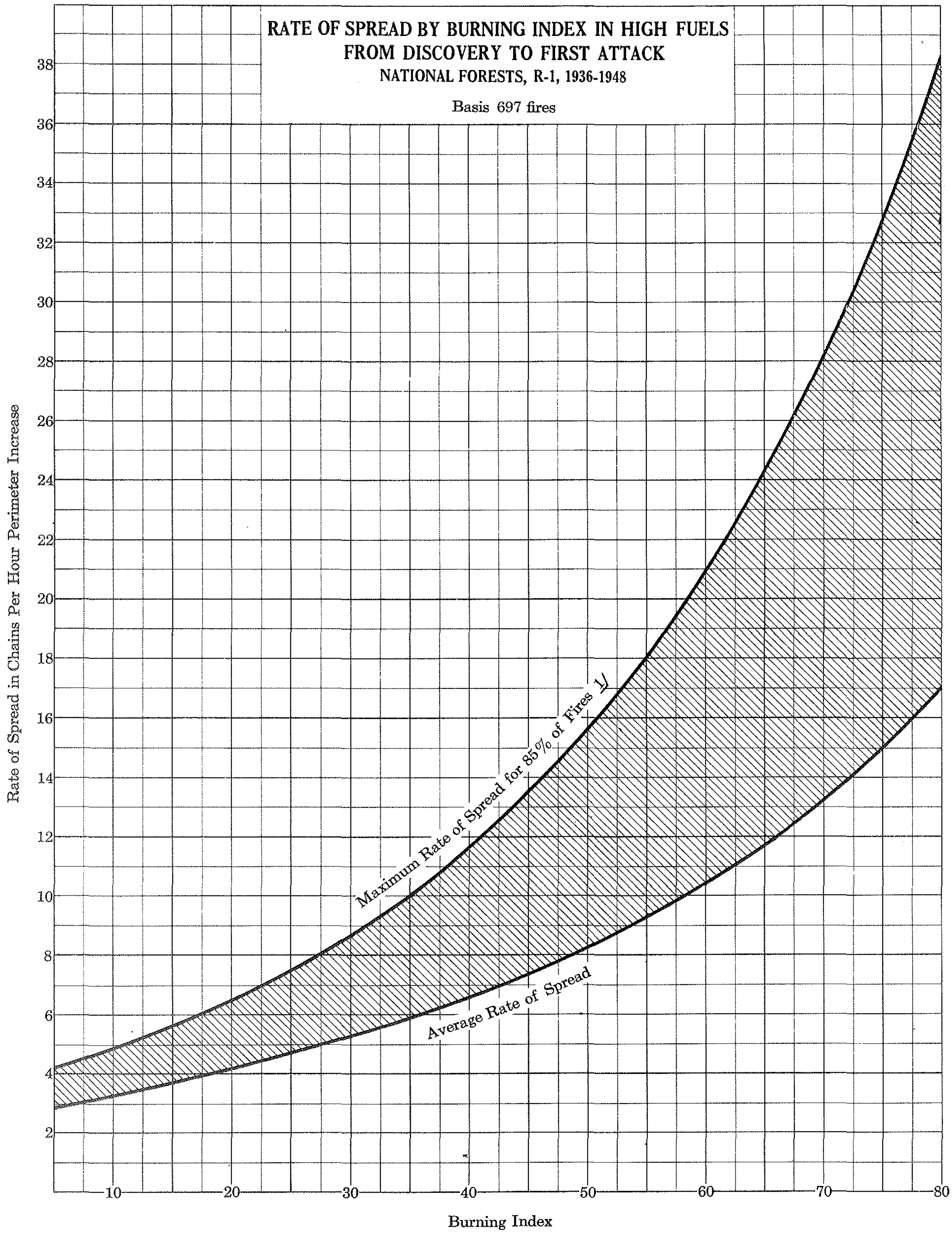
1/ 15% of the fires will spread faster

Figure 67.



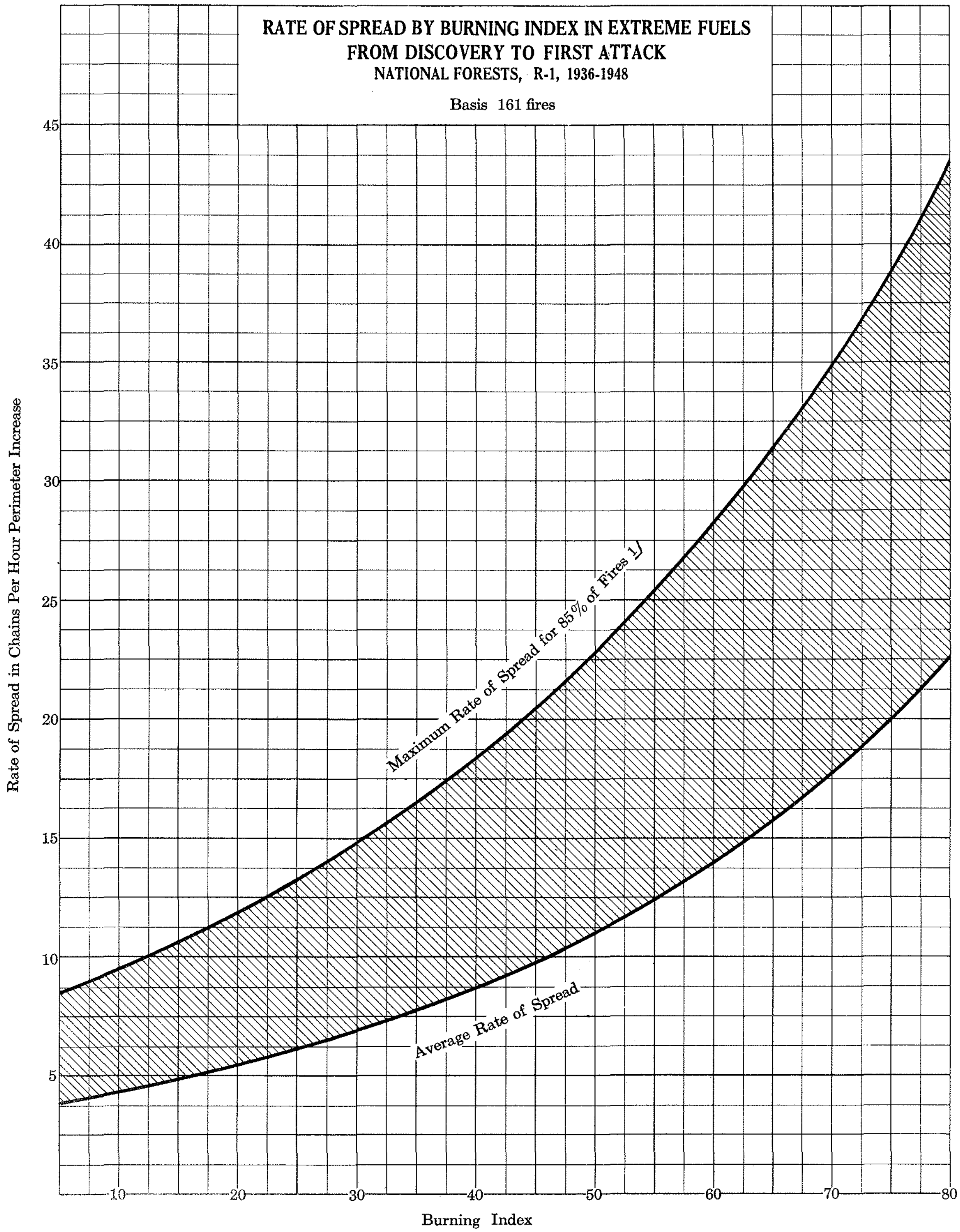
1/ 15% of the fires will spread faster

Figure 68.



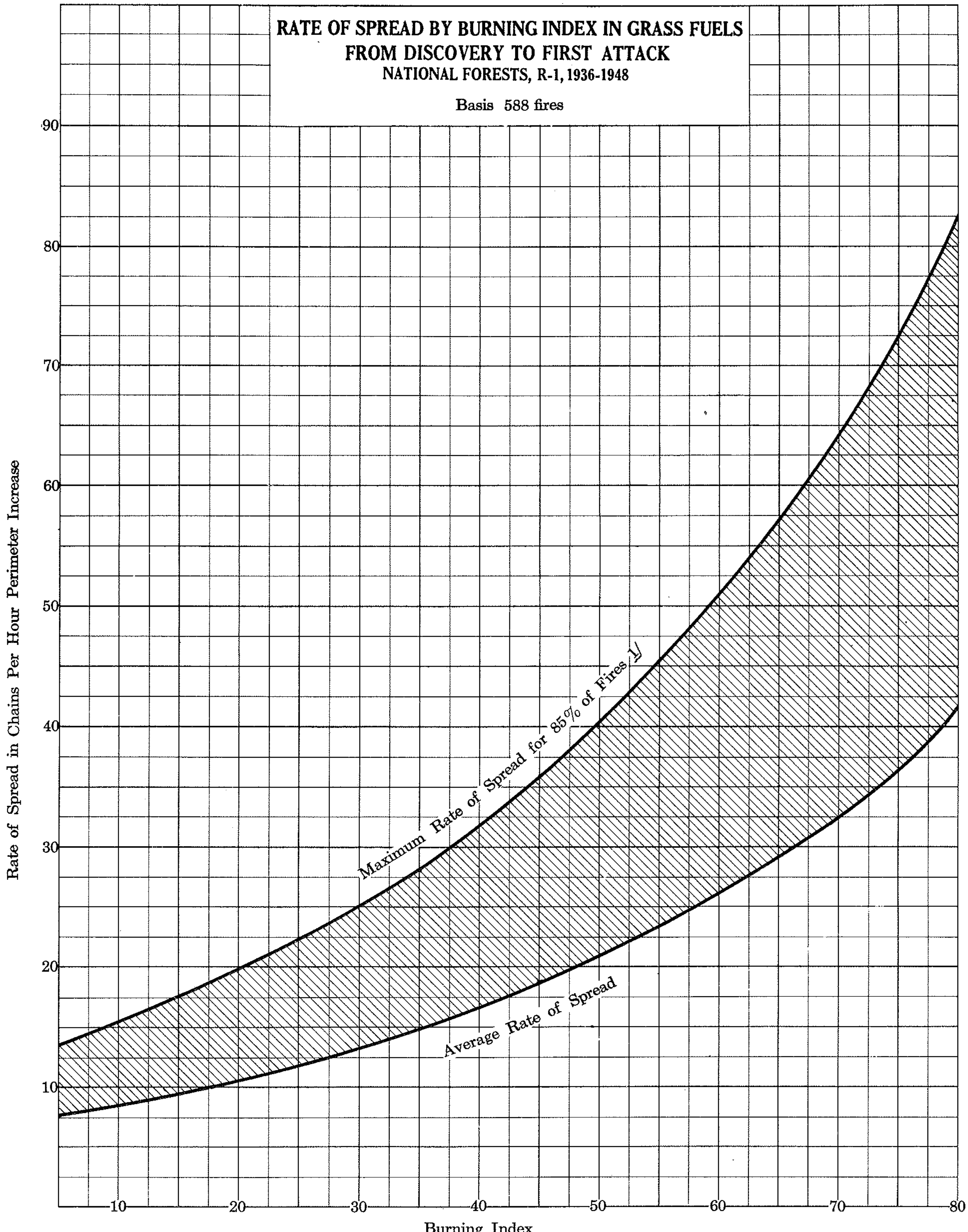
1/ 15% of the fires will spread faster

Figure 69.



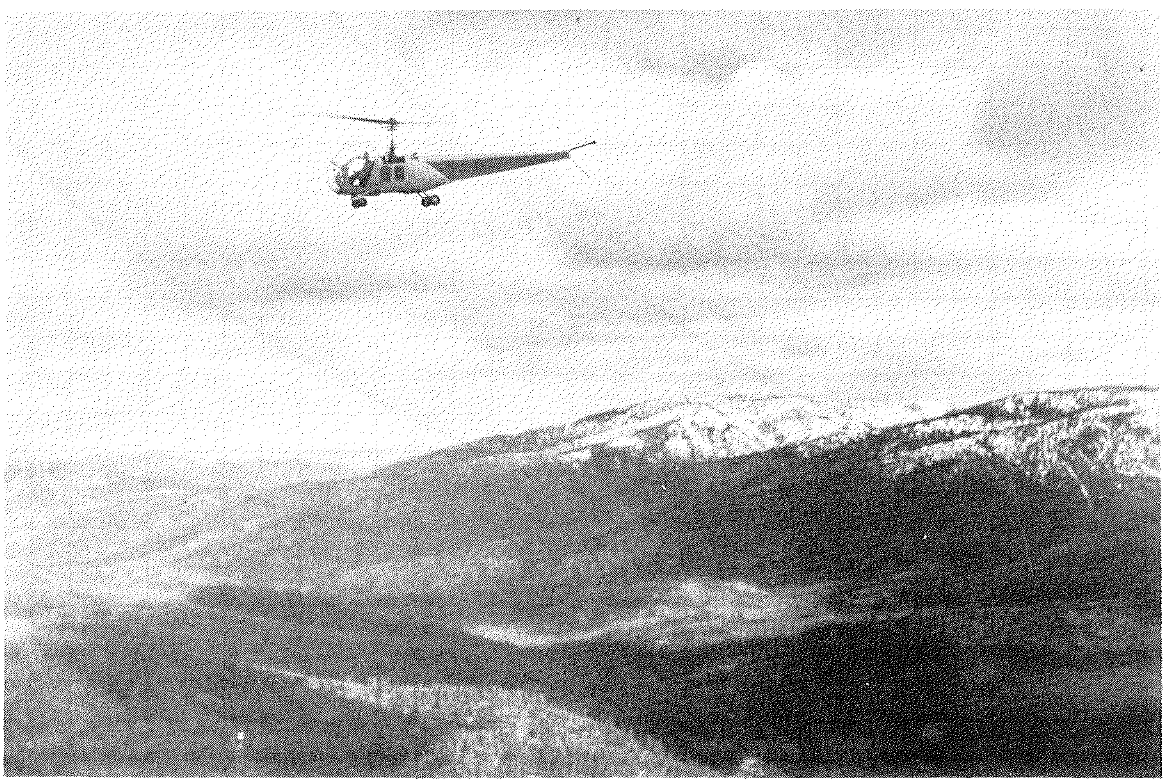
1/ 15% of the fires will spread faster

Figure 70.



1/ 15% of the fires will spread faster

Figure 71.



From the beginning of fire protection in the northern Rocky Mountains the foot-slogging smokechaser has been the backbone of the fire control organization. His superb efforts are gradually being backed up by machines.

PART III

FIRE CONTROL

Forest fire control has often been described as both an art and a science. Labeling the job as an art stems from the fact that some men seem to apply a sixth sense, like that of a great painter or an orchestra conductor, in carrying out an attack on an unruly fire. But fire control also is unmistakably a science calling for the highest degree of professional knowledge of forest conditions and suppression measures. In analyzing the control aspect of thousands of fires a primary objective was to obtain information that might lead to improved technical skill in all phases of the job -- prevention, detection, communication, transportation, and suppression. Foremost in our minds was the question -- what are the requirements for adequate fire control at least cost?

1. FIRE PREVENTION

Organized fire control begins with fire prevention. Protection programs cannot be based upon fire suppression efforts alone. To do so would amount to tacit approval of negligent and malicious setting of fires. In the northern Rocky Mountains the efforts which necessarily have been focused on the great lightning fire problems have sometimes resulted in obscure attention to man-caused fires. Analysis of man-caused fires shows that they have caused relatively large areas to be burned. Study of these fires clearly shows that fire prevention is an important phase of the fire control program, and one which can produce lucrative results. Future developments in cloud-seeding may bring lightning prevention within the grasp of forest protection agencies. However, in the immediate future the big prevention effort must be focused on man-caused fires.

The Fire Prevention Problem

On some protection units the greatest number of fires are man-caused. During the 1931-1945 period 29 percent of the fires in the western zone and 45 percent in the eastern zone were man-caused. However, as shown by the following summary, on some protection units in both zones the greatest number of fires were man-caused:

Protection Unit	Western Zone Percent Man-Caused Fires	Eastern Zone Percent Man-Caused Fires
National forests	22	40
National parks	42	51
Indian reservations	40	68
State forestry departments	75	--
Private protection associations	47	--

On many protection units man-caused fires account for the greatest area burned. During the 1931-1945 period 44 percent of the area burned in the western zone and 81 percent in the eastern zone resulted from man-caused fires. A summary by protection units is as follows:

Protection Unit	Western Zone Percent Burned By Man-Caused Fires	Eastern Zone Percent Burned By Man-Caused Fires
National forests	38	78
National parks	25	3
Indian reservations	40	97
State forestry departments	73	--
Private protection associations	95	--

The average size of man-caused fires is over 3 times greater than lightning fires. A study of nearly 30,000 fires on lands protected by federal, state, and private agencies showed that man-caused fires averaged 73 acres in size as compared to only 20 acres for lightning fires. As illustrated in figure 72, this difference is even greater in the eastern

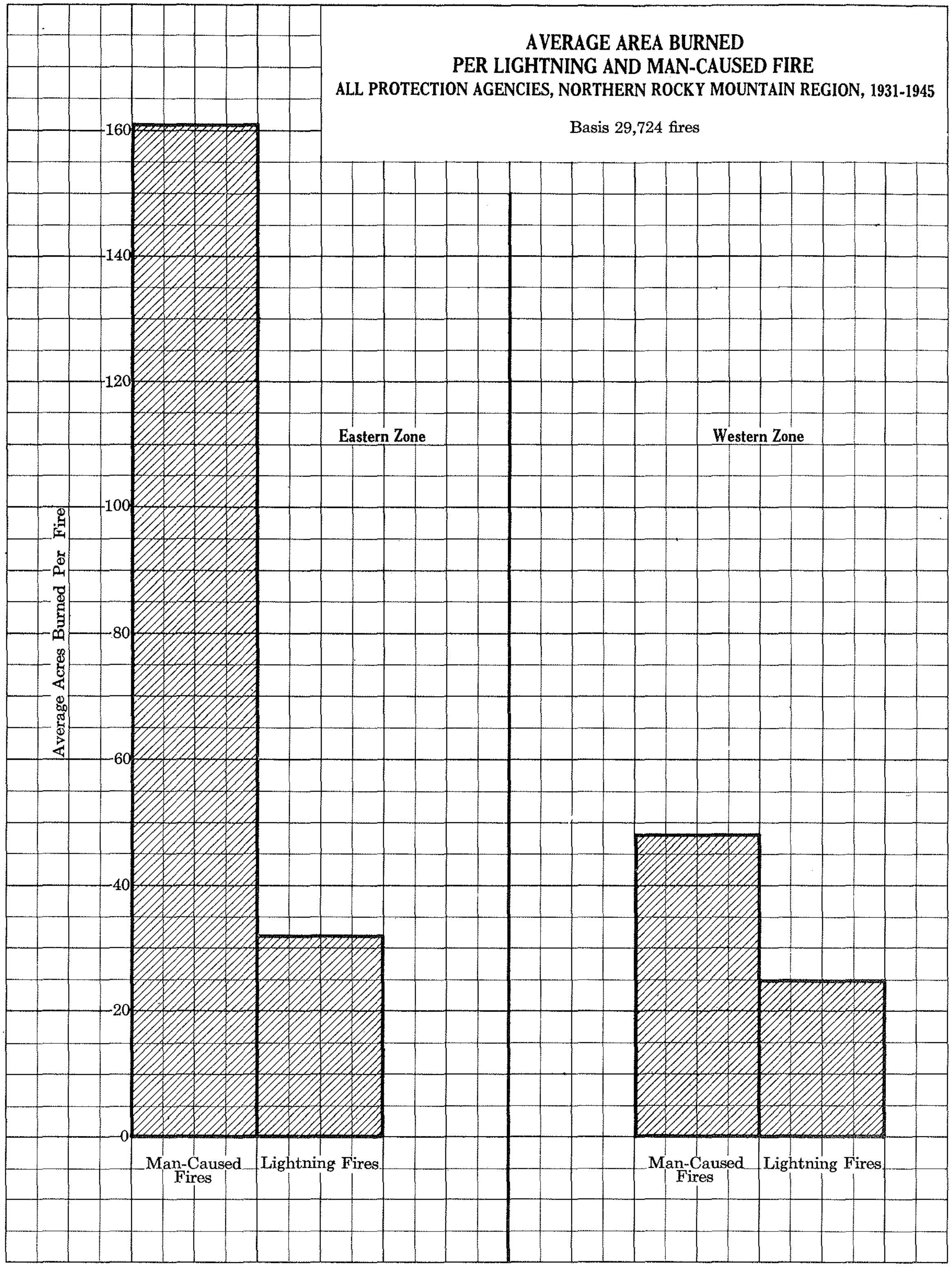

AVERAGE AREA BURNED
PER LIGHTNING AND MAN-CAUSED FIRE
ALL PROTECTION AGENCIES, NORTHERN ROCKY MOUNTAIN REGION, 1931-1945
Basis 29,724 fires
Average Acres Burned Per Fire
160
140
120
100
80
60
40
20
0
Eastern Zone
Western Zone
Man-Caused Fires
Lightning Fires
Man-Caused Fires
Lightning Fires

Figure 72.

zone, while in the western zone man-caused fires average about twice the size of lightning fires. The relatively large size of man-caused fires demonstrates the need for aggressive fire prevention measures.

On the national forests man-caused fires have many characteristics that distinguish them from lightning fires. In a study of over 22,000 fires the following differences were observed:

Factor	Man-Caused Fires	Lightning Fires
Peak occurrence period	Daytime-10 a.m. to 6 p.m.	Late day and evening-2 p.m. to 10 p.m.
Average size per fire	63 acres	46 acres
Size on detection	68% at 0.1 acre or less	88% at 0.1 acre or less
Speed of detection	48% within 1 hour	34% within 1 hour
Travel time	84% within 1 hour	34% within 1 hour
Travel method	31% by auto	4% by auto
Slash fires	58% man-caused	42% lightning-caused
Final size class	60% class A	84% class A

On the national forests man-caused fires have burned more area than lightning fires in 10 out of 15 years. The area burned per million acres protected on Region 1 national forests during the 1931-1945 period is shown in table 33. Over the 15-year period lightning fires burned 872 acres and man-caused 686 acres per million. However, if the two very large lightning fires which occurred in 1934 (the Pete King and McLendon Butte fires on the old Selway forest) are eliminated from these figures, the area burned per million is about the same for both lightning and man-caused fires.

Causes of Fires

Smokers are responsible for the greatest number of man-caused fires. As shown in table 34, smokers are responsible for 45 percent of the man-caused fires in the eastern zone and 36 percent in the western zone. Railroads are the next greatest cause of fires in the western zone, but rank fifth in the eastern zone. Campfires are a major problem in both zones, and especially in the eastern zone where they account for 20 percent of the man-caused fires. Debris burning and miscellaneous causes are equally important sources of fires in both zones.

Incendiary fires have been reduced. The downward trend in incendiary-caused fires is illustrated in table 35. On the Region 1 national forests a reduction in incendiary fires occurred in each 5-year period from 1931 through 1945. During the first 5-year period the national forests had an average of 48 incendiary fires per year as compared to only 2.2 in the last 5-year period.

A reduction in man-caused fires was achieved during the war years. As shown in table 35, there was a general reduction in all causes of fires except railroads, lumbering, and debris burning. The large reductions in smoker and camper fires reflect the decreased travel and recreational

Table 33. Annual Area Burned by Lightning and Man-Caused Fires Per Million Acres Protected, National Forests, R-1, 1931-1945, inclusive

Year	Lightning	Man-Caused	Total
	acres		
1931	1,044	3,840	4,884
1932	199	286	485
1933	270	308	578
1934	9,000	1,424	10,424
1935	196	373	569
1936	520	1,807	2,327
1937	48	100	148
1938	35	56	91
1939	420	969	1,389
1940	915	252	1,167
1941	18	5	23
1942	43	15	58
1943	64	33	97
1944	84	191	275
1945	224	636	860
AVERAGE 1931-1945	872	686	1,558

Table 34. Percent of Man-Caused Fires by General Causes and Protection Agency, 1931-1945, inclusive

(Basis 9297 fires)

Protection Agency	Cause: Smokers	Campfire	Lumber-ing	Debris Burning	Incend-iary	Rail-roads	Misc.
National Forests	38	18	6	8	7	15	8
National Parks	64	11	0	11	5	1	8
Indian Reservations	32	11	3	32	4	10	8
State Forestry Depts. 1/	20	4	2	14	4	25	31
Private Protection Assns.	37	8	1	18	14	7	15
WESTERN ZONE	36	13	4	12	8	14	13
National Forests	49	24	2	7	3	5	10
National Parks	53	25	0	11	4	1	7
Indian Reservations	31	7	1	23	1	12	25
EASTERN ZONE	45	20	1	12	3	6	13

1/ Includes only Idaho and Montana

Table 35. Number of Fires Classified by Major Causes, National Forests, R-1, 1931-1945, inclusive

(Basis 22,485 fires)

Year	Cause								Total Man-Caused Fires	Percent Man-Caused Fires	Total All Fires
	Lightning	Smokers	Campfire	Lumbering	Debris Burning	Incendiary	Railroads	Miscellaneous			
1931	963	252	87	6	64	104	52	47	612	39	1,575
1932	806	172	71	12	29	82	22	15	403	33	1,209
1933	652	209	56	11	17	17	8	16	334	34	986
1934	817	227	65	14	27	30	38	32	433	35	1,250
1935	959	233	91	6	32	7	26	44	439	31	1,398
1936	1,355	176	78	16	38	5	50	22	385	22	1,740
1937	1,154	172	93	13	21	8	59	37	403	26	1,557
1938	1,136	156	48	14	14	6	32	24	294	21	1,430
1939	1,372	191	101	15	44	20	60	29	460	25	1,832
1940	3,109	220	79	11	20	27	77	52	486	14	3,595
1941	1,196	51	21	1	17	1	30	13	134	10	1,330
1942	867	63	16	6	22	1	35	35	178	17	1,045
1943	538	97	31	8	17	4	109	24	290	35	828
1944	1,227	83	26	26	44	2	58	13	252	17	1,479
1945	911	117	33	19	25	3	89	34	320	26	1,231
TOTAL	17,062	2,419	896	178	431	317	745	437	5,423	24	22,485
AVERAGE	1,137	161	60	12	29	21	50	29	362	24	1,499
PERCENT OF TOTAL	75.9	10.7	4.0	0.8	1.9	1.4	3.3	2.0	24.1		

use in the national forests during that period. Railroad fires increased during the war because of greatly increased traffic. However, since the end of the war widespread use of the diesel locomotive has helped materially in reducing railroad fires.

Two national forests have major fire prevention problems. As shown in tables 36 and 37, the Cabinet, with over 46 percent of its fires man-caused, and the Deerlodge, with 58 percent, have the greatest prevention job in the western and eastern zones. The Cabinet has the greatest number of railroad fires of any national forest in the region. Likewise, the Deerlodge has the greatest number of smoker fires.

People working in or near forest areas cause large numbers of fires. Local residents, including farmers, stockmen, miners, timbermen, and construction workers, were responsible for 28 percent of the man-caused fires which occurred on the national forests during the 1931-1945 period. As illustrated in figure 73, people engaged in forest recreation activities, including fishermen, hunters, campers, and picnickers, accounted for 22 percent of the man-caused fires. Thus one-half of the man-caused fires may be traced to these identifiable sources:

1. Local farms, ranches, and grazing areas.
2. Construction projects.
3. Timber sale areas.
4. Recreation areas.
5. Hunting and fishing areas.

From this study it was concluded that fire prevention begins at home. At least half of the man-caused fires are started by local workers and recreationists.

Period of Occurrence

August is the peak month for man-caused fires. As illustrated in figure 74, over 31 percent of the man-caused fires occur in August. July, with 27 percent, and September, with 15 percent, are the next greatest months for man-caused fires. The peak occurrence in August reflects two factors which may govern the timing of fire prevention efforts:

1. Fuels normally reach their driest condition during this month.
2. Forest use is heavy at this time.

Sunday is the peak day of the week for man-caused fires. As illustrated in figure 74, nearly 20 percent of the man-caused fires on the national forests occur on Sunday. In each month from May through October, Sunday is the worst day for man-caused fires. In other months when weekend recreational use of the national forests is light, man-caused fires may peak on other days of the week. An unusual feature was the fact that both Monday and Friday showed a greater number of man-caused fires than

Table 36. Number and Percent of Fires Classified by Major Causes, National Forests, R-1, Western Zone, 1931-1945, inclusive

Forest	Unit	Cause: Lightning	Smokers	Campfire	Lumbering	Debris Burning	Incendiary	Railroads	Miscellaneous	Total Man-Caused Fires
Bitterroot	No.	1,709	117	46	13	14	15	2	9	216
	%	88.7	6.1	2.4	0.7	0.7	0.8	0.1	0.5	11.3
Cabinet	No.	953	210	88	20	26	16	427	40	827
	%	53.5	11.8	5.0	1.1	1.5	0.9	24.0	2.2	46.5
Clearwater	No.	1,832	33	35	1	5	4	0	7	85
	%	95.5	1.7	1.8	0.1	0.3	0.2	0.0	0.4	4.5
Coeur d'Alene	No.	725	226	42	13	52	11	7	61	412
	%	63.8	19.9	3.7	1.1	4.6	0.9	0.6	5.4	36.2
Flathead	No.	1,335	112	53	3	15	3	3	19	208
	%	86.5	7.3	3.4	0.2	1.0	0.2	0.2	1.2	13.5
Kaniksu	No.	1,474	166	51	19	49	36	34	36	391
	%	79.0	8.9	2.8	1.0	2.7	1.9	1.8	1.9	21.0
Kootenai	No.	1,315	180	46	17	37	54	48	32	414
	%	76.0	10.4	2.7	1.0	2.1	3.1	2.8	1.9	24.0
Lolo	No.	1,807	263	87	6	32	29	137	40	594
	%	75.3	11.0	3.6	0.2	1.3	1.2	5.7	1.7	24.7
Nezperce	No.	1,937	127	48	3	15	25	0	20	238
	%	89.1	5.8	2.2	0.1	0.7	1.2	0.0	0.9	10.9
St. Joe	No.	1,305	204	71	47	37	29	34	21	443
	%	74.7	11.7	4.0	2.7	2.1	1.7	1.9	1.2	25.3
WESTERN ZONE	No.	14,392	1,638	567	142	282	222	692	285	3,828
	%	79.0	9.0	3.1	0.8	1.5	1.2	3.8	1.6	21.0

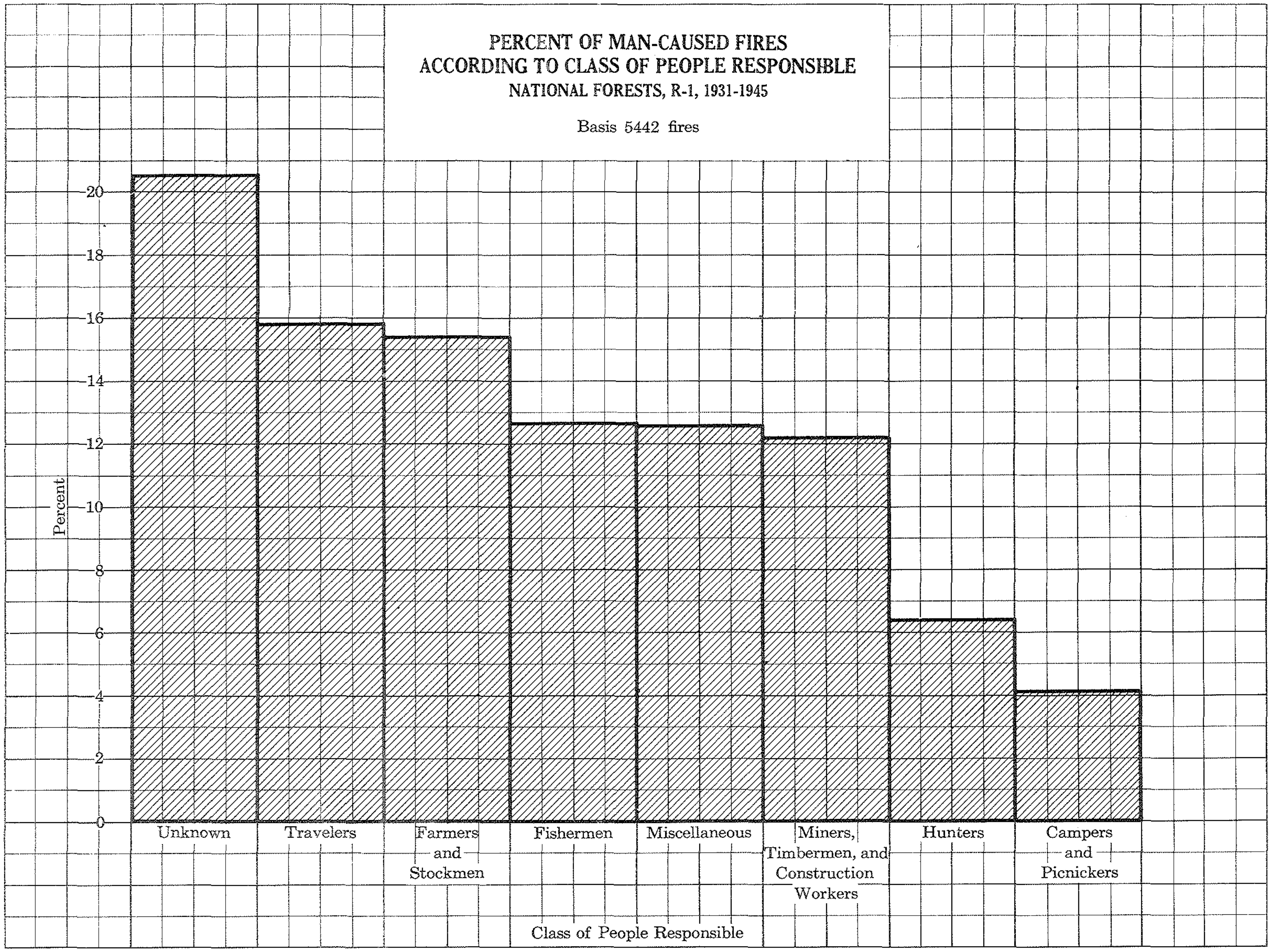
Total No. of Fires 18,220

Table 37. Number and Percent of Fires Classified by Major Causes, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

Forest	Unit	Cause: Lightning	Smokers	Campfire	Lumbering	Debris Burning	Incendiary	Railroads	Miscellaneous	Total Man-Caused Fires
Beaverhead	No.	229	69	40	0	11	2	0	8	130
	%	63.8	19.2	11.1	0.0	3.1	0.6	0.0	2.2	36.2
Custer	No.	356	40	12	4	8	2	0	11	77
	%	82.2	9.2	2.8	0.9	1.9	0.5	0.0	2.5	17.8
Deerlodge	No.	415	310	126	9	39	12	27	63	586
	%	41.5	30.9	12.6	0.9	3.9	1.2	2.7	6.3	58.5
Gallatin 1/	No.	231	123	62	6	16	5	8	26	246
	%	48.4	25.8	13.0	1.3	3.3	1.0	1.7	5.5	51.6
Helena	No.	498	124	50	5	48	20	10	19	276
	%	64.3	16.0	6.5	0.6	6.2	2.6	1.3	2.5	35.7
Lewis and Clark	No.	293	49	25	3	3	0	2	8	90
	%	76.5	12.8	6.5	0.8	0.8	0.0	0.5	2.1	23.5
EASTERN ZONE	No.	2,022	715	315	27	125	41	47	135	1,405
	%	59.0	20.9	9.2	0.8	3.6	1.2	1.4	3.9	41.0

Total No. of Fires 3,427

1/ Includes Absaroka


PERCENT OF MAN-CAUSED FIRES
ACCORDING TO CLASS OF PEOPLE RESPONSIBLE
NATIONAL FORESTS, R-1, 1931-1945
Basis 5442 fires
Percent
0
2
4
6
8
10
12
14
16
18
20
Unknown
Travelers
Farmers and Stockmen
Fishermen
Miscellaneous
Miners, Timbermen, and Construction Workers
Hunters
Campers and Picnickers
Class of People Responsible

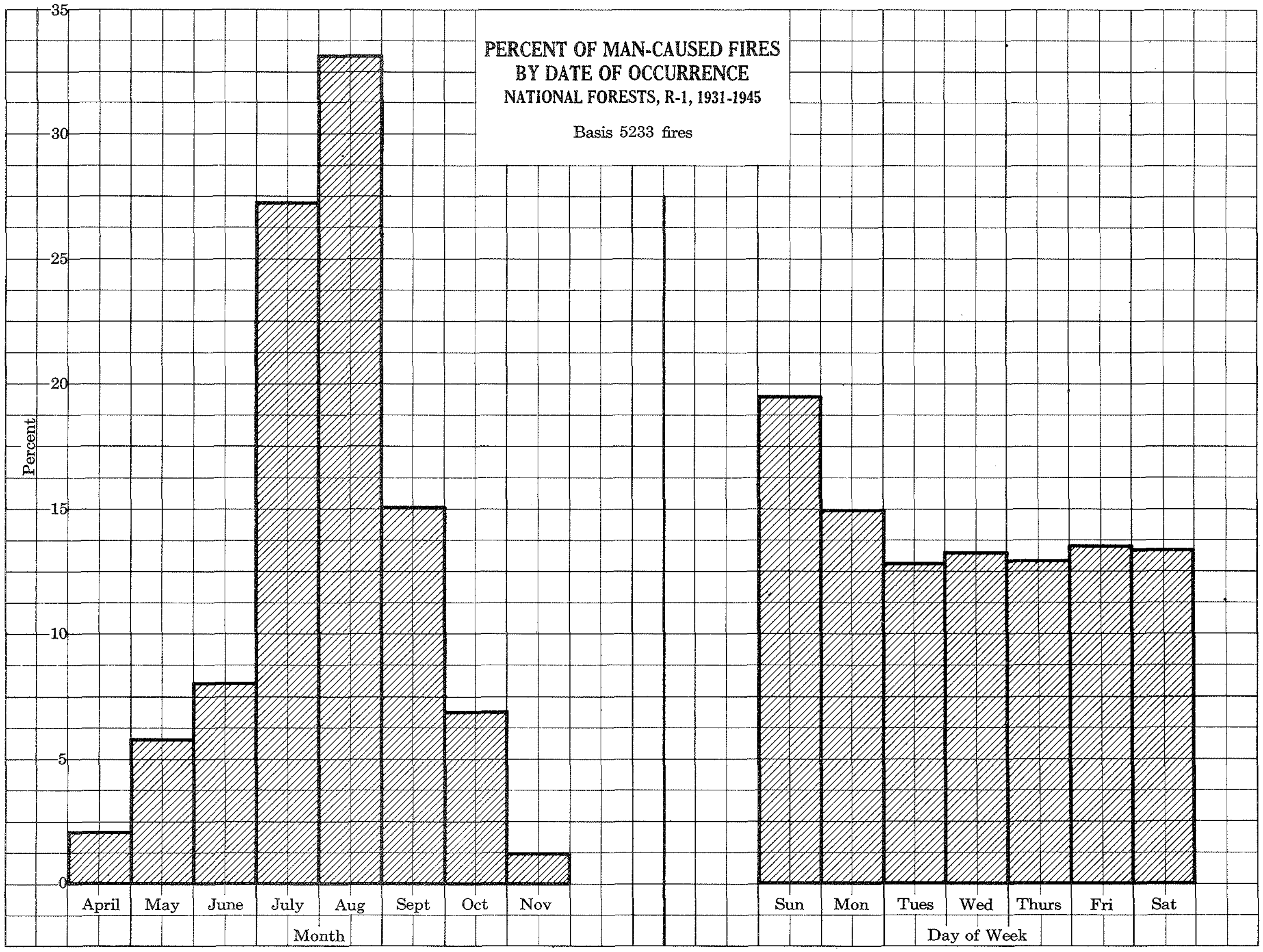

PERCENT OF MAN-CAUSED FIRES
BY DATE OF OCCURRENCE
NATIONAL FORESTS, R-1, 1931-1945
Basis 5233 fires
Percent
35
30
25
20
15
10
5
0
April
May
June
July
Aug
Sept
Oct
Nov
Month
Sun
Mon
Tues
Wed
Thurs
Fri
Sat
Day of Week

Figure 74.

Saturday. However, with the trend toward shorter work weeks, Saturday may become an increasingly important fire prevention day in the future. The distribution of over 5000 fires by day of the week according to years and months is shown in tables 38 and 39.

Table 38. Number of Man-Caused Fires by Day and Year of Origin, National Forests, R-1, 1931-1945, inclusive

Year	Day of Week							Total
	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	
1931	129	84	78	86	79	87	72	615
1932	70	76	52	42	57	55	54	406
1933	51	47	45	51	52	52	38	336
1934	79	59	50	64	67	58	58	435
1935	91	67	66	55	45	53	57	434
1936	76	51	43	51	48	53	65	387
1937	86	55	53	47	68	46	50	405
1938	79	49	32	32	39	38	36	305
1939	95	79	67	59	39	53	67	459
1940	79	83	67	70	64	66	67	496
1941	30	21	19	26	11	16	10	133
1942	41	20	25	23	19	24	26	178
1943	74	41	29	36	34	40	35	289
1944	37	39	27	39	35	40	32	249
1945	54	39	40	37	44	51	57	322
TOTAL	1,071	810	693	718	701	732	724	5,449
PERCENT	19.6	14.9	12.7	13.2	12.9	13.4	13.3	

Table 39. Number of Man-Caused Fires by Day and Month of Origin, National Forests, R-1, 1931-1945, inclusive

Month	Day of Week							Total
	Sun	Mon	Tues	Wed	Thurs	Fri	Sat	
January			1					1
February					1			1
March	1	1						2
April	19	15	22	19	20	8	14	117
May	56	42	42	52	40	47	42	321
June	88	68	60	55	65	53	55	444
July	299	224	191	205	163	203	198	1,483
August	342	255	224	247	245	257	239	1,809
September	168	144	89	86	111	101	123	822
October	83	47	46	45	52	53	51	377
November	15	13	15	9	4	10	2	68
December		1	3					4
TOTAL	1,071	810	693	718	701	732	724	5,449
PERCENT	19.6	14.9	12.7	13.2	12.9	13.4	13.3	

2. FIRE DETECTION

Once a fire starts detection is the first requirement in control operations. The efficiency of a detection system is dependent upon its ability to cover the maximum possible area where fires may start, to discover fires quickly enough so that they will be of small size, and to describe them accurately with respect to location and behavior. A system that will detect the greatest number of fires in the fastest time at the lowest cost is the major objective.

Detection History

From the beginning of organized protection the fire lookout station has been the principal means of detection. In the northern Rocky Mountains an early objective of the control organizations was to place observers at strategic locations for the detection of fires. In the last 40 years well over 1000 lookout stations have been constructed. However, fire control planners were quick to recognize that it is not economically feasible to use lookout stations to cover 100 percent of the forest areas in rough, mountainous country. In the Region 1 national forests Hornby showed that it would require 170 lookout stations per million acres to provide 85 to 90 percent coverage (4).

Lookout-firemen have served the dual purposes of detection and initial attack on fires. During the period 1931-1940 the lookout-fireman was the backbone of the Region 1 fire organization. This was one of Hornby's methods in fire control planning of cutting down the back-country distances which had to be traveled by control forces (4). He reasoned that by distributing smokechasers at lookout stations throughout each forest, they could detect fires and also reach these fires reasonably fast to make the initial attack. Over 1200 such dual-purpose stations were planned to meet worst conditions, and during the 1940 fire season 847 of these were manned. Fuel classification was used as a major guide in determining the location of these stations with the objective of providing the best coverage for the most dangerous fuels. The points selected were those which would make the best dual-purpose stations for detection and smokechasing. For this reason many stations were not placed on the points best for detection alone.

Fire danger rating has played an important role in the management of detection systems. Fire control men in Region 1 reasoned that few detection stations, as well as smokechasers and crews, were needed when measured fire danger was low, and that as danger increased the control forces should be strengthened. Accordingly, a Prevention and Presuppression Organization and Placement Chart, as shown in figure 75, was developed to provide a uniform system of manning in accordance with variations in fire danger. Since 1938 this system has guided the placement of detectors and smokechasers in the Region 1 national forests.

Aerial fire control operations have forced major changes in the detection system. On many forests in Region 1 smokejumpers have taken over the initial attack job formerly handled by lookout-firemen. As a result major changes have been made in the detection system with many dual-purpose

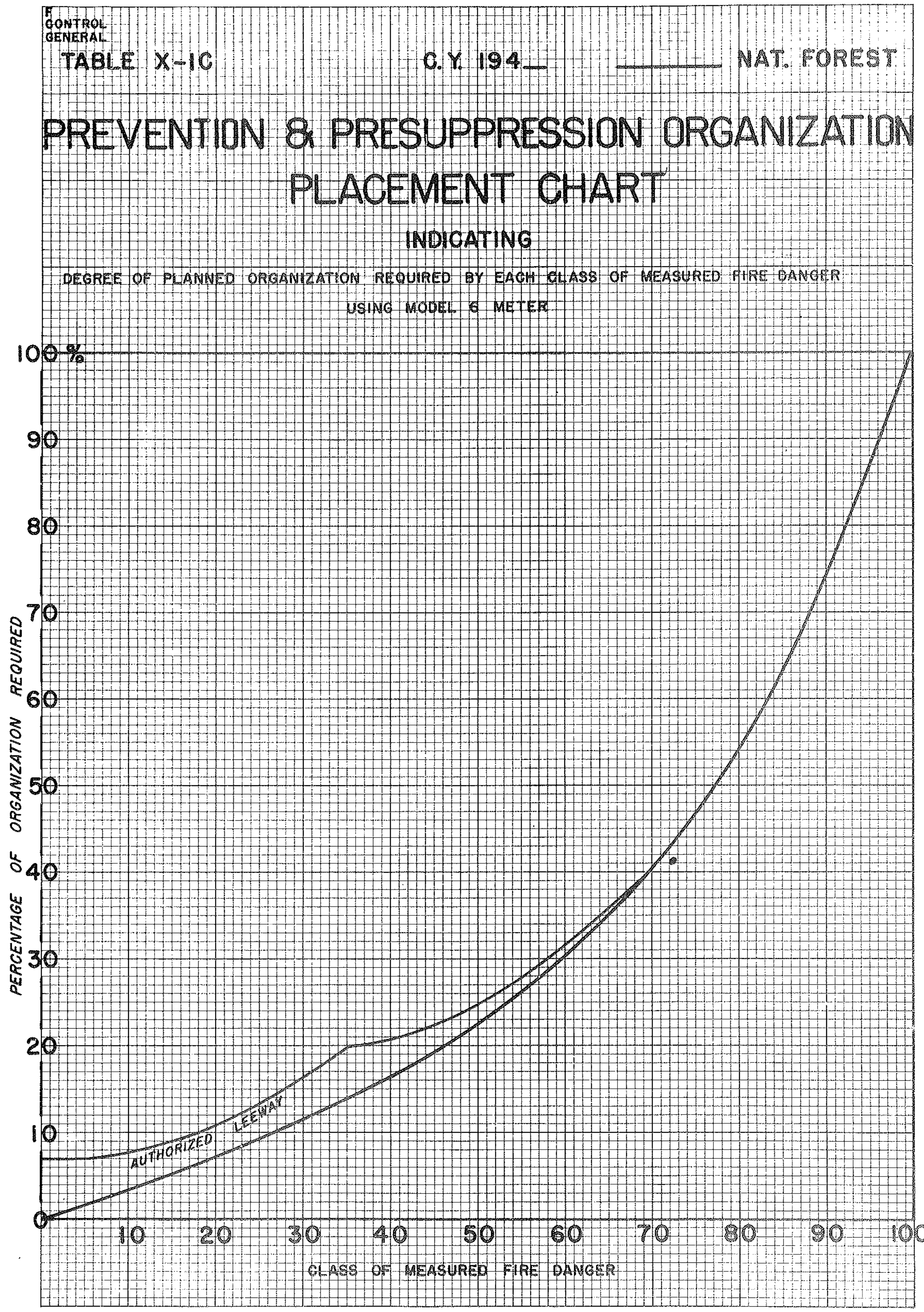

F
CONTROL
GENERAL
TABLE X-IC
C.Y. 194__
______ NAT. FOREST
PREVENTION & PRESUPPRESSION ORGANIZATION
PLACEMENT CHART
INDICATING
DEGREE OF PLANNED ORGANIZATION REQUIRED BY EACH CLASS OF MEASURED FIRE DANGER
USING MODEL 6 METER
100 %
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
100
PERCENTAGE OF ORGANIZATION REQUIRED
NUMBER OF MEN REQUIRED
AUTHORIZED LEEWAY
CLASS OF MEASURED FIRE DANGER

Figure 75.

lookout-fireman stations being abandoned in favor of a smaller number of single-purpose detection stations located on the best points for visibility and covering the most dangerous fuel and occurrence areas. In addition, the increased use of aircraft for detection has brought about other changes in the lookout system and its relation to the suppression forces. The magnitude of these changes is illustrated by the 1950 Region 1 fire plan which calls for manning a total of 567 lookout stations at the peak of the fire season as compared to 847 stations in 1940. In 10 years nearly 300 lookout stations have been abandoned because of lack of funds or because increased aerial fire control activities have changed the detection plans.

Detection Methods

Lookout observers detect 54 percent of the fires. In a study of over 22,000 fires which occurred on the national forests during the period 1931-1945, lookout stations clearly were the most important means of detection. As illustrated in figure 76, other planned methods of detection made the first discovery on a relatively small number of fires, with patrolmen being credited with 4.28 percent and cooperators with 3.50 percent. Very limited use of aircraft for detection was made during this period. Unplanned means of detection, such as forest visitors and permittees, detected more fires than any of the planned systems except lookout stations.

Lookout observers detect a higher percentage of lightning fires than man-caused fires. As illustrated in tables 40 through 43, lookout observers made a better record in the detection of lightning fires in both the western and eastern zones. Only 6.23 percent of the man-caused fires in the eastern zone were detected by lookout observers. In both zones the entire planned detection system, including lookout observers, patrolmen, and cooperators, was found to be relatively inefficient in discovering man-caused fires. Over half of the man-caused fires in the eastern zone and one-third in the western zone were detected by other means.

Detection Distance and Time

Over 80 percent of the fires are within 12 miles of the detector. As illustrated in figure 77, a study of over 21,000 fires showed that only 10 percent of the man-caused and 17 percent of the lightning fires were over 12 miles from the person making first discovery. Also, it was found that detectors are usually close to a large number of man-caused fires. Nearly 60 percent of the man-caused fires were within 2 miles. This resulted from a large number of these fires being discovered by persons living, working, or traveling near the site of the fire rather than from lookout stations which are normally situated in more remote positions from the areas where man-caused fires are likely to start.

The greatest number of fires are discovered in the afternoon hours. As illustrated in figure 78 and 79, the greatest number of man-caused fires are discovered between 2 p.m. and 4 p.m., while the peak period for lightning discoveries is between 4 p.m. and 6 p.m. Under average conditions in Region 1 the most important 8-hour period for the

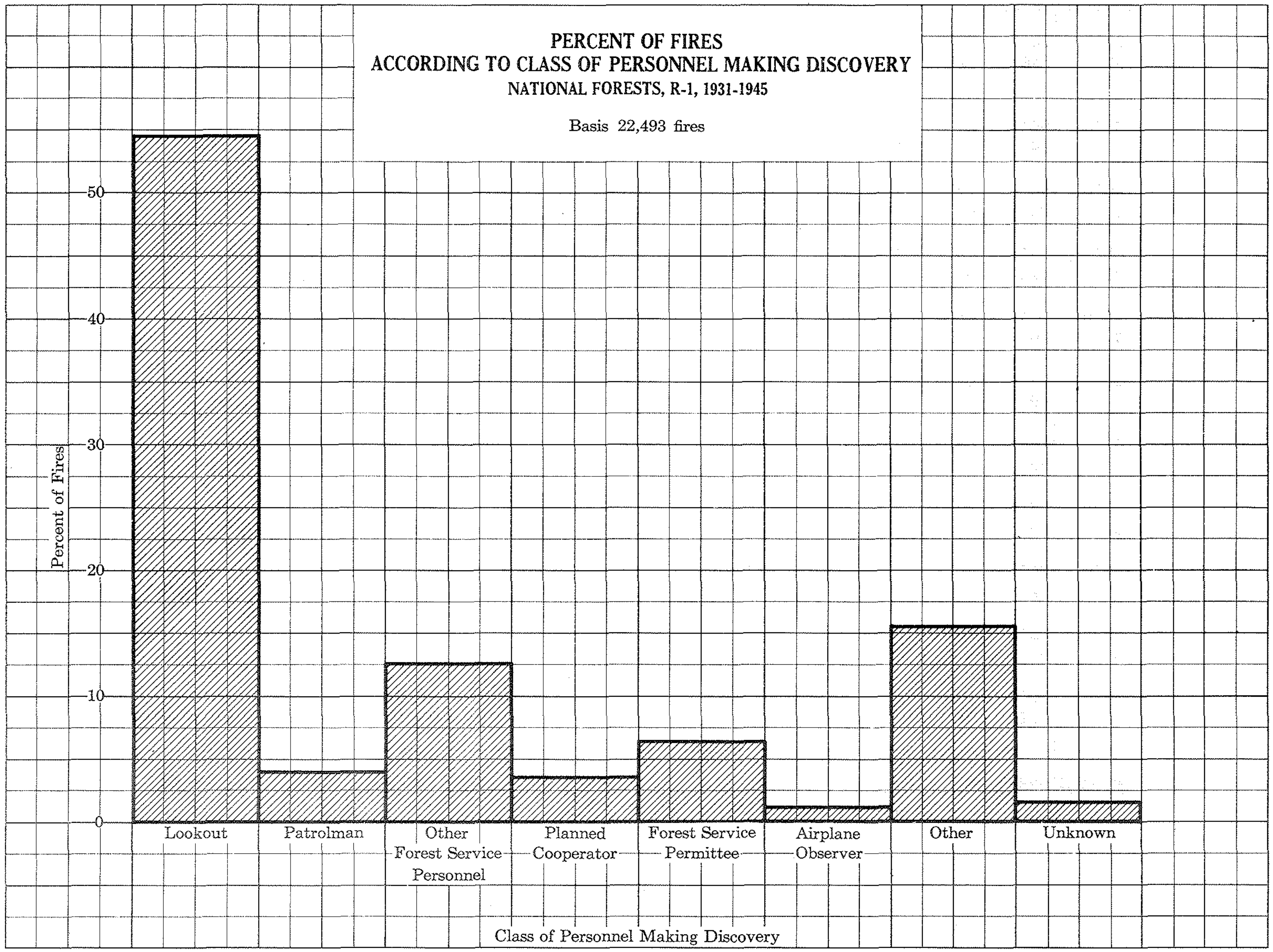

PERCENT OF FIRES
ACCORDING TO CLASS OF PERSONNEL MAKING DISCOVERY
NATIONAL FORESTS, R-1, 1931-1945
Basis 22,493 fires
Percent of Fires
50
40
30
20
10
0
Lookout
Patrolman
Other Forest Service Personnel
Planned Cooperator
Forest Service Permittee
Airplane Observer
Other
Unknown
Class of Personnel Making Discovery

Table 40. Number and Percent of Lightning Fires According to Class of Personnel Making Discovery, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 14,462 fires)

Forest	Unit	Class of Personnel Making Discovery							
		Lookout	Patrolman	Other F.S. Personnel	Planned Cooperator	F.S. Permittee	Airplane Observer	Other	Unknown
Bitterroot	No.	1,136	88	179	45	81	40	138	2
	%	66.47	5.14	10.47	2.63	4.73	2.34	8.07	0.11
Cabinet	No.	638	30	127	61	47	9	88	9
	%	63.23	2.97	12.58	6.04	4.65	0.89	8.72	0.89
Clearwater	No.	1,277	74	269	12	143	20	36	1
	%	69.70	4.03	14.68	0.65	7.80	1.09	1.96	0.05
Coeur d'Alene	No.	516	31	76	13	18	0	69	0
	%	71.36	4.28	10.51	1.79	2.48	0.00	9.54	0.00
Flathead	No.	957	101	105	54	43	9	66	1
	%	71.63	7.55	7.85	4.04	3.21	0.67	4.94	0.07
Kaniksu	No.	1,112	29	148	15	81	2	83	4
	%	75.44	1.96	10.04	1.01	5.49	0.13	5.63	0.27
Kootenai	No.	956	74	126	21	40	6	93	2
	%	72.53	5.61	9.55	1.59	3.03	0.45	7.05	0.15
Lolo	No.	1,221	63	229	32	86	25	137	26
	%	67.12	3.46	12.58	1.75	4.72	1.37	7.53	1.42
Nezperce	No.	1,476	41	219	8	111	8	73	1
	%	76.20	2.11	11.30	0.41	5.73	0.41	3.76	0.05
St. Joe	No.	930	36	131	46	102	0	57	3
	%	71.26	2.75	10.03	3.52	7.81	0.00	4.36	0.22
WESTERN ZONE	No.	10,219	567	1,609	307	752	119	840	49
	%	70.66	3.92	11.12	2.12	5.19	0.82	5.80	0.33

Table 41. Number and Percent of Lightning Fires According to Class of Personnel Making Discovery, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 2,024 fires)

Forest	Unit	Class of Personnel Making Discovery							
		Lookout	Patrolman	Other F.S. Personnel	Planned Cooperator	F.S. Permittee	Airplane Observer	Other	Unknown
Beaverhead	No.	14	17	31	27	26	2	103	8
	%	6.14	7.45	13.59	11.84	11.40	0.87	45.17	3.50
Custer	No.	60	16	36	18	81	2	137	6
	%	16.85	4.49	10.11	5.05	22.75	0.56	38.48	1.68
Deerlodge	No.	88	6	67	35	29	9	169	13
	%	21.15	1.44	16.10	8.41	6.97	2.16	40.62	3.12
Gallatin 1/	No.	13	7	40	23	21	4	111	14
	%	5.57	3.00	17.16	9.87	9.01	1.71	47.63	6.00
Helena	No.	162	2	65	31	25	12	180	21
	%	32.53	0.40	13.05	6.22	5.02	2.40	36.14	4.21
Lewis and Clark	No.	94	19	34	19	20	3	101	3
	%	32.08	6.48	11.60	6.48	6.82	1.02	34.47	1.02
EASTERN ZONE	No.	431	67	273	153	202	32	801	65
	%	21.29	3.31	13.48	7.55	9.98	1.58	39.57	3.21

1/ Includes Absaroka

Table 42. Number and Percent of Man-Caused Fires According to Class of Personnel Making Discovery, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 3,762 fires)

Forest	Unit	Class of Personnel Making Discovery							
		Lookout	Patrolman	Other F.S. Personnel	Planned Cooperator	F.S. Permittee	Airplane Observer	Other	Unknown
Bitterroot	No.	51	8	39	12	16	2	87	2
	%	23.50	3.68	17.97	5.52	7.37	0.92	40.09	0.92
Cabinet	No.	257	18	130	69	46	43	181	27
	%	33.33	2.33	16.86	8.94	5.96	5.57	23.47	3.50
Clearwater	No.	17	3	19	3	23	0	20	0
	%	20.00	3.52	22.35	3.52	27.05	0.00	23.52	0.00
Coeur d'Alene	No.	124	14	59	25	33	13	130	14
	%	30.09	3.39	14.32	6.06	8.00	3.15	31.55	3.39
Flathead	No.	47	7	24	20	15	5	82	7
	%	22.70	3.38	11.59	9.66	7.24	2.41	39.61	3.38
Kaniksu	No.	146	11	65	4	46	2	111	7
	%	37.24	2.80	16.58	1.02	11.73	0.51	28.31	1.78
Kootenai	No.	126	31	66	10	37	4	119	19
	%	30.58	7.52	16.01	2.42	8.98	0.97	28.88	4.61
Lolo	No.	166	14	120	19	30	6	188	39
	%	28.52	2.40	20.61	3.26	5.15	1.03	32.30	6.70
Nezperce	No.	61	11	49	4	28	5	81	1
	%	25.41	4.58	20.41	1.66	11.66	2.08	33.75	0.41
St. Joe	No.	121	9	53	45	42	6	153	15
	%	27.25	2.02	11.93	10.13	9.45	1.35	34.45	3.37
WESTERN ZONE	No.	1,116	126	624	211	316	86	1,152	131
	%	29.66	3.34	16.58	5.60	8.39	2.28	30.62	3.48

Table 43. Number and Percent of Man-Caused Fires According to Class of Personnel Making Discovery, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 1,411 fires)

Forest	Unit	Class of Personnel Making Discovery							
		Lookout	Patrolman	Other F.S. Personnel	Planned Cooperator	F.S. Permittee	Airplane Observer	Other	Unknown
Beaverhead	No.	6	3	20	10	15	1	68	7
	%	4.61	2.30	15.38	7.69	11.53	0.76	52.30	5.38
Custer	No.	3	3	10	2	4	0	49	7
	%	3.84	3.84	12.82	2.56	5.12	0.00	62.82	8.97
Deerlodge	No.	42	21	110	29	37	23	281	42
	%	7.17	3.58	18.80	4.95	6.32	3.93	48.03	7.17
Gallatin 1/	No.	8	7	56	10	22	7	116	24
	%	3.20	2.80	22.40	4.00	8.80	2.80	46.40	9.60
Helena	No.	22	5	36	7	14	10	168	16
	%	7.91	1.79	12.94	2.51	5.03	3.59	60.43	5.75
Lewis and Clark	No.	7	3	12	4	14	1	46	3
	%	7.77	3.33	13.33	4.44	15.55	1.11	51.11	3.33
EASTERN ZONE	No.	88	42	244	62	106	42	728	99
	%	6.23	2.97	17.29	4.39	7.51	2.97	51.59	7.01

1/ Includes Absaroka

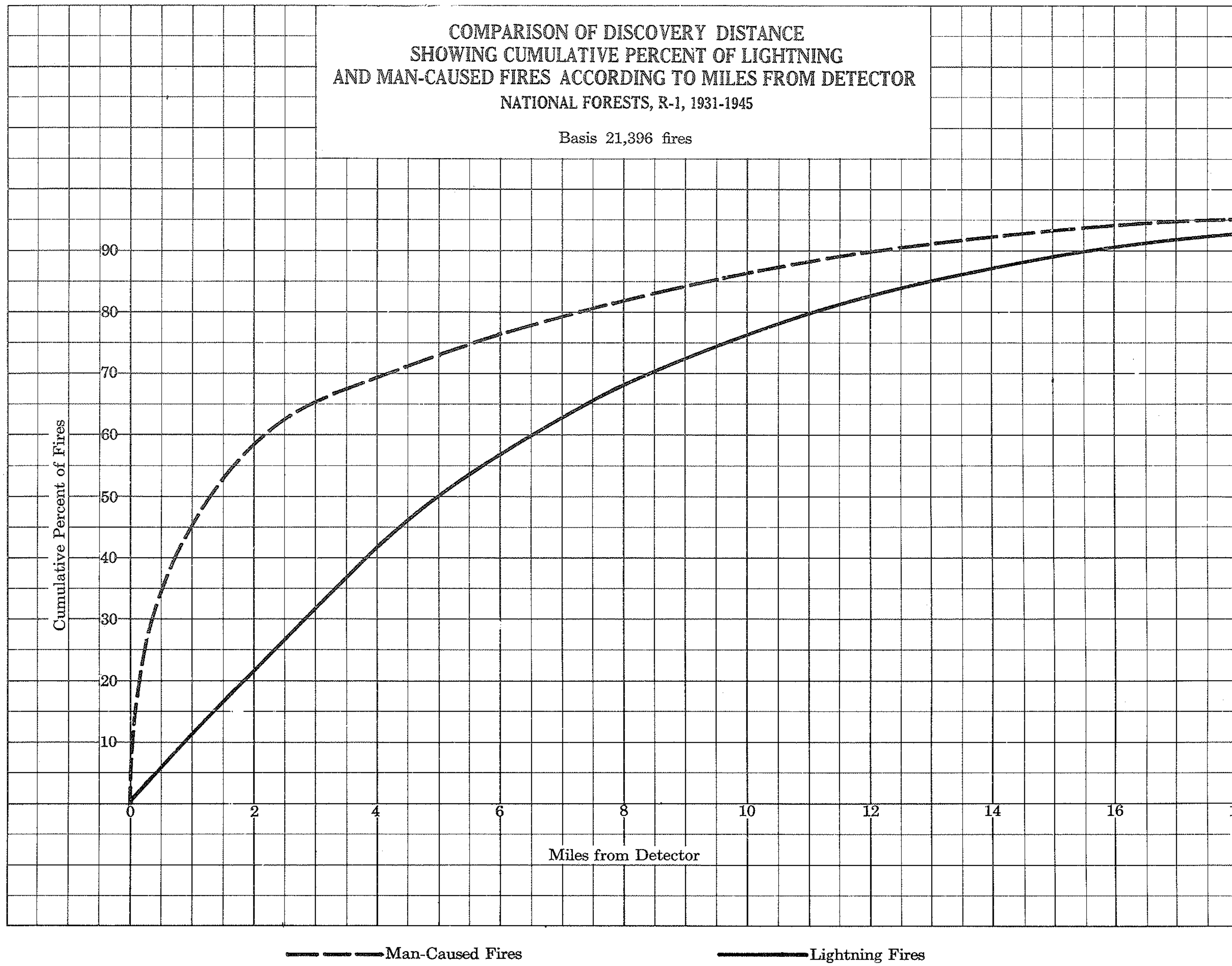

COMPARISON OF DISCOVERY DISTANCE
SHOWING CUMULATIVE PERCENT OF LIGHTNING
AND MAN-CAUSED FIRES ACCORDING TO MILES FROM DETECTOR
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,396 fires
Cumulative Percent of Fires
90
80
70
60
50
40
30
20
10
0
2
4
6
8
10
12
14
16
18
Miles from Detector
Man-Caused Fires
Lightning Fires

Figure 77.

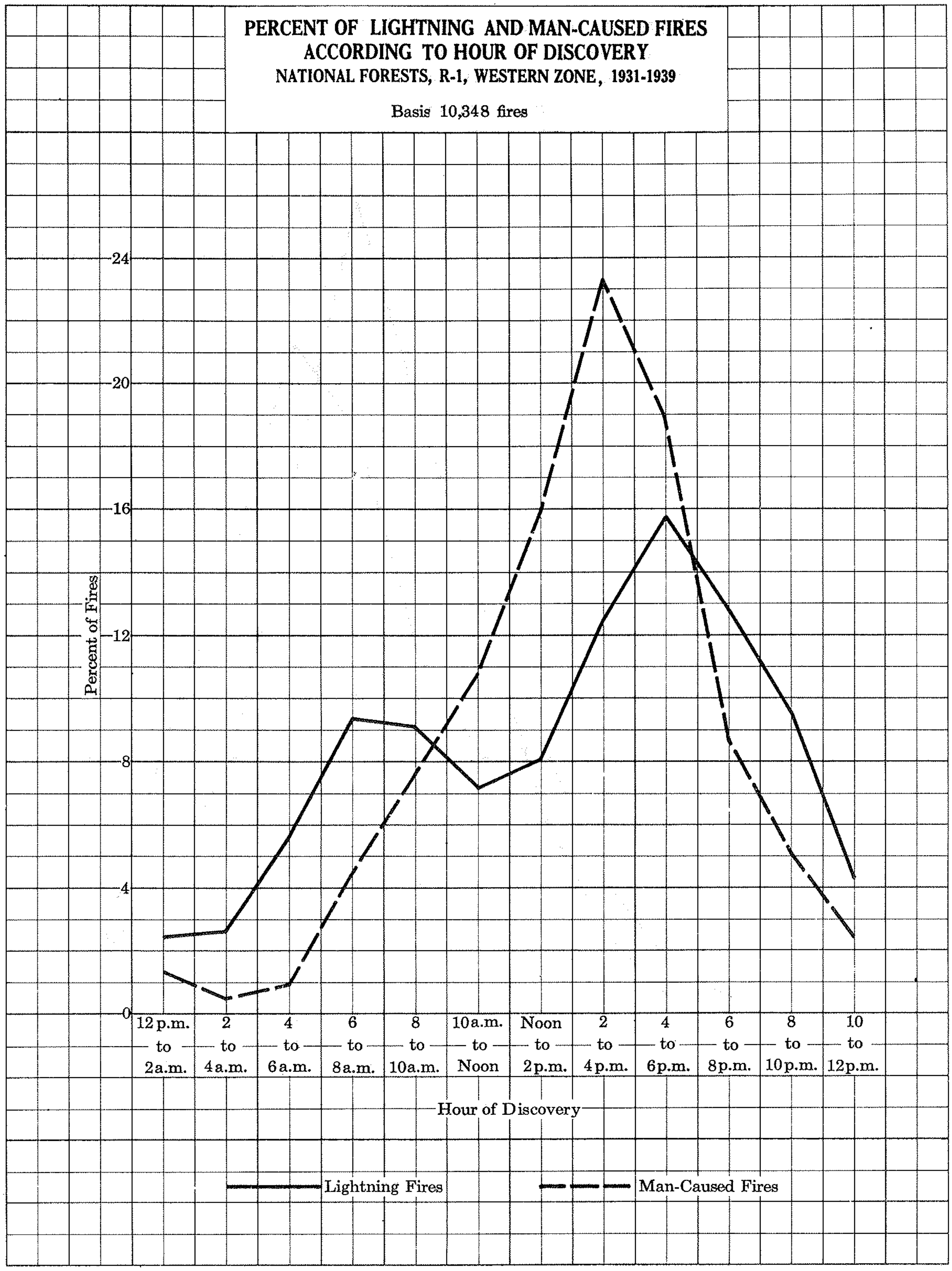

PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO HOUR OF DISCOVERY
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1939
Basis 10,348 fires
Percent of Fires
24
20
16
12
8
4
0
12 p.m. to 2 a.m.
2 to 4 a.m.
4 to 6 a.m.
6 to 8 a.m.
8 to 10 a.m.
10 a.m. to Noon
Noon to 2 p.m.
2 to 4 p.m.
4 to 6 p.m.
6 to 8 p.m.
8 to 10 p.m.
10 to 12 p.m.
Hour of Discovery
Lightning Fires
Man-Caused Fires

Figure 78.

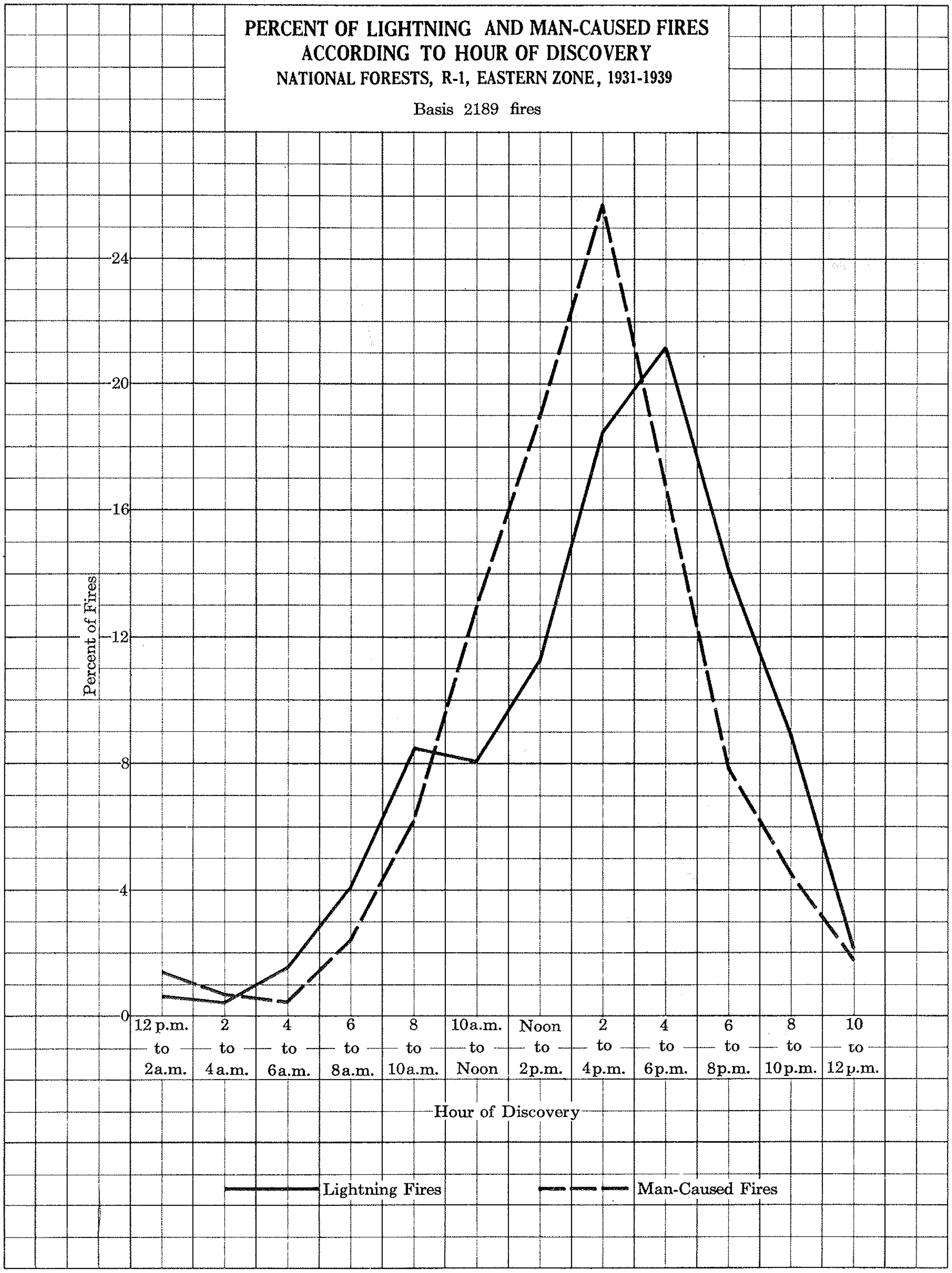

PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO HOUR OF DISCOVERY
NATIONAL FORESTS, R-1, EASTERN ZONE, 1931-1939
Basis 2189 fires
Percent of Fires
24
20
16
12
8
4
0
12 p.m. to 2a.m.
2 to 4a.m.
4 to 6a.m.
6 to 8a.m.
8 to 10a.m.
10a.m. to Noon
Noon to 2p.m.
2 to 4p.m.
4 to 6p.m.
6 to 8p.m.
8 to 10p.m.
10 to 12p.m.
Hour of Discovery
Lightning Fires
Man-Caused Fires

Figure 79.

detection of fires is from noon to 8 p.m. In a study of nearly 13,000 fires it was found that 57 percent were detected during this 8-hour period. As pointed out in the chapter on FIRE OCCURRENCE, there will be some fluctuation in these hours on various forests. Also, there will be day-to-day fluctuations according to general weather conditions and the time of occurrence of lightning storms. For general planning purposes the study of time of origin and detection revealed these significant factors:

1. The hours of work for detectors should be planned to extend after the normal quitting hour of 5 p.m. Over one-fourth of the fires may be expected between 5 p.m. and the hour of darkness.

2. The first hours of daylight in the morning are important for the detection of lightning fires. Nearly 14 percent of the lightning fires are discovered during the period from 4 a.m. to 8 a.m.

3. A lull in lightning fire discoveries may be expected from 10 a.m. to noon. Only 7 percent of the lightning fires have been discovered during this period which is the lowest for any 2-hour daylight period after 6 a.m.

4. Over 90 percent of the man-caused fires may be expected during daylight hours, with the period from noon to 6 p.m. clearly being most important for detection.

Hours of detection for lightning and man-caused fires in the eastern and western zones are shown in tables 44 through 47.

Man-caused fires are detected faster than lightning fires. As illustrated in figures 80 and 81, over 61 percent of the man-caused fires in the western zone are discovered within 2 hours after origin, and 52 percent in the eastern zone. Only 43 percent of the lightning fires in the western zone and 35 percent in the eastern zone are detected within 2 hours.

During the first 12 hours after origin fires in the western zone are detected faster than in the eastern zone. This better detection record in the western zone during the first burning period is illustrated in figures 80 and 81. It is a direct result of the more intensive detection system. However, after the first 12 hours the forests in the eastern zone show a better detection record. As shown in tables 48 through 51, a large number of fires in the western zone hang over for 24 hours or more. In the western forests 9 percent of the lightning fires have a detection time of over 72 hours as compared to 6 percent in the eastern forests. Likewise, more hangover man-caused fires occur in the western zone. One reason for the smaller number of hangover fires in the eastern zone is the general flashy character of the fuels.

Table 44. Number and Percent of Lightning Fires According to Hour of Discovery, National Forests, R-1, Western Zone, 1931-1939, inclusive

(Basis 7,639 fires)

Forest	Unit	Midnight to 2 a.m.	2 a.m. to 4 a.m.	4 a.m. to 6 a.m.	6 a.m. to 8 a.m.	8 a.m. to 10 a.m.	10 a.m. to Noon	Noon to 2 p.m.	2 p.m. to 4 p.m.	4 p.m. to 6 p.m.	6 p.m. to 8 p.m.	8 p.m. to 10 p.m.	10 p.m. to Midnight
		Number of Fires and Area Burned Classified by Known Hour of Discovery											
Bitterroot	No. Fires	10	11	19	68	79	59	90	154	184	121	83	19
	%	1.115	1.224	2.118	7.581	8.807	6.577	10.033	17.168	20.512	13.489	9.253	2.118
Cabinet	No. Fires	12	9	18	39	39	35	46	42	35	62	71	35
	%	2.709	2.032	4.063	8.804	8.804	7.901	10.384	9.481	7.901	13.995	16.027	7.901
Clearwater	No. Fires	28	32	75	79	74	62	47	89	135	128	95	45
	%	3.150	3.591	8.436	8.863	8.324	6.974	5.286	10.011	15.185	14.398	10.686	5.062
Coeur d'Alene	No. Fires	13	8	28	30	26	23	18	29	40	36	29	10
	%	4.483	2.759	9.655	10.345	8.966	7.931	6.207	10.000	13.793	12.414	10.000	3.448
Flathead	No. Fires	17	13	20	83	83	58	69	93	110	143	76	46
	%	2.096	1.603	2.466	10.234	10.234	7.152	8.508	11.467	13.564	16.400	9.371	5.672
Kaniksu	No. Fires	29	15	79	86	80	74	77	109	128	86	95	42
	%	3.222	1.667	8.778	9.556	8.889	8.222	8.556	12.111	14.222	9.556	10.556	4.667
Kootenai	No. Fires	21	10	11	48	57	57	43	96	103	61	50	23
	%	3.621	1.724	1.897	8.276	9.828	9.828	7.414	16.552	17.757	10.517	8.621	3.966
Lolo	No. Fires	17	15	30	86	98	73	98	103	215	140	88	31
	%	1.710	1.509	3.018	8.652	9.859	7.344	9.859	10.362	21.630	14.085	8.853	3.119
Nezperce	No. Fires	18	41	83	98	93	67	95	179	165	128	56	26
	%	1.716	3.908	7.912	9.342	8.866	6.387	9.056	17.064	15.729	12.202	5.338	2.479
St. Joe	No. Fires	24	43	66	104	73	48	40	68	89	87	91	53
	%	3.053	5.402	8.397	13.232	9.288	6.107	5.089	8.651	11.323	11.069	11.578	6.743
TOTAL	No. Fires	189	197	429	721	702	556	623	962	1204	992	734	330
	%	2.474	2.579	5.616	9.438	9.190	7.278	8.156	12.593	15.761	12.986	9.609	4.320

Table 45. Number and Percent of Lightning Fires According to Hour of Discovery, National Forests, R-1, Eastern Zone, 1931-1939, inclusive

(Basis 1,156 fires)

Forest	Unit	Number of Fires and Area Burned Classified by Known Hour of Discovery											
		Midnight to 2 a.m.	2 a.m. to 4 a.m.	4 a.m. to 6 a.m.	6 a.m. to 8 a.m.	8 a.m. to 10 a.m.	10 a.m. to Noon	Noon to 2 p.m.	2 p.m. to 4 p.m.	4 p.m. to 6 p.m.	6 p.m. to 8 p.m.	8 p.m. to 10 p.m.	10 p.m. to Midnight
Beaverhead	No. Fires	0	1	3	2	9	12	12	24	44	11	14	2
	%	0.000	0.746	2.239	1.493	6.716	8.955	8.955	17.910	32.836	8.209	10.448	1.493
Custer	No. Fires	1	0	5	12	19	20	21	47	31	26	23	3
	%	0.481	0.000	2.404	5.769	9.135	9.615	10.096	22.596	14.904	12.500	11.058	1.442
Deerlodge	No. Fires	1	0	2	4	19	18	28	44	49	33	17	6
	%	0.452	0.000	0.905	1.810	8.597	8.145	12.670	19.910	22.172	14.932	7.692	2.715
Gallatin 1/	No. Fires	0	1	4	10	12	16	14	22	23	18	17	4
	%	0.000	0.709	2.837	7.092	8.511	11.348	9.929	15.603	16.312	12.766	12.057	2.837
Helena	No. Fires	4	2	4	12	24	16	25	47	62	40	22	6
	%	1.515	0.758	1.515	4.545	9.091	6.061	9.470	17.803	23.485	15.152	8.333	2.273
Lewis and Clark	No. Fires	2	1	1	8	16	12	30	31	37	36	10	4
	%	1.064	0.532	0.532	4.255	8.511	6.383	15.957	16.489	19.681	19.149	5.319	2.128
TOTAL	No. Fires	8	5	19	48	99	94	130	215	246	164	103	25
	%	0.692	0.433	1.644	4.152	8.564	8.131	11.246	18.599	21.280	14.187	8.910	2.163

1/ Includes Absaroka

Table 46. Number and Percent of Man-Caused Fires According to Hour of Discovery, National Forests, R-1, Western Zone, 1931-1939, inclusive

(Basis 2,709 fires)

Forest	Unit	Number of Fires and Area Burned Classified by Known Hour of Discovery											
		Midnight to 2 a.m.	2 a.m. to 4 a.m.	4 a.m. to 6 a.m.	6 a.m. to 8 a.m.	8 a.m. to 10 a.m.	10 a.m. to Noon	Noon to 2 p.m.	2 p.m. to 4 p.m.	4 p.m. to 6 p.m.	6 p.m. to 8 p.m.	8 p.m. to 10 p.m.	10 p.m. to Midnight
Bitterroot	No. Fires	2	2	1	4	10	16	27	26	20	17	9	2
	%	1.471	1.471	0.735	2.941	7.353	11.765	19.853	19.118	14.706	12.500	6.618	1.471
Cabinet	No. Fires	3	0	0	16	33	38	82	141	111	40	24	9
	%	0.604	0.000	0.000	3.219	6.640	7.646	16.499	28.370	22.334	8.048	4.829	1.812
Clearwater	No. Fires	1	0	1	5	6	18	12	10	11	7	1	0
	%	1.389	0.000	1.389	6.944	8.333	25.000	16.667	13.889	15.278	9.722	1.389	0.000
Coeur d'Alene	No. Fires	4	3	6	14	27	39	42	58	44	20	11	6
	%	1.460	1.095	2.190	5.109	9.854	14.234	15.328	21.168	16.058	7.299	4.015	2.190
Flathead	No. Fires	4	2	2	7	15	21	23	36	28	19	12	7
	%	2.273	1.136	1.136	3.977	8.523	11.932	13.068	20.455	15.909	10.795	6.818	3.977
Kaniksu	No. Fires	9	4	5	20	33	40	51	78	65	27	34	14
	%	2.368	1.053	1.316	5.263	8.684	10.526	13.421	20.526	17.105	7.105	8.947	3.684
Kootenai	No. Fires	2	1	3	15	15	18	46	90	67	21	13	5
	%	0.676	0.338	1.014	5.068	5.068	6.081	15.541	30.405	22.635	7.095	4.392	1.689
Lolo	No. Fires	2	1	3	9	26	33	65	89	76	45	13	14
	%	0.532	0.266	0.798	2.394	6.915	8.777	17.287	23.670	20.213	11.968	3.457	3.723
Nezperce	No. Fires	1	1	1	13	10	29	36	33	36	14	6	2
	%	0.549	0.549	0.549	7.143	5.495	15.934	19.780	18.132	19.780	7.692	3.297	1.099
St. Joe	No. Fires	9	2	5	18	31	45	47	71	55	23	13	1
	%	2.813	0.625	1.563	5.625	9.688	14.063	14.688	22.188	17.188	7.188	4.063	0.313
TOTAL	No. Fires	37	16	27	121	206	297	431	632	513	233	136	60
	%	1.366	0.591	0.997	4.467	7.604	10.963	15.910	23.330	18.938	8.601	5.020	2.215

Table 47. Number and Percent of Man-Caused Fires According to Hour of Discovery, National Forests, R-1, Eastern Zone, 1931-1939, inclusive

(Basis 1,033 fires)

Forest	Unit	Number of Fires and Area Burned Classified by Known Hour of Discovery											
		Midnight to 2 a.m.	2 a.m. to 4 a.m.	4 a.m. to 6 a.m.	6 a.m. to 8 a.m.	8 a.m. to 10 a.m.	10 a.m. to Noon	Noon to: 2 p.m.	2 p.m. to 4 p.m.	4 p.m. to 6 p.m.	6 p.m. to 8 p.m.	8 p.m. to 10 p.m.	10 p.m. to Midnight
Beaverhead	No. Fires	5	0	0	3	5	15	12	23	17	7	4	3
	%	5.319	0.000	0.000	3.191	5.319	15.957	12.766	24.468	18.085	7.477	4.255	3.191
Custer	No. Fires	1	0	1	3	5	11	16	16	10	2	2	1
	%	1.471	0.000	1.471	4.411	7.353	16.176	23.529	23.529	14.706	2.941	2.941	1.471
Deerlodge	No. Fires	2	1	3	8	24	45	86	117	78	33	16	4
	%	0.480	0.240	0.719	1.918	5.755	10.791	20.624	28.058	18.705	7.914	3.837	0.959
Gallatin 1/	No. Fires	0	2	1	2	13	25	38	54	35	15	6	4
	%	0.000	1.026	0.513	1.026	6.667	12.821	19.487	27.692	17.949	7.692	3.077	2.051
Helena	No. Fires	6	2	0	6	13	28	29	44	24	22	17	5
	%	3.061	1.020	0.000	3.061	6.633	14.286	14.796	22.449	12.245	11.224	8.673	2.551
Lewis and Clark	No. Fires	1	2	1	1	4	9	15	13	11	2	2	2
	%	1.587	3.175	1.587	1.587	6.349	14.286	23.810	20.635	17.460	3.175	3.175	3.175
TOTAL	No. Fires	15	7	6	23	64	133	196	267	175	81	47	19
	%	1.452	0.678	0.581	2.227	6.196	12.875	18.974	25.847	16.941	7.841	4.550	1.839

1/ Includes Absaroka

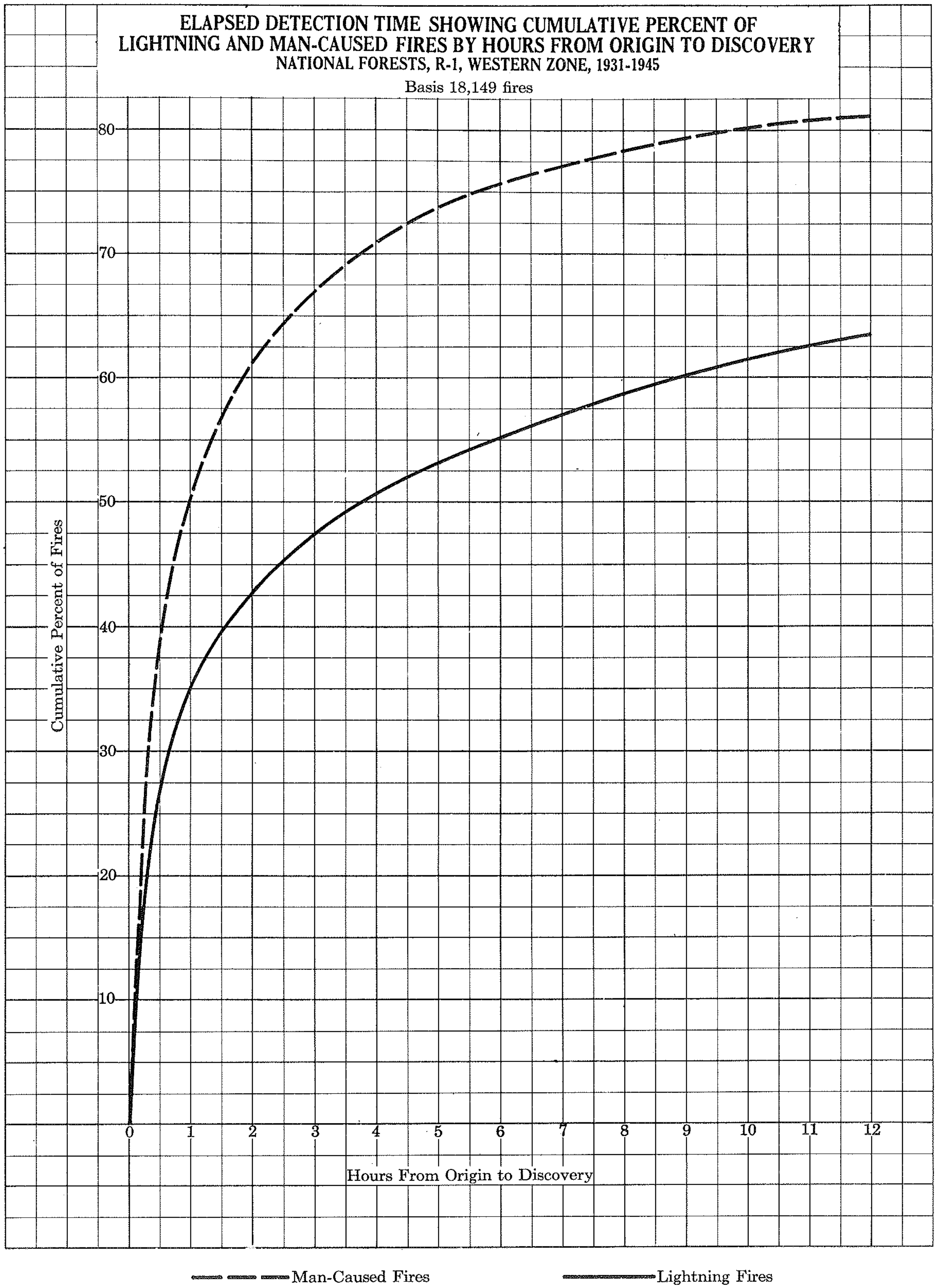

ELAPSED DETECTION TIME SHOWING CUMULATIVE PERCENT OF
LIGHTNING AND MAN-CAUSED FIRES BY HOURS FROM ORIGIN TO DISCOVERY
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1945
Basis 18,149 fires
Cumulative Percent of Fires
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours From Origin to Discovery
Man-Caused Fires
Lightning Fires

Figure 80.

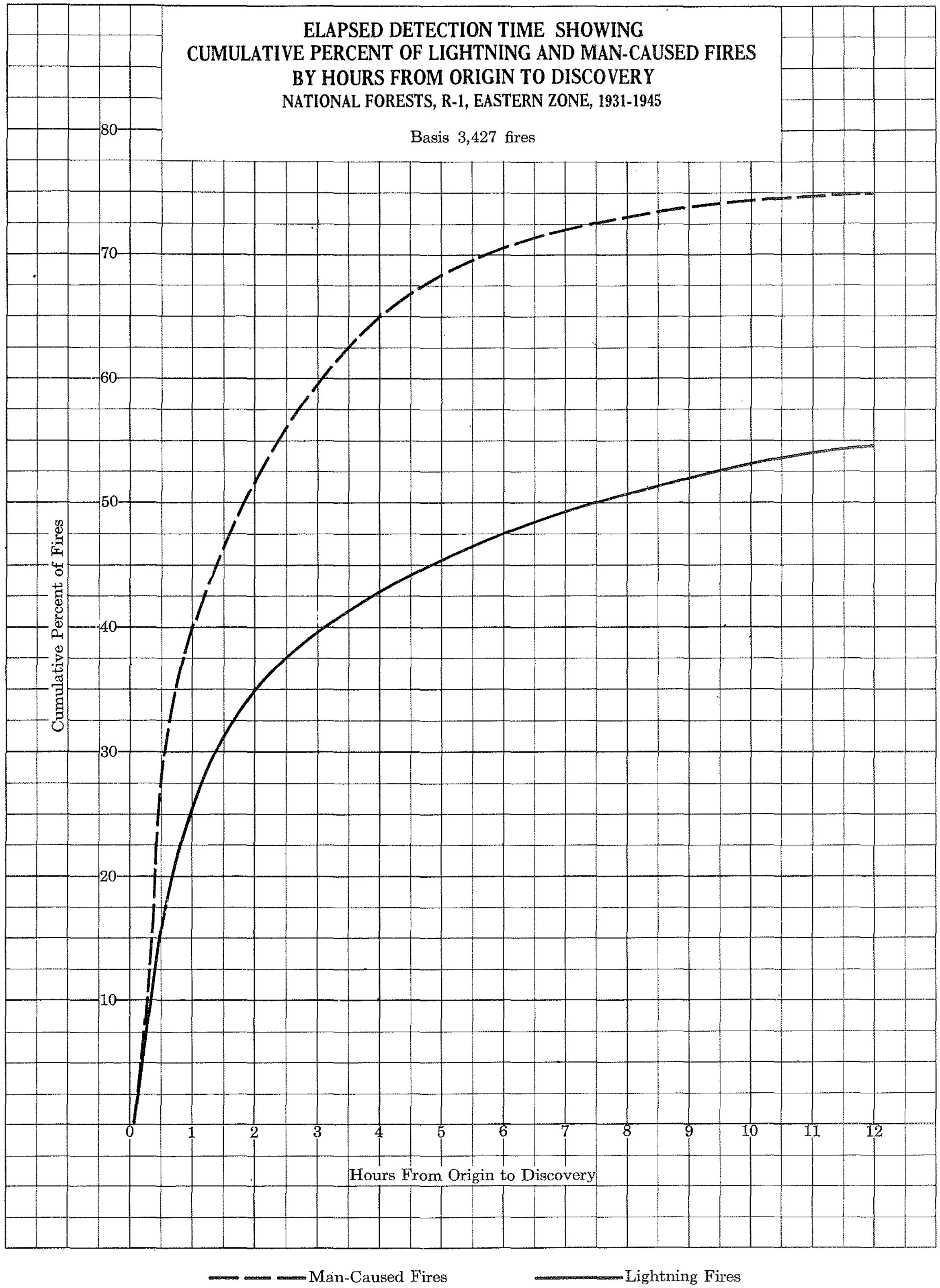

ELAPSED DETECTION TIME SHOWING
CUMULATIVE PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
BY HOURS FROM ORIGIN TO DISCOVERY
NATIONAL FORESTS, R-1, EASTERN ZONE, 1931-1945
Basis 3,427 fires
Cumulative Percent of Fires
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
11
12
Hours From Origin to Discovery
Man-Caused Fires
Lightning Fires

Figure 81.

Table 48. Number and Percent of Lightning Fires Classified by Known Discovery Time, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 14,348 fires)

Forest	Unit	Known Discovery Time ¼ hour	½ hour	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	12 hours	24 hours	48 hours	72 hours	Over 72 hours
Bitterroot	No.	325	118	142	156	75	73	43	23	121	279	148	60	143
	%	19.1	6.9	8.3	9.1	4.4	4.3	2.5	1.3	7.1	16.4	8.7	3.5	8.4
Cabinet	No.	199	65	84	79	51	36	24	17	88	145	64	27	73
	%	20.9	6.8	8.8	8.3	5.4	3.9	2.5	1.8	9.2	15.2	6.7	2.8	7.7
Clearwater	No.	360	127	152	168	102	60	44	21	158	239	150	68	182
	%	19.7	6.9	8.3	9.2	5.6	3.3	2.4	1.1	8.6	13.1	8.2	3.7	9.9
Coeur d'Alene	No.	170	45	53	68	37	20	19	9	69	94	52	21	62
	%	23.6	6.3	7.4	9.5	5.1	2.8	2.6	1.3	9.6	13.1	7.2	2.9	8.6
Flathead	No.	305	76	90	85	50	34	20	20	134	207	126	71	112
	%	22.9	5.7	6.8	6.4	3.8	2.5	1.5	1.5	10.1	15.6	9.5	5.3	8.4
Kaniksu	No.	320	89	116	131	81	41	35	31	138	203	95	53	140
	%	21.7	6.0	7.9	8.9	5.5	2.8	2.4	2.1	9.4	13.8	6.4	3.6	9.5
Kootenai	No.	250	66	99	103	48	30	37	27	145	234	132	53	90
	%	19.0	5.0	7.5	7.8	3.7	2.3	2.8	2.1	11.0	17.8	10.1	4.0	6.9
Lolo	No.	326	129	143	134	73	48	43	30	138	323	165	67	171
	%	18.2	7.2	8.0	7.5	4.1	2.7	2.4	1.7	7.7	18.0	9.2	3.7	9.6
Nezperce	No.	403	104	157	163	77	52	38	34	156	297	157	78	213
	%	20.9	5.4	8.1	8.4	4.0	2.7	2.0	1.8	8.1	15.4	8.1	4.0	11.1
St. Joe	No.	336	73	99	77	54	36	26	16	164	166	116	42	99
	%	25.8	5.6	7.6	5.9	4.1	2.8	2.0	1.2	12.6	12.7	8.9	3.2	7.6
WESTERN ZONE	No.	2,994	892	1,135	1,164	648	430	329	228	1,311	2,187	1,205	540	1,285
	%	20.9	6.2	7.9	8.1	4.5	3.0	2.3	1.6	9.1	15.2	8.4	3.8	9.0

Table 49. Number and Percent of Lightning Fires Classified by Known Discovery Time, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 2,020 fires)

Forest	Unit	Known Discovery Time ¼ hour	½ hour	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	12 hours	24 hours	48 hours	72 hours	Over 72 hours
Beaverhead	No.	22	13	18	22	12	5	5	9	14	43	36	12	18
	%	9.6	5.7	7.9	9.6	5.2	2.2	2.2	3.9	6.1	18.8	15.7	5.2	7.9
Custer	No.	43	22	35	33	13	12	11	5	41	113	19	5	3
	%	12.1	6.2	9.9	9.3	3.7	3.4	3.1	1.4	11.5	31.8	5.4	1.4	0.8
Deerlodge	No.	39	20	25	43	22	12	15	9	24	98	43	21	44
	%	9.4	4.8	6.0	10.4	5.3	2.9	3.6	2.1	5.8	23.6	10.4	5.1	10.6
Gallatin 1/	No.	38	14	18	17	9	7	6	8	11	54	18	11	20
	%	16.4	6.1	7.8	7.3	3.9	3.0	2.6	3.5	4.8	23.4	7.8	4.8	8.6
Helena	No.	66	30	32	52	27	14	17	12	38	113	59	13	25
	%	13.3	6.0	6.4	10.5	5.4	2.8	3.4	2.4	7.6	22.7	11.9	2.6	5.0
Lewis and Clark	No.	33	22	30	29	10	0	8	2	18	79	28	15	18
	%	11.3	7.5	10.3	9.9	3.4	0.0	2.7	0.7	6.2	27.1	9.6	5.1	6.2
EASTERN ZONE	No.	241	121	158	196	93	50	62	45	146	500	203	77	128
	%	11.9	6.0	7.8	9.7	4.6	2.5	3.1	2.2	7.2	24.8	10.1	3.8	6.3

1/ Includes Absaroka

Table 50. Number and Percent of Man-Caused Fires Classified by Known Discovery Time, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 3,801 fires)

Forest	Unit	Known Discovery Time: ¼ hour	½ hour	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	12 hours	24 hours	48 hours	72 hours	Over 72 hours
Bitterroot	No.	26	19	27	29	16	11	6	6	13	26	18	4	10
	%	12.3	9.0	12.8	13.7	7.6	5.2	2.9	2.9	6.2	12.3	8.5	1.9	4.7
Cabinet	No.	401	107	97	66	31	18	8	10	16	35	13	4	20
	%	48.5	13.0	11.7	8.0	3.8	2.2	1.0	1.2	1.9	4.2	1.6	0.5	2.4
Clearwater	No.	7	3	7	4	4	3	5	6	10	10	11	3	12
	%	8.2	3.5	8.2	4.7	4.7	3.5	5.9	7.1	11.8	11.8	13.0	3.5	14.1
Coeur d'Alene	No.	77	59	60	49	24	21	7	8	28	40	16	12	9
	%	18.8	14.4	14.6	12.0	5.9	5.1	1.7	1.9	6.8	9.8	3.9	2.9	2.2
Flathead	No.	22	14	24	26	19	18	7	4	16	25	8	7	15
	%	10.7	6.8	11.7	12.7	9.3	8.8	3.4	2.0	7.8	12.2	3.9	3.4	7.3
Kaniksu	No.	71	40	50	57	27	14	14	11	27	37	19	6	18
	%	18.2	10.2	12.8	14.6	6.9	3.6	3.6	2.8	6.9	9.5	4.8	1.5	4.6
Kootenai	No.	83	52	65	55	28	16	12	7	18	32	14	11	21
	%	20.0	12.6	15.7	13.3	6.8	3.9	2.9	1.7	4.3	7.7	3.4	2.6	5.1
Lolo	No.	198	72	63	50	28	17	13	10	26	55	25	6	17
	%	34.1	12.4	10.9	8.6	4.8	2.9	2.3	1.7	4.5	9.5	4.3	1.1	2.9
Nezperce	No.	31	25	15	21	10	12	11	7	25	31	23	18	7
	%	13.1	10.6	6.4	8.9	4.2	5.1	4.7	3.0	10.6	13.1	9.7	7.6	3.0
St. Joe	No.	78	60	67	56	25	22	11	9	31	39	17	5	23
	%	17.6	13.6	15.1	12.7	5.6	5.0	2.5	2.0	7.0	8.8	3.8	1.1	5.2
WESTERN ZONE	No.	994	451	475	413	212	152	94	78	210	330	164	76	152
	%	26.1	11.9	12.5	10.9	5.6	4.0	2.5	2.0	5.5	8.7	4.3	2.0	4.0

Table 51. Number and Percent of Man-Caused Fires Classified by Known Discovery Time, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 1,407 fires)

Forest	Unit	Known Discovery Time ¼ hour	½ hour	1 hour	2 hours	3 hours	4 hours	5 hours	6 hours	12 hours	24 hours	48 hours	72 hours	Over 72 hours
Beaverhead	No.	22	16	11	12	10	9	5	4	4	17	10	5	5
	%	16.9	12.4	8.5	9.2	7.7	6.9	3.8	3.1	3.1	13.1	7.7	3.8	3.8
Custer	No.	16	19	8	7	6	3	2	1	4	7	4	0	0
	%	20.8	24.6	10.4	9.1	7.8	3.9	2.6	1.3	5.2	9.1	5.2	0.0	0.0
Deerlodge	No.	72	68	79	81	57	26	18	11	23	78	37	23	11
	%	12.3	11.6	13.5	13.9	9.8	4.5	3.1	1.9	3.9	13.4	6.3	3.9	1.9
Gallatin 1/	No.	42	29	32	36	18	11	9	4	12	31	12	6	9
	%	16.7	11.5	12.7	14.3	7.2	4.4	3.6	1.6	4.8	12.4	4.8	2.4	3.6
Helena	No.	46	34	32	29	20	13	10	7	15	37	17	5	11
	%	16.7	12.3	11.6	10.5	7.3	4.7	3.6	2.5	5.4	13.4	6.2	1.8	4.0
Lewis and Clark	No.	16	8	12	10	6	4	1	1	9	13	6	2	1
	%	18.0	9.0	13.5	11.2	6.8	4.5	1.1	1.1	10.1	14.6	6.8	2.2	1.1
EASTERN ZONE	No.	214	174	174	175	117	66	45	28	67	183	86	41	37
	%	15.2	12.4	12.4	12.4	8.3	4.7	3.2	2.0	4.8	13.0	6.1	2.9	2.6

1/ Includes Absaroka

Lookout Station Coverage

During the peak of the fire season lookout stations cover less than half of the national forest areas requiring fire protection. During the season of 1940 fire plans called for the manning of an average of 30 lookout stations per million acres when fire danger reached class 70. This level of manning provided detection coverage for approximately 60 percent of the area requiring protection. In 1950 plans called for the manning of 20 lookout stations per million acres at fire danger class 70. This provides coverage for approximately 45 percent of the area. The reduction in number of lookout stations on nearly all forests is shown in figure 82.

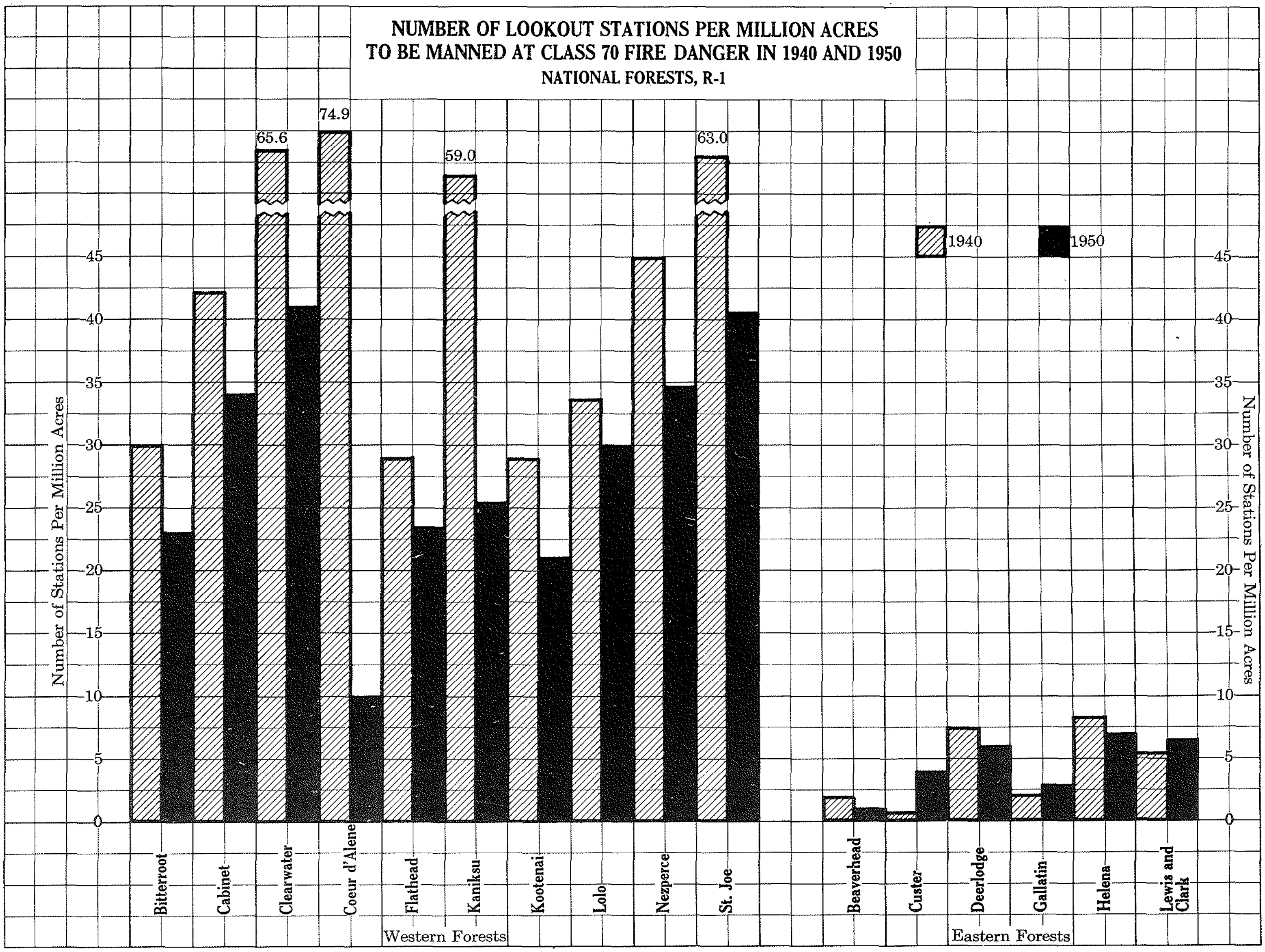
More lightning fires are directly visible to lookout stations than man-caused fires. During the period 1931-1944 over 77 percent of the lightning fires were directly visible to manned lookout stations as compared to only 54 percent of the man-caused fires. As illustrated in figure 83, there was a considerable variation in the number of fires directly visible to lookout stations during this 14-year period. After 1933 the lookout station construction program carried on by the Civilian Conservation Corps resulted in a greatly increased number of fires which were directly visible to manned stations. The peak coverage occurred in 1938, and since that time there has been a general reduction in the number of fires directly visible to manned stations. The lookout station coverage for lightning and man-caused fires on all forests is shown in tables 52 through 55.

Lookout observers are more efficient in detecting lightning than man-caused fires. During the 1931-1944 period over 12,000 lightning fires occurred within the area covered by manned lookout stations. Lookout observers detected 83 percent of these fires. During the same period nearly 3000 man-caused fires occurred in the seen area of occupied stations, but only 43 percent of these fires were detected from these stations. Thus lookout observers were nearly twice as efficient in discovering lightning fires.

A large number of fires are seen by two or more lookout observers. One of the results of the lookout station construction program in the early years of the Civilian Conservation Corps was to provide multiple detection coverage for many fires. As illustrated in figure 84, in 1938 over 50 percent of the fires occurred within the seen area of two or more manned lookout stations. During this period many of these stations were manned just as much for smokechasing purposes as for detection. The selection of the sites for many stations was made on this basis, and the results often provided additional coverage for territory already seen from a lookout station rather than adding much new visible area.

Aerial Detection

Several national forests have provided tests of combined air-ground detection systems. Beginning in 1945 portions of the Lolo, Lewis and Clark, Helena, and Flathead National Forests were operated under a new system of detection involving a greatly reduced number of lookout stations and the addition of regularly planned patrols by aircraft. In 1947 the


NUMBER OF LOOKOUT STATIONS PER MILLION ACRES
TO BE MANNED AT CLASS 70 FIRE DANGER IN 1940 AND 1950
NATIONAL FORESTS, R-1
1940
1950
65.6
74.9
59.0
63.0
Number of Stations Per Million Acres
0
5
10
15
20
25
30
35
40
45
Bitterroot
Cabinet
Clearwater
Coeur d'Alene
Flathead
Kaniksu
Kootenai
Lolo
Nezperce
St. Joe
Western Forests
Beaverhead
Custer
Deerlodge
Gallatin
Helena
Lewis and Clark
Eastern Forests

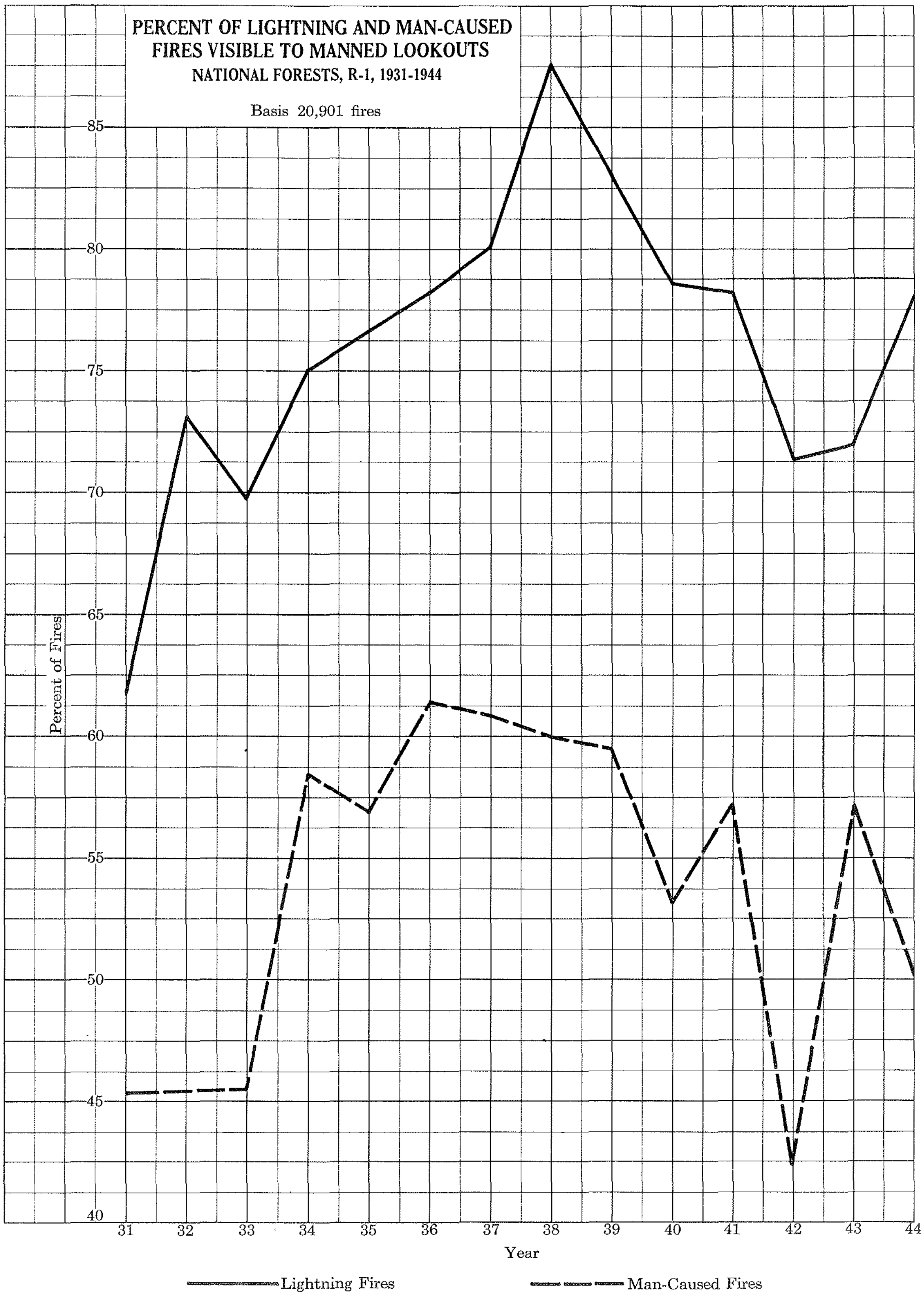

PERCENT OF LIGHTNING AND MAN-CAUSED
FIRES VISIBLE TO MANNED LOOKOUTS
NATIONAL FORESTS, R-1, 1931-1944
Basis 20,901 fires
85
80
75
70
65
60
55
50
45
40
Percent of Fires
31
32
33
34
35
36
37
38
39
40
41
42
43
44
Year
Lightning Fires
Man-Caused Fires

Figure 83.

Table 52. Number and Percent of Lightning Fires Classified by Detection Coverage at Point of Origin, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 13,701 fires)

Forest	Unit	Detection Coverage at Point of Origin: In Blind Area	1 Manned Lookout	2 Manned Lookouts	3 Manned Lookouts	Unmanned L. O. or Indirect	Unknown	Total Directly Visible
Bitterroot	No.	147	619	344	288	234	1	1,251
	%	9.00	37.90	21.06	17.63	14.32	0.06	76.60
Cabinet	No.	32	358	250	194	124	8	802
	%	3.31	37.06	25.87	20.08	12.83	0.82	83.02
Clearwater	No.	60	553	452	507	164	8	1,512
	%	3.44	31.70	25.91	29.07	9.40	0.45	86.69
Coeur d'Alene	No.	42	245	178	163	76	3	586
	%	5.94	34.65	25.17	23.05	10.74	0.42	82.88
Flathead	No.	50	488	334	272	118	8	1,094
	%	3.93	38.42	26.29	21.41	9.29	0.62	86.14
Kaniksu	No.	31	424	342	458	126	22	1,224
	%	2.20	30.22	24.37	32.64	8.98	1.56	87.24
Kootenai	No.	57	427	301	239	156	3	967
	%	4.81	36.09	25.44	20.20	13.18	0.25	81.74
Lolo	No.	123	715	338	245	270	42	1,298
	%	7.09	41.25	19.50	14.13	15.57	2.42	74.89
Nezperce	No.	53	573	520	539	187	4	1,632
	%	2.82	30.54	27.71	28.73	9.96	0.21	86.99
St. Joe	No.	38	376	345	285	116	26	1,006
	%	3.20	31.70	29.08	24.03	9.78	2.19	84.82
WESTERN ZONE	No.	633	4,778	3,404	3,190	1,571	125	11,372
	%	4.62	34.87	24.84	23.28	11.46	0.91	83.00

Table 53. Number and Percent of Lightning Fires Classified by Detection Coverage at Point of Origin, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 1,964 fires)

Forest	Unit	Detection Coverage at Point of Origin: In Blind Area	1 Manned Lookout	2 Manned Lookouts	3 Manned Lookouts	Unmanned L. O. or Indirect	Unknown	Total Directly Visible
Beaverhead	No.	97	34	10	3	26	52	47
	%	43.69	15.31	4.50	1.35	11.71	23.42	21.16
Custer	No.	121	90	13	1	70	58	104
	%	34.27	25.49	3.68	0.28	19.83	16.43	29.17
Deerlodge	No.	171	105	21	4	57	41	130
	%	42.85	26.31	5.26	1.00	14.28	10.27	32.57
Gallatin 1/	No.	118	31	3	2	27	46	36
	%	51.98	13.65	1.32	0.88	11.89	20.26	15.85
Helena	No.	114	166	48	15	106	21	229
	%	24.25	35.31	10.21	3.19	22.55	4.46	48.72
Lewis and Clark	No.	141	71	20	5	39	17	96
	%	48.12	24.23	6.82	1.70	13.31	5.80	32.76
EASTERN ZONE	No.	762	497	115	30	325	235	642
	%	38.79	25.30	5.85	1.52	16.54	11.96	32.68

1/ Includes Absaroka

Table 54. Number and Percent of Man-Caused Fires Classified by Detection Coverage at Point of Origin, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 3,650 fires)

Forest	Unit	Detection Coverage at Point of Origin: In Blind Area	1 Manned Lookout	2 Manned Lookouts	3 Manned Lookouts	Unmanned L. O. or Indirect	Unknown	Total Directly Visible
Bitterroot	No.	53	49	29	15	61	0	93
	%	25.60	23.67	14.00	7.24	29.46	0.00	44.92
Cabinet	No.	70	226	188	139	131	6	553
	%	9.21	29.73	24.73	18.28	17.23	0.78	72.76
Clearwater	No.	10	17	19	17	20	1	53
	%	11.90	20.23	22.61	20.23	23.80	1.19	63.09
Coeur d'Alene	No.	77	127	72	25	90	5	224
	%	19.44	32.07	18.18	6.31	22.72	1.26	56.56
Flathead	No.	14	68	44	42	26	6	154
	%	7.00	34.00	22.00	21.00	13.00	3.00	77.00
Kaniksu	No.	20	118	95	88	49	7	301
	%	5.30	31.29	25.19	23.34	12.99	1.85	79.84
Kootenai	No.	44	132	113	40	66	4	285
	%	11.02	33.08	28.32	10.02	16.54	1.00	71.42
Lolo	No.	118	235	60	33	100	12	328
	%	21.14	42.11	10.75	5.91	17.92	2.15	58.78
Nezperce	No.	35	82	32	26	64	2	140
	%	14.52	34.02	13.27	10.78	26.55	0.82	58.09
St. Joe	No.	51	111	103	61	84	18	275
	%	11.91	25.93	24.06	14.25	19.62	4.20	64.25
WESTERN ZONE	No.	492	1,165	755	486	691	61	2,406
	%	13.47	31.91	20.68	13.31	18.93	1.67	65.91

Table 55. Number and Percent of Man-Caused Fires Classified by Detection Coverage at Point of Origin, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 1,388 fires)

Forest	Unit	Detection Coverage at Point of Origin: In Blind Area	1 Manned Lookout	2 Manned Lookouts	3 Manned Lookouts	Unmanned L. O. or Indirect	Unknown	Total Directly Visible
Beaverhead	No.	63	17	1	0	20	27	18
	%	49.21	13.28	0.78	0.00	15.62	21.09	14.06
Custer	No.	29	8	0	3	8	30	11
	%	37.17	10.25	0.00	3.84	10.25	38.46	14.09
Deerlodge	No.	258	96	16	4	73	128	116
	%	44.86	16.69	2.78	0.69	12.69	22.26	20.16
Gallatin 1/	No.	103	42	4	1	19	80	47
	%	41.36	16.86	1.60	0.40	7.63	32.12	18.87
Helena	No.	94	66	12	6	78	13	84
	%	34.94	24.53	4.46	2.23	28.99	4.83	31.22
Lewis and Clark	No.	56	7	2	0	14	10	9
	%	62.92	7.86	2.24	0.00	15.73	11.23	10.11
EASTERN ZONE	No.	603	236	35	14	212	288	285
	%	43.44	17.00	2.52	1.00	15.27	20.74	20.53

1/ Includes Absaroka

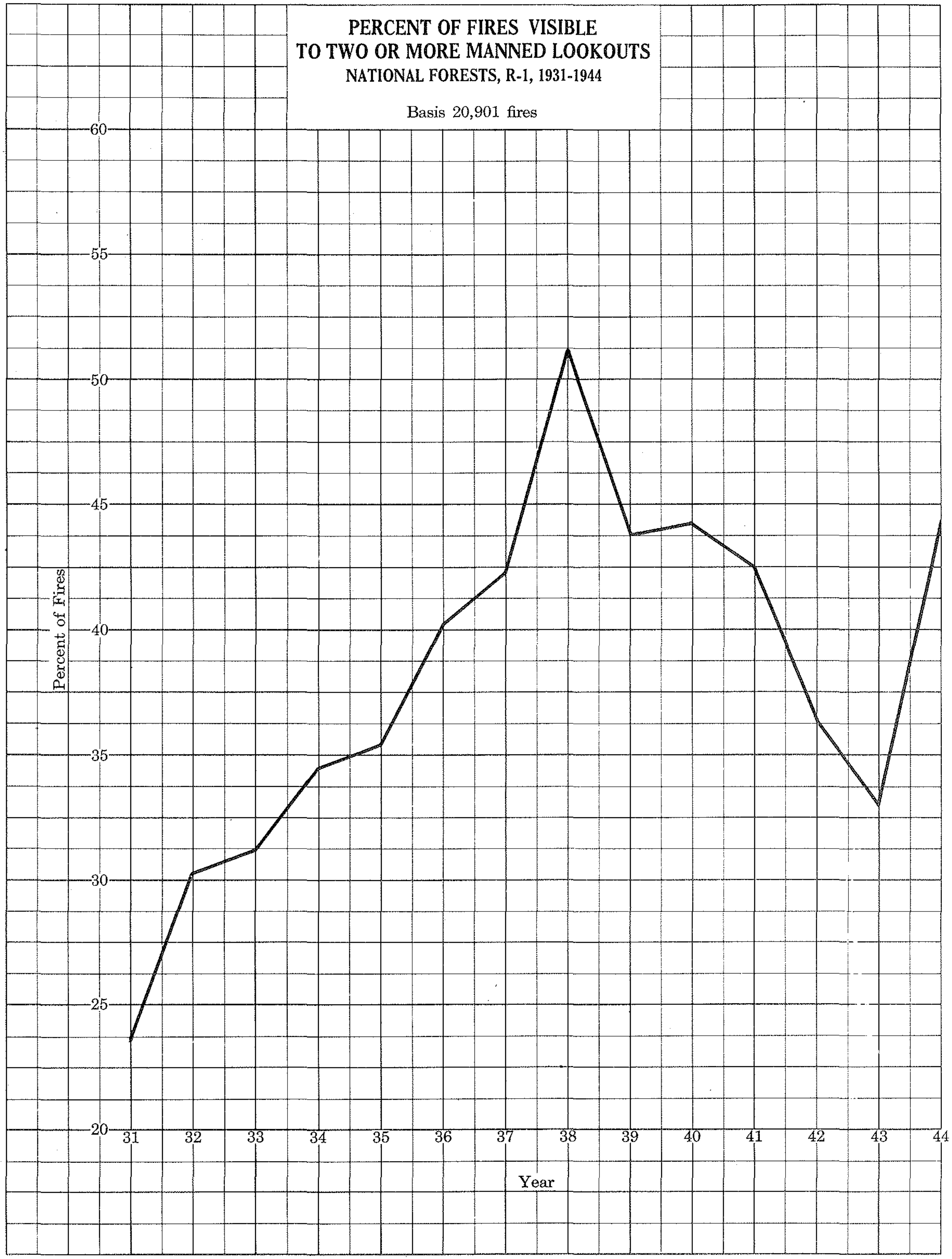

PERCENT OF FIRES VISIBLE
TO TWO OR MORE MANNED LOOKOUTS
NATIONAL FORESTS, R-1, 1931-1944
Basis 20,901 fires
Percent of Fires
60
55
50
45
40
35
30
25
20
31
32
33
34
35
36
37
38
39
40
41
42
43
44
Year

Figure 84.

entire Coeur d'Alene forest was placed on this system. As a means of analyzing the results obtained under this new system, a special study of fire detection was made on the Flathead, Lolo, and Coeur d'Alene forests.

In combined air-ground detection systems lookout observers make fewer first discoveries of fires. As shown in figure 85, prior to the introduction of regular air patrols on the Flathead, Lolo, and Coeur d'Alene forests lookout observers made nearly 60 percent of the first discoveries. After the air-ground detection system was introduced lookout observers detected only 37 percent of the fires. At the same time discoveries from patrol aircraft jumped from 1 percent to 23 percent. The percent of fires detected by other means increased only 1 percent.

Lookout observer efficiency in first discoveries has decreased. This surprising fact is vividly illustrated on the Coeur d'Alene where ground and combined air-ground detection systems could be analyzed on an entire forest. During the 14-year period prior to the introduction of the air-ground system lookout observers detected 78 percent of the fires occurring within their seen area. Under the new system lookout observers detected only 60 percent of the fires occurring within the area visible from manned stations. This decrease is probably due to:

1. Reduction in the area having multiple coverage from lookout stations, thus reducing the chance for several observers to see the same fire.

2. Reduction in the number of observation hours per day because of the 40-hour week.

3. First discoveries made from aircraft flying over areas covered by manned lookout stations. (On the Coeur d'Alene 14 percent of the fires occurring within areas visible to manned stations were detected from aircraft.)

Elapsed detection time has not changed under the air-ground system. As illustrated in figure 86, the elapsed time from origin to discovery has not changed materially. Under both the old and new systems about 60 percent of the fires are detected within 10 hours after origin. The air-ground system has made a slightly better record on fires which hang over for several hours before being detected.

Lookout observers are more efficient than aircraft observers in detecting fires that smoke up quickly after origin. As illustrated in figure 87, nearly 60 percent of the fires detected by lookout observers operating in air-ground systems were discovered within 4 hours as compared to only 23 percent for aircraft observers. In the next 16 hours lookout observers detect an additional 20 percent of the fires, while aircraft observers gain 50 percent. One of the reasons for faster detection by lookout observers is the fact that the time of the aircraft patrol flights is often deliberately delayed until the period of the day when smokes are likely to show up readily.

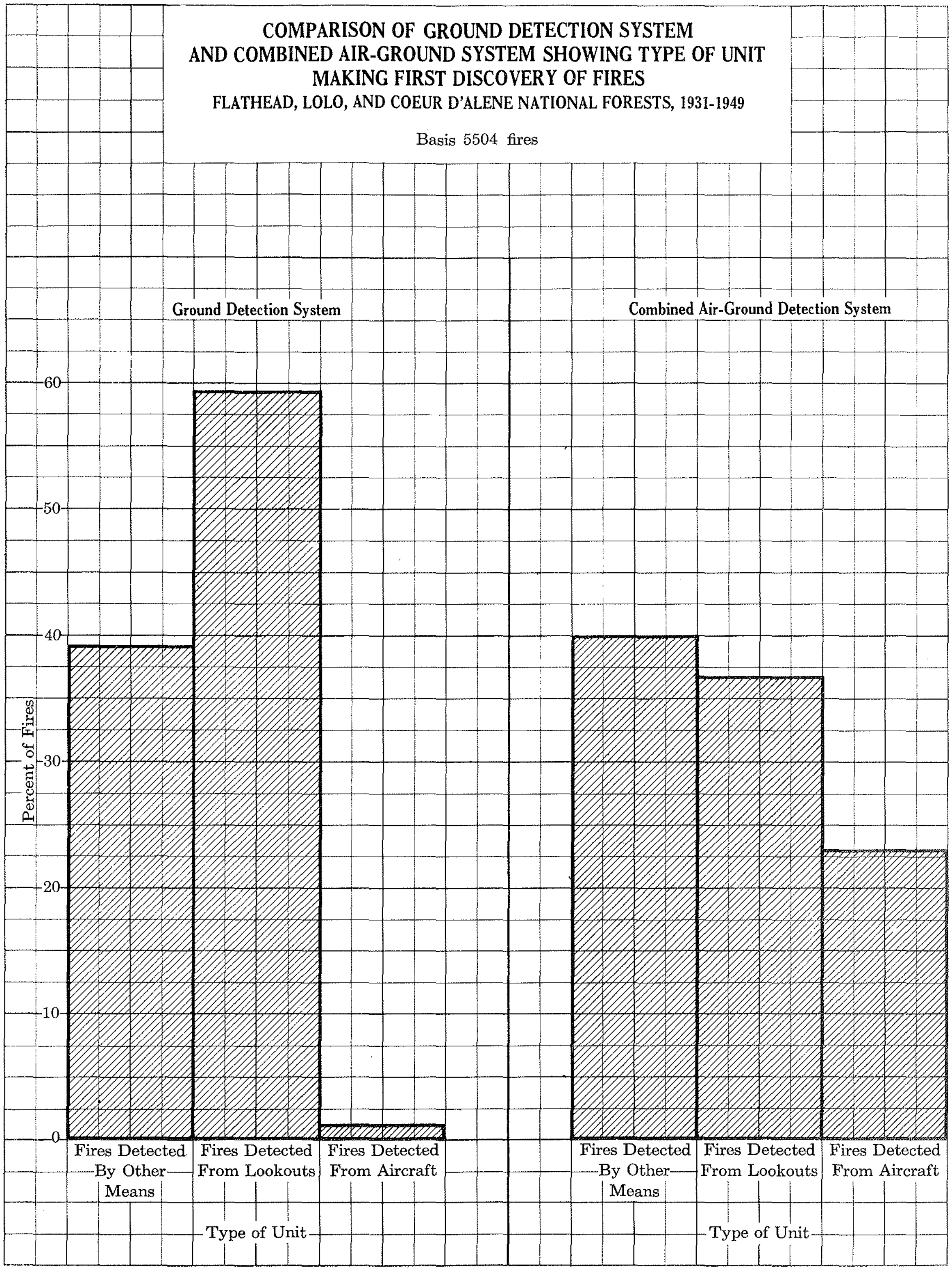

COMPARISON OF GROUND DETECTION SYSTEM
AND COMBINED AIR-GROUND SYSTEM SHOWING TYPE OF UNIT
MAKING FIRST DISCOVERY OF FIRES
FLATHEAD, LOLO, AND COEUR D'ALENE NATIONAL FORESTS, 1931-1949
Basis 5504 fires
Ground Detection System
Combined Air-Ground Detection System
Percent of Fires
60
50
40
30
20
10
0
Fires Detected By Other Means
Fires Detected From Lookouts
Fires Detected From Aircraft
Type of Unit
Fires Detected By Other Means
Fires Detected From Lookouts
Fires Detected From Aircraft
Type of Unit

Figure 85.

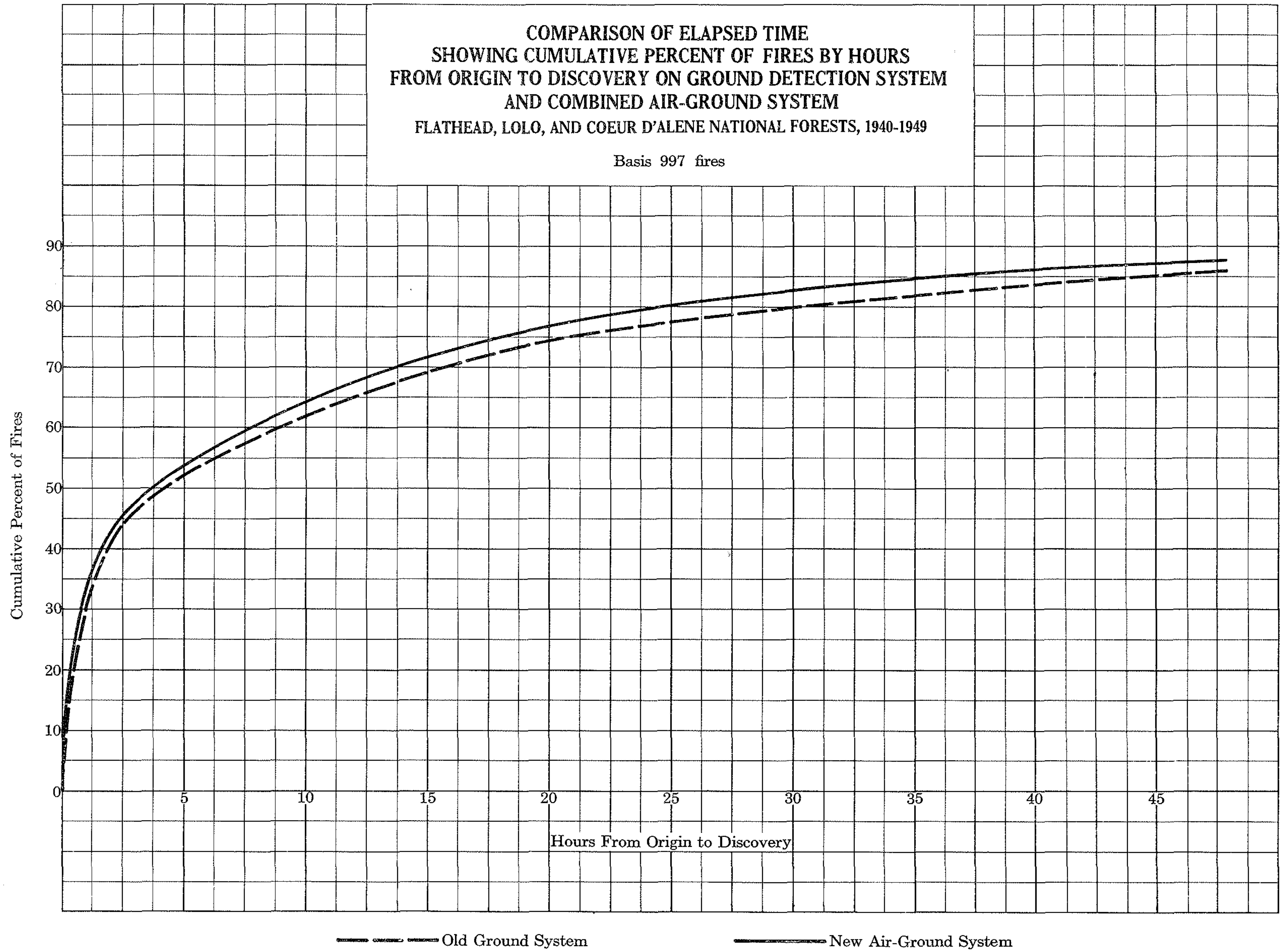

COMPARISON OF ELAPSED TIME
SHOWING CUMULATIVE PERCENT OF FIRES BY HOURS
FROM ORIGIN TO DISCOVERY ON GROUND DETECTION SYSTEM
AND COMBINED AIR-GROUND SYSTEM
FLATHEAD, LOLO, AND COEUR D'ALENE NATIONAL FORESTS, 1940-1949
Basis 997 fires
Cumulative Percent of Fires
0
10
20
30
40
50
60
70
80
90
5
10
15
20
25
30
35
40
45
Hours From Origin to Discovery
Old Ground System
New Air-Ground System

Figure 86.

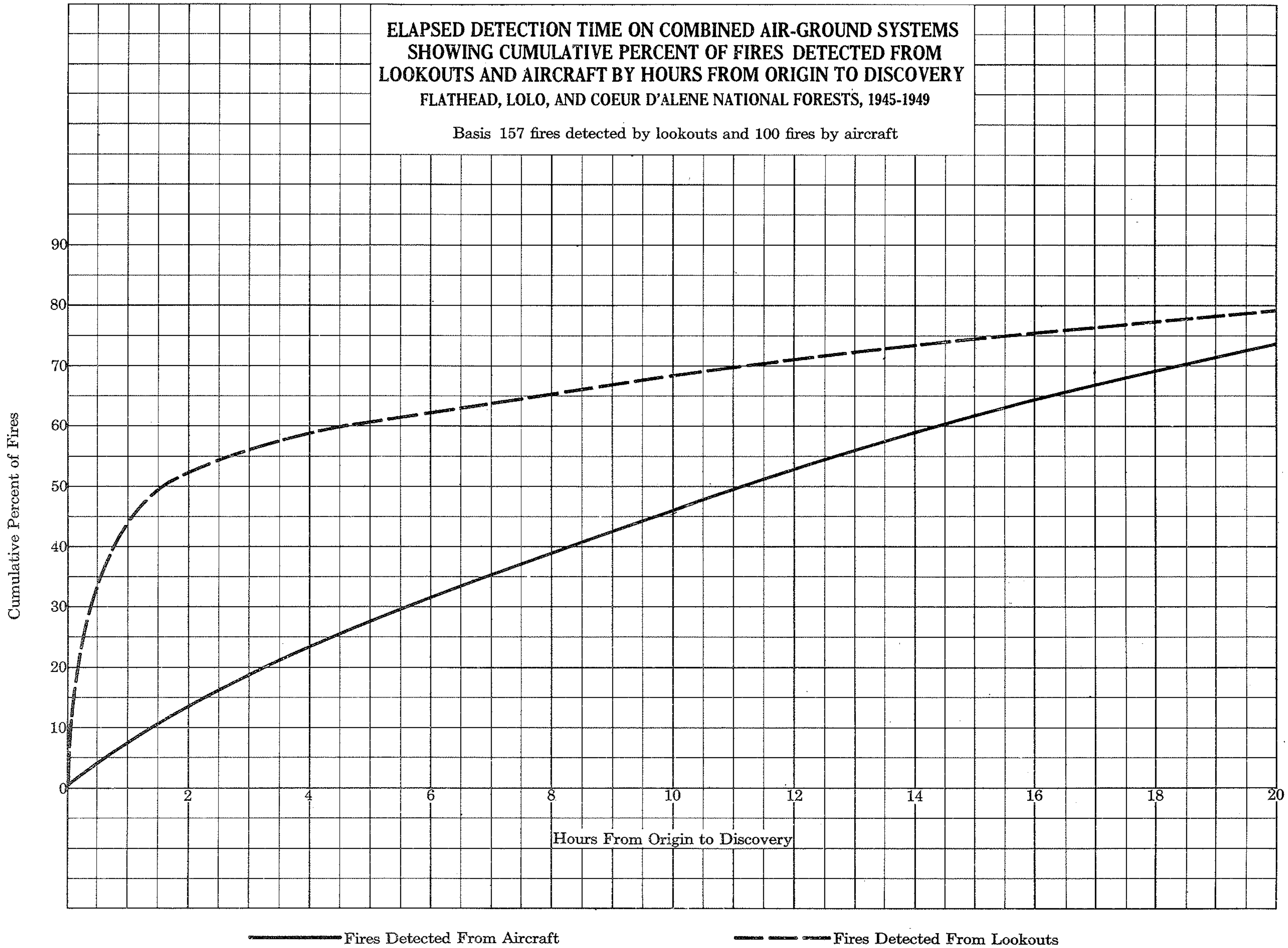

ELAPSED DETECTION TIME ON COMBINED AIR-GROUND SYSTEMS
SHOWING CUMULATIVE PERCENT OF FIRES DETECTED FROM
LOOKOUTS AND AIRCRAFT BY HOURS FROM ORIGIN TO DISCOVERY
FLATHEAD, LOLO, AND COEUR D'ALENE NATIONAL FORESTS, 1945-1949
Basis 157 fires detected by lookouts and 100 fires by aircraft
Cumulative Percent of Fires
0
10
20
30
40
50
60
70
80
90
2
4
6
8
10
12
14
16
18
20
Hours From Origin to Discovery
Fires Detected From Aircraft
Fires Detected From Lookouts

Figure 87.

Fuel classification and burning index ratings are important factors in planning and managing air-ground detection systems. A study of nearly 1000 fires which have occured on air-ground detection units showed these factors to be especially significant:

1. Greater coverage from lookout stations is necessary in areas having a high percentage of dangerous fuels. Where fuel rate-of-spread classification shows large areas of high, extreme, or grass fuels, the fast detection required can best be provided from lookout stations.

2. As burning index increases the area covered by patrol aircraft must be increased. This means more frequent flights over areas already covered and extension of the flights to observe areas that may not require regular patrols when burning index is low.

3. As burning index increases more speed is required in patrol aircraft takeoff time following lightning storms. When burning index is high, more fires will have high rates of spread, and therefore more speed is required in detection. This often means before-dark flights following late afternoon lightning storms and early-morning flights following night storms.

3. COMMUNICATION AND TRANSPORTATION

Communication and transportation systems mean the same thing to fire control forces as they do to armies engaged in battle. To both fire chiefs and generals they provide the means for directing and moving forces. During the 20-year period 1930-1949 revolutionary changes occurred in fire communication and transportation systems in the northern Rocky Mountains. Telephone service was greatly expanded, and radio was introduced as a regular part of the communication system. During the years prior to World War II roads built by Civilian Conservation Corps labor enabled large areas to be brought within more acceptable travel time standards. In more recent years widespread use of aircraft has brought about an even greater change in the fire transportation problem.

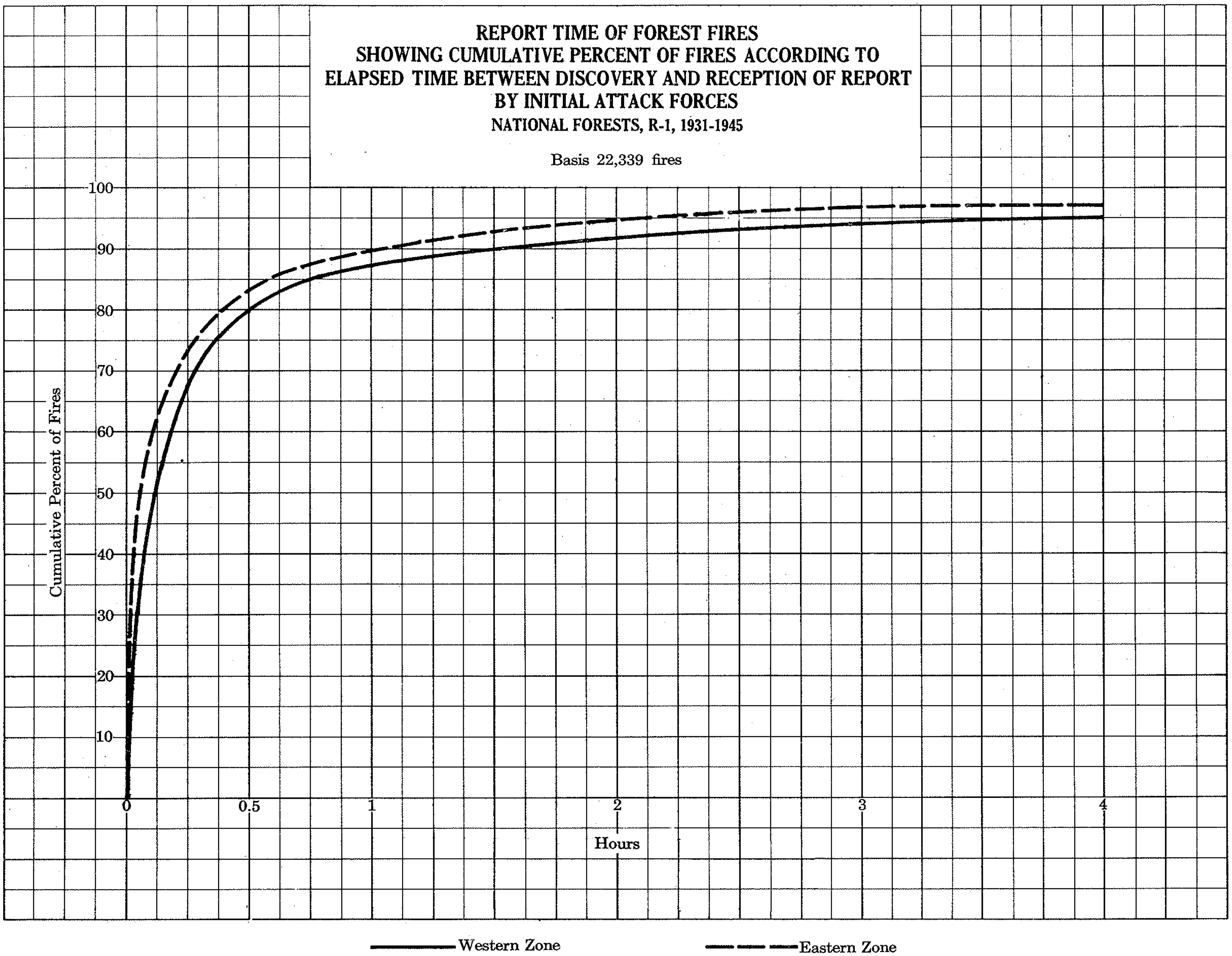
Communication

Over 80 percent of the fires on the national forests are reported to the initial attack forces within 30 minutes after discovery. As illustrated in figure 88, over 82 percent of the fires in the eastern zone and 80 percent in the western zone were reported within 30 minutes during the 1931-1945 period. Study of report time on over 22,000 fires showed that only 3 percent of the fires in the eastern zone and 5 percent in the western zone had a report time greater than 4 hours.

Communication difficulties are directly responsible for delays on less than 3 percent of the fires. In a study of errors and delays on over 13,000 fires it was found that telephone trouble and congestion were major factors on 2 percent of the fires, and lack of communication for the initial report on only 1/10 of 1 percent. Communication systems have proved satisfactory for initial reporting purposes.

Improved communication is needed on the fire line. As will be shown later in chapter 5, REINFORCEMENT ACTION, 25 percent of the fires require some type of reinforcement action. The speed of obtaining these reinforcements is often a vital factor in successful control. Communication on the fire line is needed to improve this follow-up action. In addition communication on the fire line is needed to promote greater efficiency in coordinating control forces and in many cases to provide for the safety of suppression crews. In the expansion of communication facilities improved control action can be achieved through greater use of highly portable radios directly on the fire line.

Radio communication is a vital part of aerial fire control. In the studies of combined aerial and ground detection systems, discussed in chapter 2, FIRE DETECTION, it was found that a radio network between lookouts, dispatchers, and patrol aircraft is needed to promote efficiency. Likewise, radio communication is needed in controlling smokejumper operations. Over 15 percent of the smokejumper fires required reinforcement action. Radio communication in most cases offers the best means of ordering and controlling these reinforcements. Air-to-ground communication also can aid in cargo dropping from



REPORT TIME OF FOREST FIRES
SHOWING CUMULATIVE PERCENT OF FIRES ACCORDING TO
ELAPSED TIME BETWEEN DISCOVERY AND RECEPTION OF REPORT
BY INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, 1931-1945

Basis 22,339 fires

aircraft. During the 5-year period 1945-1949 an annual average of 43 cargo-dropping flights were made on the national forests. These dropping activities are directly correlated with successful suppression action, and in numerous cases radio communication is needed to control the timing and location of the operation.

Travel Method

During the 1931-1939 period foot travel was involved in 80 percent of the fires. As illustrated in figure 89, foot travel was the only method used by initial attack forces in reaching 46 percent of the lightning fires and 28 percent of the man-caused fires. In addition foot travel was used in combination with automobiles and horses on 42 percent of the lightning fires and 33 percent of the man-caused fires.

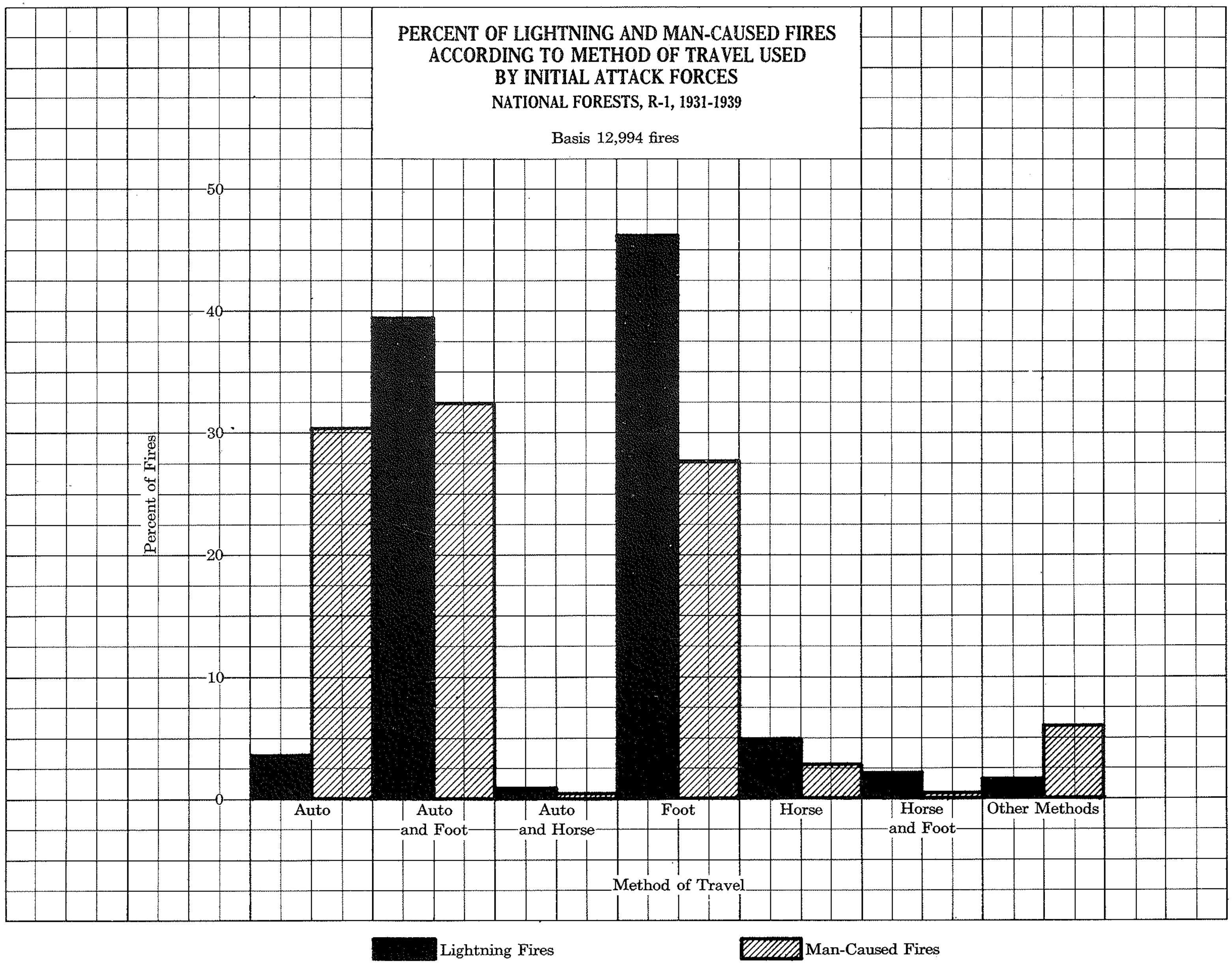
The use of automobiles by initial attack forces has increased. During the 1931-1939 period automobiles were used to travel all or part of the distance on 44 percent of the lightning fires and 65 percent of the man-caused fires. As illustrated in figure 90, there was a general increase in the use of automobiles to travel to fires during the 9-year period. In 1939 over 46 percent of all fires involved automobile travel for part of the distance, as compared to only 28 percent in 1931. This trend has continued, although the exact increase in more recent years is not known because this type of information was eliminated from Forest Service fire reports beginning in 1940.

Since 1940 aircraft have been used to transport initial attack forces to some fires. With the smokejumper program becoming increasingly important, aircraft have become a vital cog in the transportation system. As illustrated in figure 91, over 8 percent of the fires in some years involve aircraft in transporting the initial attack forces. The magnitude of this program is evidenced by the use of aircraft for initial attack forces on the Region 1 national forests during 1949. On 103 fires fixed-wing aircraft were used, and on 3 fires the initial attack forces were transported by helicopter.

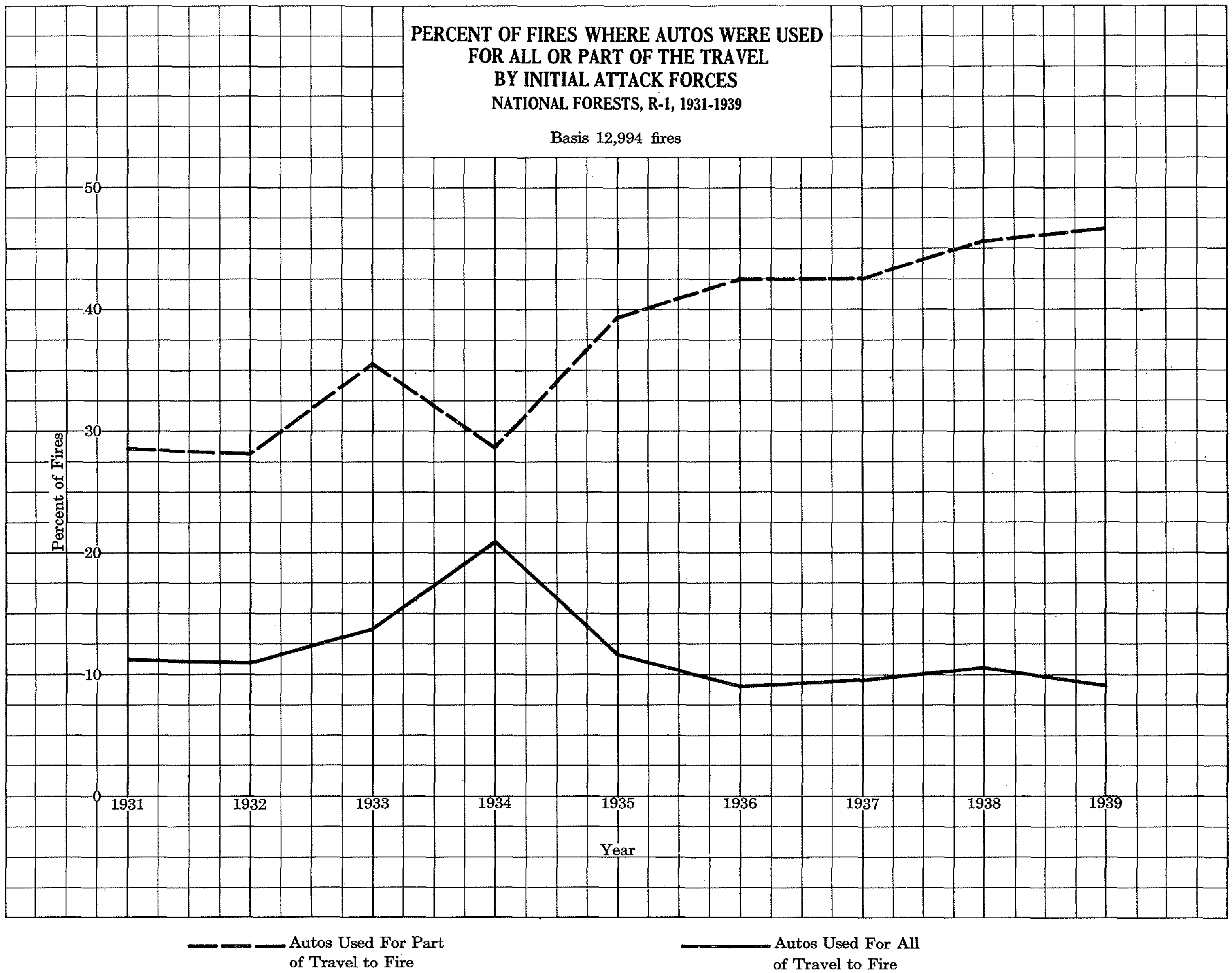
Travel Time and Distance

In the Region 1 national forests nearly one-fifth of the fires involve a travel time greater than 4 hours. On over 22,000 fires which occurred during the 1931-1945 period the travel time was over 4 hours for 18 percent of the fires. Accessibility has always been a major problem in fire control in the northern Rocky Mountains. However, as will be shown later in this chapter, real progress has been made in the development of better transportation systems. These efforts have been directed toward faster and more economical transportation for initial attack forces, reinforcements, and service of supply operations.

Lightning fires are the greatest transportation problem. As illustrated in figures 92 and 93, more lightning fires than man-caused fires, in both the western and eastern zones, are in long travel time classifications. In the western forests of Region 1 over 22 percent of the lightning fires require more than 4 hours' travel time, and over 11 percent require more



PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO METHOD OF TRAVEL USED
BY INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,994 fires
Percent of Fires
50
40
30
20
10
0
Auto
Auto and Foot
Auto and Horse
Foot
Horse
Horse and Foot
Other Methods
Method of Travel
Lightning Fires
Man-Caused Fires


PERCENT OF FIRES WHERE AUTOS WERE USED
FOR ALL OR PART OF THE TRAVEL
BY INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, 1931-1939
Basis 12,994 fires
Percent of Fires
50
40
30
20
10
0
1931
1932
1933
1934
1935
1936
1937
1938
1939
Year
Autos Used For Part of Travel to Fire
Autos Used For All of Travel to Fire

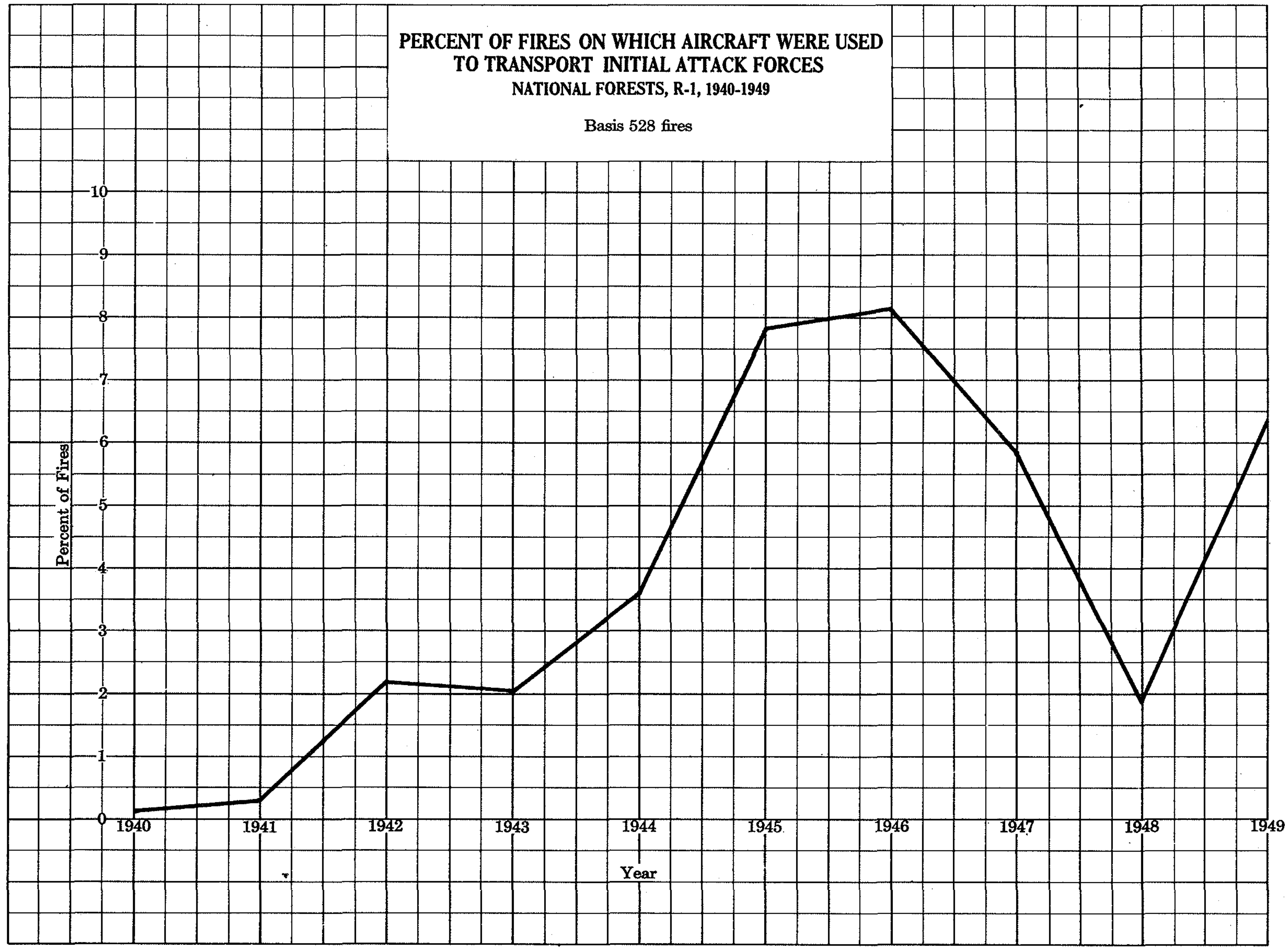
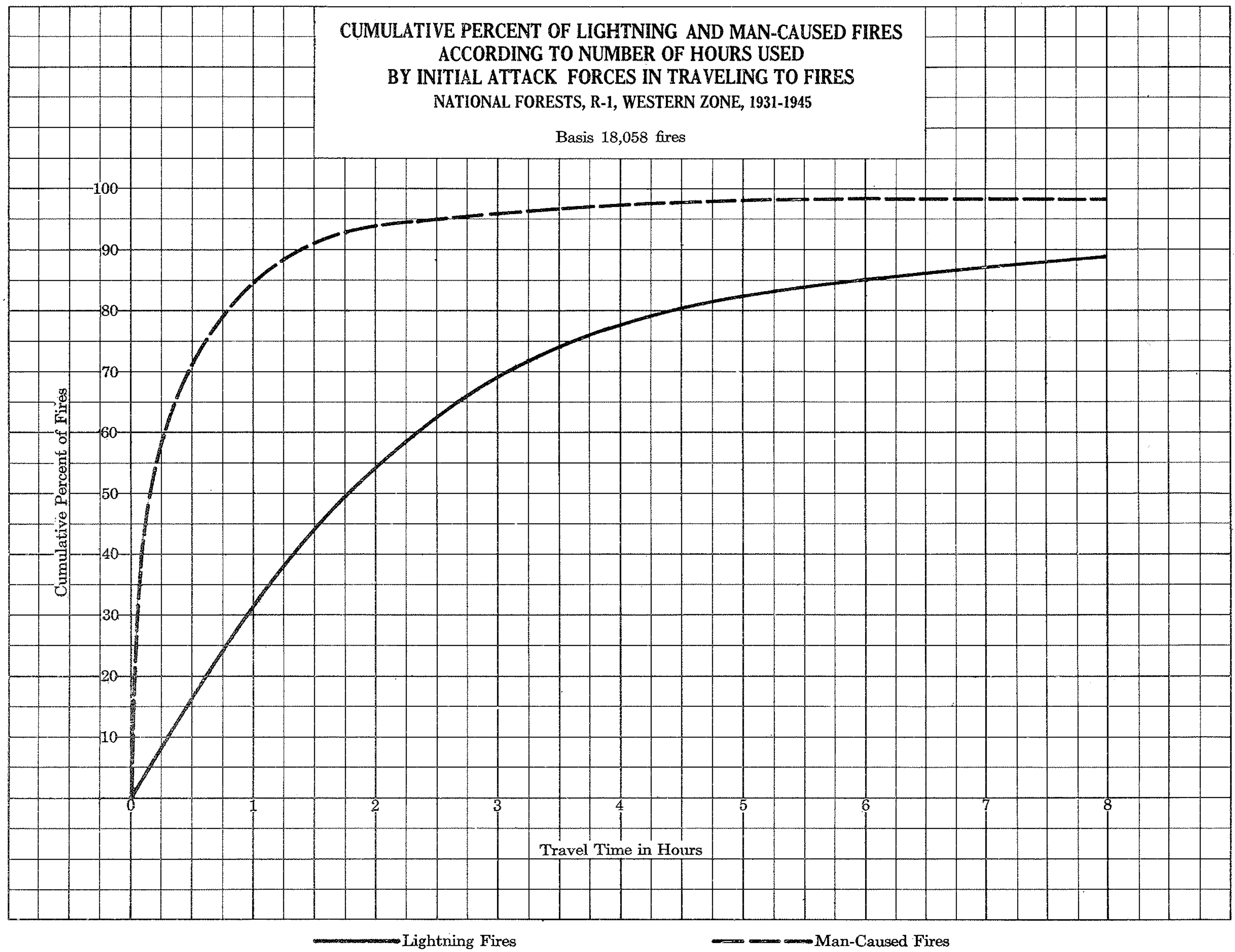
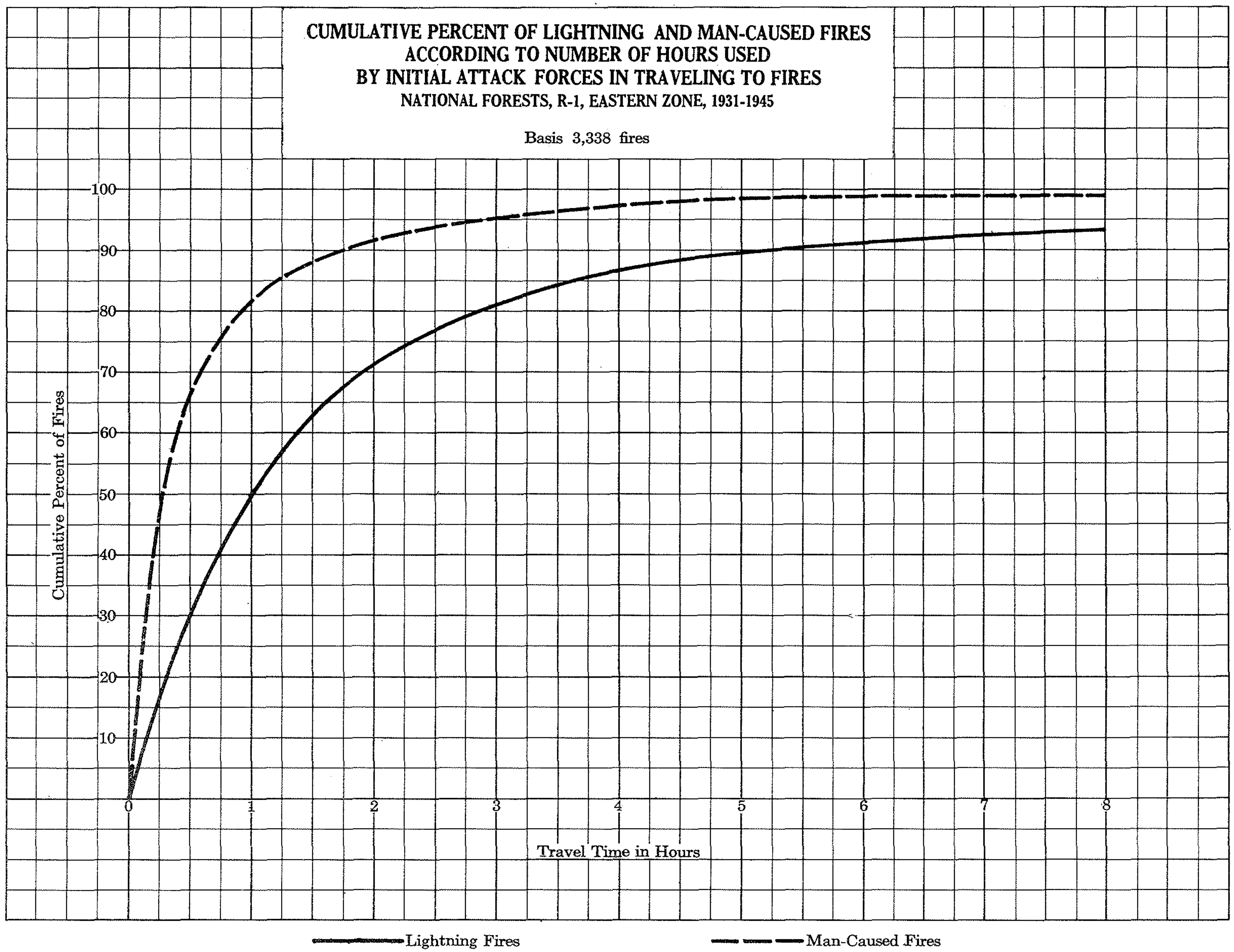

PERCENT OF FIRES ON WHICH AIRCRAFT WERE USED
TO TRANSPORT INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, 1940-1949
Basis 528 fires
Percent of Fires
0
1
2
3
4
5
6
7
8
9
10
Year
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949

Figure 91.


CUMULATIVE PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO NUMBER OF HOURS USED
BY INITIAL ATTACK FORCES IN TRAVELING TO FIRES
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1945
Basis 18,058 fires
Cumulative Percent of Fires
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
Travel Time in Hours
Lightning Fires
Man-Caused Fires


CUMULATIVE PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO NUMBER OF HOURS USED
BY INITIAL ATTACK FORCES IN TRAVELING TO FIRES
NATIONAL FORESTS, R-1, EASTERN ZONE, 1931-1945
Basis 3,338 fires
Cumulative Percent of Fires
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
Travel Time in Hours
Lightning Fires
Man-Caused Fires

than 8 hours. On the other hand only 3 percent of the man-caused fires require more than 4 hours' travel time. The distribution of over 22,000 lightning and man-caused fires according to travel time is shown in tables 56 through 59.

The travel distance is greater on lightning fires. On the western forests during the 1931-1939 period nearly 50 percent of the lightning fires involved travel distances of over 5 miles, and 25 percent over 10 miles. On the eastern forests even greater distances are involved in travel to lightning fires. As illustrated in figures 94 and 95, man-caused fires are generally closer to the initial attack forces.

Extension of the road system has had a major effect on fire action. During the 5-year period 1931-1935 the average fire was over $3\frac{1}{2}$ miles from the nearest road. During the 1941-1945 period this distance had been reduced to slightly over 2 miles. As illustrated in figure 96, the general trend over a 15-year period has been to reduce the distance between fires and roads. By 1945 the average fire was less than $1\frac{1}{2}$ miles from a road. This extension of the road system is especially important in improving reinforcement action and service of supply operations. The best utilization of the greater road mileage for initial attack forces is dependent upon adjusting the type, strength, and location of those forces according to fuel classification. These adjustments also must be coordinated with aerial transportation plans.

On several national forests large areas remain inaccessible to roads. This fact is vividly illustrated in figures 97 and 98. In the western zone the average fire on the Bitterroot, Clearwater, Flathead, and Nezperce National Forests is more than 3 miles from the nearest road. On the Lewis and Clark forest in the eastern zone the average fire is nearly 5 miles from a road. The most accessible forests are the Cabinet, Coeur d'Alene, Custer, Deerlodge, and Helena. On all of these forests the average fire is less than 2 miles from a road.

Air Transportation

Nearly 300 individual flights are made in average fire years. As illustrated in figure 99, aircraft made 297 individual flights for smokejumping, cargo dropping, and general fire service of supply purposes during 1945. In 1949 a total of 240 flights of this character were made. During critical fire seasons the total number of flights will probably be much greater. These totals do not include flights made for detection or scouting purposes.

The three principal types of aircraft used to transport men and supplies will fly over 900 hours in an average fire year. As shown in figure 100, Ford Trimotor, Curtis Travelair, and Douglas C-47 aircraft were flown 905 hours in the fire season of 1945. Again, in critical years this total will probably be much higher. Smokejumper flights account for nearly half of the flying hours, with cargo dropping and general fire service of supply flights next in that order.

Table 56. Number and Percent of Lightning Fires Classified by Travel Time, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 14,299 fires)

Forest	Unit	Travel Time: ½ Hour	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	7 Hours	8 Hours	Over 8 Hours
Bitterroot	No.	220	242	363	255	165	99	62	33	24	245
	%	12.88	14.17	21.26	14.93	9.66	5.80	3.63	1.93	1.40	14.34
Cabinet	No.	152	150	208	134	89	62	29	12	12	96
	%	16.10	15.89	22.04	14.19	9.43	6.57	3.07	1.27	1.27	10.17
Clearwater	No.	291	240	436	253	146	99	75	55	25	209
	%	15.91	13.12	23.84	13.83	7.98	5.41	4.10	3.01	1.37	11.43
Coeur d'Alene	No.	136	136	213	105	39	30	12	13	5	28
	%	18.97	18.97	29.72	14.64	5.44	4.18	1.67	1.81	0.70	3.90
Flathead	No.	175	158	244	194	144	88	52	35	27	208
	%	13.21	11.92	18.42	14.64	10.87	6.64	3.92	2.64	2.04	15.70
Kaniksu	No.	299	268	386	210	84	59	39	19	13	91
	%	20.37	18.26	26.30	14.30	5.72	4.02	2.66	1.29	0.88	6.20
Kootenai	No.	219	188	296	173	133	68	40	29	11	150
	%	16.76	14.38	22.64	13.24	10.18	5.20	3.06	2.22	0.84	11.48
Lolo	No.	291	262	447	300	152	69	45	38	20	153
	%	16.38	14.74	25.16	16.89	8.55	3.88	2.53	2.14	1.12	8.61
Nezperce	No.	327	280	428	277	163	93	63	32	29	237
	%	16.95	14.52	22.19	14.36	8.45	4.82	3.26	1.66	1.50	12.29
St. Joe	No.	248	213	315	187	105	58	30	17	18	104
	%	19.15	16.45	24.32	14.44	8.11	4.48	2.32	1.31	1.39	8.03
WESTERN ZONE	No.	2358	2137	3336	2088	1220	725	447	283	184	1521
	%	16.49	14.94	23.33	14.60	8.53	5.07	3.13	1.98	1.29	10.64

Table 57. Number and Percent of Lightning Fires Classified by Travel Time, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 1,973 fires)

Forest	Unit	Travel Time ½ Hour	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	7 Hours	8 Hours	Over 8 Hours
Beaverhead	No.	41	44	50	29	24	7	9	4	3	13
	%	18.30	19.65	22.33	12.95	10.71	3.12	4.02	1.78	1.34	5.80
Custer	No.	195	88	36	16	4	3	2	1	0	6
	%	55.56	25.07	10.26	4.56	1.14	0.85	0.57	0.28	0.00	1.71
Deerlodge	No.	92	80	101	47	26	11	8	2	3	33
	%	22.83	19.85	25.07	11.66	6.45	2.73	1.98	0.50	0.74	8.19
Gallatin 1/	No.	46	33	52	20	17	11	8	7	2	26
	%	20.73	14.86	23.43	9.01	7.66	4.95	3.60	3.15	0.90	11.71
Helena	No.	135	105	116	56	21	13	3	8	3	25
	%	27.83	21.65	23.92	11.55	4.33	2.68	0.62	1.65	0.62	5.15
Lewis and Clark	No.	79	55	55	34	22	9	9	1	3	21
	%	27.43	19.10	19.10	11.80	7.64	3.12	3.12	0.36	1.04	7.29
EASTERN ZONE	No.	588	405	410	202	114	54	39	23	14	124
	%	29.80	20.53	20.78	10.24	5.78	2.74	1.98	1.16	0.71	6.28

1/ Includes Absaroka

Table 58. Number and Percent of Man-Caused Fires Classified by Travel Time, National Forests, R-1, Western Zone, 1931-1945, inclusive

(Basis 3,759 fires)

Forest	Unit	½ Hour	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	7 Hours	8 Hours	Over 8 Hours
Bitterroot	No.	116	39	28	11	8	3	3	2	2	5
	%	53.46	17.97	12.90	5.07	3.69	1.38	1.38	0.92	0.92	2.30
Cabinet	No.	704	68	23	9	2	2	0	0	0	6
	%	86.49	8.35	2.82	1.10	0.25	0.25	0.00	0.00	0.00	0.74
Clearwater	No.	54	6	11	8	2	1	0	0	0	0
	%	65.85	7.32	13.41	9.76	2.44	1.22	0.00	0.00	0.00	0.00
Coeur d'Alene	No.	285	79	33	8	2	0	0	0	1	2
	%	69.51	19.27	8.05	1.95	0.49	0.00	0.00	0.00	0.24	0.49
Flathead	No.	146	22	17	9	1	3	1	1	0	2
	%	72.27	10.88	8.42	4.46	0.50	1.48	0.50	0.50	0.00	0.99
Kaniksu	No.	256	78	35	4	0	0	0	0	0	6
	%	67.55	20.58	9.23	1.06	0.00	0.00	0.00	0.00	0.00	1.58
Kootenai	No.	285	64	37	13	4	0	1	0	1	1
	%	70.20	15.76	9.11	3.20	0.98	0.00	0.25	0.00	0.25	0.25
Lolo	No.	442	75	35	7	3	3	1	0	1	9
	%	76.74	13.02	6.08	1.22	0.52	0.52	0.17	0.00	0.17	1.56
Nezperce	No.	115	32	40	20	10	6	2	1	1	9
	%	48.74	13.56	16.95	8.47	4.24	2.54	0.85	0.42	0.42	3.81
St. Joe	No.	270	81	58	14	3	1	1	1	0	8
	%	61.78	18.54	13.27	3.20	0.69	0.23	0.23	0.23	0.00	1.83
WESTERN ZONE	No.	2673	544	317	103	35	19	9	5	6	48
	%	71.12	14.47	8.43	2.74	0.93	0.50	0.24	0.13	0.16	1.28

Table 59. Number and Percent of Man-Caused Fires Classified By Travel Time, National Forests, R-1, Eastern Zone, 1931-1945, inclusive

(Basis 1,365 fires)

Forest	Unit	Travel Time: ½ Hour	1 Hour	2 Hours	3 Hours	4 Hours	5 Hours	6 Hours	7 Hours	8 Hours	Over 8 Hours
Beaverhead	No.	76	17	17	9	4	0	0	0	0	3
	%	60.33	13.49	13.49	7.14	3.17	0.00	0.00	0.00	0.00	2.38
Custer	No.	55	4	5	2	2	2	0	0	0	0
	%	78.57	5.71	7.14	2.86	2.86	2.86	0.00	0.00	0.00	0.00
Deerlodge	No.	367	107	49	22	8	2	1	0	1	11
	%	64.60	18.84	8.63	3.87	1.41	0.35	0.18	0.00	0.18	1.94
Gallatin 1/	No.	184	26	15	12	4	1	0	0	0	2
	%	75.40	10.66	6.15	4.92	1.64	0.41	0.00	0.00	0.00	0.82
Helena	No.	174	46	34	6	6	0	0	1	0	3
	%	64.45	17.04	12.59	2.22	2.22	0.00	0.00	0.37	0.00	1.11
Lewis and Clark	No.	61	13	7	2	2	2	0	0	0	0
	%	70.12	14.94	8.04	2.30	2.30	2.30	0.00	0.00	0.00	0.00
EASTERN ZONE	No.	917	213	127	53	26	7	1	1	1	19
	%	67.18	15.60	9.30	3.88	1.90	0.51	0.08	0.08	0.08	1.39

1/ Includes Absaroka

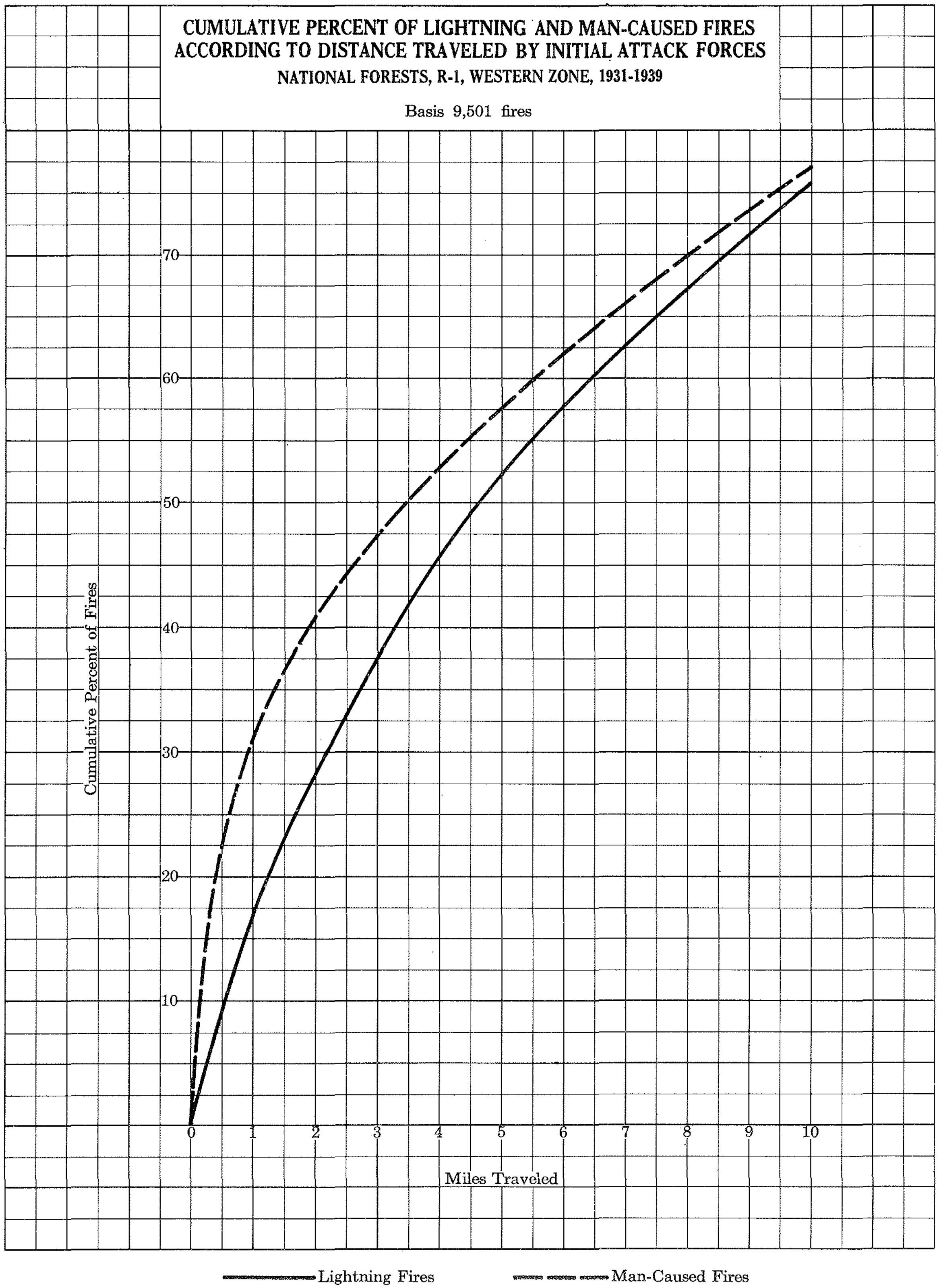

CUMULATIVE PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO DISTANCE TRAVELED BY INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1939
Basis 9,501 fires
Cumulative Percent of Fires
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Miles Traveled
Lightning Fires
Man-Caused Fires

Figure 94.

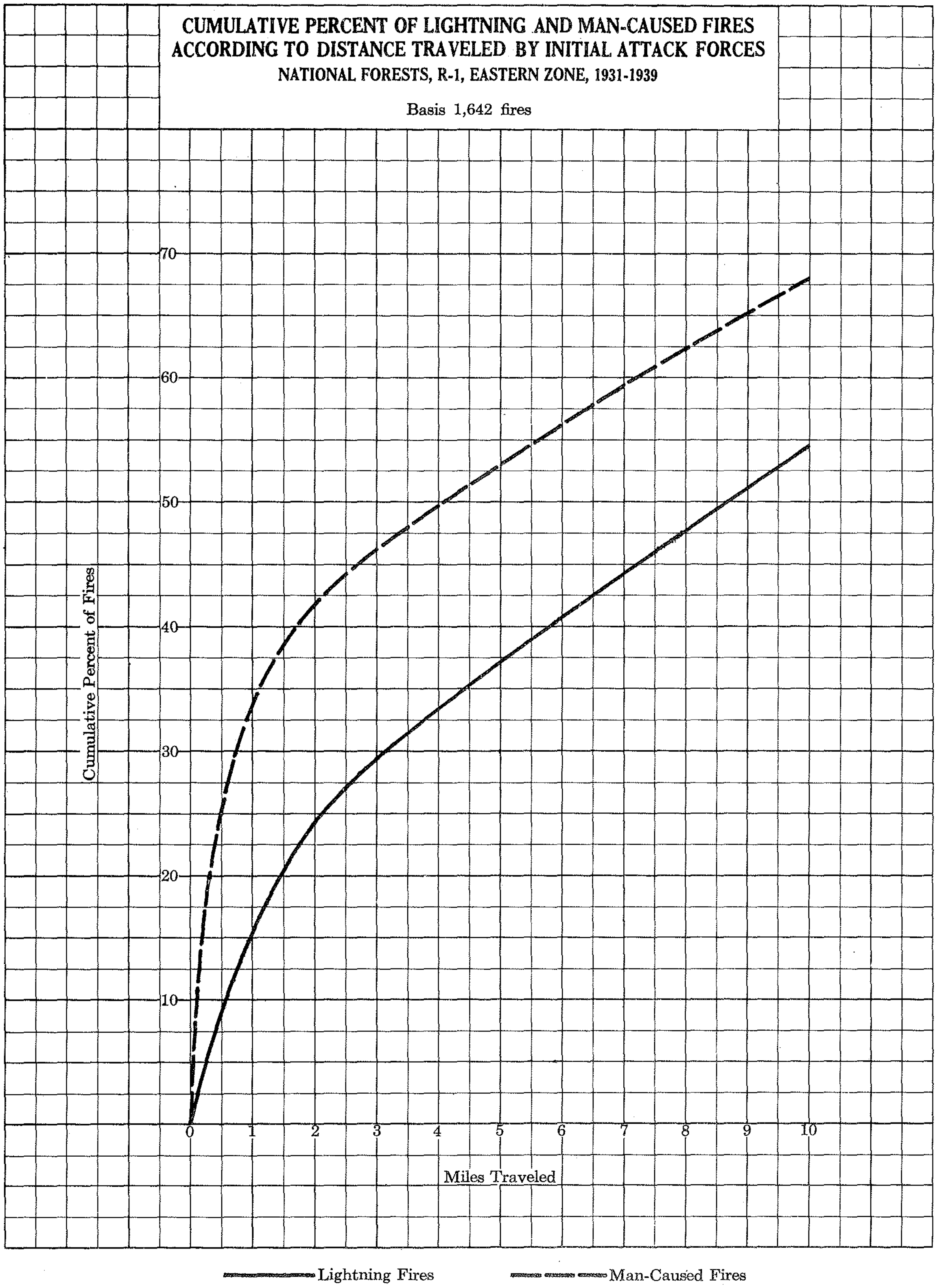

CUMULATIVE PERCENT OF LIGHTNING AND MAN-CAUSED FIRES
ACCORDING TO DISTANCE TRAVELED BY INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, EASTERN ZONE, 1931-1939
Basis 1,642 fires
Cumulative Percent of Fires
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
10
Miles Traveled
Lightning Fires
Man-Caused Fires

Figure 95.

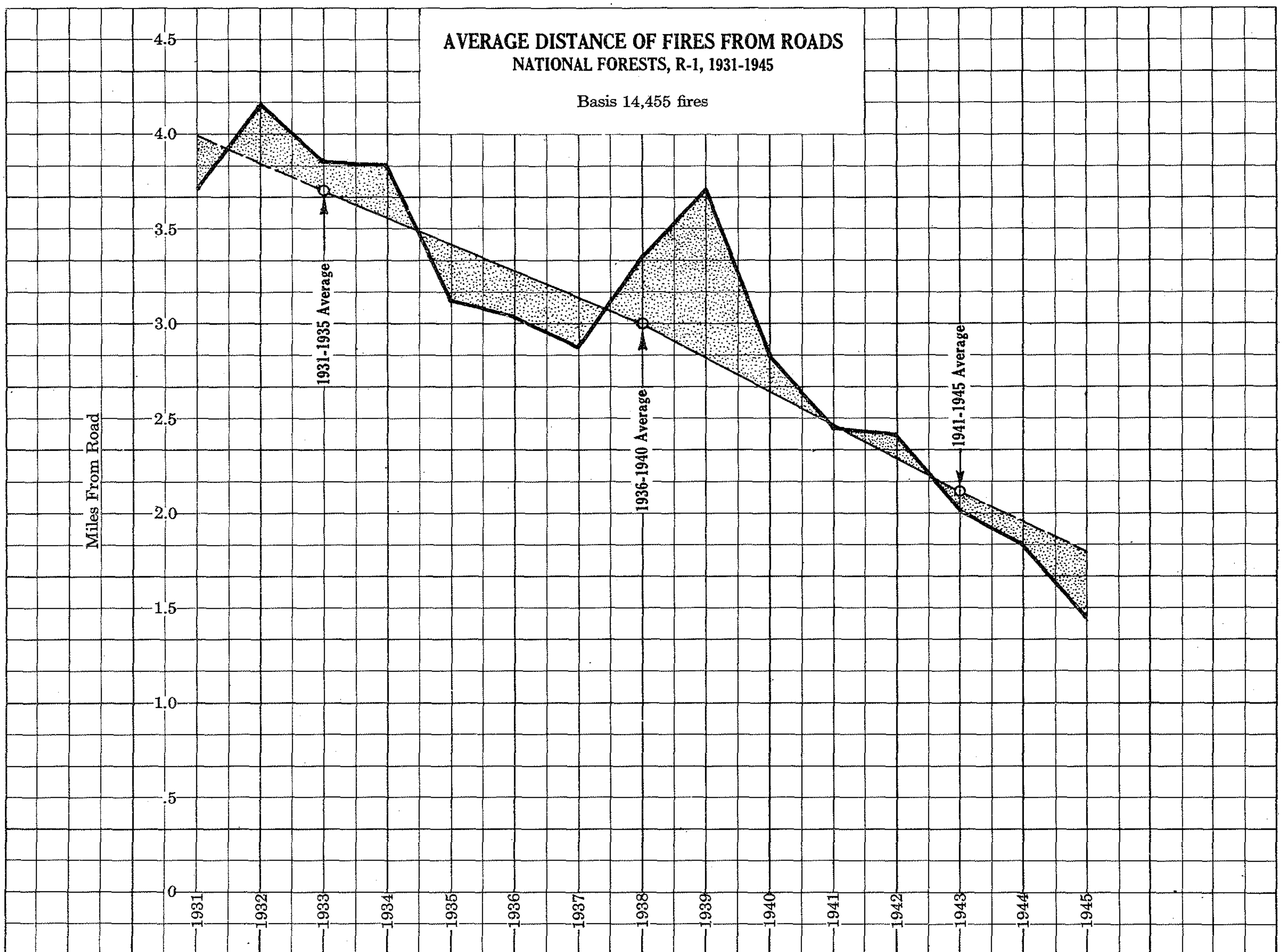

AVERAGE DISTANCE OF FIRES FROM ROADS
NATIONAL FORESTS, R-1, 1931-1945
Basis 14,455 fires
Miles From Road
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
1931-1935 Average
1936-1940 Average
1941-1945 Average
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
Year

Figure 96.

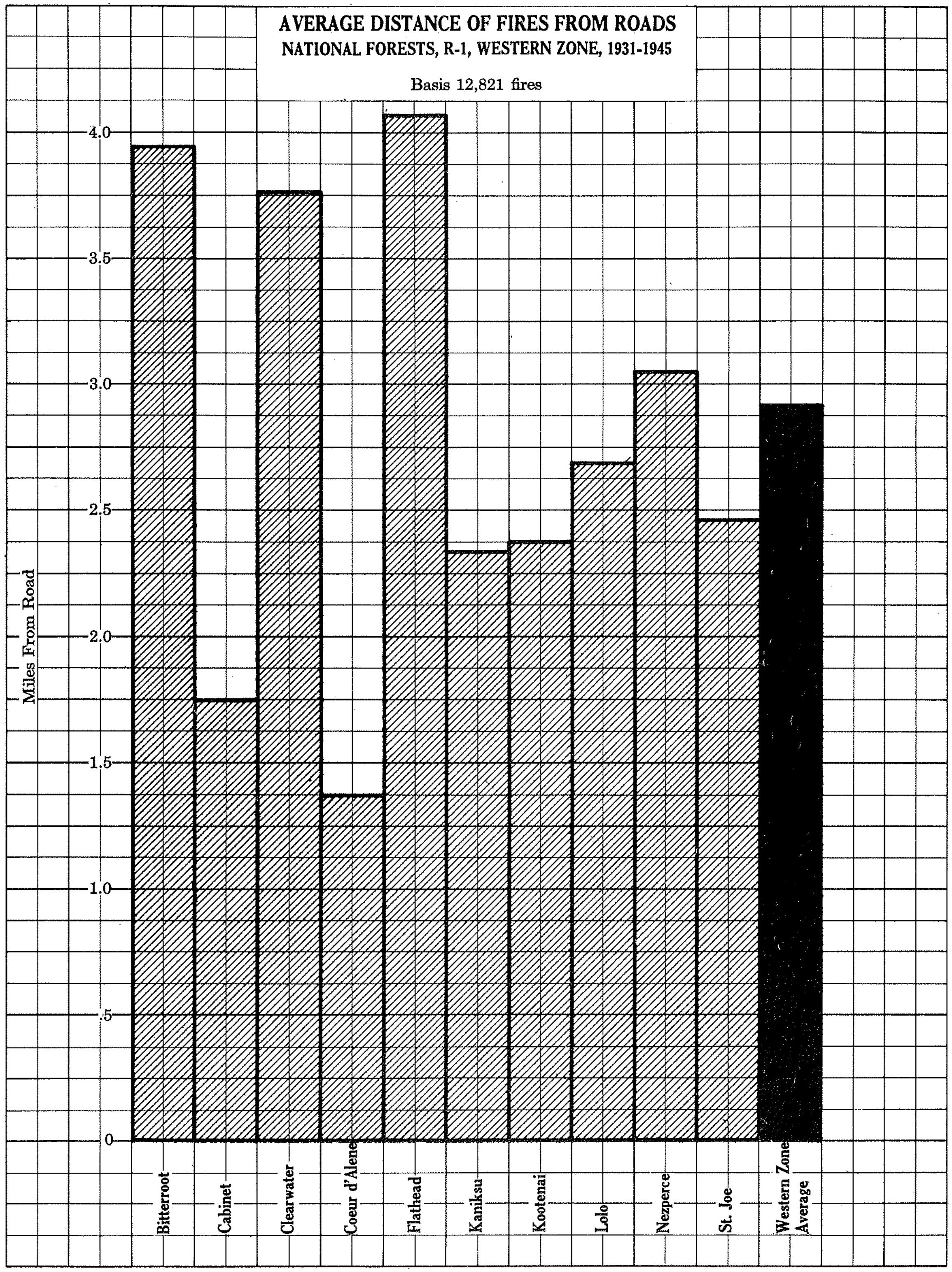

AVERAGE DISTANCE OF FIRES FROM ROADS
NATIONAL FORESTS, R-1, WESTERN ZONE, 1931-1945
Basis 12,821 fires
Miles From Road
4.0
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
Bitterroot
Cabinet
Clearwater
Coeur d'Alene
Flathead
Kaniksu
Kootenai
Lolo
Nezperce
St. Joe
Western Zone Average

Figure 97.

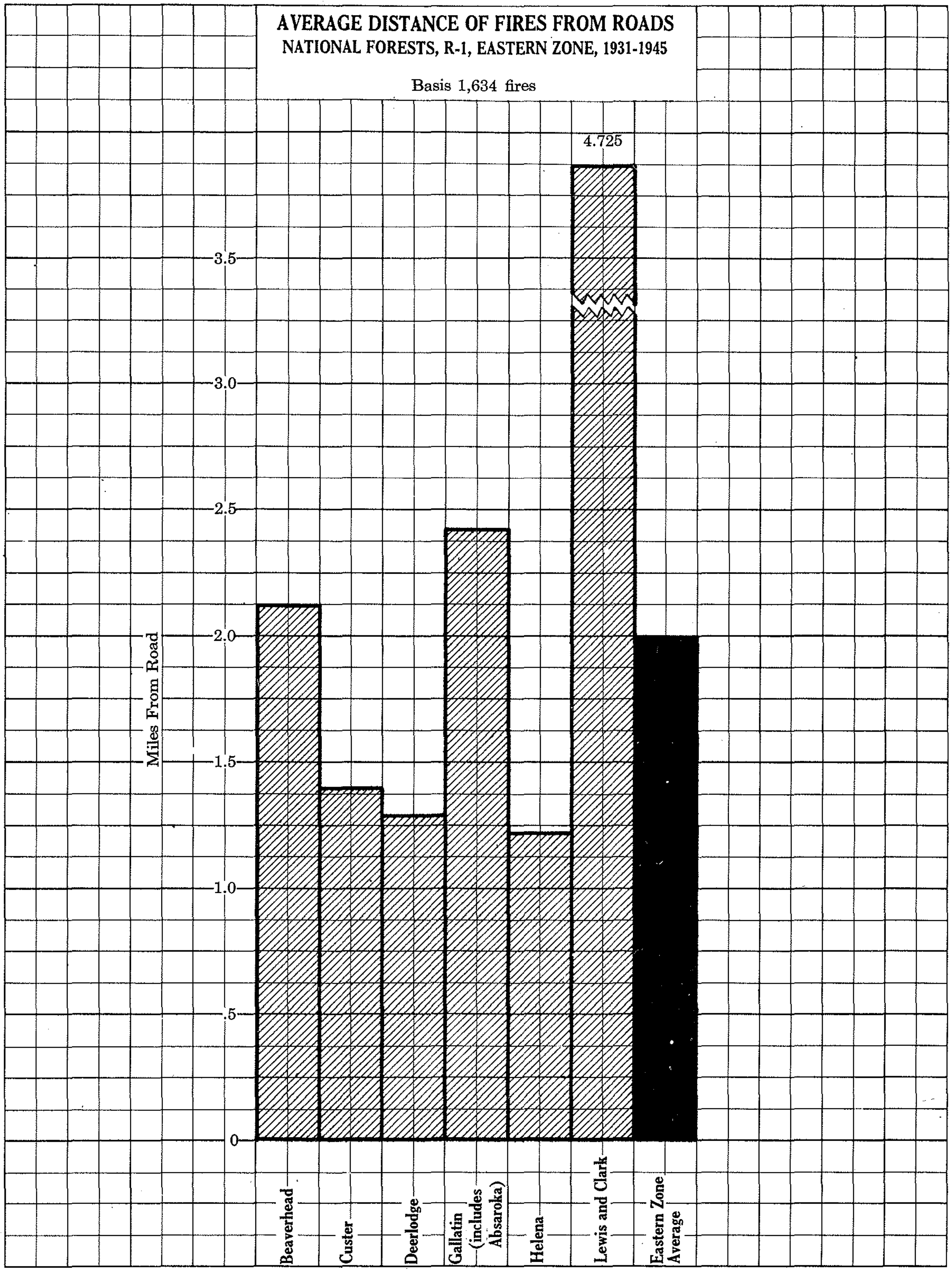

AVERAGE DISTANCE OF FIRES FROM ROADS
NATIONAL FORESTS, R-1, EASTERN ZONE, 1931-1945
Basis 1,634 fires
4.725
3.5
3.0
2.5
2.0
1.5
1.0
.5
0
Miles From Road
Beaverhead
Custer
Deerlodge
Gallatin (includes Absaroka)
Helena
Lewis and Clark
Eastern Zone Average

Figure 98.

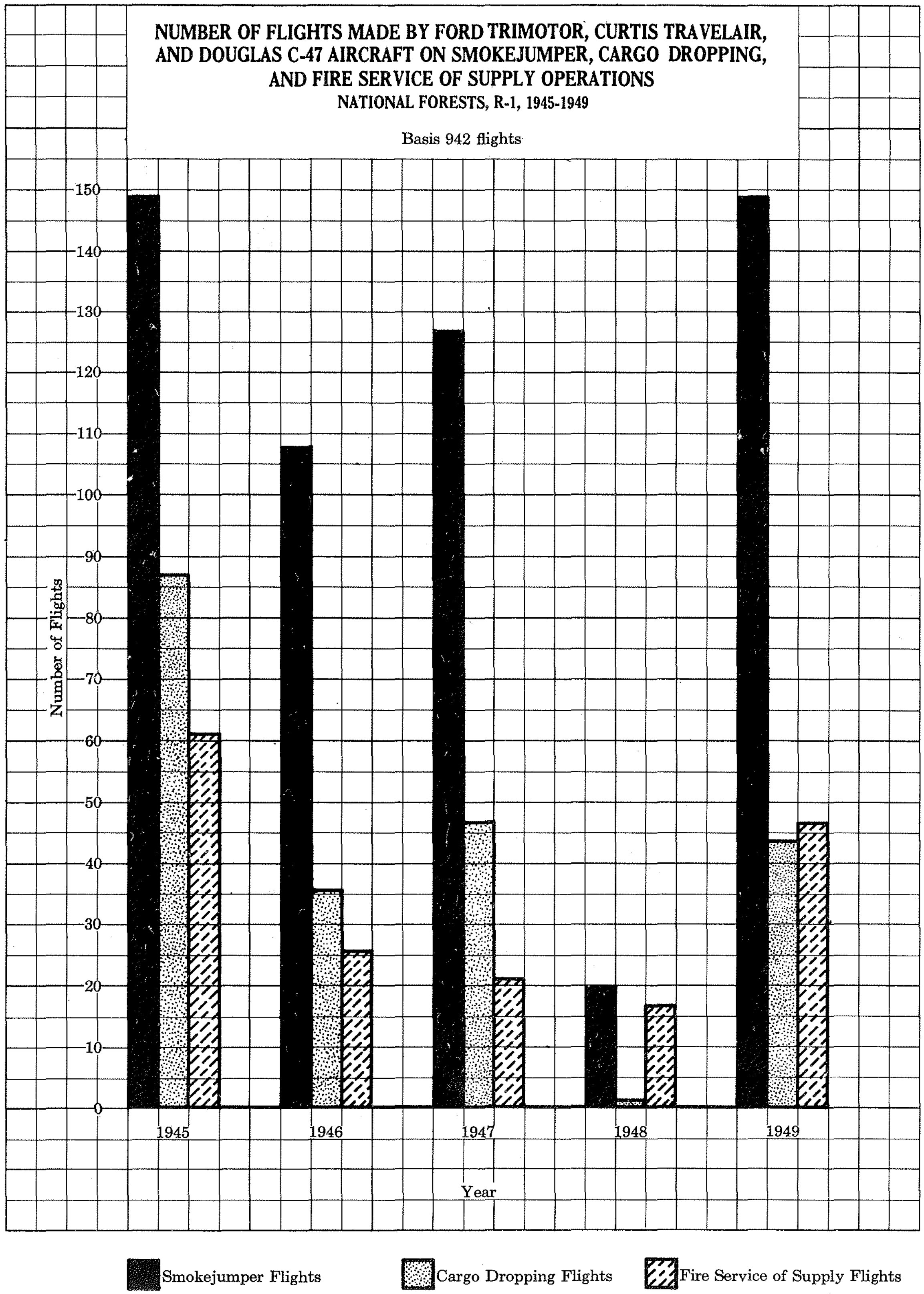
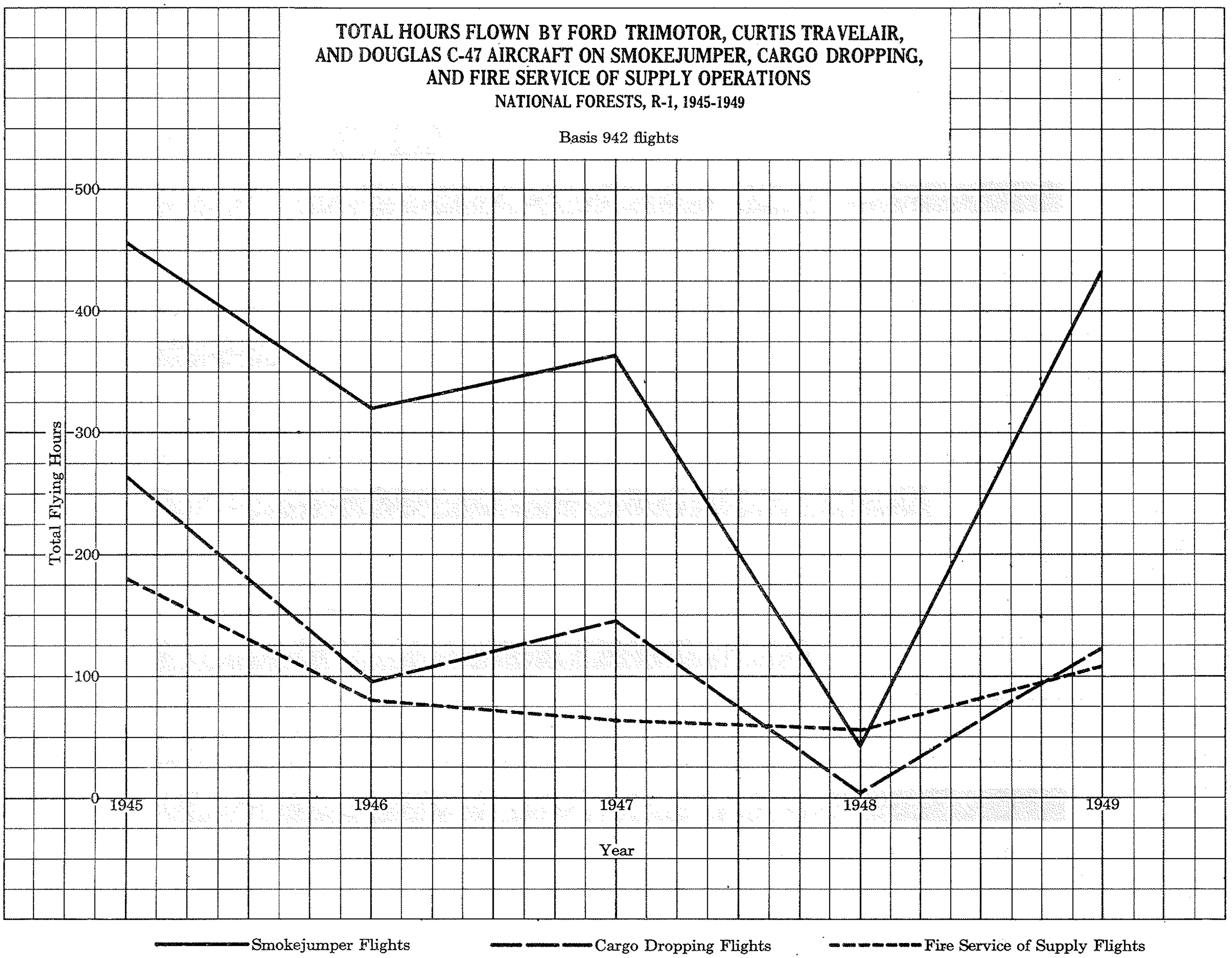

NUMBER OF FLIGHTS MADE BY FORD TRIMOTOR, CURTIS TRAVELAIR, AND DOUGLAS C-47 AIRCRAFT ON SMOKEJUMPER, CARGO DROPPING, AND FIRE SERVICE OF SUPPLY OPERATIONS
NATIONAL FORESTS, R-1, 1945-1949
Basis 942 flights
Number of Flights
150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
1945
1946
1947
1948
1949
Year
Smokejumper Flights
Cargo Dropping Flights
Fire Service of Supply Flights

Figure 99.

TOTAL HOURS FLOWN BY FORD TRIMOTOR, CURTIS TRAVELAIR, AND DOUGLAS C-47 AIRCRAFT ON SMOKEJUMPER, CARGO DROPPING, AND FIRE SERVICE OF SUPPLY OPERATIONS
NATIONAL FORESTS, R-1, 1945-1949

Basis 942 flights



The average time per flight is 3 hours. As illustrated in figure 101, this time will vary according to the type of aircraft and the purpose of the flight. Obviously, it will vary also according to the distance flown, headwinds encountered, and many other factors. However, these average time factors point out a significant feature of action planning on going fires. When a Ford Trimotor leaves Missoula with a load of smokejumpers, under average conditions that aircraft cannot be counted on for dispatching of another load for at least 3 hours exclusive of the time required for refueling and servicing. Thus the number of fires which can be attacked quickly by aerial means is dependent upon the number of aircraft available. Because of the tendency of lightning fires to occur in bunches, this factor is often a critical feature in initial attack. The six aircraft normally available at Missoula (2 Ford Trimotors, 2 Curtis Travelairs, and 2 Douglas C-47's) can transport a total of 52 smokejumpers and their equipment. Assuming 2 men per fire, a total of 26 fires could be reached with jumpers. Repetition of peak lightning loads such as occurred in July 1940 or August 1939 would require a much larger force. For this reason air transportation plans must call for :

1. Careful zoning of the areas where air transportation is needed to meet acceptable hour control standards.

2. Priorities for fires burning in the worst fuel conditions and in areas where burning index is high.

3. Alternate plans for handling fires by ground attack forces.

Over 90 percent of the forested areas of Region 1 are within 2 hours' flying time. As illustrated in figure 102, the great bulk of the forest area is within 2 hours' flying time by Ford Trimotor and Curtis Travelair, or 1.5 hours by Douglas C-47, from the central air base at Missoula. These elapsed time figures are based upon average conditions and will vary widely according to wind and other weather conditions. They are based upon the following average ground speeds for the three types of aircraft:

Ford Trimotor	90 miles per hour
Curtis Travelair	90 miles per hour
Douglas C-47	150 miles per hour

Report and getaway time are important factors in air transportation. As explained previously, over 80 percent of the fires in Region 1 are reported to the initial attack forces within 30 minutes after discovery. However, on fires involving air transportation only 42 percent are reported within 30 minutes. Once the report is received additional time is required to load and check the airplane and take off. Obviously, the objective is to keep these report and getaway times to a minimum. Otherwise, the gains made by fast air transportation may be lost.

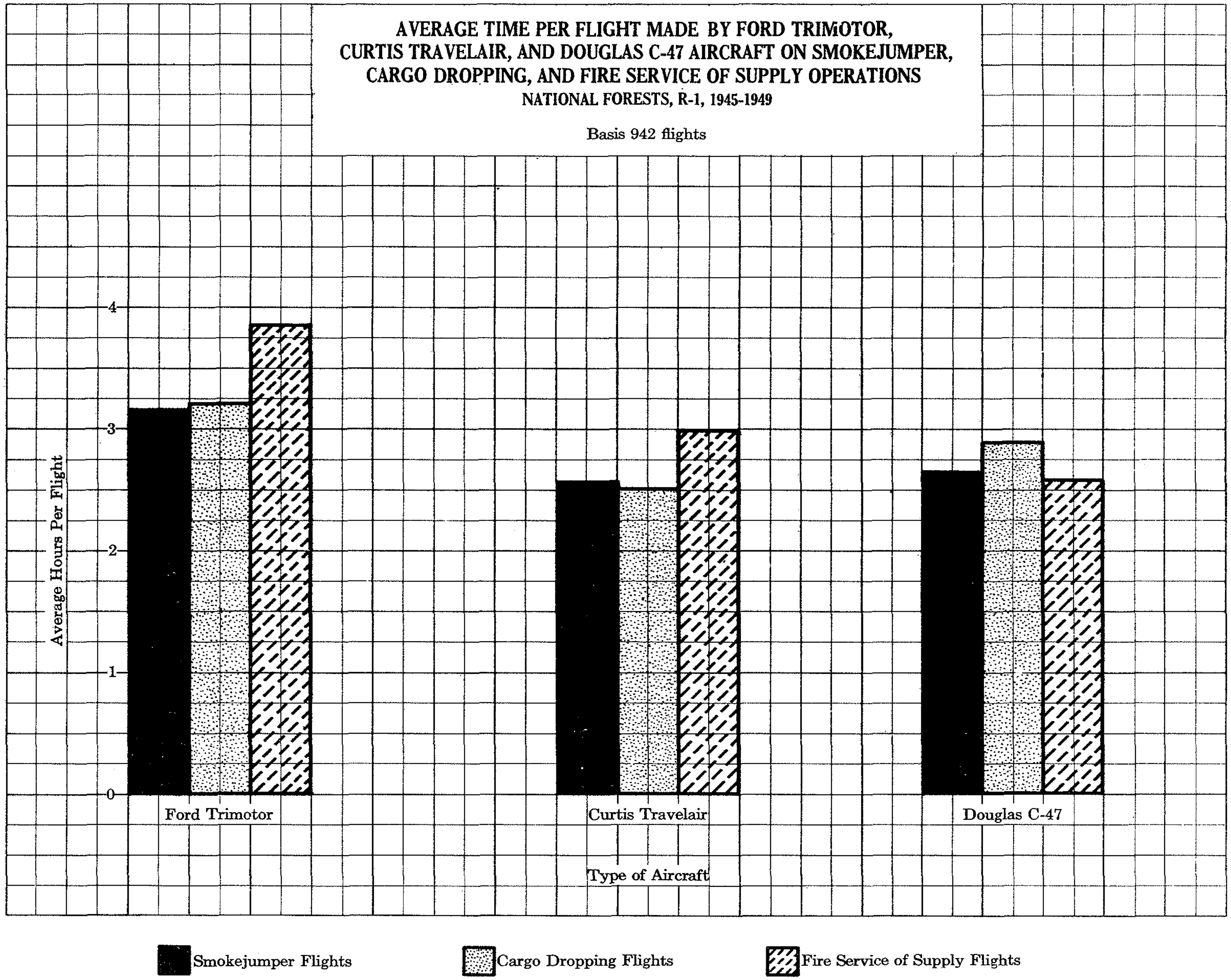

AVERAGE TIME PER FLIGHT MADE BY FORD TRIMOTOR, CURTIS TRAVELAIR, AND DOUGLAS C-47 AIRCRAFT ON SMOKEJUMPER, CARGO DROPPING, AND FIRE SERVICE OF SUPPLY OPERATIONS
NATIONAL FORESTS, R-1, 1945-1949
Basis 942 flights
Average Hours Per Flight
0
1
2
3
4
Ford Trimotor
Curtis Travelair
Douglas C-47
Type of Aircraft
Smokejumper Flights
Cargo Dropping Flights
Fire Service of Supply Flights

Figure 101

4. INITIAL ATTACK

Initial attack is the most important part of actual suppression operations on going fires. The speed, type, strength, and skill of the initial attack are principal measures of successful fire control. Many improvements have been made in this vital action during 40 years of organized fire control. However, this phase of the fire control job is still the field in which the most lucrative advancements can be made. Reaching fires quickly and then applying the most aggressive and efficient suppression methods is the number-one requirement in holding burned area to a minimum.

Initial Attack Load

Three-fourths of the fires are controlled by initial attack forces. During the period 1931-1944 initial attack forces controlled 74.7 percent of the fires without help from reinforcements of any kind. As shown in figure 103, this percentage has varied according to the character of the fire season. During 1931 and 1934 when burning conditions were critical, less than 70 percent of the fires were controlled by initial attack forces. Likewise, in 1940 when a great overload of fires occurred and burning conditions were near the critical point, a larger number of fires required reinforcements. In 1941 -- an easy year -- nearly 84 percent of the fires were handled by the initial attack forces.

As the size of the fire increases, the ability of the initial attack forces to control it decreases. Over 85 percent of the class A fires are handled by initial attack forces without reinforcements. However, only 42 percent of the class B fires are controlled by initial attack forces. As illustrated in figure 104, over half the fires of more than 30 chains perimeter require reinforcement action. Only 10 percent of the fires with perimeters of 200 chains are controlled by initial attack forces. This relationship shows the need for rate-of-spread evaluations in determining the strength of the initial attack as well as in determining the probabilities for reinforcement action.

Fires that are controlled by initial attack forces account for only a fraction of the total area burned. During the period 1931-1944 successful control by the initial attack forces resulted in a burn of only 29,525 acres, or 4.05 percent of the grand total burn. Thus nearly 96 percent of the burn resulted from fires escaping control by the initial attack. This fact points emphatically to the need for fast and aggressive action in the early stages of a fire.

Initial Attack Manpower

On nearly two-thirds of the fires the initial attack force consists of only one or two men. During the 15-year period 1931-1945 only 35 percent of the fires on the national forests had an initial attack force greater than two men. As shown in figure 105, more fires in the western zone were attacked by only one man than in the eastern zone. In both zones only 3 percent of the fires had an initial attack force greater than 15 men.

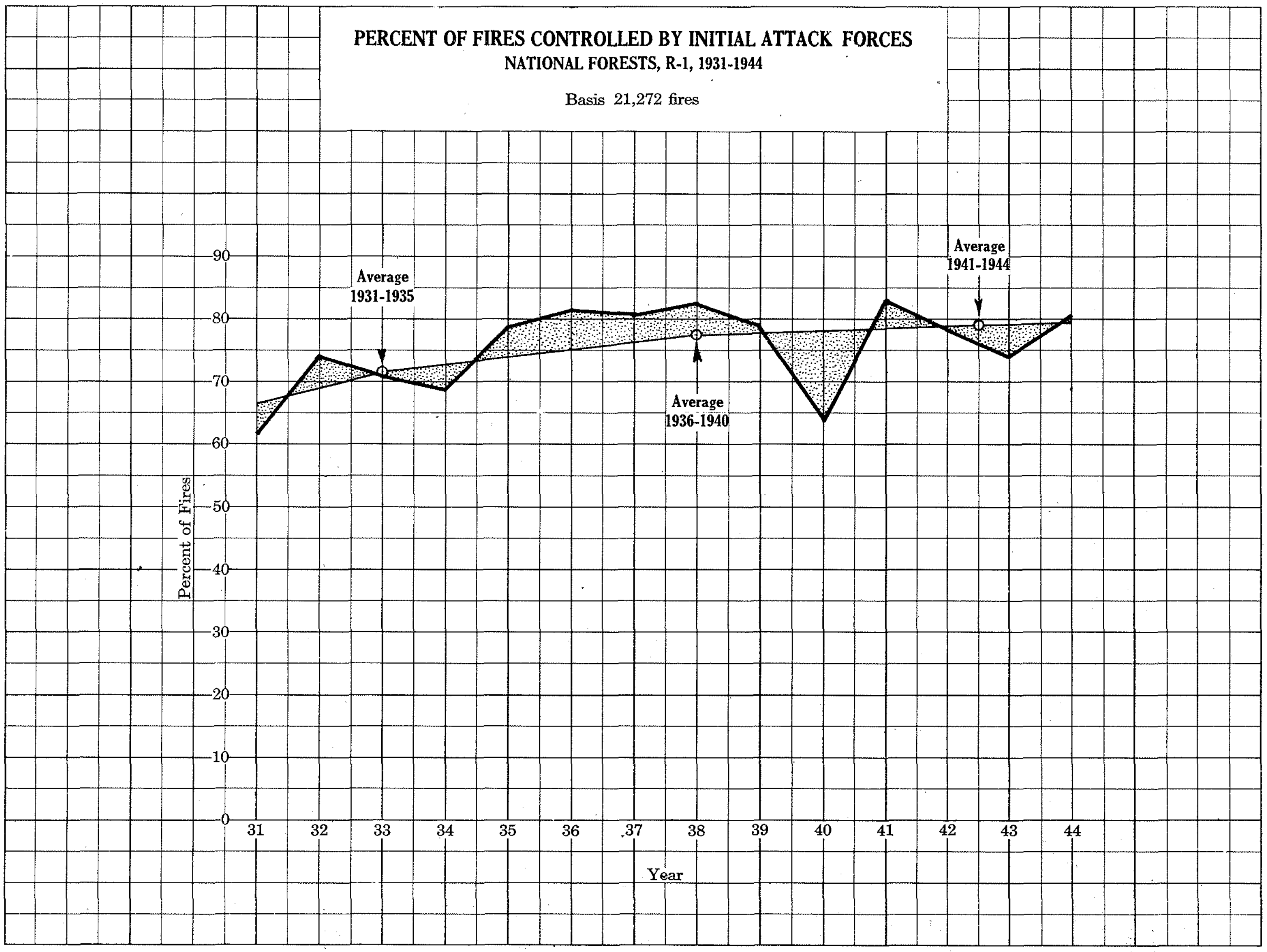
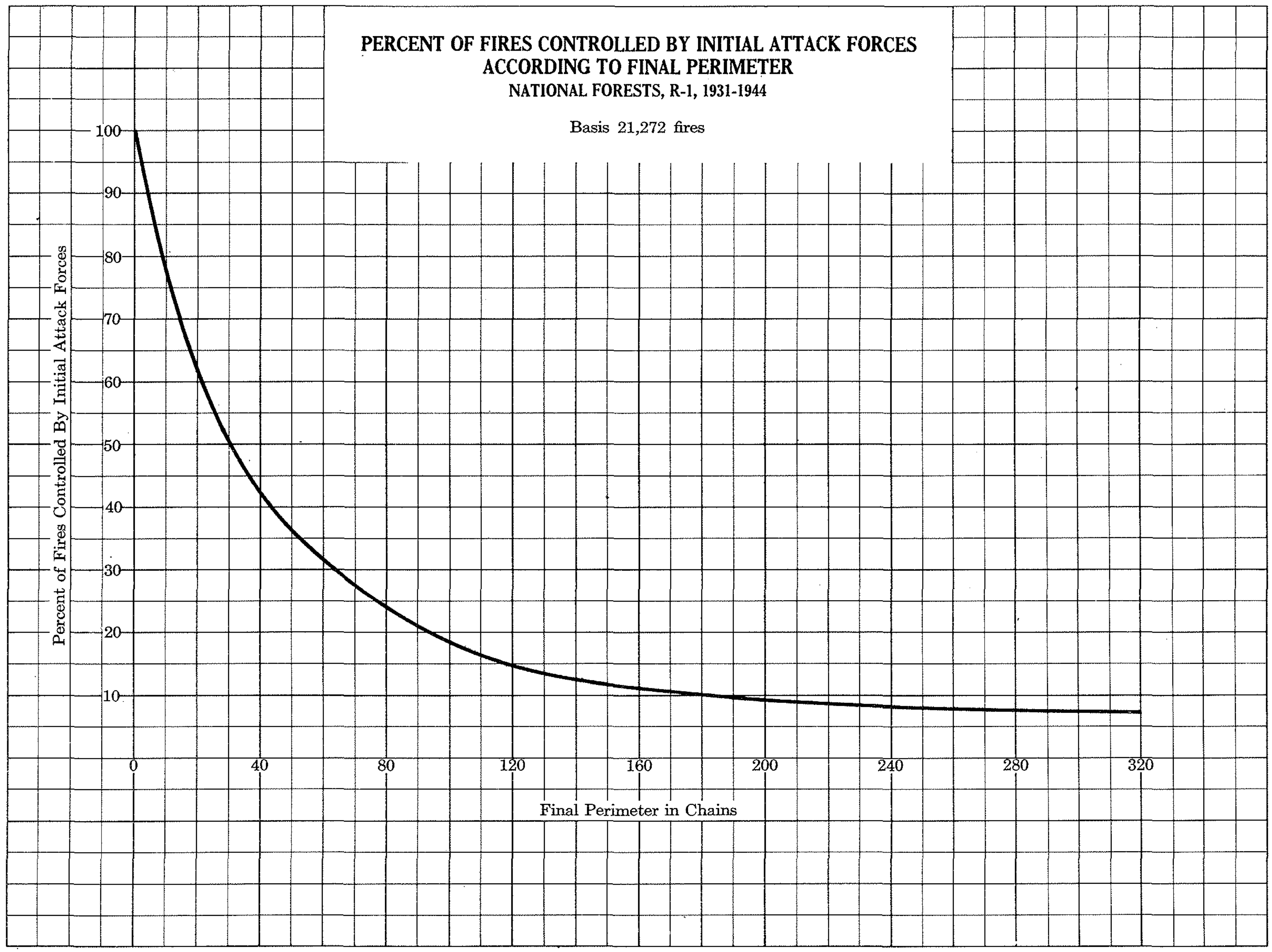

PERCENT OF FIRES CONTROLLED BY INITIAL ATTACK FORCES
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,272 fires
Average 1931-1935
Average 1936-1940
Average 1941-1944
Percent of Fires
0
10
20
30
40
50
60
70
80
90
31
32
33
34
35
36
37
38
39
40
41
42
43
44
Year

Figure 103.


PERCENT OF FIRES CONTROLLED BY INITIAL ATTACK FORCES
ACCORDING TO FINAL PERIMETER
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,272 fires
Percent of Fires Controlled By Initial Attack Forces
100
90
80
70
60
50
40
30
20
10
0
40
80
120
160
200
240
280
320
Final Perimeter in Chains

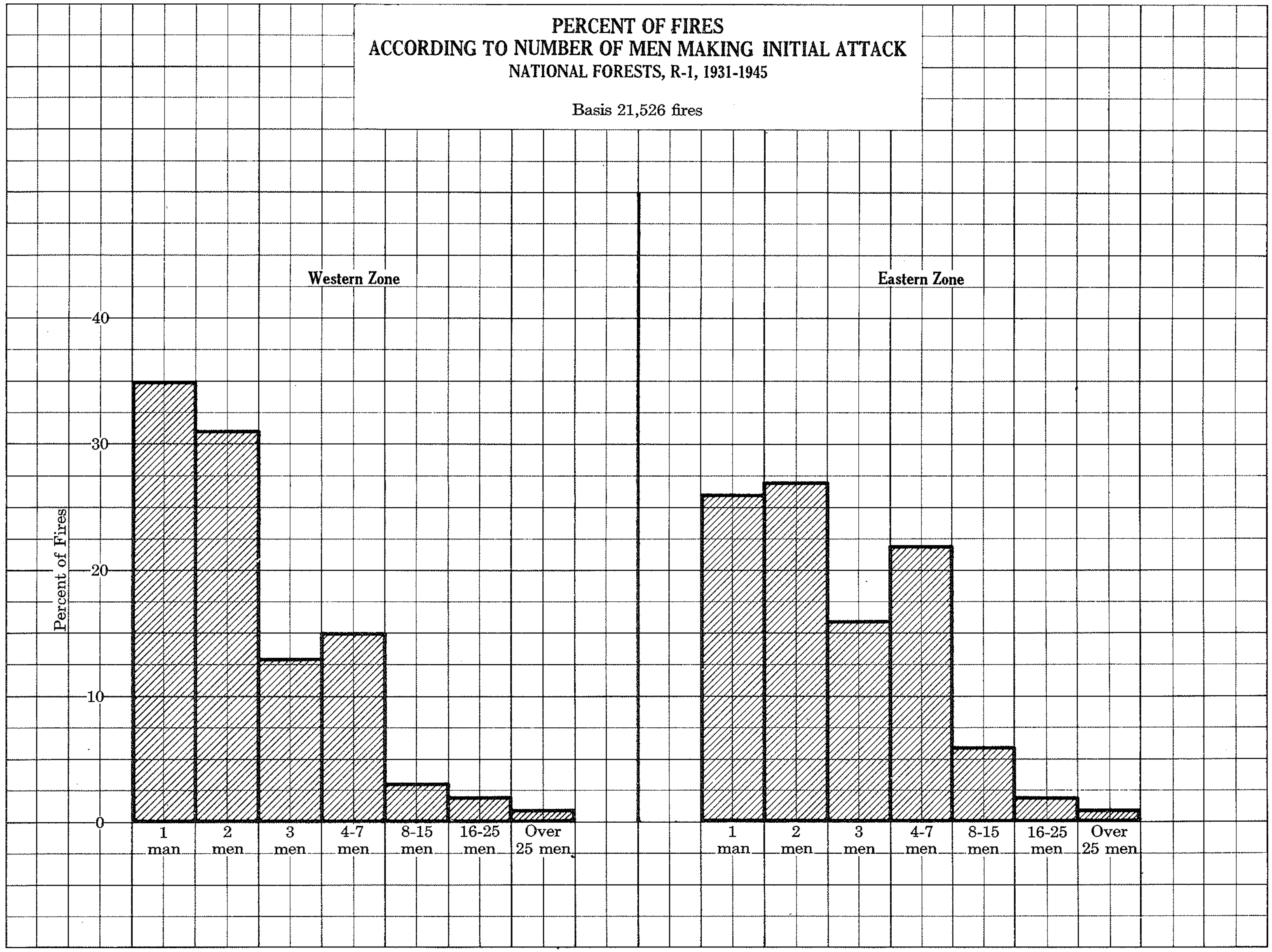

PERCENT OF FIRES
ACCORDING TO NUMBER OF MEN MAKING INITIAL ATTACK
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,526 fires
Western Zone
Eastern Zone
Percent of Fires
40
30
20
10
0
1 man
2 men
3 men
4-7 men
8-15 men
16-25 men
Over 25 men
1 man
2 men
3 men
4-7 men
8-15 men
16-25 men
Over 25 men

Figure 105.

Dispatchers have shown good ability in increasing initial attack forces on fires with a potential to burn large areas. On over 50 percent of the class E fires the initial attack force was greater than 3 men, and on 16 percent it was over 15 men. Likewise, a study of final perimeters on other than class E fires shows that dangerous conditions have been recognized by dispatchers. As illustrated in figure 106, the fires with larger perimeters have had greater strength in initial attack. Fires with an average final perimeter of 50 chains had 16 men in initial attack as compared to only 5 men for fires with a perimeter of 25 chains.

Using greater strength in the initial attack has become more common. As shown in figure 107, the number of fires involving only one man in the initial attack force decreased during the 15-year period 1931-1945. One man made the initial attack on 38 percent of the fires during the 5-year period 1931-1935 as compared to only 28 percent in 1941-1945. Nearly 80 percent of the fires in 1945 had more than one man in the initial attack force. This change is due largely to the reduction in number of one-man lookout-smokechaser stations in favor of small crews at central locations. Also, on smokejumper fires the general policy of using a minimum of two men has an influence on the tendency toward stronger initial attack.

Suppression crews of eight or more men make the initial attack on nearly 6 percent of the fires. As shown in table 60, crews of 8 to 15 men make the initial attack on 3.7 percent of the fires, 16 to 25 men on 1.4 percent, and over 25 men on 0.8 percent. The ability to recognize the conditions calling for stronger initial attack forces is one of the essential requirements for successful fire control action. Analysis of the class E fires occurring over a 15-year period shows that eight or more men were used in initial attack on 32 percent. On the remainder a less aggressive attack was made because:

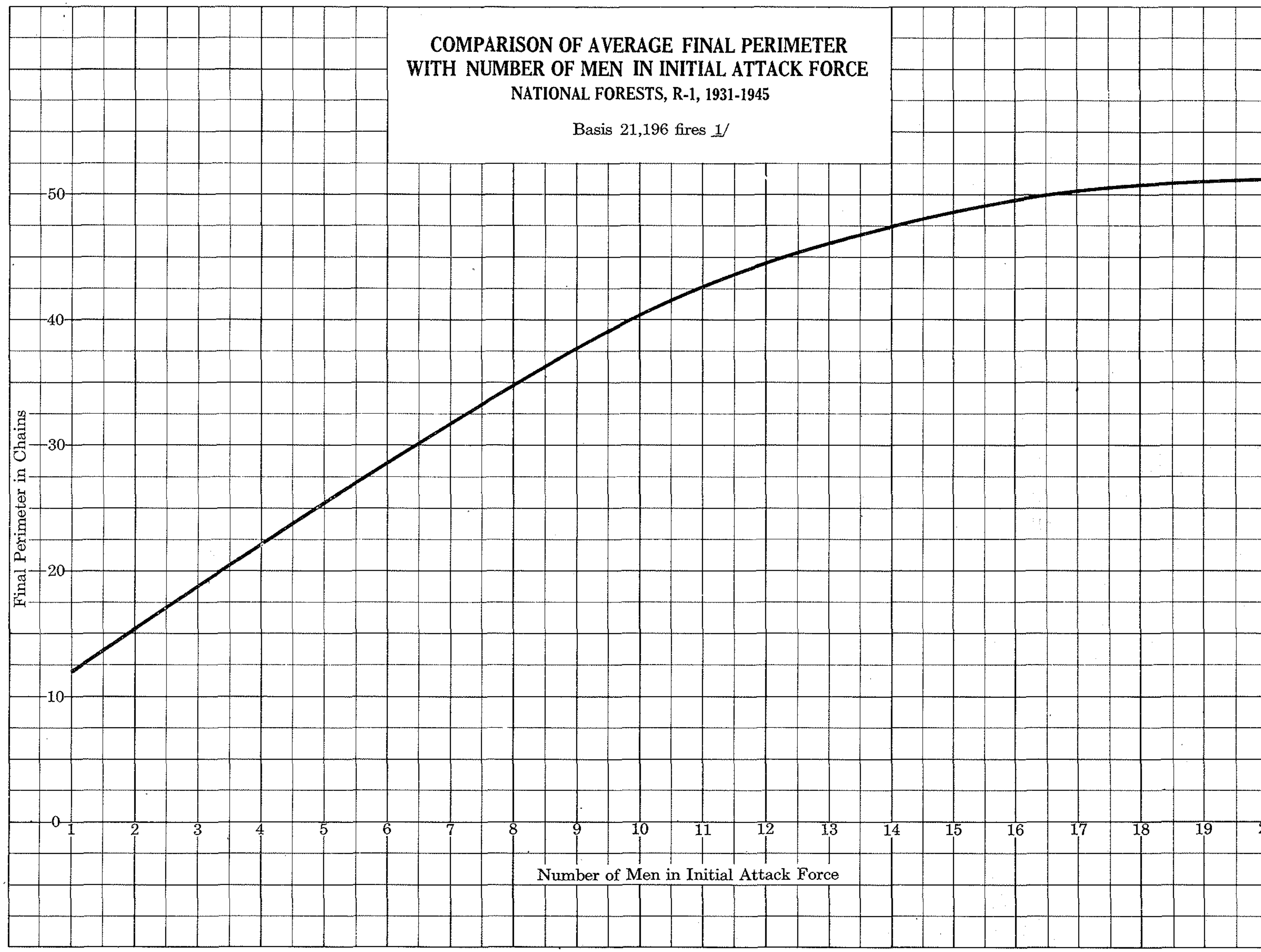
1. The critical burning conditions were not recognized.

2. The required manpower was not immediately available.

3. The critical burning conditions did not occur until after the initial attack was made.

Fire Suppression Action

The first attack is made within 6 hours on over 80 percent of the fires. In a study of nearly 22,000 fires on the national forests it was found that only 18.3 percent had an elapsed time from discovery to first attack of more than 6 hours. As illustrated in figure 108, faster attacks were made in the eastern than in the western zone. Nearly 50 percent of the fires on the eastern forests were attacked within 1 hour after discovery as compared to 35 percent on the western forests. The longer first attack time in the western zone is due mainly to the large number of lightning fires occurring at high elevations where travel is slow and difficult.



1/ Exclusive of Class E Fires

Figure 106

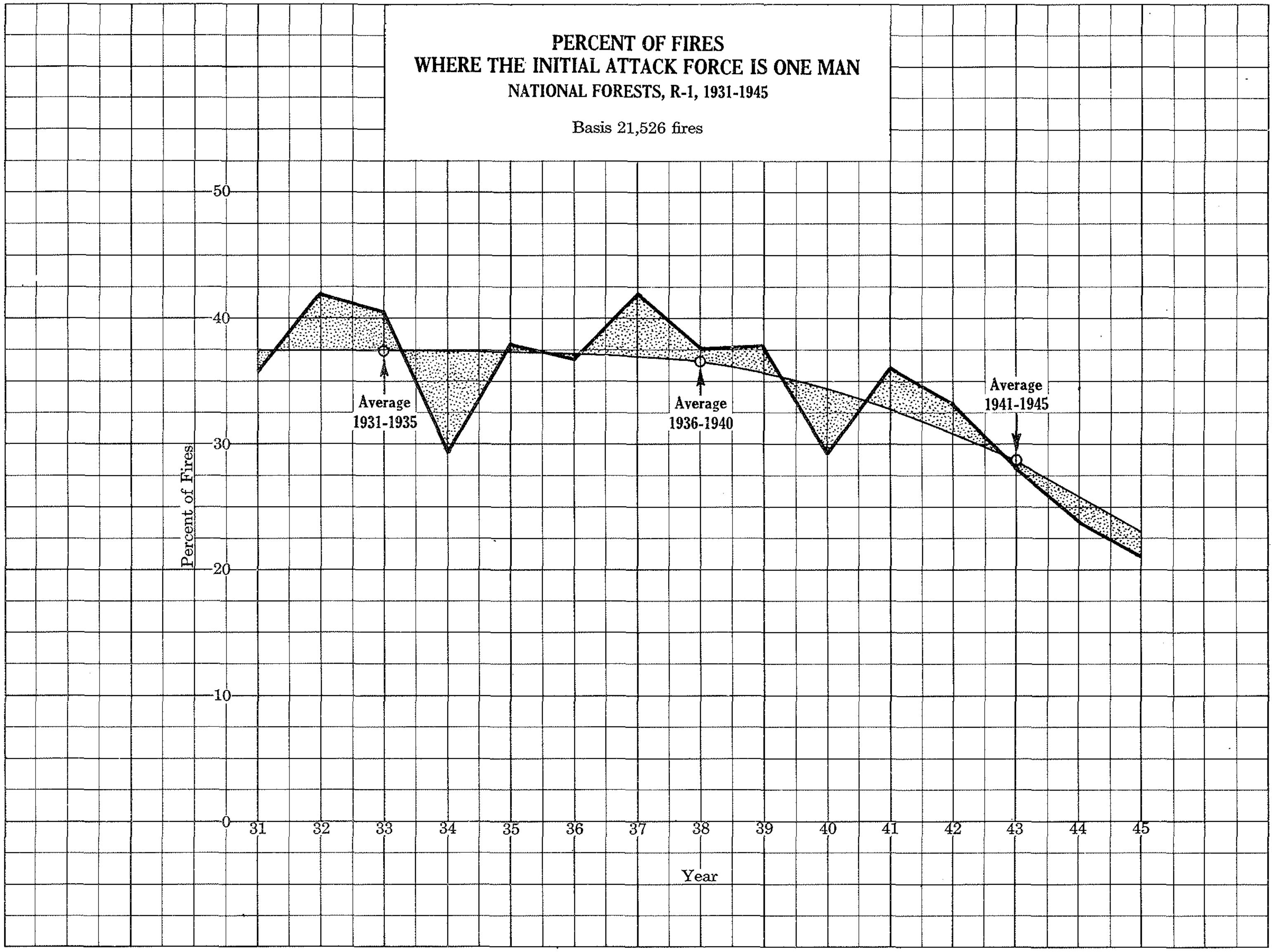

PERCENT OF FIRES
WHERE THE INITIAL ATTACK FORCE IS ONE MAN
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,526 fires
Average
1931-1935
Average
1936-1940
Average
1941-1945
Percent of Fires
50
40
30
20
10
0
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
Year

Table 60. Number and Percent of Fires Classified by Number of Men in Initial Attack, National Forests, R-1, 1931-1945, inclusive

(Basis 21,526 fires)

Year	Number of Men in Initial Attack														Total	
	1 Man		2 Men		3 Men		4-7 Men		8-15 Men		16-25 Men		Over 25 Men			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1931	503	35.9	389	27.7	173	12.3	229	16.3	66	4.7	29	2.1	14	1.0	1,403	100.0
1932	489	42.1	367	31.6	128	11.0	123	10.6	31	2.7	14	1.2	9	0.8	1,161	100.0
1933	367	40.7	245	27.1	106	11.7	126	14.0	29	3.2	21	2.3	9	1.0	903	100.0
1934	336	29.2	329	28.5	157	13.6	223	19.4	57	4.9	32	2.8	19	1.6	1,153	100.0
1935	520	38.1	375	27.4	148	10.8	219	16.0	54	4.0	29	2.1	22	1.6	1,367	100.0
1936	614	36.9	499	30.0	204	12.3	253	15.2	55	3.3	24	1.4	15	0.9	1,664	100.0
1937	594	42.0	375	26.5	163	11.5	216	15.3	41	2.9	17	1.2	9	0.6	1,415	100.0
1938	492	37.5	410	31.3	166	12.6	182	13.9	43	3.3	13	1.0	5	0.4	1,311	100.0
1939	622	37.9	439	26.8	210	12.8	277	16.9	53	3.2	27	1.6	13	0.8	1,641	100.0
1940	1,053	29.3	1,045	29.1	506	14.1	716	19.9	189	5.2	53	1.5	32	0.9	3,594	100.0
1941	482	36.3	502	37.7	199	15.0	119	8.9	22	1.7	3	0.2	3	0.2	1,330	100.0
1942	348	33.3	401	38.4	129	12.3	142	13.6	17	1.6	6	0.6	2	0.2	1,045	100.0
1943	233	28.2	308	37.3	136	16.4	117	14.1	27	3.3	4	0.4	3	0.3	828	100.0
1944	354	23.9	543	36.7	263	17.8	257	17.4	51	3.4	10	0.7	1	0.1	1,479	100.0
1945	259	21.1	446	36.2	209	17.0	245	19.9	55	4.4	10	0.8	8	0.6	1,232	100.0
TOTAL	7,266	33.7	6,673	31.0	2,897	13.4	3,444	16.0	790	3.7	292	1.4	164	0.8	21,526	100.0

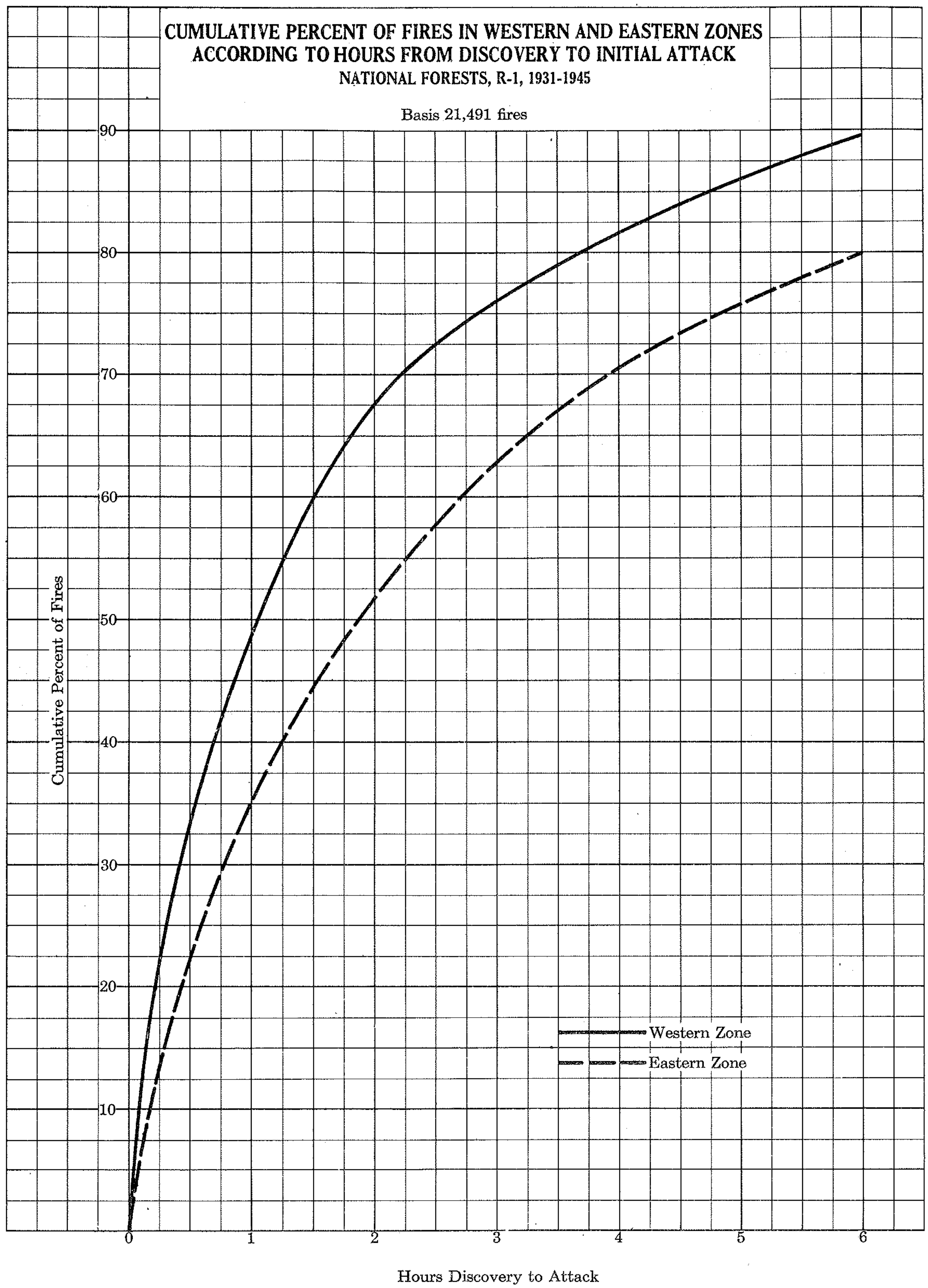

CUMULATIVE PERCENT OF FIRES IN WESTERN AND EASTERN ZONES
ACCORDING TO HOURS FROM DISCOVERY TO INITIAL ATTACK
NATIONAL FORESTS, R-1, 1931-1945
Basis 21,491 fires
Cumulative Percent of Fires
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Hours Discovery to Attack
Western Zone
Eastern Zone

Figure 108.

Over 90 percent of the fires handled by initial attack forces are class A size on arrival. As illustrated by figure 109, the size on arrival was a spot to 0.10 acre on 82 percent of the fires, and 0.11 to 0.25 acre on 9 percent. Only 4 percent of the fires controlled by initial attack forces were over 1 acre in size. The spread of these fires after arrival of the initial attack forces is indicated by the following summary:

Size on Arrival	Percent Spreading To Sizes Over 10 Acres
Spot to 0.10 acre	0.02%
0.11 to 0.25 acre	0.07%
0.26 to 1.00 acre	0.40%
1.01 to 5.00 acres	1.98%
5.01 to 10.00 acres	16.48%

Over 88 percent of the fires handled by initial attack forces are controlled within 3 hours after arrival. As illustrated in figure 110, faster control action is achieved in the eastern zone than in the western zone. This is due to the heavier fuels encountered on most fires in the western zone. Less than 2 percent of the fires handled by initial attack forces in either zone involve a control time greater than 12 hours. However, as will be shown later, much longer time occurs on fires escaping control by the initial attack forces. A summary of control time for over 16,000 fires on the national forests is shown in table 61.

Critical burning conditions cause the greatest number of fires to escape control by the initial attack. A special study was made of 143 fires which escaped control by the initial attack forces during the 1931-1939 period. These fires averaged over 3400 acres in final size and burned a total of 489,000 acres. The reasons for their escaping control by the initial attack forces were as follows:

1. Fire exploded and swept across lines -- 33%
2. Too few men -- 29%
3. Fire exploded before lines could be built -- 28%
4. Arrival too slow -- 6%
5. Fire abandoned to go for assistance -- 4%

An overload of fires causes the greatest number of errors and delays. During the 1931-1939 period known reasons for errors and delays were listed on 1206 fires as follows:

1. Overload of fires -- 33%
2. Telephone trouble and congestion -- 22%
3. Getaway delayed -- 13%
4. Smokechaser error -- 8%
5. Other suppression errors -- 8%
6. Poor planning -- 6%
7. Lookout error -- 5%
8. Fire abandoned prematurely -- 3%
9. Lack of communication for report -- 1%
10. Crew reduced prematurely -- 1%

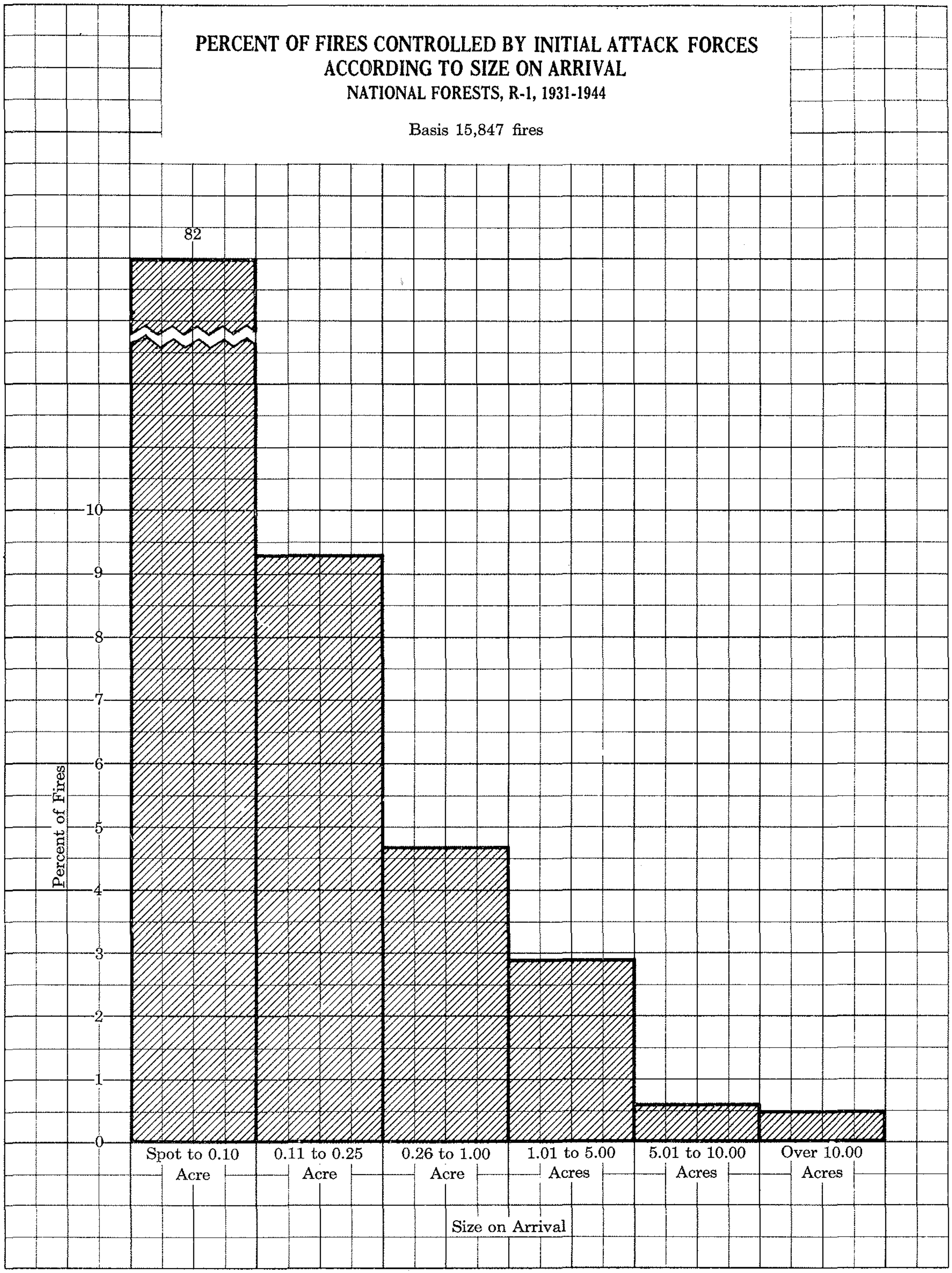

PERCENT OF FIRES CONTROLLED BY INITIAL ATTACK FORCES
ACCORDING TO SIZE ON ARRIVAL
NATIONAL FORESTS, R-1, 1931-1944
Basis 15,847 fires
82
10
9
8
7
6
5
4
3
2
1
0
Percent of Fires
Spot to 0.10 Acre
0.11 to 0.25 Acre
0.26 to 1.00 Acre
1.01 to 5.00 Acres
5.01 to 10.00 Acres
Over 10.00 Acres
Size on Arrival

Figure 109.

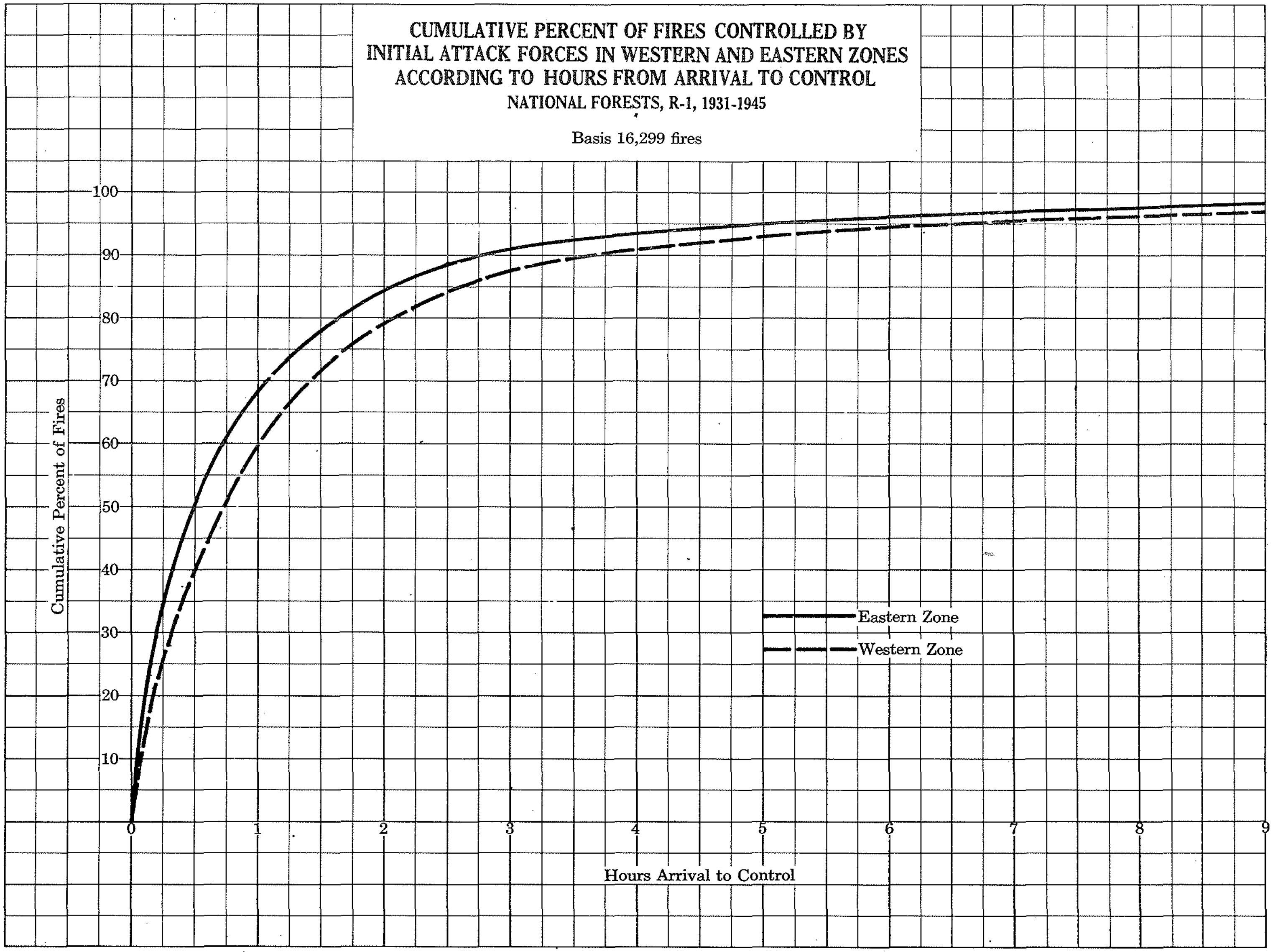

CUMULATIVE PERCENT OF FIRES CONTROLLED BY
INITIAL ATTACK FORCES IN WESTERN AND EASTERN ZONES
ACCORDING TO HOURS FROM ARRIVAL TO CONTROL
NATIONAL FORESTS, R-1, 1931-1945
Basis 16,299 fires
Cumulative Percent of Fires
100
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
7
8
9
Hours Arrival to Control
Eastern Zone
Western Zone

Figure 110.

Table 61. Number and Percent of Fires Controlled by Initial Attack Forces Classified by Control Time, National Forests, R-1, 1931-1945, inclusive

(Basis 16,299 fires)

Year	Control Time														Total	
	0-3 hrs.		3-6 hrs.		6-9 hrs.		9-12 hrs.		12-24 hrs.		24-48 hrs.		Over 48 hrs.			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
1931	778	85.6	73	8.0	22	2.4	10	1.1	21	2.3	4	0.5	1	0.1	909	100.0
1932	757	86.9	77	8.9	15	1.7	8	0.9	11	1.3	3	0.3	0	0.0	871	100.0
1933	571	87.3	60	9.2	9	1.4	2	0.3	8	1.2	3	0.4	1	0.2	654	100.0
1934	706	87.6	60	7.4	16	2.0	10	1.3	8	1.0	4	0.5	2	0.2	806	100.0
1935	1,006	94.5	40	3.7	6	0.6	2	0.2	6	0.6	4	0.4	0	0.0	1,064	100.0
1936	1,323	95.2	45	3.2	11	0.8	4	0.3	6	0.4	1	0.1	0	0.0	1,390	100.0
1937	1,096	93.6	56	4.7	12	1.0	2	0.2	3	0.3	1	0.1	1	0.1	1,171	100.0
1938	1,046	94.6	34	3.1	15	1.3	4	0.4	4	0.4	1	0.1	1	0.1	1,105	100.0
1939	1,237	93.1	65	4.9	14	1.1	5	0.4	6	0.4	1	0.1	0	0.0	1,328	100.0
1940	1,957	84.9	196	8.5	55	2.4	43	1.9	42	1.8	10	0.4	2	0.1	2,305	100.0
1941	1,001	89.4	73	6.5	25	2.2	15	1.4	6	0.5	0	0.0	0	0.0	1,120	100.0
1942	703	86.3	68	8.3	21	2.6	13	1.6	9	1.1	1	0.1	0	0.0	815	100.0
1943	548	89.1	42	6.8	11	1.8	1	0.2	12	1.9	1	0.2	0	0.0	615	100.0
1944	1,008	85.1	98	8.3	41	3.5	10	0.8	22	1.9	5	0.4	0	0.0	1,184	100.0
1945	764	79.4	100	10.4	37	3.9	21	2.2	32	3.3	5	0.5	3	0.3	962	100.0
TOTAL	14,501	88.9	1,087	6.7	310	1.9	150	0.9	196	1.2	44	0.3	11	0.1	16,299	100.0

The study of initial attack shows five factors to be of major importance in achieving effective suppression action. From the foregoing analyses which involved studies on over 22,000 fires, the following factors stand out as high priority items in planning and managing the initial attack:

1. Locating initial attack forces for quick and easy access to areas of worst fuels and highest fire occurrence.

2. Varying the strength of the readily available initial attack forces in accordance with measured fire danger.

3. Determining force requirements on each fire in accordance with the estimated size on arrival and probable speed of control as influenced by travel time, topography, fuel type, burning index, and known capabilities of the men and machines involved.

4. Training and drilling initial attack forces for the most effective action in getaway, traveling to fires, and suppression operations.

5. Preparing emergency plans in advance for action to be taken when an overload of fires occurs.

5. REINFORCEMENT ACTION

Fast, strong, and efficient reinforcement action often determines whether a fire will be controlled at reasonable size or will escape to burn a large area. Reinforcements vary from one or two men needed to assist a smokechaser on a small fire to hundreds of men on large project fires. The greatest areas are burned and the largest expenditures of funds are made on fires requiring reinforcements. Therefore an analysis of this problem is an essential phase in gaining a better understanding of the regional fire control program. In this chapter the general problem of reinforcement action is considered. In chapter 6, a more detailed analysis is made of very heavy reinforcement action on class E fires.

Reinforcement Load

One-fourth of the fires on the national forests require reinforcement action. During the period 1931-1944 reinforcements of one or more men were used on 5380 fires on the national forests, or 25.3 percent of the total number of fires occurring during this period. These fires averaged 134 acres in size and burned an area of 721,922 acres, or 96 percent of the total burn for the period.

The percent of fires requiring reinforcement action varies according to the character of the fire season and the effectiveness of the initial attack. As illustrated in figure 111, over 30 percent of the fires required reinforcement action in 1931, 1934, and 1940. The fire seasons of 1931 and 1934 were characterized by critical burning conditions. In 1940 burning conditions were very dangerous, and there was a great overload of fires. The fire season of 1936, when less than 19 percent of the fires required reinforcement action, illustrates the influence of aggressive initial attack. As explained previously in Part II, this was a year when fire danger was rated critical. However, in 1936 over 95 percent of the fires handled by initial attack forces were controlled within 3 hours after arrival, as against a 14-year average of 89 percent. This aggressive initial attack action undoubtedly was a major factor in holding down reinforcement requirements as well as area burned.

More fires require reinforcements than estimated in fire control plans. In designing a system of adequate fire control at least possible cost, Hornby estimated that the initial attack should be fast and strong enough so that only 15 percent of the fires would require reinforcement action (4). He believed that this system would be most economical. However, because of lack of funds the necessary smokechaser forces to carry out these plans have not been provided. As a result 10 percent more fires have required reinforcements than are called for under the fire control system which Hornby showed to be most economical.

A reduction in the reinforcement load would provide more effective and economical fire control. Fires which require reinforcement action are 73 times bigger than those controlled by initial attack forces. The

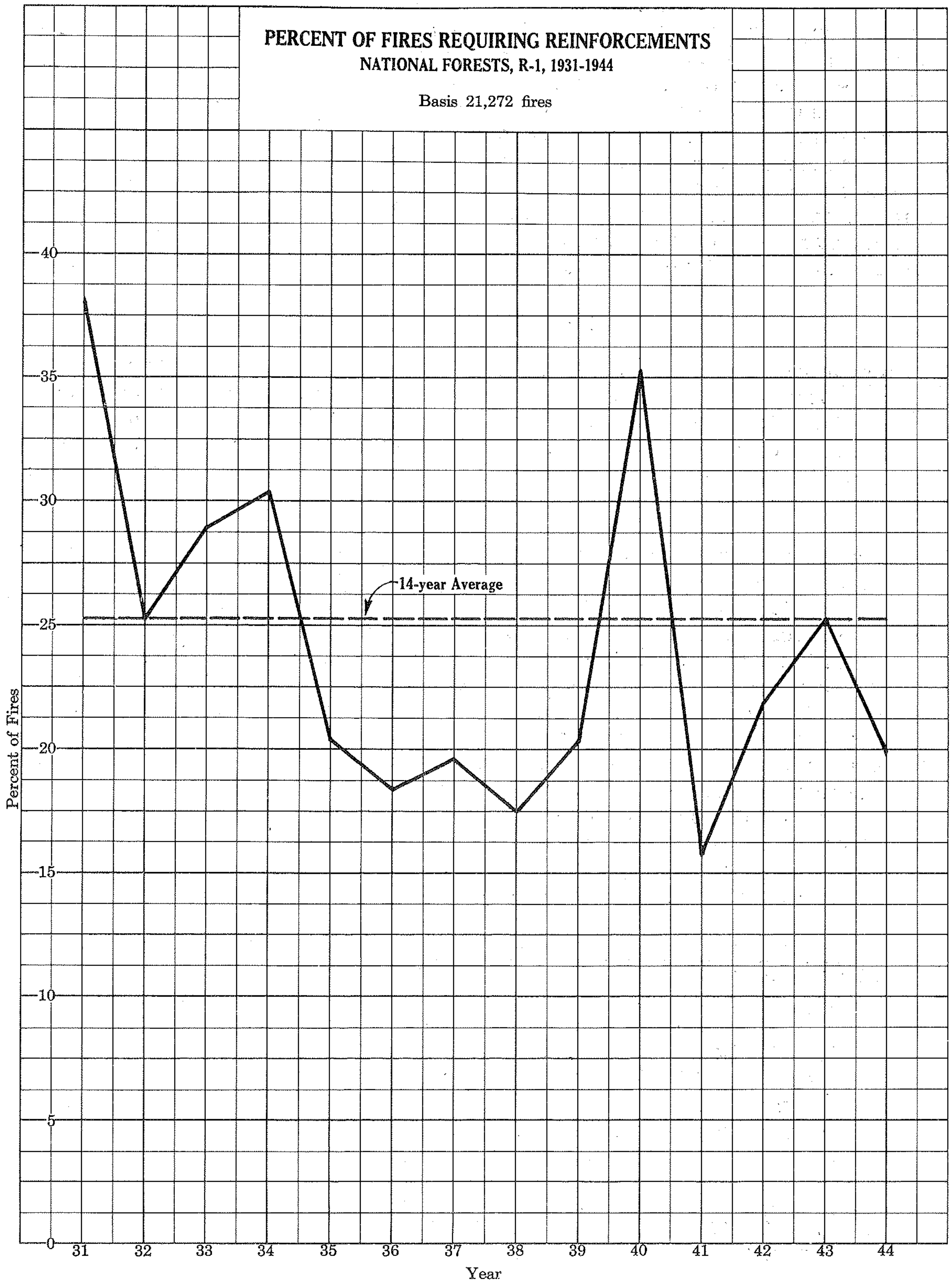

PERCENT OF FIRES REQUIRING REINFORCEMENTS
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,272 fires
14-year Average
Percent of Fires
40
35
30
25
20
15
10
5
0
31
32
33
34
35
36
37
38
39
40
41
42
43
44
Year

Figure 111.

best way to meet this problem is to provide for faster, stronger, and more efficient action in the initial attack. A reduction in money spent for initial attack preparedness has clearly resulted in more expensive fire suppression and greater losses.

The larger the fire, the greater are the requirements for reinforcements. As illustrated in figure 112, only 15 percent of the class A fires require reinforcement action. Over 58 percent of the fires which spread to class B size require reinforcements. Only 1 out of 100 class E fires are handled without reinforcement action. This continual step-up in suppression requirements as the area of the fire increases again illustrates the importance of controlling the maximum number of fires at the smallest possible size.

First Reinforcements

On 68 percent of the fires the first reinforcements are 1 to 5 men. As illustrated in figure 113, the size of the first reinforcements depends largely upon the size of the fire. Over 25 men are required on only 2 percent of the class A and B fires as compared to nearly 18 percent of the class C, D, and E fires. The fact that heavier first reinforcements have been sent to larger fires shows:

1. That lookouts and other observers have kept dispatchers informed of the progress of fires.

2. That dispatchers have shown good ability to evaluate probable conditions at the fire.

First reinforcements do not arrive until 12 or more hours after the initial attack forces on over 50 percent of the fires. As illustrated in figure 114, the arrival time of the first reinforcements has an influence on the final size of the fire. Nearly 35 percent of the fires held to class A and B size had reinforcements within 3 hours after the arrival of the initial attack forces. However, only 22 percent of the class C, D, and E fires had reinforcements within 3 hours.

Slow reinforcement action on large fires is a critical feature of the suppression operations. On nearly 40 percent of the class C, D, and E fires the first help for the initial attack forces did not arrive for more than 24 hours. This means that these fires have at least one full daylight burning period in which to spread and in many cases are in the second period prior to reinforcement. This is a critical feature of fire suppression operations. It is a result of the following factors:

1. Lack of readily available reinforcements especially during periods of high fire occurrence.

2. Lack of communication with the initial attack forces.

3. Lack of fast transportation facilities for reinforcements.

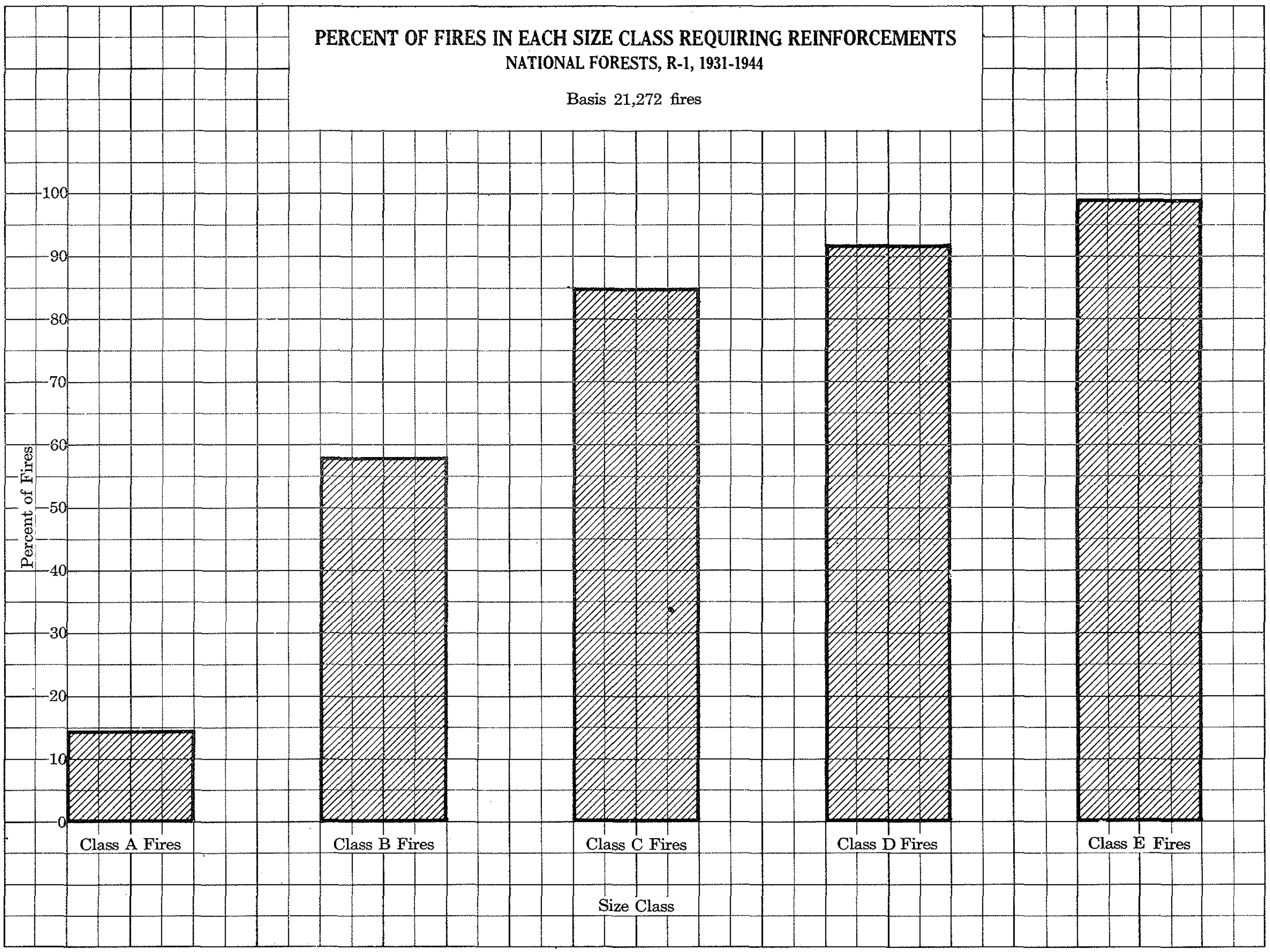

PERCENT OF FIRES IN EACH SIZE CLASS REQUIRING REINFORCEMENTS
NATIONAL FORESTS, R-1, 1931-1944
Basis 21,272 fires
100
90
80
70
60
50
40
30
20
10
0
Percent of Fires
Class A Fires
Class B Fires
Class C Fires
Class D Fires
Class E Fires
Size Class

Figure 112.

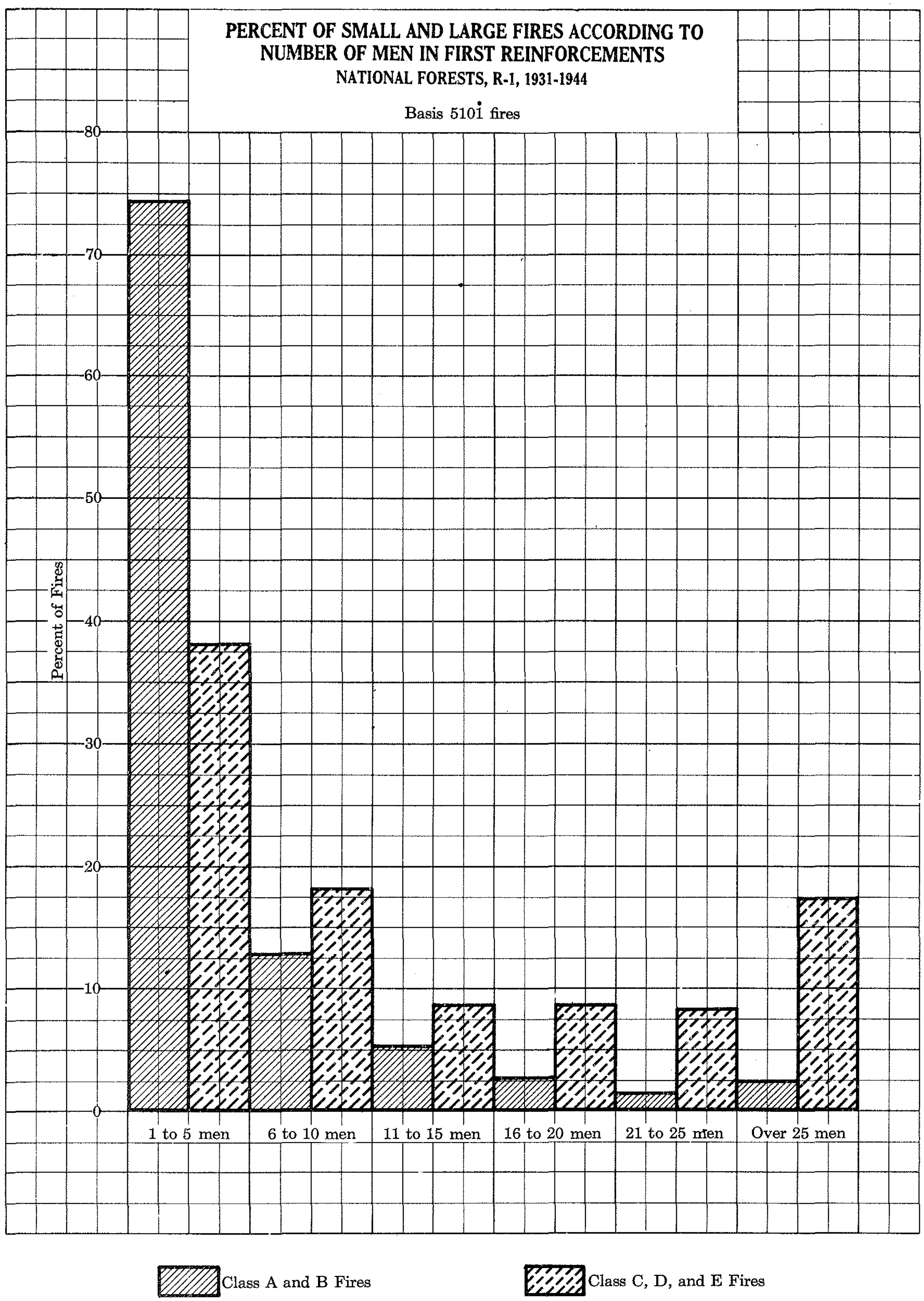

PERCENT OF SMALL AND LARGE FIRES ACCORDING TO NUMBER OF MEN IN FIRST REINFORCEMENTS
NATIONAL FORESTS, R-1, 1931-1944
Basis 5101 fires
Percent of Fires
80
70
60
50
40
30
20
10
0
1 to 5 men
6 to 10 men
11 to 15 men
16 to 20 men
21 to 25 men
Over 25 men
Class A and B Fires
Class C, D, and E Fires

Figure 113.

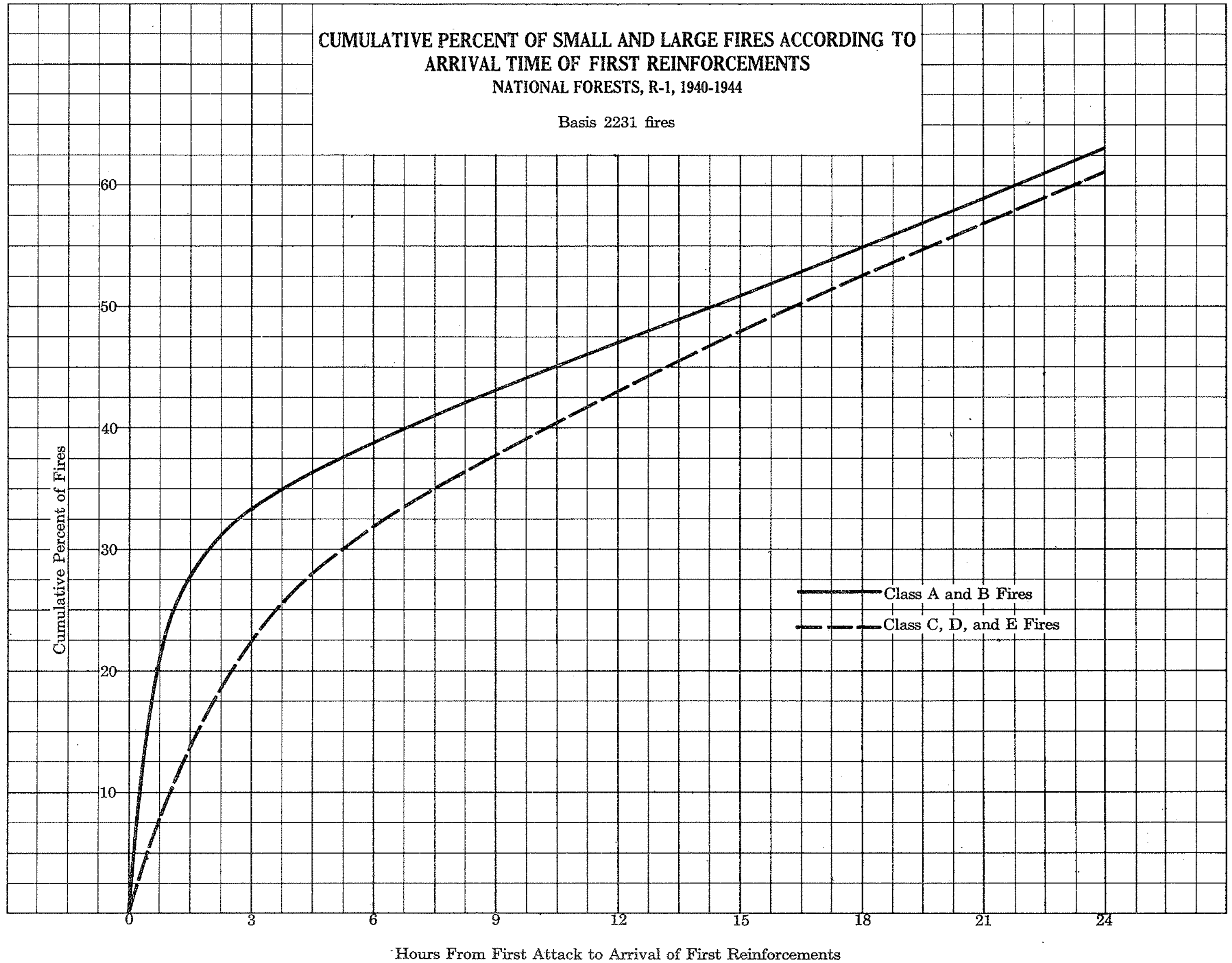

CUMULATIVE PERCENT OF SMALL AND LARGE FIRES ACCORDING TO ARRIVAL TIME OF FIRST REINFORCEMENTS
NATIONAL FORESTS, R-1, 1940-1944
Basis 2231 fires
Cumulative Percent of Fires
10
20
30
40
50
60
0
3
6
9
12
15
18
21
24
Hours From First Attack to Arrival of First Reinforcements
Class A and B Fires
Class C, D, and E Fires

Figure 114.

Character of Reinforcement Action

On nearly half of the fires the reinforcement action requires work on not more than 10 chains of fire line. As illustrated in figure 115, an annual average of 146 fires in the western zone and 30 fires in the eastern zone require reinforcement action on a perimeter of 1 to 10 chains. Forty-five percent of the fires requiring reinforcements receive this degree of follow-up action. This is generally a smoke-chaser job of applying small fire suppression methods.

Small crew action is needed on one-third of the fires requiring reinforcements. An annual average of 105 fires in the western zone and 36 fires in the eastern zone require control action on 11 to 60 chains of line. This is usually a job for small crews of 8 to 15 men. The work of the reinforcement forces will consist of line building and holding on as much as three-fourths of a mile of fire perimeter. Overhead requirements include a fire boss capable of directing up to 50 men and a small fire camp.

Ten percent of the fires requiring reinforcements require very aggressive action on 1 to 2 miles of perimeter. As illustrated in figure 115, an annual average of 29 fires in the western zone and 13 fires in the eastern zone require control action on 61 to 160 chains of fire perimeter. These are very critical fires demanding the most aggressive type of action. Their size shows that they have already made moderate runs. They are potentially big fires. Their control normally involves line building and holding by more than one 25-man crew. These are fires where bulldozers, tankers, and other mechanized units can often pay big dividends. Overhead requirements normally call for an expert fire boss, one to four crew foremen, and a medium-sized fire camp.

Seven percent of the fires requiring reinforcements need work on more than 2 miles of fire perimeter. About half of these fires are controlled prior to reaching the very large fire stage. As illustrated in figure 115, an annual average of 8 fires in the western zone and 3 fires in the eastern zone require control action on 161 to 360 chains of fire perimeter. These are potentially dangerous fires and warrant heavy reinforcement action by crews and power equipment to prevent them from burning very large areas. Overhead requirements normally include an expert fire boss, one or two sector bosses, four to eight crew foremen, and one or two standard fire camps.

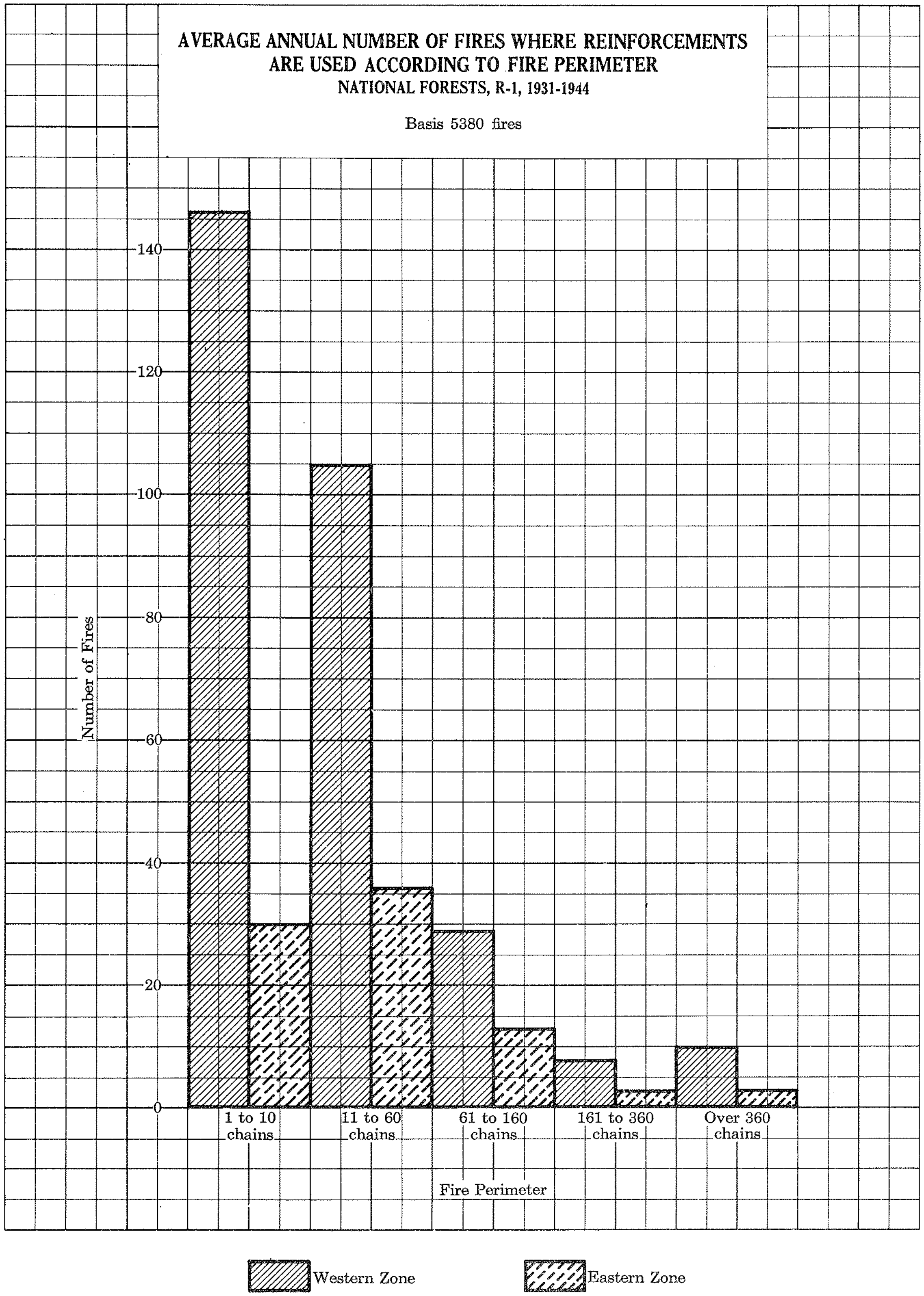

AVERAGE ANNUAL NUMBER OF FIRES WHERE REINFORCEMENTS ARE USED ACCORDING TO FIRE PERIMETER
NATIONAL FORESTS, R-1, 1931-1944
Basis 5380 fires
Number of Fires
140
120
100
80
60
40
20
0
1 to 10 chains
11 to 60 chains
61 to 160 chains
161 to 360 chains
Over 360 chains
Fire Perimeter
Western Zone
Eastern Zone

Figure 115.

6. CONTROL OF LARGE FIRES

In this study large fires are defined as those burning areas of 300 acres or more. The objective was to analyze all pertinent factors regarding large fires and in particular to attempt to determine why they reached such large size and to study the problems involved in control operations. Basic information for the analysis was obtained from all class E fires on the national forests on which complete fire reports were available.

The Large Fire Problem

Occurrence of large fires jeopardizes successful forestry. No system of forest management can survive if large fires are numerous or occur at frequent intervals. The fire history of the northern Rocky Mountain region serves as vivid documentation of this fact. During the first 20 years of organized fire protection on the national forests large fires burned over 5 million acres, or about 16 percent of the total area protected. During the last 20 years large fires have burned 3/4 million acres. These fires, while few in number, have nevertheless prevented the achievement of desirable protection objectives.

Class E fires account for over 90 percent of the total burned area. In the national forests of Region 1 less than 1 percent of the fires reached class E size during the 1931-1945 period. However, these few fires burned 775,814 acres, including area burned outside the national forest protection boundaries. This is actually 98 percent of the total burn, but deduction of the burn outside the protection boundaries makes it about 94 percent of the total. As shown in table 62, only 208 fires accounted for this great burned area. These fires had an average size of over 3700 acres.

Large fires damage more timber than is harvested in timber sales. During the 15-year period 1931-1945 class E fires burned an average of 51,720 acres per year in the national forests. During the same period an average of 15,689 acres were cut-over annually. The timber harvested in these sales averaged 133,356 M board feet per year, or 8.5 M board feet per acre. Exact figures are not available on the volume of commercial timber damaged by large fires. However, it is estimated that the fire damage amounts to 4.9 M board feet per acre of commercial forest land burned, or about 150,000 M board feet annually. Large as this volume is it measures only a part of the damage by fire. Board foot figures do not include the loss of future sawtimber yeilds in seedling, sapling, and pole trees destroyed, nor the impairment of watershed, recreation, and wildlife values by fire on both commercial and non-commercial areas. The significant point in the board foot figure is that a reoccurrence of large fire damage suffered during the 1931-1945 period will seriously affect maximum timber production as well as the achievement of desirable forest management objectives.

Large fires are costly in manpower and dollars. A special study of 129 class E fires on which personnel requirements were known revealed that an average expenditure of 30,678 man-hours is made per fire in suppression operations. At present-day firefighting costs this would

Table 62. Total Number of Class E Fires and Acreage Burned, National Forests, R-1, 1931-1945, inclusive

Forest	Number of Fires	Acreage Burned 1/
Bitterroot	22	20,906
Cabinet	11	17,763
Clearwater	13	124,612
Coeur d'Alene	5	24,136
Colville	11	28,272
Flathead	10	19,701
Kaniksu	16	108,029
Kootenai	17	14,446
Lolo	17	16,066
Nezperce	27	250,191
St. Joe	8	43,776
TOTAL WESTERN ZONE	157	667,898
Beaverhead	4	4,223
Custer	5	6,059
Deerlodge	9	4,764
Gallatin	8	12,622
Helena	13	12,907
Lewis and Clark	12	67,341
TOTAL EASTERN ZONE	51	107,916
GRAND TOTAL	208	775,814

1/ Includes all area burned by class E fires both inside and outside national forest protection boundaries.

amount to approximately $77,000 per fire. The cost of fighting class E fires would thus amount to over a million dollars per year. During critical years these costs may be much higher. The Pete King fire of 1934 required a maximum of 2700 men and nearly 800,000 man-hours of work. At present-day costs this would be a two-million-dollar fire for suppression costs alone.

Large numbers of class E fires have occurred in every very dangerous or critical fire season. In the national forests an average of 14 class E fires occur annually, but in years of high fire danger 2 or 3 times this number of large fires occur. In 1931 a total of 41 class E fires occurred. In 1940 there were 34 fires of this size; and in two other years, 1934 and 1939, more than 20 occurred. This pattern is closely correlated with the annual rating of fire seasons shown in figure 57. Although many fire control operations have increased in efficiency, there is nothing to indicate that large fires can be prevented in the future. Forest management will not be on a sound basis until more effective means are developed to reduce drastically the number of large fires during periods of high fire danger.

Factors Causing Large Fires

Dangerous fuels and high burning index are the most important factors causing large fires. Many factors may contribute to the spread of fires and cause them to reach large size. Such things as delays and mistakes in suppression operations may allow a fire that should have been checked effectively to reach large size. However, burning conditions must be in a given state to permit rapid and continued spread. Analysis of large fires clearly indicated that the potential for a conflagration is much greater in dangerous fuels and during periods of high burning index. Identification of these areas and periods is the first requirement in preventing or combating large fires.

As burning index increases, the probability of large fires increases. As illustrated in figure 116, there is a remarkable correlation between burning index and large fire occurrence. At a burning index rating of 10 or less no class E fires have occurred, and up to a rating of 44 the large fire potential is relatively low. Above this rating large fires increase rapidly in number. At a burning index of 79 or above nearly 2 out of each 100 fires may be expected to spread to sizes greater than 300 acres.

Fuel classification aids in identifying areas where large fires are likely to occur. As illustrated in figure 117, both rate-of-spread and resistance-to-control 3/ fuel classifications are useful in identifying the probable areas for large fires. Over four times as many fires will reach class E size in extreme rate-of-spread fuels as in low or medium fuels. Resistance to control is even more important in indicating

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3/ According to the R-1 fuel classification system a smokechaser will build 3.2 chains of fire line per man-hour in low resistance-to-control fuels, 2 chains in medium, 0.8 chains in high, and 0.2 chains in extreme fuels.

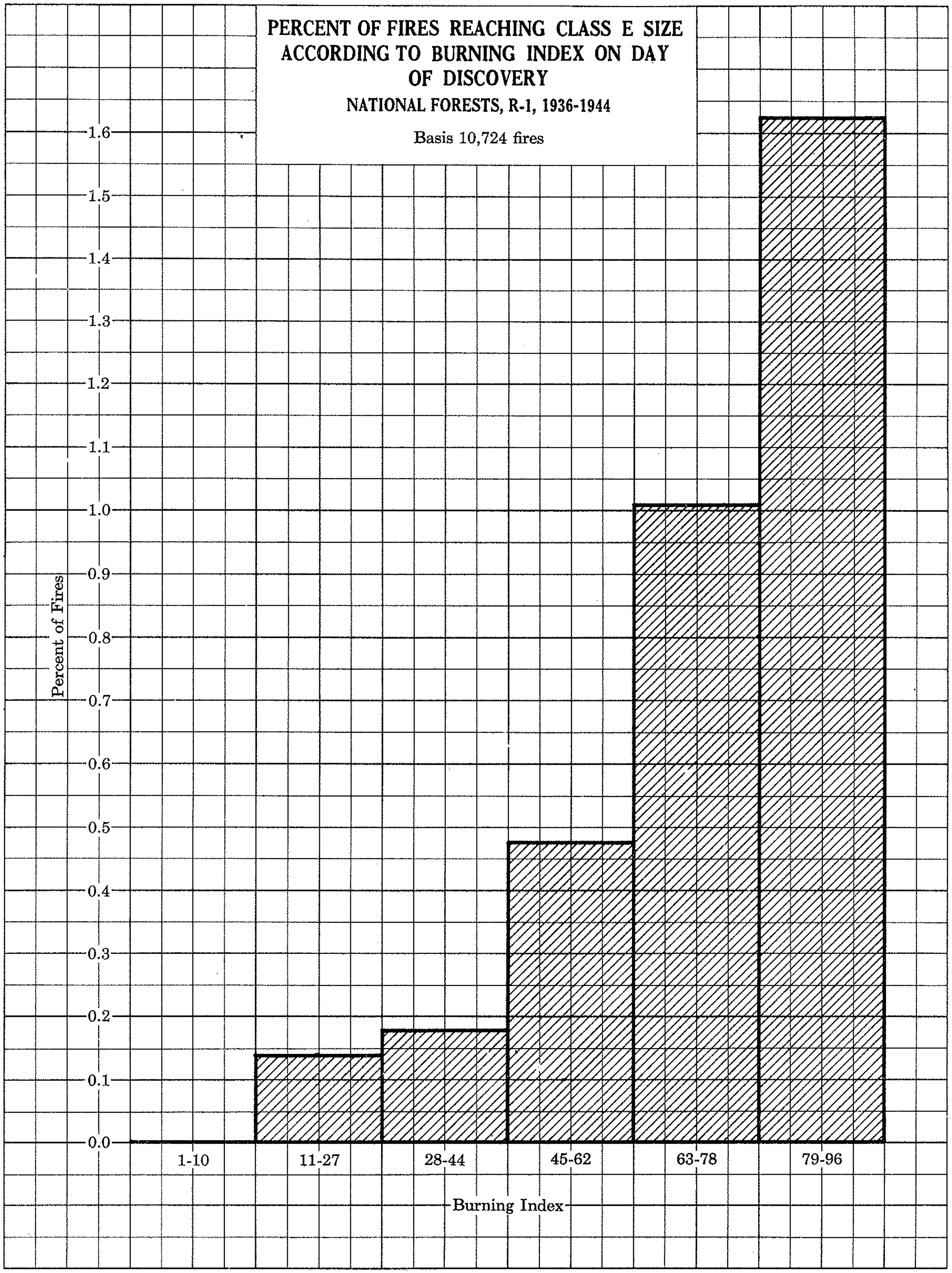

PERCENT OF FIRES REACHING CLASS E SIZE ACCORDING TO BURNING INDEX ON DAY OF DISCOVERY
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,724 fires
Percent of Fires
1.6
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1-10
11-27
28-44
45-62
63-78
79-96
Burning Index

Figure 116.

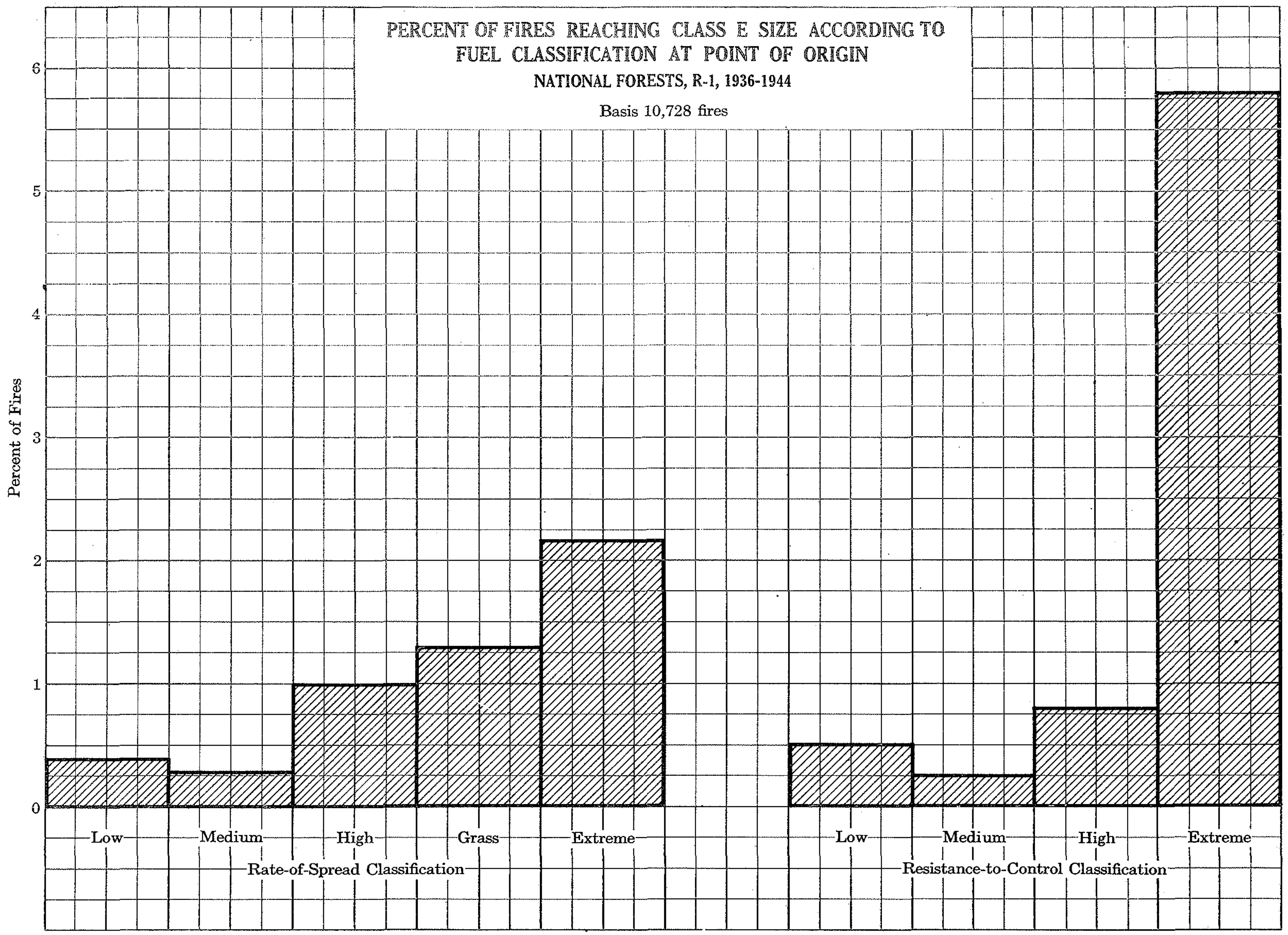

PERCENT OF FIRES REACHING CLASS E SIZE ACCORDING TO
FUEL CLASSIFICATION AT POINT OF ORIGIN
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,728 fires
Percent of Fires
0
1
2
3
4
5
6
Low
Medium
High
Grass
Extreme
Rate-of-Spread Classification
Low
Medium
High
Extreme
Resistance-to-Control Classification

Figure 117.

the probabilities of large fires. Nearly 12 times as many fires reach class E size in extreme resistance-to-control fuels as in low or medium fuels. A much larger than normal number of fires in medium and high rate-of-spread fuels have spread to large size when resistance to control is classified as extreme. In medium-extreme fuels over 5 percent of the fires reached class E size, and in high-extreme fuels nearly 7 percent.

Heavy fuels call for strong suppression action. As shown above, a relatively high percentage of fires in extreme resistance-to-control fuel types reach large size. Studies of all fires occurring in this fuel show that a smaller number are held to class A size than in any other resistance-to-control classification and that these fires have a larger final perimeter. Smokechaser attacks may often be impotent in heavy fuels. Something better than handtool firefighting is needed. Areas of very heavy fuels where handtool firefighting is painfully slow and inadequate clearly call for the use of power equipment even when a fire is in its incipient stages. The need for power equipment in areas of heavy fuels is illustrated as follows:

Resistance To Control	Man-Hours Per Fire To Control
Low	6.58
Medium	9.18
High	31.82
Extreme	227.79

High initial rates of spread are common on large fires. Nearly 70 percent of the class E fires had a perimeter greater than 25 chains upon the arrival of the first suppression forces. Only 15 percent of the fires were less than 10 chains in perimeter when reached, and 34 percent had perimeters of over 100 chains. As will be shown later, very few of these fires burned very long before they were reached. These high initial rates of spread are another result of the occurrence of fires in bad fuels and under severe weather conditions.

Factors Influencing Control of Large Fires

Fire prevention is the first requirement in reducing the number of large fires. Nearly 56 percent of the class E fires occurring during the 1931-1945 period were man-caused. This is a very high percentage when compared with the regional rate of only 24 percent of all fires being man-caused. One reason for the high rate is the occurrence of a large number of man-caused fires on cut-over lands where fuels are often more dangerous and naturally foster more large fires. As the first step in reducing the occurrence of large fires, prevention efforts must be intensified in dangerous fuel areas. This calls for a program of fuel reduction, public education, closures and patrols, and effective law enforcement action wherever necessary.

Detection efficiency on large fires is equal to that achieved on smaller fires. Over 60 percent of the class E fires are detected within one hour after origin, and only 10 percent are hangovers remaining undetected for 30 hours or more. While this record is equal to or slightly better than that achieved on smaller fires, it is not a satisfactory record. In view of the dangerous fuels where many large fires start, a high degree of detection efficiency is essential. Slow detection of fires burning in dangerous fuels and under high burning index conditions will normally mean large fire perimeters when the first suppression forces arrive and consequently enhance the probability of large fires. In reducing these probabilities detection plans must be based upon fuel classification and varied according to burning index ratings. Fuel type maps, daily measurement of weather conditions, and daily weather forecasts all provide useful guides for the location and manning of detection stations and for the timing and intensity of both aerial and ground patrols.

Nearly three-fourths of the class E fires require travel time of 2 hours or less. As illustrated in figure 118, over 59 percent of the large fires required a travel time up to 1 hour, and 14 percent up to 2 hours. On 60 percent of the fires the initial attack force traveled less than 10 miles. These records compare favorably with those made on smaller fires. However, travel time on large fires should be reduced. Normal speed and normal attacks are not good enough for fires burning under conditions where rapid spread is likely.

Strong initial attacks are common on large fires. Detailed studies on 197 class E fires revealed that the first attacks were much stronger than are normally made on fires in this region. As illustrated in figure 119, over 62 percent of the large fires had 4 or more men in the initial attack force, and 19 percent had over 15 men. Less than 15 percent had only one man in the first suppression force. These represent much stronger initial attacks than are normally made on fires in this region and indicate that the probabilities of dangerous burning conditions were recognized.

Over 40 percent of the class E fires receive first reinforcements in crew-sized strength. As illustrated in figure 119, there were 16 or more men in the first reinforcement action on 42 percent of the large fires. Over 25 men were dispatched to 26 percent of the fires, and smokechaser-type reinforcements of 1 to 3 men were made on only 15 percent. Thus it is evident that the need for strong forces is generally recognized both in the first attack and first reinforcement stages. However, it is equally evident that strong manpower forces alone are not sufficient to reduce large fires to an acceptable number. Improved suppression methods and more mechanization are needed.

More effective suppression methods in the early stages of dangerous fires are essential. As shown in the previous paragraphs, a large number of dangerous fires receive reasonably fast and strong attacks in the early stages. Nearly 100 percent of these attacks involve only handtool firefighting. During the past 20 years good progress has been made in stepping up the speed and strength of the firefighting force. This has been made possible largely through the smokejumper program and extensive use of air transportation. But when these men arrive on the fires they must fight it with their hands. Very little progress has been made in actual suppression methods. The analysis of large fires clearly shows that new and more efficient suppression methods are called for. The

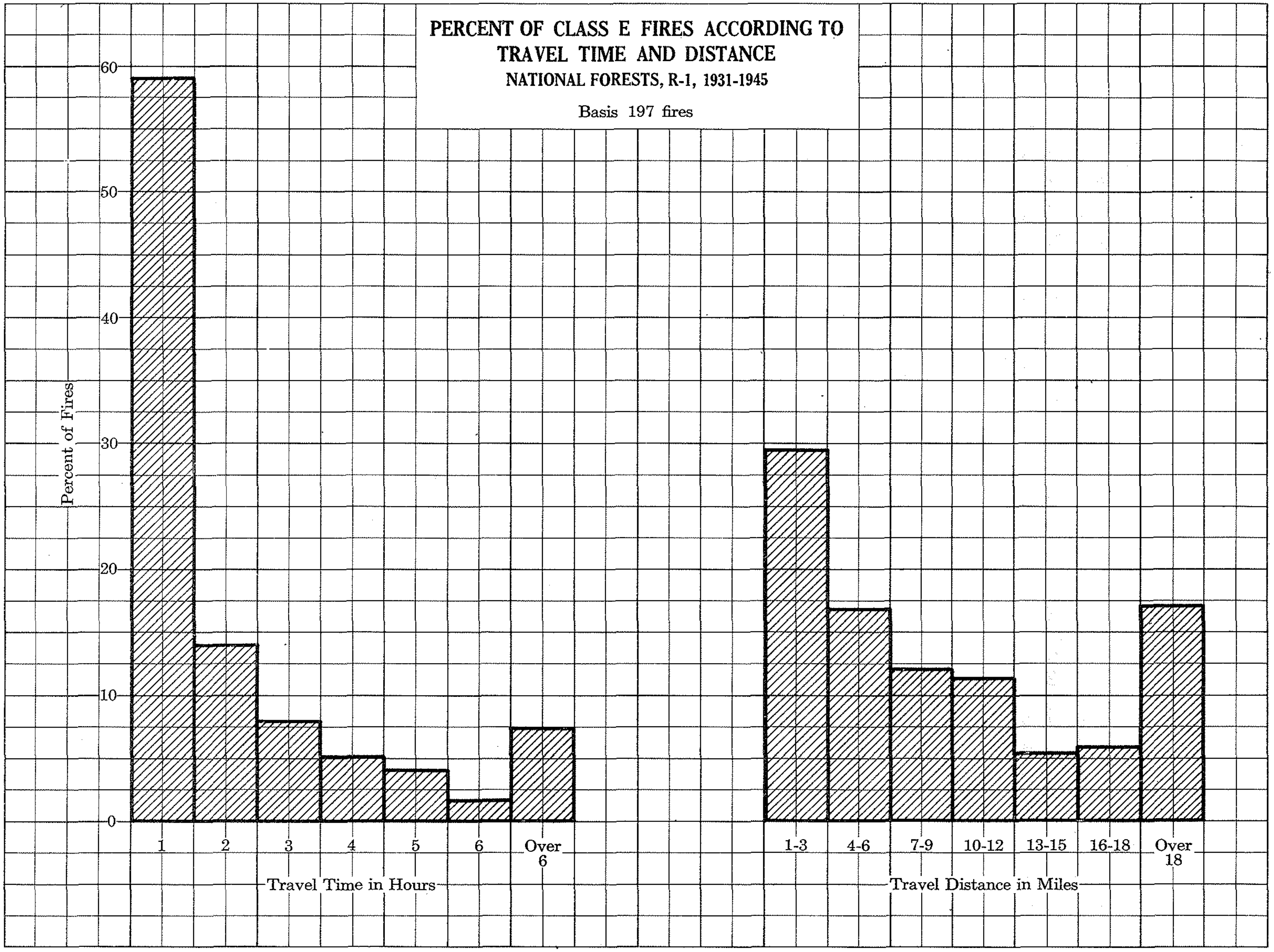

PERCENT OF CLASS E FIRES ACCORDING TO
TRAVEL TIME AND DISTANCE
NATIONAL FORESTS, R-1, 1931-1945
Basis 197 fires
Percent of Fires
0
10
20
30
40
50
60
1
2
3
4
5
6
Over 6
Travel Time in Hours
1-3
4-6
7-9
10-12
13-15
16-18
Over 18
Travel Distance in Miles

Figure 118.

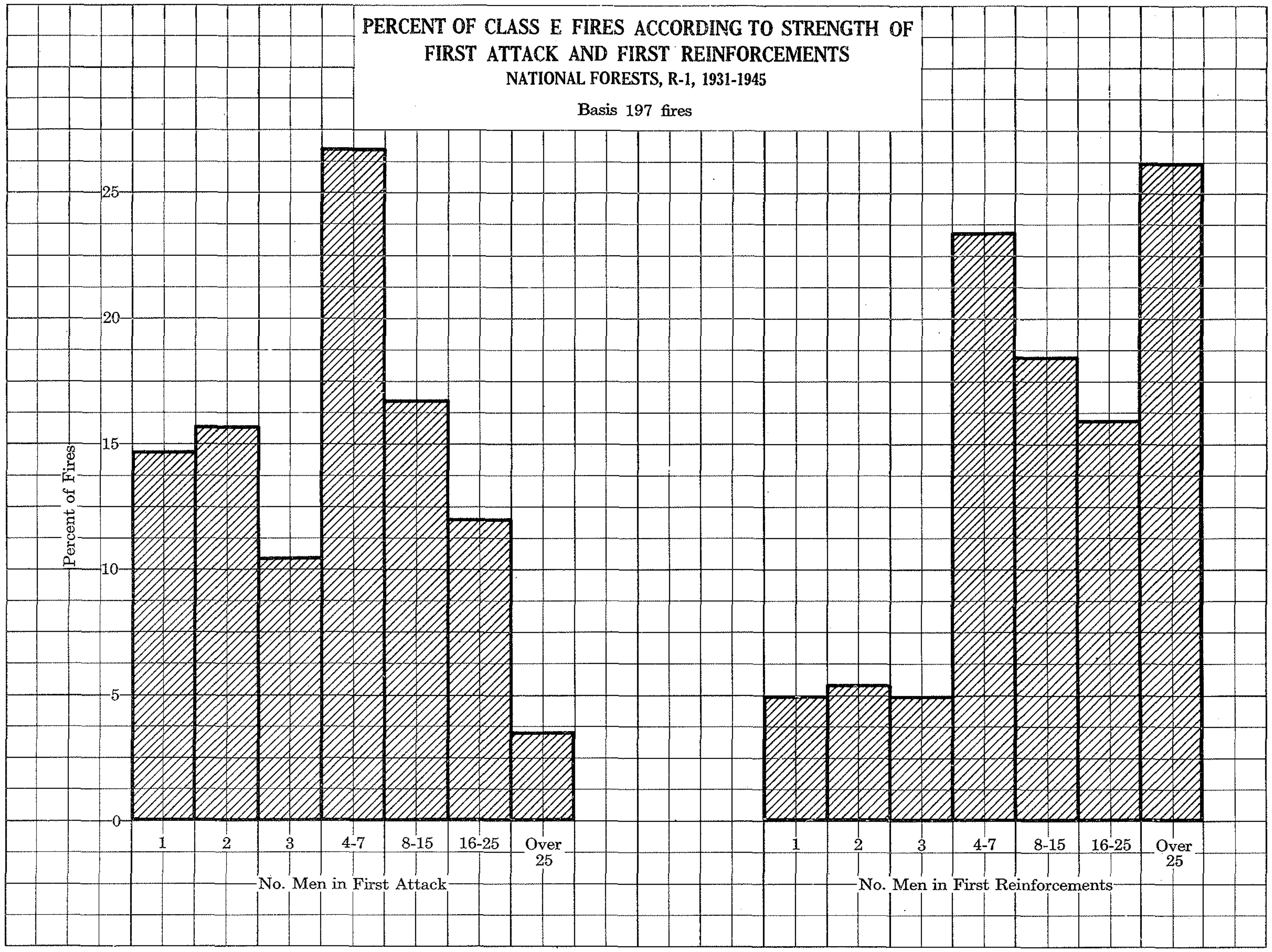

PERCENT OF CLASS E FIRES ACCORDING TO STRENGTH OF FIRST ATTACK AND FIRST REINFORCEMENTS
NATIONAL FORESTS, R-1, 1931-1945
Basis 197 fires
Percent of Fires
0
5
10
15
20
25
1
2
3
4-7
8-15
16-25
Over 25
No. Men in First Attack
1
2
3
4-7
8-15
16-25
Over 25
No. Men in First Reinforcements

Figure 119.

development of these methods and the accompanying equipment must be aimed toward use in initial attack so that the large burns can be reduced or prevented. Here is one of the most challenging and lucrative fields for future fire research.

Output per man-hour is low on large fires. Once a fire reaches a perimeter where a large suppression force is called for, the efficiency per man employed drops rapidly. Studies of 100 fires requiring multiple crew action showed that the output of held fire line is only 0.08 chains per man-hour. This is less than 6 feet of held fire line per man-hour. Part of this low output is caused by losses of line, but the greater part must be charged to inefficient methods of fire suppression. Long travel times from fire camp to fire line, fatigue, and the use of large numbers of pick-up firefighters untrained or unconditioned for the job are major factors contributing to this inefficiency. Again it is clear that far better methods are needed, not only in initial attack but also in the latter stages of those fires which escape quick control.

Nearly half of the man-hours on large fires are devoted to mop-up operations. An average of 15,174 man-hours per fire, or 49.5 percent of the total suppression man-hours, was devoted to mop-up on large fires occurring during the 15-year period 1931-1945. Man-hour requirements for mop-up vary according to fuels. As illustrated in table 63, mop-up requirements are lowest in light fuels, such as grass, and heaviest in heavy fuels such as found in the cedar-grand fir type. In subalpine forests mop-up requirements on large fires are great because of the tendency of these fires to spot and not burn clean.

Table 63. Man-Hours to Control and Mop-Up by Timber Types, National Forests, R-1, 1931-1945, inclusive

(Basis 129 Class E fires)

Timber Type	Number of Fires	Man-Hours to Control	Man-Hours to Mop-Up	Average Hours Control Per Fire	Average Hours Mop-Up Per Fire
White Pine	17	359,705	319,674	21,159	18,804
Ponderosa Pine	21	147,419	177,030	7,020	8,430
Spruce	5	70,735	80,256	14,147	16,051
Larch-Fir	10	232,349	224,335	23,235	22,434
Cedar-Hemlock	2	35,823	34,048	17,911	17,024
Grand Fir	8	623,489	413,097	77,936	51,637
Douglas-fir	12	187,769	230,699	15,647	19,224
Lodgepole Pine	18	67,463	116,306	3,747	6,461
Subalpine	13	100,440	176,338	7,726	13,564
Brush	4	132,504	146,046	33,126	36,511
Grass	19	42,388	39,665	2,230	2,087
TOTAL	129	2,000,084	1,957,494	15,504	15,174
PERCENT				50.5	49.5

7. FIRE SUPPRESSION REQUIREMENTS

What are the requirements for effective fire suppression at least cost? This is the foremost question asked by forest officers planning a fire control system, dispatchers taking initial action on going fires, or fire bosses directing control of large fires. The answer involves consideration of the complex factors influencing the ignition and spread of fires and the capabilities of men and machines in checking the spread. In a sense all of the various phases of this report present fragments of the answer. This final chapter summarizes the experience on the national forests in meeting basic fire suppression requirements.

Fire Suppression Objectives

Controlling each fire during the first burning period is a fundamental objective. The burning period consists of the hours when a fire is most likely to spread at a rapid rate. In this region the burning period normally starts in the mid-morning hours, reaches a peak in the late afternoon, and tapers off gradually in the evening. Obviously, it is good business to attempt to prevent a fire from remaining uncontrolled during more than one burning period. Each time a fire enters a new burning period there is a likelihood that it may spread to large size. Established Forest Service policy requires that all fires burning under possibly dangerous conditions be controlled within the first burning period or not later than 10 a.m. of the day following discovery (11).

The policy of control by 10 a.m. has proved sound. It was not possible in this study to determine the exact hour of the day when each fire was controlled. However, the available data gave an excellent idea of the soundness of the 10 a.m. policy. For example:

1. Ninety-six percent of the area burned resulted from fires escaping control by the initial attack forces.

2. Ninety-nine percent of the fires controlled within 12 hours were held to class A or B size.

Achieving the 10 a.m. objective requires that held line be built faster than the fire gains perimeter. For example: Assume that a fire is discovered at 4 p.m., and from that hour to 10 a.m. the next day it spreads to a total perimeter of 50 chains or an average rate of spread of 2.77 chains per hour over the 18-hour period. The suppression force reaches the fire at 6 p.m. Because of darkness only about 8 hours are available for fully effective suppression action prior to 10 a.m. Therefore, the suppression force must be capable of building held fire line at a rate not less than 6.25 chains per hour. The number of men required to do the job will depend upon their capabilities as firefighters and the resistance to control of the fuels involved.

Fuel Classification and Fire Suppression Requirements

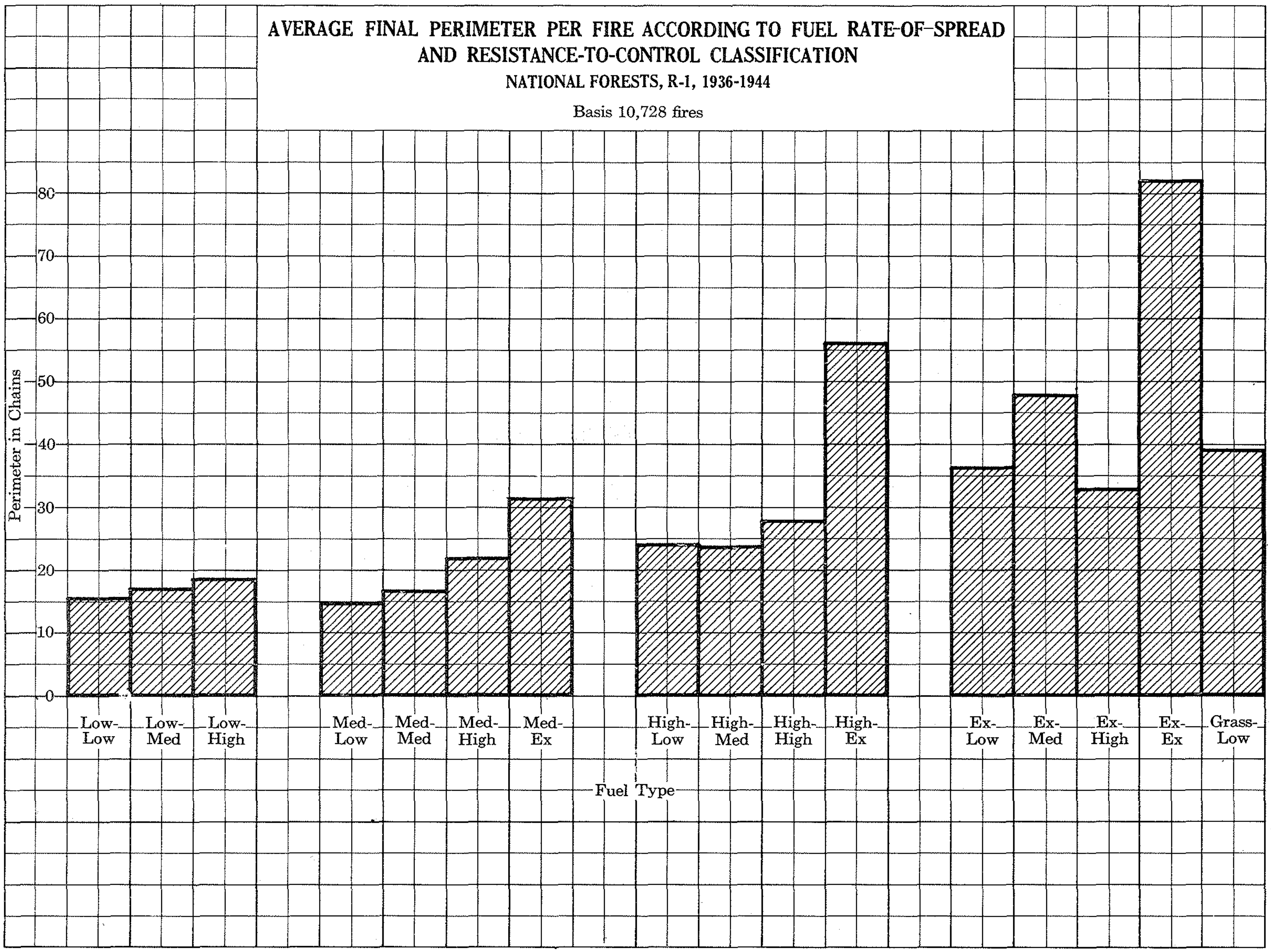
Fuels have a major influence on fire suppression requirements. Both rate-of-spread and resistance-to-control ratings indicate the size of the job on a fire. As illustrated in figure 120, a remarkable correlation was found between fuel classification and average final perimeter of fires. With each increase in rate-of-spread classification the final perimeter increases. Likewise, as resistance to control increases, the final perimeter increases. Thus the size of the fire and consequently the size of the suppression job are determined by how fast the fire gains perimeter and how fast the control forces can check the spread.

Production of held fire line decreases as resistance to control increases. Studies of nearly 11,000 fires indicated that fuel type mappers have done a good job in recognizing the conditions governing the production of held fire line. Average held line production was found to vary from 0.72 chains per man-hour in low resistance-to-control fuels to 0.22 chains in extreme fuels. As explained previously in chapter 6, held line production is much lower on large fires. On smokechaser and small crew fires it is higher. The following is a comparison between the R-1 resistance-to-control standards and actual performance on 5409 fires where fuel type, manpower, and line production were known:

Resistance To Control	Chains of Held Line Per Man-Hour: R-1, Smokechaser Standards	Chains of Held Line Per Man-Hour: Average For 5409 Fires
Low	3.2	0.72
Medium	2.0	0.57
High	0.8	0.43
Extreme	0.2	0.22

Fuel classification indicates probabilities of successful attacks by smokechasers and small crews. Over 96 percent of the fires in this region are handled successfully by smokechasers or small crews of not over 15 men. However, the remaining 4 percent of the fires account for 49 percent of the fire perimeter on which suppression action is required. As fuels become more dangerous, a smaller portion of the suppression job can be handled successfully by smokechasers or small crews. Table 64 shows that more than 50 percent of the fire perimeter requires large crew suppression action in all fuel types except one when the rating is higher than medium-medium. This indicates clearly that as fuels become more dangerous, the suppression requirements become higher. Fuel classification is the first factor to be considered in determining suppression requirements.

In extreme resistance fuels only a small part of the suppression job can be handled by smokechasers or small crews. As illustrated in figure 120, fires in fuels rated extreme resistance to control have greater average final perimeters than any other types. These fires call for something stronger than smokechaser or small crew action. As shown in table 64, large crews were required on the great bulk of the fire



AVERAGE FINAL PERIMETER PER FIRE ACCORDING TO FUEL RATE-OF-SPREAD AND RESISTANCE-TO-CONTROL CLASSIFICATION
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,728 fires
Perimeter in Chains
0
10
20
30
40
50
60
70
80
Low-Low
Low-Med
Low-High
Med-Low
Med-Med
Med-High
Med-Ex
High-Low
High-Med
High-High
High-Ex
Ex-Low
Ex-Med
Ex-High
Ex-Ex
Grass-Low
Fuel Type

Figure 120.

Table 64. Average Annual Chains of Fire Perimeter Handled By Smokechasers and Small Crews and Large Crews in Each Fuel Type, National Forests, R-1, 1936-1944, inclusive

(Basis 10,728 fires)

Fuel Type: Rate of Spread	Fuel Type: Resistance To Control	Chains of Fire Perimeter: Smokechasers and Small Crews	Chains of Fire Perimeter: Large Crews	Chains of Fire Perimeter: Total	Percent of Fire Perimeter Handled By Large Crews
Low	Low	1,816	1,264	3,080	41.04
Low	Medium	1,230	911	2,141	42.55
Low	High	65	42	107	39.25
Medium	Low	1,987	847	2,834	29.89
Medium	Medium	3,088	2,175	5,263	41.33
Medium	High	495	709	1,204	58.89
Medium	Extreme	15	49	64	76.56
High	Low	1,273	1,426	2,699	52.83
High	Medium	684	830	1,514	54.82
High	High	617	1,236	1,853	66.70
High	Extreme	32	62	94	65.96
Extreme	Low	10	33	43	76.74
Extreme	Medium	2	158	160	98.75
Extreme	High	6	0	6	0.00
Extreme	Extreme	0	14	14	100.00
Grass	Low	1,074	2,255	3,329	67.74
TOTAL		12,394	12,011	24,405	49.21

perimeter in these fuels. This illustrates that slow production of held fire line not only causes increased perimeter, but also lessens the chances for successful control by small suppression forces. The difficulty of control in these types indicates the need for fuel reduction programs.

Burning Index and Fire Suppression Requirements

Burning index provides a useful guide to suppression force requirements. In previous chapters it has been pointed out that as burning index increases, rate of spread and final perimeter will likewise increase. Translated in terms of suppression action, this means that more powerful attacks are required when burning index reaches high ratings. It also means that the chances are increased for fires to escape control by normal attacks as burning index increases. This fact is strikingly illustrated in figure 121. At a burning index of 10 nearly 90 percent of the total fire perimeter can be handled successfully by smokechasers or small crews. At a burning index of 80 less than 30 percent of the total fire perimeter can be handled by these small forces.

Smokechaser and small crew fires require greater forces as burning index increases. Studies of 10,728 fires showed that 10,332, or 96.3 percent, were handled by smokechasers or small crews. As burning index increased, these smokechaser and small crew fires became larger, and consequently the suppression job became more difficult. Figure 122 illustrates how final perimeters of these fires varied from an average of 8 chains at a burning index of 10 to nearly 18 chains at a burning index of 80. These fires averaged less than 10 chains in perimeter up to a burning index of 45. Above this rating perimeters were found to increase sharply.

Fire Suppression Efficiency

Fire suppression costs vary according to fuel type, burning index, and the success of the initial attack. As fuels become more dangerous and as burning index increases, fires spread faster and reach greater final size. These two factors thus combine to exert a major influence on the difficulty of the suppression operation and consequently the cost. If a fire is controlled successfully in its initial stages, suppression costs are normally moderate. However, if the fire escapes early control and spreads to large size, the costs of suppression become very great. This is illustrated by the following comparison:

Average Suppression Man-Hours Per Fire
From Initial Attack to Control

Class A and B Fires	18
Class C and D Fires	455
Class E Fires	16,426

The most economical method of fire suppression is one which will provide high efficiency in initial attack. Throughout this report the importance of controlling fires at small size has been emphasized. Fire suppression costs are directly related to the ability of control forces to achieve this essential objective. The foresters who design the protection systems, the forest administrators who manage these systems, the dispatchers who

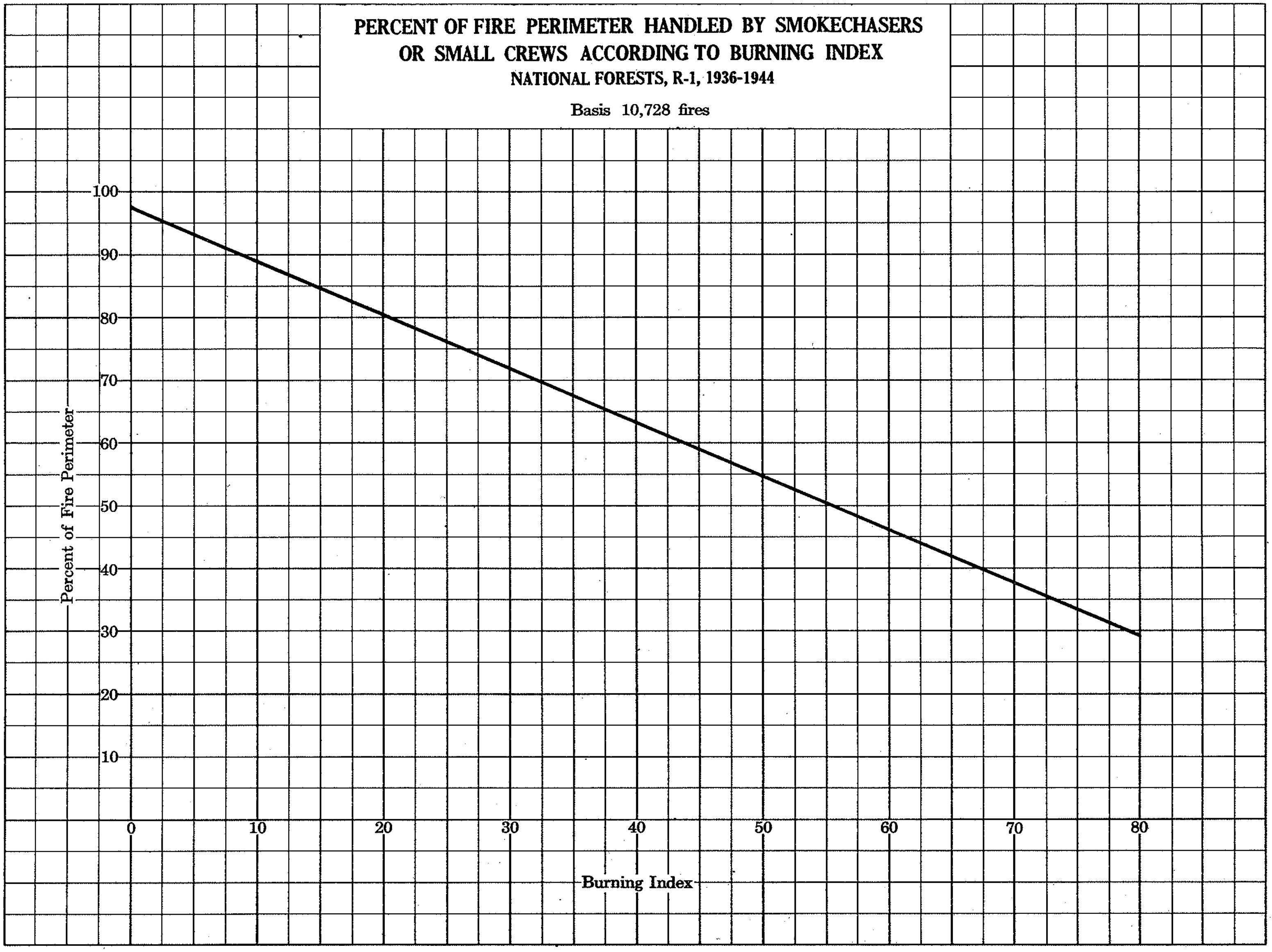

PERCENT OF FIRE PERIMETER HANDLED BY SMOKECHASERS
OR SMALL CREWS ACCORDING TO BURNING INDEX
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,728 fires
Percent of Fire Perimeter
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
Burning Index

Figure 121.

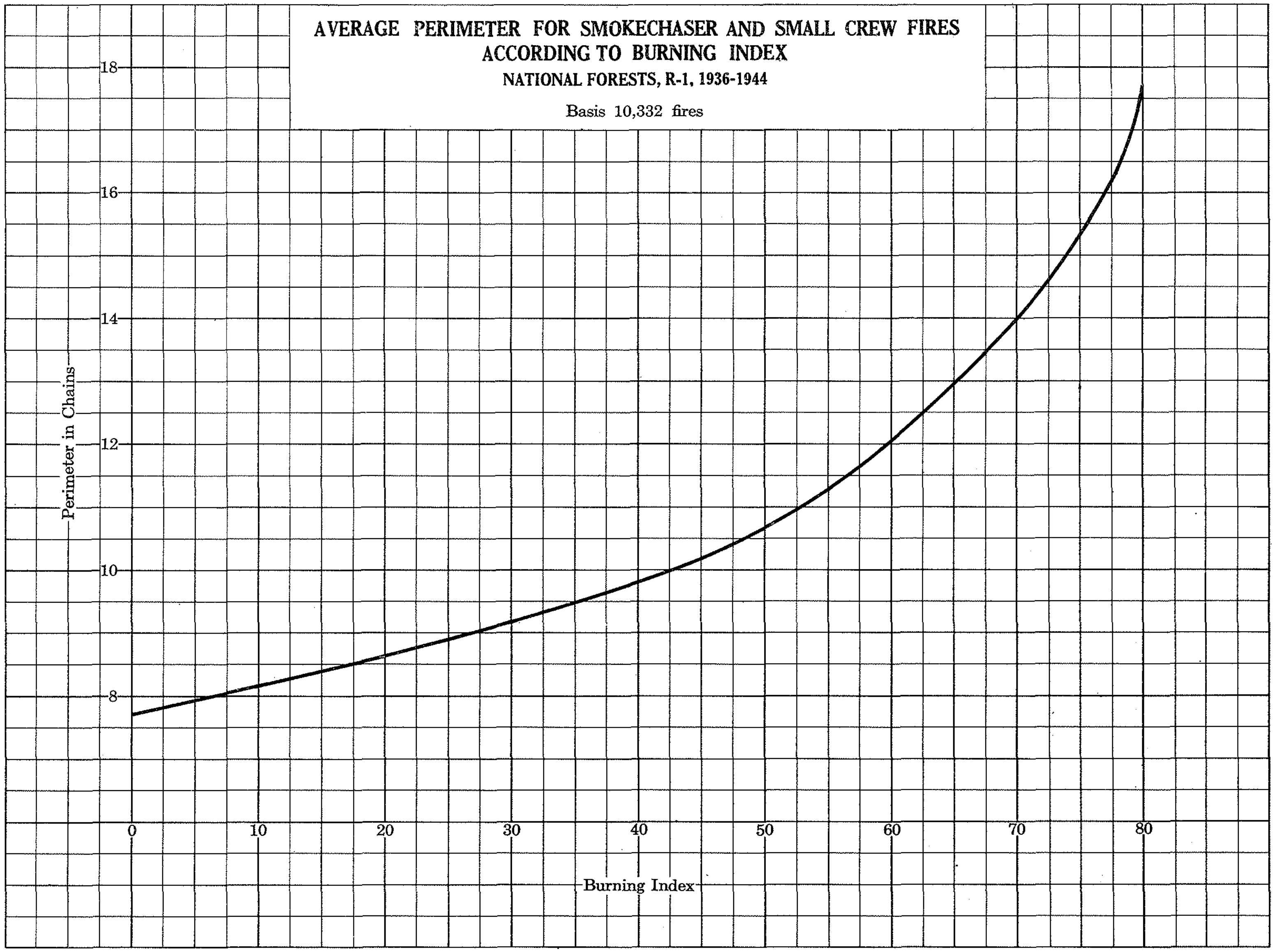

AVERAGE PERIMETER FOR SMOKECHASER AND SMALL CREW FIRES
ACCORDING TO BURNING INDEX
NATIONAL FORESTS, R-1, 1936-1944
Basis 10,332 fires
Perimeter in Chains
18
16
14
12
10
8
0
10
20
30
40
50
60
70
80
Burning Index

Figure 122.

initiate action on going fires, and the men who direct operations on the fire line all must play a part in preventing large and costly fires. The thousands of fires analyzed in this research project have provided many facts which can guide fire control organizations in achieving effective and economical suppression action. In summary these things stand out:

1. The fire control planner is guided by many factors, but above all he must classify and rate fuels as the major basis for determining the type, strength, and location of suppression forces.

2. The fire control manager needs to vary the type, strength, and location of his forces to meet changing conditions during a fire season. Burning index ratings provide the major basis for making these changes.

3. The fire dispatcher needs to consider the probable rate of spread on each fire in determining suppression force requirements. Burning index and fuel type provide the first basis for these estimates which then must be raised or lowered according to topographic factors at the site of the fire. Furthermore, if burning index is high and fuels are tough, the fire dispatcher must realize that the chances are decreased for a successful initial attack and make preparations for strong reinforcement action which may still prevent the disaster of a large fire.

4. The men directing operations on the fire line must make their own estimate of rate of spread and resistance to control in accordance with existing weather, fuel, and topographic conditions. The results of this estimate must be used promptly to alter the strength, type, and location of the suppression force as necessary.

5. The efficiency displayed in each of the above steps largely determines how successful a fire organization will be in preventing large fires. In the final analysis the fire control job boils down to the competence of personnel. Few phases of the forestry profession require greater technical skill than does fire control.

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