FOREST FIRE CONTROL IN THE UNITED STATES OF AMERICA.

by.

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Forestry Commission of ~~N.S.~~ New South Wales
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The Secretary,
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SYDNEY.

Forest Fire Control in the United States of America
~~INVESTIGATIONS INTO FORESTRY MATTERS IN N.S.W.~~

Submitted herewith is a comprehensive report on Forest Fire Control in the United States of America which has been prepared following investigations into the subject, in U.S.A., from November 1939 to May 1940.

The abovementioned investigations were initiated at the School of Forestry, Yale University, Connecticut, U.S.A., during a period of four months from November 1939 to February 1940. Despite the wealth of literature available in U.S.A. on all details of fire control practice and administration, there is no comprehensive publication covering all phases of the problem. For this reason, the time spent at Yale School of Forestry was devoted to an assembly and review of all available literature on fire control in U.S.A.

Under the aegis of the United States Forest Service, an additional period of three months was later spent in a necessarily brief inspection of fire control practice and administration throughout the various forest regions of U.S.A. Because of the need for studying methods of fire control under a diversity of climatic and forest conditions, this tour of inspection involved some 18,000 miles of travel in the United States, including short journeys made to Eastern Canada, and to British Columbia, in order to study Canadian aspects of the fire control problem.

The results of all investigations made have been summarized in the general report submitted herewith. No apology is made for the volume of material included within the report, as any adequate description of the extremely comprehensive fire control administration developed in the United States must cover a very wide range of subjects. The standard already reached by Americans in their fire control organisation is so far removed from any Australian standards that no attempt has been made, in this report, to apply any American standards to present Australian practice in fire control. In addition, climatic and forest conditions vary just as much within Australia as they do in U.S.A., so that any attempted generalizations between the two countries would be inaccurate in detail.

It has been considered more advisable to furnish a full report on present American practice, so that Australian foresters can study any or all of its many phases, according to the climatic conditions, forest types, or fire problems with which they are concerned.

This report would be quite incomplete if full and grateful acknowledgment was not made to the staff of the Yale School of Forestry, of the United States Forest Service, of the Los Angeles County Forest Department, and to numerous State, County and private foresters, for their unfailing courtesy and assistance.

The report submitted deals largely with the activities, standards, practice etc. of the U.S. Forest Service, as it was scarcely possible, in the time at my disposal, to make any adequate investigation of fire control standards attained by State, County and other administrations.

WMuir (W.D. Muir)

Divisional Officer.

Map showing National Forests of U.S.A. and boundaries of the Administrative Regions - U.S. Forest Service.
Route of travel taken during Fire Control Investigation shown by firm violet line (rail travel) and broken violet line (car travel).

I N D E X.

PART III - PREPAREDNESS ACTIVITY.

PART IV - SUPPRESSION ACTIVITY.

PART V - ECONOMICS.

INTRODUCTORY - THE ROLE OF FOREST FIRES IN THE MANAGEMENT OF UNITED STATES FORESTS.

A. The Influence of Fire on Forests.

The old adage describing "Fire as a good servant but a bad master" is nowhere more applicable than in the case of forests. The constituents of a forest utilise the process of photosynthesis to manufacture wood cellulose from carbon dioxide, water and solar energy. This process is an extremely slow one, but its steady maintenance is a major aim of forest management. Forest fires, on the other hand, result in an extremely rapid reversal of the entire process, plant forms and their woody cellulose being quickly converted to carbon dioxide, moisture and heat energy.

It must be conceded at the outset that other major factors such as exploitation, attack by fungi and/or insects, play a large part in the normal depletion of the wood capital in living forests. Under forest management, however, exploitation usually has some correlation with increment, while losses from insect or fungal attack usually proceed at such a slow rate that the natural equilibrium of the living forest is not unduly disturbed. In the case of the United States it has been stated (76) that more damage to living forests has occurred from insect attack than from fires, but it must be remembered that much insect (and fungal) attack is the direct result of minor injury to trees by fires. If fire prevention measures in U.S.A. were as poorly organised as insect control measures, it is reasonable to assume that fire damage would soon exceed that shown by insect attack.

Early training in forestry in U.S.A., influenced as it was by European schools of thought and tradition gave little serious attention to the fire problem. Foresters trained along these lines often found themselves soon afterwards engaged in work almost wholly connected with fire protection. It is not surprising that many of these men developed the impression that all fires were detrimental to forest management and, as such, merited only ruthless suppression. Because the injurious effects of forest fires were so numerous and so apparent, little thought was given to any beneficial result of fires, and the use of fire in silvicultural practice was consistently overlooked.

Fire protection, or Fire Control, has developed in a scientific way only during the last two decades. No general technique has yet been developed because of the ramifications of the subject, and because it is necessary to test by experience many theories and ideas which may later become integral parts of the Fire Control organisation. It is necessary for foresters to recognise the variety of factors which influence both the causes and effects of forest fires, while they must also learn to grasp the significance of any dominating factors. They must not rely too much on personal experience of fire control and suppression, as few fires show comparable behaviour and there is always the likelihood of having to combat fires under wholly unpredictable burning conditions.

Above all things he learns in studying the fire problem, the forester must not fail to regard fire in the forest as a natural phenomena, which, if allowed to become uncontrolled, may nullify years of silvicultural practice in the space of as many hours.

B. Historical record of forest fires in U.S.A.

(i) Prior to colonization -

Definite evidence is available that fires have occurred in Northern America for very many centuries. Examinations made by Sears of the peat deposits in the Medecine Bow Mountains of Wyoming show evidence of fires for 10 to 15 centuries past.

Plummer (152) produces evidence of extensive fires long before any early discoveries of the territory now included in the United States. Firo scars on California big-trees are reported (140) to reveal the occurrence of fires in the years 245, 1441, 1580 and 1797. There is similar evidence of extensive fires in Colorado during the 17th and 18th centuries, and in Maine (200 square miles) at the end of the 18th century.

Early travellers noted that extensive burning was practised by the Indians. Dwight (41) supplied information of such burning and expressed the opinion that it had been in progress for more than 1000 years. Similar accounts are given by Percy (151) in 1625, and by the Dutchman, de Vries (40) in 1644.

Conclusive evidence of firing many centuries ago can also be gathered from studies made of the succession of various tree types which are now centuries old, and of the gradual withdrawal of tree species from the edges of the Prairies, and from the Chaparral lands of California.

Lightning was probably the cause of many early conflagrations, either during drought years, or under severe burning conditions. Fires lighted by Indians for hunting game or in tribal fighting were probably less serious in extent or character, as Indian tribes seem inherently afraid of fires. It is safe to assume that severe fires occurred in pre-colonization days at longer intervals than at present, while in the absence of the unnatural fuel hazards since produced in forests by the white man - the intensity of fire damage was greatly reduced in extent and in area.

(ii) From early settlement to the end of the 19th century -

The extensive nature of the forests which confronted early settlers caused an intensification of the traditional use of fire in the clearing of agricultural land. The overabundance of timber supplies induced a still more reckless destruction of timber lands even when the land itself was not required for agriculture. Even during the earliest settlement, however, there was some attempt to control the orgy of destruction. The necessity for protecting forests from fires was emphasised by State fire laws passed in Massachusetts in 1743 and in North Carolina in 1777 (94A).

In 1788 the State of New York instructed its officials to combat forest fires, and to summon civilian assistance for the purpose.

The sphere of agricultural activity moved from the timbered lands of the East to the more sparsely timbered areas of the middle West, about the middle of the 19th century. There was a consequent reduction in the general effort to destroy the Eastern forests, but the fire situation was scarcely improved. The early antagonism of Eastern settlers gave way to an indifference which allowed destruction by fire to continue unabated in forest areas. It was during this period that some enormous fires were recorded throughout settled areas. Folweiler and Brown (51) and other observers give a chronological list of these holocausts, as shown in Table No. 1. The records do not reveal the loss of life in all cases, and give no conception of the tremendous damage which resulted from fires of such magnitude. The holocausts of October 1871 undoubtedly caused some serious thinking, and were largely responsible for action by Congress in 1873, when the Timber Culture Act was passed. This Act was directed primarily towards the conservation of dwindling timber supplies in the now settled Prairie regions, and was the first public recognition of any necessity for safeguarding timber supplies. Illick (92) reports that shortly afterwards (1885) several States initiated active steps towards the conservation of forest lands within their boundaries, but the organisation set up in New York State for this purpose was apparently the only one to survive. In 1885 the States of New York and Colorado introduced State-wide fire warden organisations. In 1898 Pennsylvania State initiated forest conservation on the recently acquired watersheds of several of its main rivers, while in the succeeding year the State of Minnesota commenced the care of a forest domain.

While these early efforts did not accomplish any material benefits, they were at least some evidence of a slowly awakening public interest in forest conservation. This feeling became even more active towards the end of the 19th century, and at last forced Federal Congress into definite action towards the more general conservation of the national resources of the country. The support for forest conservation was perhaps actuated by the rise in Eastern lumber prices, and by a fear of future timber famines. The first significant action of the new conservation policy was taken by Congress in 1891 when the President was empowered to create Timber Reserves from the remnants of the Public Domain, (= Federally-owned land) but no great progress was made until 1897, when an administration was set up to control these Reserves. By the end of the century nearly 47 million acres of reserves had been created, and the nucleus of a Forest Service organisation developed.

(iii) From the beginning of the 20th century.

The 20th century was ushered in by several fires of historical character, the most notable of these being the Columbia fire (Oregon and Washington) of 1902 which traversed 604,000 acres and caused 18 deaths; the Adirondack fire (New York) of 1903 which burnt 450,000 acres; the Baudette fire (Ontario and Minnesota) of 1910 which covered 300,000 acres and caused 42 deaths; the Great Idaho fire (Idaho and Montana) also in 1910 which traversed two million acres and resulted in 85

TABLE NO. I.

Table giving details of fires occurring in U.S.A. in the 19th Century.

YEAR	MONTH	NAME OF FIRE	STATE OR PROVINCE	ACREAGE BURNED	LIVES LOST
1825	October	Miramichi	Maine-New Brunswick	3,000,000	160
1846	---	Yaquina	Oregon	450,000	
1853	May	Pontiac	Quebec (Canada)	1,600,000	
1853	---	Nestucoa	Oregon	320,000	
1865	---	Silverton	Oregon	1,000,000	
1868	September	Coos	Oregon	300,000	
1868	September	St. Helens	Oregon	300,000	
1871	October	Peshtigo	Wisconsin	1,280,000	1500
1871	October	Michigan	Michigan	2,000,000	138
1876	---	Big Horn	Wyoming	500,000	
1881	September	Michigan	Michigan	1,000,000	138
1894	---	Phillips	Wisconsin	100,000	300
1894	September	Hinckley	Minnesota	160,000	418

deaths; and the Cloquet fire (Minnesota) of 1918 which swept 250,000 acres and caused 438 deaths. Such large fires gradually decreased in number and in frequency of occurrence, but even in recent years there have been several tremendous outbreaks. The most recent of these were the Matilja Canyon fire of California in 1932 (220,000 acres), the Tillamook Burn of Oregon in 1933 (245,000 acres), the Selway fire of Idaho in 1934 (250,000 acres) and a "re-burn" of the Tillamook area (200,000 acres) in 1939.

Statistics of forest fires prepared by the U.S. Forest Service have been summarised in Table II. It will be noted that recent years have shown a marked but steady increase in the number of fires occurring, but despite such increase there has been a steady decrease in the percentage of protected area burnt over. The improvement in fire protection is reflected in each of these trends, improved detection measures are responsible for an increased number of reported fires, while more efficient methods of prevention and suppression have greatly decreased the percentage of protected area burnt over.

From the details already given of outstanding fires in the past hundred years it will be noted that the location of these huge outbreaks moved from the North-East regions to the Lakes States, and thence to the Western regions. No mention has been made of extensive fires in the Southern region and it is perhaps opportune to note at this stage that no forest areas in U.S.A. have been so consistently and deliberately burned over during the past century as those of the Southern States. The doubtful distinction of having the largest area of annual burn, and the greatest number of fires per annum still remains with the Southern States. So much has fire become a part of Southern forestry, that it is extremely doubtful whether any scheme for the total exclusion of fire from Southern forests can hope to succeed. It would appear that a very necessary reduction in the number and extent of Southern fires can only be effected by efforts to educate the residents in the intelligent use of fire, and by honest endeavours to sift the various claims made by local inhabitants respecting the advantages of periodic forest fires.

C. The development of organised fire protection.

The preliminary efforts made by the States in this direction, together with the establishment in 1897 of an administration to control the national Timber Reserves, have already been noted.

Federal activity in fire protection did not commence in earnest until the forestry administration was transferred, in 1905, from the Department of the Interior, and the nucleus of the existing U.S. Forest Service created under the Department of Agriculture. The first ten years of the century were notable for the remarkable increase in the area of National Forests (from 47 to 195 Million acres). The latter figure is actually the highest acreage ever included within such forests - slight reductions following in later years as boundaries were improved, and as agricultural areas were released from forest use. The conservation policy of Theodore Roosevelt and the dynamic influence of Gifford Pinchot, Chief Forester of the United States, were mainly responsible for such rapid acquisition of forest areas by the Federal Government.

During the 19th century, the Government's policy had been directed towards general national development by the wholesale transfer of the Public Domain to private enterprise. The conservation era, sponsored by President Theodore Roosevelt, reversed the national policy of land disposal, and saw the foundations of forest management and protection laid in the United States.

When H. S. Graves succeeded to the position of Chief Forester in 1910, active interest in fire protection soon became the theme of his administration. In Graves' own words (64) of 1910 was laid down a basic principle - "The first measure necessary for the successful practice of forestry is protection from forest fires." This theme was soon developed and such development can be studied in Forest Service Bulletins (152) and (153) issued in 1912.

The Forest Service soon achieved a marked measure of success in the protection of National Forests from fire, but only a limited percentage of the forest area of the nation was included in these areas, and burning on private and State forest lands remained largely uncontrolled.

The first step taken in the co-ordination of protective efforts on all types of forest land, Federal, State or Private, was the passing of the Weekes Law by Congress in 1911. This law empowered the Forest Service to co-operate with the States in organising and maintaining a system of fire protection on any private or State lands "situated on the watershed of navigable rivers". Co-operation was not possible unless the State in question had provided by-laws for a system of forest fire protection. During the first year after the passing of the Weekes Law, co-operation with eleven States had been initiated and the following expenditures had been incurred by contributing bodies:- Federal Government-$36,692, States-$165,975 and Private landowners - $54,790. Co-operative efforts were steadily increased, and in 1925 there were 29 States included in the scheme - expenditures on fire protection from the various sources having increased to $397,651 by Federal authorities, and to $1,844,192 by States and private landowners.

In 1924 the Weekes Law was superseded when Congress passed the Clarke-McNary Act. The latter Act removed the limitation of protection to the forested watersheds of navigable streams, provided for co-operation through the States with private owners of forests, and for joint action with the States in the establishment of windbreaks, shelter belts, farm woodlots, and in farm forestry extension generally.

Under the combined provisions of the two above mentioned laws, the following expenditures were incurred (215) from March, 1911, to June, 1932, on fire protection and on other improvements to private and State forest lands:-

Federal Government Expenditure -------	$10,787,197
State Governments and Private Owners -	$36,637,286
TOTAL ------	$47,424,483

The improvement effected can best be summarized with the observation that the area of State and private forest land under protection increased from approximately 95 million acres in 1915 to 226 million acres in 1931, and to 308 million acres in 1938. As the total area of such lands needing protection was stated (187) to be 467 million acres in 1938, there is still room for considerable improvement. Meanwhile the 192 million acres included within National Forests at the end of 1938 are entirely under protection - bringing the total area under fire protection in the United States in 1938 to slightly more than 500 million acres.

These achievements have not been brought about without considerable difficulties, principal among these being the limited area within State forests and the consequent indifference of many States to the organisation of protective schemes. As far back as 1906, Idaho landowners had attempted to organise the co-operative protection of private forest lands and similar efforts were later made in Washington and Oregon. Difficulties which arose in these private schemes owing to the refusal of some landowners to co-operate, were later solved by several States which passed laws compelling all landowners within a protective area to make contributions to the local protective association.

The provisions of the Clarke-McNary Act have now been extended to 42 out of 48 States in the Union. Only four of these States have State Forests exceeding 400,000 acres in extent and the primary function of most State forestry administrations is the fire protection of extensive private forests and of limited areas of State Forests. In some instances the State assumes directly responsibility for fire suppression on all private forests. Elsewhere this responsibility is limited to those areas where landowners co-operate in meeting the costs of fire protection. In other cases the State admits no responsibility, but provides forest owners with financial assistance where concrete schemes for the prevention and suppression of fires have been originated. In all cases, the State acts as an intermediary for the Federal Government in the financial assistance provided by the latter to private owners of forests who undertake fire protection - while the State Forester and the Federal Forest Service jointly develop plans for fire protection.

As fire control measures on National Forests and on other forest areas became improved, there was a pressing need for more liberal expenditure if planned improvements for the protection of forests were to become realities. The Copeland Report (215) of 1933 recommended that existing annual expenditure on fire control in National Forest areas be increased from 5·72 to 6·853 cents per acre. Of the additional expenditure 74% was allocated for the improvement of transportation facilities by the construction of roads and trails. This Report also recommended that annual costs for the protection of other forest areas be increased from an amount of 7¼ million dollars in 1931 to a figure approximating 20 million dollars. Other increases in expenditure were also recommended for the adequate fire protection of National Park areas, Indian Reservations, and the unclassified areas in Federal ownership known as the Public Domain. The total amount involved in the increased expenditures recommended for the protection of all forests was approximately 21½ million dollars per annum.

Details are not available of the extent to which this programme of expenditure was actually followed, but much of

T A B L E N O. II.

Number of Fires and Percentage of PROTECTED Area Burned Annually in U.S.A 1926-1938 inc.

YEAR	GROSS AREA PROTECTED			AREA BURNED			% OF PROTECTED AREA BURNED			NUMBER OF FIRES			AVERAGE SIZE OF EACH FIRE		
	(1)	(2)	TOTAL	(1)	(2)	TOTAL	(1)	(2)	TOTAL	(1)	(2)	TOTAL	(1)	(2)	TOTAL
1926	-----	-----	339,237,910	---	----	4,754,580	--	--	1·40	--	---	33,867	-	-	140
1927	-----	-----	359,724,000	---	----	2,784,450	--	--	0·77	--	---	35,300	-	-	79
1928	-----	-----	367,605,460	---	----	4,110,690	--	--	1·12	--	---	39,260	-	-	105
1929	-----	-----	395,674,620	---	----	4,876,320	--	--	1·23	--	---	44,076	-	-	110
1930	-----	-----	399,141,870	---	----	5,809,320	--	--	1·46	--	---	70,832	-	-	82
1931	134,609,800	266,173,460	400,783,260	550,920	5,885,580	6,436,500	0·41	2·20	1·60	5715	56,459	62,174	96	104	104
1932	138,524,970	266,722,820	405,247,790	418,600	3,233,610	3,652,210	0·30	1·21	0·90	4933	55,567	60,500	85	58	60
1933	176,696,120	266,259,000	442,955,120	380,230	3,342,690	3,722,920	0·22	1·26	0·84	4517	48,770	53,287	84	69	70
1934	182,167,240	282,979,000	465,146,240	658,470	3,514,570	4,173,040	0·36	1·24	0·90	8064	61,254	69,318	82	57	60
1935	180,443,270	288,750,920	469,194,190	227,680	2,311,430	2,539,110	0·13	0·80	0·54	7962	54,592	62,554	29	42	41
1936	187,122,400	298,364,660	485,487,060	424,620	3,792,310	4,216,930	0·23	1·27	0·87	11144	73,709	84,853	38	51	50
1937	182,872,370	301,911,350	484,783,720	89,770	1,254,120	1,343,890	0·05	0·42	0·28	9468	54,292	63,760	9	23	21
1938	191,860,240	308,458,000	500,318,240	315,600	2,623,270	2,938,870	0·16	0·85	0·59	9873	76,326	86,199	32	35	34
1945					2,456,795						48,176				
1946					2,252,795					11,886	66,103				

(1) = National Forests.
(2) = State and Private Land.

T A B L E N O. III.

Summary of the Extent of Fire Occurrence and Damage in U.S.A. During Recent Years.

OWNERSHIP OF FOREST	FOREST AREA REQUIRING PROTECTION (acres)	PROTECTED AREA					UNPROTECTED AREA				
		AREA UNDER PROTECTION (acres)	NUMBER OF FIRES	AREA BURNT (acres)	ESTIMATED DAMAGE	% OF TOTAL AREA BURNT	AREA NOT UNDER PROTECTION (acres)	NUMBER OF FIRES	AREA BURNT (acres)	ESTIMATED DAMAGE	% OF TOTAL AREA BURNT
YEAR - 1938											
Federal	191,860,000	191,860,000	9,873	315,600	$ 907,370	0·16	-----------	-------	----------	-----------	-----
State & Private	467,341,850	308,458,000	76,326	2,623,270	$7,179,630	0·85	158,883,850	146,030	30,876,230	$28,801,460	19·43
TOTAL	659,202,290	500,318,240	86,199	2,938,870	$8,087,000	0·59	158,883,850	146,030	30,876,230	$28,801,460	19·43
AVERAGE FOR 5 YEARS:- 1934-38											
Federal	184,824,290	184,824,290	9,301	343,228	$1,011,930	0·19	-----------	-------	----------	-----------	----
State & Private	486,406,270	296,127,810	64,033	2,699,140	$6,382,306	0·91	190,278,460	117,608	31,397,025	$31,045,624	16·50
TOTAL	671,230,560	480,952,100	73,334	3,042,368	$7,394,236	0·63	190,278,460	117,608	31,397,025	$31,045,624	16·50

the work planned for completion under such programme has been undertaken since the formation in 1933 of the Civilian Conservation Corps. This organisation had the dual objectives of placing legions of American youth in employment and of completing many public works and improvements to benefit all spheres of American national life.

Figures made available (45) show that, for the six year period ending March 31st 1939, some 2,500,000 youths, war veterans, Indians and others had been so employed. Among the major tasks allotted to the Corps was the improvement of forest areas throughout the country, and the following figures summarise the major achievements towards improving fire protection of both Government and Private Forests:-

9½ Million Man-days spent on fire-fighting, fire prevention, and pre-suppression works.

New Construction -	100,000	miles of truck trails or minor roads
"	20,000	" " foot, horse, and other trails
"	70,000	" " telephone lines
"	62,300	" " fire breaks
"	43,000	bridges
"	2,700	lookout towers
"	70	radio stations
"	57	aerodromes

Reduction of fire hazard on approximately 2 million acres of forest, and along 70,000 miles of roads.

Generally speaking the provision of labour under the C.C.C. scheme has enabled foresters to achieve many improvements to the fire protection of their areas which would have been denied them for many years under existing or hoped-for expenditure appropriations.

D. The extent of the fire problem in U.S. forestry.

(1) Number of fires and acreage burned over annually.

The extent of the fire problem as it now exists in U.S.A. is illustrated in Table No. III, which gives particulars of the number of fires, acreage burned over etc. during the year 1938, and also for the 5 year period from 1934 to 1938. As the 5 year period is less dependent on variable conditions of fire hazard than a single year - figures from the longer period only will be quoted hereunder. During such period there was an annual average of 190,942 fires, which covered 34,439,393 acres in area, and caused annual damage estimated at $38,439,860. The effectiveness of fire protection on forests of different ownership is illustrated in Table No. 4. This table shows that although the area included under unprotected State and Private forests was only 30 per cent of the total area of forests in U.S.A. - no less than 62 per cent of all fires, 91 per cent of the area burnt, and 80 per cent of all damage, took place on this unprotected area during the period 1934-38. These latter figures provide a remarkable comparison with the percentages given for the National Forests, which embrace almost the same total area of forest. No other figures could more effectively demonstrate the comparative efficiency of protection measures on National Forest Areas, and the magnitude of the problem still existing on unprotected State and Private forest lands.

TABLE NO. 4.

Showing variations in fire damage in U.S. forests according to classes of forest ownership (for the five period 1934-38)

CLASS OF OWNERSHIP	AREA OF FORESTS (ac)	PERCENTAGES			
		OF TOTAL FOREST AREA	OF TOTAL NO. OF FIRES	OF TOTAL AREA OF ALL FIRES	OF TOTAL DAMAGE BY ALL FIRES
National Forests (all protected)	184,824,290	(30%)	5%	1%	3%
State & Private Forests (protected)	296,127,810	(40%)	33%	8%	17%
State & Private Forests (unprotected)	190,278,460	(30%)	62%	91%	80%
TOTAL	671,230,560	(100%)	100%	100%	100%

The major importance of the fire problem in the Southern States can best be gauged when it is revealed that, for the period 1934-38, 78 per cent of all forest fires in U.S.A., 94 per cent of the area burnt, and 83 per cent of all resultant damage, took place in the Southern Region of the country-embracing the States of Alabama, Arkansas, Florida, Georgia, Louisiana, Mississippi, North and South Carolina, Eastern Oklahoma, Tennessee and Texas. The extent of the damage on unprotected areas of State and Private forest land has already been mentioned, and on this class of forest ownership 96 per cent of all fires, 98 per cent of the area burnt and 96 per cent of all damage, took place in the Southern Region. Of the grand total of 34,439,393 acres burned over annually in the entire country during the years 1934-38, the huge area of 30,904,814 acres or 90 per cent of the total was actually burnt annually on the unprotected State and Private forest lands in the Southern Region.

Even if one concedes the fact that 34 per cent of the entire area of United States forests (over 671 million acres) is located in the Southern region, and that 60 per cent of all unprotected State and Private forests are also located there - the percentage of fires credited to Southern regions can only be regarded as out of all proportion. Chief notoriety in respect of uncontrolled fires must go to the Southern States of Florida, Mississippi, Georgia and Oklahoma in that order. These four States have a forest area equal to only 12 per cent of the entire forest area of the country, but the area burnt annually within these States during the five year period was 72 per cent of the total area burnt in U.S.A. During the years abovementioned, an average of 55 per cent of the forest area in the State of Florida was burned over during each year - surely an unenviable distinction.

The information set out in Table No. III has been subdivided in Table No. 5 in order to illustrate the comparative occurrence of fire damage in the various forest regions of U.S.A.

(ii) <u>The cost of Fire Protection and Estimates of Annual Fire Damage</u>.

The latest available figures (185) and (156) detailing expenditure by the U.S. Forest Service have been condensed, and appear in Tables Nos. 6 and 7.

Table No. 6 includes total expenditure by the Service not only on National Forests, but also in its efforts at Co-operative Fire Protection with State and Private agencies. As it does not include expenditures by such State and Private agencies it does not give the full cost of Fire Control throughout the country. Both Tables Nos. 6 and 7 include expenditure by C.C.C. and other "relief" labour, which has been assessed by Forest Service accountants as being equivalent to $1·50 per day per man. Both Tables also include "cost adjustments" by the Service for the maintenance, depreciation and use of improvements, equipment, tools etc. in the proportion for which they are used in Fire Control. It will be noted from Table No. 7 that the total annual expenditure per acre on National Forests exceeded, during the financial year 1936-37, the figure of 6·853 cents per acre recommended by the National Plan for American Forestry (The Copeland Report) - (see Page 7).

TABLE NO. 5.

Showing Variations Between Forest Regions in the Occurrence and Extent of Forest Fires (see Table No. 4).

FOREST OWNERSHIP & REGION	FOREST AREA REQUIRING PROTECTION (acres)	PROTECTED AREA					UNPROTECTED AREA				
		AREA UNDER PROTECTION (acres)	NUMBER OF FIRES	AREA BURNT (acres)	ESTIMATED DAMAGE	% OF TOTAL AREA BURNT	AREA NOT PROTECTED (acres)	NUMBER OF FIRES	AREA BURNT (acres)	ESTIMATED DAMAGE	% OF TOTAL AREA BURNT
SOUTHERN-1938											
Federal	11,043,300	11,043,300	1,617	38,270	47,330	0·35	------	---	-------	-----	---
State & Private	195,175,720	81,627,240	43,804	1,617,480	2,093,200	1.98	113,548,480	139,573	30,241,450	27,769,510	26·63
TOTAL	206,219,020	92,670,540	45,421	1,655,750	2,140,530	1·79	113,548,480	139,573	30,241,450	27,769,510	26·63
Do. - 1934-38											
Federal	7,763,630	7,763,050	1,583	47,476	47,654	0·61	-------	---	-------	-----	---
State & Private	209,506,860	72,693,620	34,117	1,540,116	1,936,862	2·12	136,813,240	112,833	30,904,814	29,952,004	22·59
TOTAL	217,270,490	80,457,250	35,700	1,587,592	1,984,516	1·97	136,813,240	112,833	30,904,814	29,952,004	22·59
EASTERN-1938											
Federal	4,246,720	4,246,720	188	1,370	3,330	0·03	-------	---	--------	-----	---
State & Private	106,040,790	91,027,390	18,433	319,840	1,192,560	0·35	15,013,400	4,799	432,670	783,680	2·88
TOTAL	110,287,510	95,274,110	18,621	321,210	1,195,890	0·34	15,013,400	4,799	432,670	783,680	2·88
Do. - 1934-38											
Federal	3,693,210	3,693,210	250	3,118	10,344	0·08	-------	---	--------	-----	---
State & Private	109,156,020	89,397,420	15,825	357,486	1,090,704	0·40	19,758,600	2,813	221,467	435,967	1·12
TOTAL	112,849,230	93,090,630	16,075	360,604	1,101,048	0·39	19,758,600	2,813	221,467	435,967	1·12
NORTH CENTRAL-1938											
Federal	8,701,600	8,701,600	1,181	13,460	20,730	0·15	-------	----	-------	-------	----
State & Private	75,390,010	61,040,550	5,901	271,210	1,104,500	0·44	14,349,460	1,538	194,980	238,120	1·36
TOTAL	84,091,610	69,742,150	7,082	284,670	1,125,230	0.41	14,349,460	1,538	194,980	238,120	1·36
Do. - 1934-38											
Federal	7,470,910	7,470,910	867	32,082	103,538	0·43	-------	---	------	-----	--
State & Private	77,002,700	59,020,290	7,005	311,890	1,242,544	0·53	17,982,410	1,805	244,720	604,067	1·36
TOTAL	84,473,610	66,491,200	7,872	343,972	1,346,082	0·52	17,982,410	1,805	244,720	604,067	1·36
ROCKY MTN. 1938											
Federal	118,493,440	118,493,440	3,676	16,600	29,020	0·01	--------	---	-------	-----	--
State & Private	38,201,720	23,760,210	1,176	12,230	28,760	0·05	14,441,510	94	4,650	2,800	0·03
TOTAL	156,695,160	142,253,650	4,852	28,830	57,780	0·02	14,441,510	94	4,650	2,800	0·03
Do. 1934 - 38											
Federal	118,079,180	118,079,180	4,136	154,580	383,582	0·13	--------	---	-----	-----	--
State & Private	38,721,620	23,913,610	1,234	28,840	114,140	0·12	14,808,010	132	11,698	42,072	0·08
TOTAL	156,800,800	141,992,790	5,370	183,420	497,722	0·13	14,808,010	132	11,698	42,072	0·08
PACIFIC - 1938											
Federal	49,375,180	49,375,180	3,211	245,910	806,960	0·50	-------	--	---	---	--
State & Private	52,533,610	52,533,610	7,012	402,510	2,760,610	0·79	1,531,000	26	2,480	7,350	0·16
TOTAL	101,908,790	100,377,790	10,233	648,410	3,567,570	0·65	1,531,000	26	2,480	7,350	0·16
Do. - 1934-38											
Federal	47,817,360	47,817,360	2,465	105,972	466,812	0·22	-----	--	----	----	--
State & Private	52,019,070	51,102,870	5,852	460,808	1,998,056	0·90	916,200	25	14,326	11,514	1·56
TOTAL	99,836,430	98,920,230	8,317	566,780	2,464,868	0·57	916,200	25	14,326	11,514	1·56

TABLE NO. 6.

Showing Total Expenditure by the U.S. Forest Service on Fire Control during recent years:-

DETAILS OF EXPENDITURE (Including cost adjustments for depreciation etc.)	AMOUNTS EXPENDED 1935/36	AMOUNTS EXPENDED 1936/37
Fire Equipment	$ 446,990	$ 504,565
" Prevention	2,164,866	2,190,379
" Pre-Suppression	9,280,145	11,756,465
" Suppression	1,771,612	2,666,080
" Co-operation (with other bodies)	2,258,312	2,164,051
TOTAL EXP. ON FIRE CONTROL	$15,921,925	$19,281,540
" " BY FOREST SERVICE	$128,966,657	$119,446,660
PROPORTION OF FIRE CONTROL) COSTS TO TOTAL EXPENDITURE)	12·4%	16·1%

TABLE NO. 7.

Showing per acre Costs of Fire Control Expenditure on National Forests, under various headings, during recent years:-

DETAILS OF EXPENDITURE	AMOUNTS EXPENDED (In cents per acre)			
	1933/34	1934/35	1935/36	1936/37
Fire Prevention	0·64	1·00	1·03	1·02
" Pre-suppression	2·54	3·25	4·43	5·49
" Suppression	0·40	1·55	0·83	1·25
TOTAL	3·58	5·80	6·29	7·76

From the last Annual Report of the Chief of the Forest Service (195) figures are available to show the cost of fire protection and the extent of fire damage on all forests, Public or Private, during the year 1938/39. These figures are tabulated hereunder:-

Fire Control Expenditures under Clarke-McNary Act etc.

Contributed by Federal Government	$ 1,736,201	
" " State Governments	$ 4,322,011	
" " Private owners etc.	$ 1,952,341	$ 8,010,553

Expenditures on National Forests

Fire Suppression	$ 2,587,041	
Prevention and Pre-Suppression (estimated)	$ 14,500,000	$17,087,041
C.C.C. expenditures (at valuation) on State and Private Forests (approximately)-		$17,000,000
TOTAL EXPENDITURES-		$42,097,594

ESTIMATES OF FIRE DAMAGE (see Table No. 3)

FEDERAL FORESTS (PROTECTED)	$ 907,370
STATE AND PRIVATE FORESTS (PROTECTED)	$ 7,179,630
STATE AND PRIVATE FORESTS (UNPROTECTED)	$28,801,460
TOTAL DAMAGE ESTIMATES -	$36,888,460

It will be noted from the above figures that if one combines the total costs of Fire Control with the total valuations of damage, it can be demonstrated that the total cost of fires to the nation was in the vicinity of 79 million dollars during 1938/39. At first sight the total figures for expenditures seem unduly high in comparison with those showing the damage resulting from fires. Protected areas however, embrace some 500 million acres (see Table No. 3) and on such area the total expenditure and damage amounted to some 50 million dollars. By comparison the damage which resulted on some 159 million acres of unprotected forest amounted to 29 million dollars (approximately). The areas under protection include the most valuable forests so that if they had been left without protection, it is reasonable to assume that damage to such areas would have approximated at least 100 million dollars (on the basis of the respective acreage, and of the damage indicated above for unprotected areas).

Apart from the value of fire control expenditures in conserving forest resources it can be said that they are justified on a broad basis of economy. It must be remembered also that current expenditures include the heavy initial costs of many capital improvements such as roads, trails, telephone systems, lookout stations, which are necessary during the introduction of planned Fire Control.

(iii) What modern fire protection entails.

Although much has been done recently to co-ordinate the whole complex subject of modern fire protection technique and methods, it is premature at this stage to prepare an outline that would include all the essentials of protective effort. Any discussion on the scope of modern fire protection must therefore remain general until the various aspects are dealt with individually. The ensuing pages of this report will deal specifically with the following major phases of fire control:-

(a) Study of the origin and effects of fires and how far remedial treatment is applicable in any scheme of protection.

(b) Preliminary efforts at fire control - known as Prevention Activities" - including a study of forest fuels and their inter-relation with fire behaviour, the lessons to be gained from studying the history of past fires, the organisation of educational, co-operative, and legislative agencies on the side of fire protection.

(c) "Preparedness Activity" - or the careful planning and organisation of detection, transportation and communication systems, the disposal of equipment and personnel, and the integration of all units so as to provide the forest with adequate and prompt fire fighting forces under any conditions of risk and hazard.

(d) "Suppression Activity" - the actual suppression policy to be adopted in order to make the best use of the man-power planned for the job, and to effect satisfactory suppression within economic limits.

(e) Economics - the economics of fire protection, as a whole and in respect of individual forest areas, the problem of forest fire insurance etc.

Foresters must face the inescapable fact that no matter how intensive their protective efforts, fires will occur with frequency for many years to come. In fact, a study of recent fire statistics in U.S.A. shows a steady increase in fire occurrence.

This may be due to a variety of reasons, such as the more complete record of fire occurrence available with intensive protection, changes in forest values such as the common disregard for the value of regrowth once virgin or mature timber crops are exploited, and the increasing use of forests by the general public as havens of recreation since the development of motor travel facilities.

Once adequate measures for "Preparedness" and "Suppression" have been achieved foresters may be able to reduce the occurrence of fires by concentrating efforts and expenditure on the "Prevention" phase. Meanwhile a comprehensive study of every aspect of fire protection and the general co-ordination of all protective effort is required, the financial aspect of protection to be constantly kept in mind, if efforts are to be concentrated, in the first place, on forests which warrant most intensive protection.

PART I.

FOREST FIRES

THEIR ORIGIN AND EFFECTS.

CHAPTER I.

CAUSES OF FOREST FIRES.

A. Classification of causative agencies.

It is necessary to have an intimate knowledge of all causative agencies before any system of planned protection can be formulated or intelligently applied. The U.S. Forest Service has maintained careful records of this and other branches of forest fire statistics, and has co-operated with State and other bodies in obtaining the most complete information possible in relation to fires on protected areas. Little information is available, however, regarding the causes of fires on unprotected forest areas.

The classification of various fire causes which has been used for many years by the U.S. Forest Service for fires on protected forest areas is as follows:-

(i) Lightning - Caused directly or indirectly by lightning.

(ii) Railroads - Fires caused by sparks and cinders from locomotives, from clearing or maintaining the right of way, or from any other operations incidental to the construction or operation of railroads.

(iii) Camp Fires - Fires resulting from carelessness of persons camping in or travelling through the forest, such as stockmen, forest employees, prospectors, picnickers, surveyors, berry-pickers, hunters, fisherman, etc.

(iv) Smokers - Fires traced to smokers' matches or to burning tobacco, hot ashes etc.

(v) Brush burning - Any fires used for clearing land, except along railroad rights of way, or in conjunction with logging operations. Fires caused by the burning of rubbish, garbage, stubble or grass are included herein.

(vi) Incendiary - Fires which, with a reasonable degree of certainty, are set wilfully in order to burn forest lands or lands not the property of the person involved.

(vii) Lumbering - All fires incidental to sawmilling operations such as those caused by sawmill donkey or logging engines. Fires due to smoking or camping by employees should be listed under "Smokers" or "Campers" fires.

(viii) Miscellaneous - Fires which cannot be properly classified under any of the other standard headings.

(ix) Unknown - This heading is used by many State agencies, and thus appears in annual statistics of forest fires. Its use is not recognised by the administrative branch of the Forest Service - any "doubtful" fires being assigned to the most likely cause.

Excluding lightning fires, and an extremely limited number of fires caused by spontaneous combustion and classed as "Miscellaneous" it will be noted from Table No. 8 that 90 per cent of all fires are caused either by carelessness, thoughtlessness or wilfulness on the part of man. The majority of man-caused fires are not deliberately wilful in their intent, but follow careless or thoughtless actions which result in fire occurrence or fire spread.

The causes of forest fires vary greatly from year to year and even between average periods of 5 years, according to seasonal or climatic trends, changes in the economic development of forests and increasing use of the forests by particular individuals. The figures shown in Table No. 8 indicate that the most common causes of fire on protected areas in U.S.A. are Incendiary Action and the results of Smoking. Each of these causes is responsible for approximately one-quarter of all fires on such areas and each of them shows a regrettable tendency to increase. Debris burning is another serious source of fire origin, while lightning which is not a serious general factor throughout the country, is responsible for more than half the fires on the National Forests. Most of these forests are in Western areas where lightning is an extremely serious factor in causing fires (see Tables No. 10 and 11).

The study of the various causes in relation to the number of fires occurring is not complete without some reference to the area burnt over by such fires. As will be seen from Table No. 9 - Incendiary fires are easily the most serious in respect of the extent of fires, due probably to the fact that they are lighted when conditions for spread of fire are most critical. On National Forests, lightning fires show something of the same tendency due to difficulties in detecting such outbreaks, many of which occur in inaccessible areas, or which may not be visible for some time after actual lightning "strike".

While averages for the whole country, or for groups of States are of value in furnishing general trends, studies of fire causes should be made as local as possible. From Table No. 11, which illustrates the extremes of fire occurrence by causative agencies for various States, it will be noted that there is a remarkable variation between States in the incidence of fires from various causes. Further subdivision of this Table into zones of fire occurrence by various agencies, would show still more remarkable variations.

The average annual fire loss, from various causes, for the 5 year period ending 1938, and on all protected forest areas, is shown in Table No. 12.

B. <u>The trend shown by various sources of fire origin.</u>

It has already been mentioned that fires caused from Smoking and Incendiary action show a tendency to increase, so that they now constitute the origin of more than half the fires occurring on protected areas of forest. On National Forests such tendency is not so marked, especially in the case of Smokers' fires, and this may be due to seasonal restrictions recently imposed by the Forest Service on smoking within National Forests.

Lightning fires also show tendency to increase - particularly on National Forests (see Table No. 8). This increase is doubtless due to the better identification of lightning fires as a result of improved detection, but some of the increase may be due to the increasing number of fire or insect killed "snag" trees in Western forests providing better conditions for effective lightning "strike".

Campers' fires show a small decrease which is understandable when one considers the better patrol measures now used on protected forest areas, and the "fire-proofing" of camping sites.

Fires caused by Railroads or from Lumbering operations have shown such a decline as to be now almost negligible in importance.

There is little general change in the percentages of Debris-burning fires - some reduction in fires from this cause should follow the concentration of protective effort on sections of forest most liable to damage from this cause.

The reduction in National Forest fire statistics of the "Miscellaneous" class of fire and the virtual elimination of "Unknown" fires has been forced on Forest Service administrations in order to place in correct focus the remaining causes of forest fires. Improved detection measures will in any case gradually reduce the element of doubt in the origin of any forest fires.

The administrators of Federal and State Forests can claim considerable success in their endeavours to improve fire prevention if they succeed only in holding the number and extent of man-caused fires to existing figures. This reasoning is based on the tremendous increase in the use of National and State Forests by visitors, recreationists, hunters etc. during the summer and autumn months, with a corresponding increase in the fire risk despite well directed prevention measures.

C. Lightning Fires

As previously noted, lightning is responsible for the occurrence of 9 per cent of all fires on protected forest areas in U.S.A., and for 51 per cent of all fires on National Forests.

Lightning fires are largely confined to the Western regions of the country and to the Rocky Mountain area in particular (see Table No. 10), where 66% of all fires on protected areas are traceable to lightning. A total of 6,628 lightning fires, covering an area of 180,142 acres, was the annual average for the 5 year period ending 1938 (see Table No. 12).

During the same period, the following States in the Rocky Mountain area had the largest percentages of fires of lightning origin - Arizona 81·3% of all fires, New Mexico 68·1%, Idaho 64·1% and Montana 60·2%. In addition both South Dakota and Colorado traced almost half their fires to lightning. In the Pacific Coast area the State of Oregon recorded 36·2% of all fires in the same period as due to lightning.

Other States in which lightning fires predominate over all other causes, include Wyoming and Utah.

Investigations into the characteristics and results of lightning "strikes" in forest areas have been made at the various Western Forest Experiment Stations.

TABLE NO. 8.

Showing origin of fires by various causative agencies on National Forests and for all areas protected from fire - expressed as percentages of the number of fires occurring.

CAUSE OF FIRES	ALL PROTECTED FORESTS IN U.S. (excluding) (Alaska)				NATIONAL FORESTS ONLY			
	Average for various periods							
	1921-25	1926-30	1931-35	1934-38	1921-25	1926-30	1931-35	1934-38
Lightning	6.3	9.5	7.2	9.0	42.0	48.4	38.6	50.7
Railroads	11.1	9.1	4.3	4.3	5.7	4.0	1.9	1.1
Campers	20.0	7.9	7.5	6.0	26.6	9.6	10.0	7.5
Smokers		21.1	24.6	25.0		17.9	23.9	17.6
Debris-burning	16.1	12.5	12.6	13.6	3.9	3.5	5.4	5.3
Incendiary	21.4	17.1	25.3	25.4	13.0	10.7	13.7	12.4
Lumbering	5.6	3.9	1.5	1.8	2.4	1.6	1.4	1.1
Miscellaneous	8.1	9.2	9.5	8.3	6.4	4.3	5.1	3.8
Unknown	11.4	9.7	7.5	6.6	----	----	----	0.5
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE NO. 9.

Showing percentage of area burnt over due to various causative agencies on National Forests and for all protected forest areas in U.S.A.

CAUSE OF FIRES	ALL PROTECTED FORESTS IN U.S. (excluding Alaska)				NATIONAL FORESTS ONLY			
	Average for various periods							
	1926-30	1931-35	1934-38	1938	1931	1931-35	1934-38	1938
Lightning	6·2	3·7	6·0	8·3	29·1	30·8	38·8	62·1
Railroads	4·1	2·4	2·9	2·0	0·2	1·5	3·0	1·3
Campers	6·3	6·7	4·3	5·0	4·6	15·0	2·9	0·9
Smokers	16·0	14·8	16·1	21·3	13·4	17·7	20·4	7·2
Debris burning	12·5	11·9	14·5	12·7	2·4	4·4	8·4	2·2
Incendiary	29·5	36·0	36·4	32·2	37·2	24·2	17·6	17·4
Lumbering	5·0	3·6	3·8	4·1	5·3	2·0	2·0	1·4
Miscellaneous	10·0	13·0	9·2	9·3	7·8	4·4	6·5	6·5
Unknown	10·4	7·9	6·8	5·1	----	----	0·4	1·0
TOTAL	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

TABLE NO. 10.

Showing percentages of various numbers of fires caused by different agencies for the 5 year period 1934 to 1938, for all protected forest areas in U.S.A., and variations shown by various regions.

CAUSES	WHOLE OF U. S. A.	EASTERN REGION	SOUTHERN REGION	NORTH CENTRAL REGION	ROCKY MTN. REGION	PACIFIC REGION
Lightning	9·0	0·9	1·2	3·1	65·8	27·6
Railroads	4·3	8·9	2·4	6·1	1·9	2·9
Campers	6·0	6·4	5·1	5·4	7·8	8·0
Smokers	25·0	36·8	19·4	31·3	14·9	27·2
Debris Burning	13·6	17·1	11·6	27·5	3·3	9·2
Incendiary	25·4	9·6	42·1	11·9	1·3	12·2
Lumbering	1·8	0·7	2·4	1·2	0·7	2·6
Miscellaneous	8·3	8·6	7·9	11·0	3·1	10·2
Unknown	6·6	11·0	7·9	2·5	1·2	0·1
TOTAL	100·0	100·0	100·0	100·0	100·0	100·0

TABLE NO. 11.

Causes of fires in Selected States expressed in Percentage of the Total Number of fires.

CAUSES	AVERAGE FOR 5 YEAR PERIOD - 1934-38							
	ARIZONA	NEW JERSEY	WYOMING	MICHIGAN	DELAWARE	OKLAHOMA	MAINE	GEORGIA
Lightning	81·3	0·2	42·9	4·2	----	1·2	11·7	1·5
Railroads	0·5	20·6	0·5	4·3	12·2	0·5	2·6	3·7
Campers	5·2	0·8	21·7	6·1	0·8	1·5	14·3	3·0
Smokers	8·6	14·2	26·3	50·3	16·3	7·0	42·9	2·3
Debris Burning	1·2	9·7	2·5	15·8	54·5	1·8	10·8	9·1
Incendiary	0·8	5·4	0·5	7·3	1·6	83·5	5·6	45·1
Lumbering	0·3	----	1·0	1·0	3·2	1·3	4·3	1·3
Miscellaneous	1·5	3·1	4·1	8·5	5·7	3·2	4·3	25·1
Unknown	0·6	46·0	0·5	2·5	5·7	---	3·5	8·9
TOTAL	100·0	100·0	100·0	100·0	100·0	100·0	100·0	100·0

TABLE NO. 12.

Summary of annual fire losses for the 5 year period 1934-38, on various classes of protected forest land, and according to causes of fire origin.

CAUSES	NUMBER OF FIRES			AREA BURNT OVER (acres)		
	FEDERAL FORESTS	STATE & PRIVATE FORESTS	TOTAL	FEDERAL FORESTS	STATE & PRIVATE FORESTS	TOTAL
Lightning	4,712	1,916	6,628	125,520	54,622	180,142
Railroads	98	3,017	3,115	9,628	77,498	87,126
Campers	701	3,677	4,378	9,404	120,148	129,552
Smokers	1,642	16,708	18,350	65,982	419,814	485,796
Debris burning	494	9,491	9,985	27,208	411,748	438,956
Incendiary	1,151	17,444	18,595	57,118	1,045,312	1,102,430
Lumbering	105	1,224	1,329	6,642	108,368	115,010
Miscellaneous	350	5,736	6,086	20,898	256,172	277,070
Unknown	48	4,820	4,868	1,450	204,080	205,530
TOTAL	9,301	64,033	73,334	323,850 ac.	2,697,762 ac.	3,021,612 ac.

The data enumerated hereunder summarise the findings of Morris (136), Gisborne (57 and Show and Kotok (167) at these Experiment Stations:-

(i) Lightning strike - may occur in such numbers from a single storm that fire outbreaks result which are far beyond the capacity of any planned measures for fire protection. Headley (79) records the occurrence of at least 153 strikes in 1926 from a single storm on Kaniksu National Forest - an area of 600,000 acres. In the Pacific North West Region during the 1939 fire season one lightning storm which persisted overnight, caused 822 recorded fires on a total of nineteen National Forests, including 127 fires on a single Forest. This happened just after the Regional personnel on Fire Control had been increased by 8500 men because of unduly severe fire hazards then operating. In the same season a large storm persisted in Northern California for almost three days and caused 320 recorded fires on five National Forests.

(ii) Wet and dry storms - In the Northern Rocky Mountains, approximately 10 per cent of all storms were accompanied by no rain, or by so little as to be classed as dry storms. Dry storms do not necessarily mean increased fire danger as 68 per cent of dry storms and 66 per cent of wet storms were classed as harmless.

(iii) Safe storms - Gisborne (57) found that "scud" rain preceding lightning flashes averaged 12 minutes in duration, and that "secondary" rain which followed the flashes averaged thirty seven minutes. The heavier these two types of rain the less likelihood there was of fire occurrence.

A small shower of rain after a lightning "strike" does not necessarily render conditions at all safe. On the contrary, experienced observers in California found that storms which resulted in a rainfall approximating ten points were more dangerous than dry storms as regards forest fire occurrence, because of "delayed action" spread.

Safe storms may occur when 75 per cent of lightning flashes are from "cloud to cloud," but if more than 50 per cent of these flashes are from "cloud to ground" the storm is dangerous.

(iv) "Sleepers" or delayed action storms are very common. About half the fires caused by lightning are discovered within three hours, but in cases of delayed action as much as two weeks may elapse before "sleeper" fires are detected.

(v) Occurrence of lightning fires - In the Pacific North West region a surprisingly large proportion occur at night - for the period 10 p.m. to 4 a.m., 28% of all lightning fires occur as compared with 6% for the same period in the Northern Rockies.

Storms may be confined to definite zones, but this cannot always be relied upon. While there may be definite areas where storms originate, their probable direction can not be anticipated.

(vi) Mapping of storm paths has shown that storms are usually dissipated after travelling less than 80 miles, although instances of storms travelling up to 280 miles are recorded. Speed of travel is usually from 6 to 20 M.P.H. and rarely exceeds 40 M.P.H. The usual direction of storms is from South to North or North East, but in the Northern Rockies the direction may be more Easterly.

(vii) Effect of topography on storms - There is no apparent correlation between altitude and storm occurrence, but there is some definite relation between storm frequency and rough topography in regions of warm to hot summer temperatures.

(viii) Fuels - most readily ignited by lightning are duff, live and dead trees in that order.

The common occurrence of lightning fires in very inaccessible mountain areas causes delayed detection, slow travel time and difficult conditions for suppression. For instance the Cedar Camp lightning fire on Siskiyou National Forest in 1938 burned 34,000 acres and had to be fought for 26 consecutive days in rough topography before it was brought under control. It was actually the largest fire on National Forests during the 1938 season.

Show and Kotok (167) emphasise that lightning fires may be easily controlled the morning after the storm if they can be reached within that time. Lightning fires have acquired a reputation for breaking out after they have been apparently suppressed. This characteristic, however, is due probably to hurried suppression measures at times when numerous fires have followed one or two severe lightning storms and where inefficiently trained fire-fighters have had to be pressed into service.

D. Man-caused fires.

As will be seen in Table No. 8, man-caused fires are responsible for 91 per cent of all forest fires in U.S.A. and for 49 per cent of fires occurring on National Forests.

The States of Arizona, New Mexico, Idaho and Montana, where lightning occurrence is most pronounced, are the only territories where man-caused fires are not the most serious source of forest fire occurrence.

Most man-caused fires are not due to wilful burning of forests or of neighbouring lands. Even in the case of incendiary fires malice may not be always proved, although all incendiary fires may be described as wilful.

As the great majority of man-caused fires is due to either carelessness or thoughtlessness, there would seem to be much room for improved methods of educating the general public towards greater care of their forest areas.

Greeley - former Chief of the U.S. Forest Service has stated (65) quite recently that:- "The big job of conservation to-day is in the field of public responsibility for forest fires". That this statement is a true reflection of the position is proved by a close analysis of fire origin on protected areas of forest, which indicates that some 70 per cent of all man-caused fires result from the actions of the general public, while only some 30 per cent of these fires can be attributed to landowners or lessees in and around forest boundaries. The present position regarding various types of man-caused forest fires, and their possible diminution, is as follows:-

(1) <u>Railroads</u> - No longer a serious source of fire danger except in certain middle Atlantic States, such as New Jersey, where a combination of numerous railroads, heavy traffic, and high fuel hazard is found. In New Jersey 20·6 per cent of all fires on protected areas are caused by railroads (Table No. 11) as against a general figure for the whole country of 4·3 per cent. The once frequent origin (11·1 per cent in 1921-25) of railroad fires in U.S.A. has been reduced by the screening of smoke-stacks, clearing of fuels from the right-of-way etc. The character of fuel used, the density of rail traffic, and the efficient maintenance of spark arresters, ashpans and rights of way are the main factors influencing the occurrence of railroad fires. The marked increase in the use of large Diesel engine combinations for drawing express trains will undoubtedly assist in reducing the fire hazard.

Experience in California shows that even Diesel engined locomotives may be responsible for forest fires if adequate precautions are not taken for the screening of flues. If Diesel fuel oil of low viscosity is used, such oil is not properly atomised and fires may be caused along the railroad right of way. Some railroad companies are not yet convinced of the economics of systematic hazard reduction along their rights of way, and many of them prefer instead to meet payment of bills presented by the Forest Services for the cost of efficient fire prevention and suppression along such rights of way. Some companies even arrange for Forest Service employees to "fireproof" their rights of way at the expense of the company concerned.

Close scrutiny of railroad fires has indicated that sparks and cinders from smoke stacks, flues, grates etc. are not the only cause of ignition, as the latter may be caused by a variety of factors including red hot pieces of brake shoe; passengers' cigarettes etc. A careful analysis of railroad fire origin is important, as foresters must produce evidence that fires were the result of the actual operation of locomotives, cars etc., before damages or suppression costs can be recovered.

In the Rocky Mountain Region, most Trans-Continental railroad companies have adopted oil burning locomotives for the double reason that they are more efficient to operate, and cause less fires along the right of way.

At least one Company takes the precaution of notifying forest officers on the rare occasions when they place a coal burning locomotive on their Rocky Mountain "run".

In a Californian study of railroad fires Gustafson (69) concluded that the occurrence of these fires was due to the following causes in order of importance:- Brake Shoes, Engine sparks from indiscriminate sanding of engines, discarded burning waste (cinders, coals etc) or fusees, burning of the Right of way. The danger from brake shoes was found to be very real, red hot material "sloughing off" both shoes and wheels due to fast speeds and heavy braking on down grades. Pieces of such material two or three pounds in weight were found up to 16 feet from the rails.

(ii) Campers - Fires from this source cause 6 per cent of all outbreaks on protected areas - the most severe damage from campers' fires being experienced in Wyoming, where 21·7 per cent of fires are so caused. They are also important in the States of Utah and Colorado. Campers' fires are due almost entirely to carelessness. While educational efforts, personal or group contacts may assist in the general reduction of their number, the permit system applied in the case of all persons desiring to enter National Forests during the fire season, is probably the best insurance from campers fires. At periods of most severe hazard - permit of entry may be entirely refused, while at other times patrols can check up on the movements and carefulness of visitors.

For the most part, the concentration of campers and picnickers on specially designed and well equipped camp and picnic grounds has greatly assisted in controlling the movements of these visitors, to the extent that they can be kept under surveillance by prevention or suppression patrols. The extent of the facilities available to visitors on public Forest and Park lands can best be gauged when one considers that some 50,000 acres of "fireproofed" small camp and picnic grounds have been developed on such lands. The lone camper with a bent for exploration has been found to be more of a fire protection problem than his numerous confreres who are content to follow the beaten track.

In some cases, as in the canyons of Southern Californian forests, it has been found necessary to develop numerous camp grounds away from valley sites in efforts to move visitors out of areas which are already noted for severe fire risk.

(iii) Smokers - cause 25 per cent of all fires on protected areas, Michigan, with 50·3 per cent being the most notorious State for smokers' fires. Fires from this cause have shown a persistent increase due probably to increased use by the public, for recreational purposes, of forest areas, and to difficulty in preventing the actual occurrence of such fires. Smokers' fires are usually confined to definite areas, or to routes of travel most commonly used.

In some States foresters are now empowered to prohibit all smoking on forest areas, even in the case of persons using public roads which traverse forests, except at specified "fag stations".

Care is necessary in many cases to correctly define smoking as the cause of fires - some of the increase may be due to a too ready attempt to classify doubtful fires under this heading. Smokers' fires are the chief causes of fire occurrence in 17 States - the preponderance being most marked among North Eastern States.

In Western U.S.A. several States have gone to the trouble of passing special legislation which prohibits the throwing of smoking material, matches etc. from any moving vehicle (Cars, trains etc.)

Stickel (181) has studied various firebrands and found that cigarettes would only ignite duff which had an excessively low (6%) moisture content. Matches, however, may actually ignite duff under fairly safe conditions, when its moisture content was 17-22 per cent.

(v) Debris burning (Brush burning) was once identified with the pioneering of land for agriculture, so that it is surprising to find a small, closely settled, State like Delaware, with 54·5 per cent of all its fires on protected areas due to this cause, as compared with a general figure of 13·6% for the entire country. Other States where debris burning is a prolific source of fires are - Missouri (44%), Indiana (37%) and Minnesota (35%). Fires originating from this cause are often most common where the poorer types of "marginal" agricultural land are found intermixed with forest areas. As with other causes of fire, the introduction of a permit system by some States, has undoubtedly been a factor in controlling indiscriminate occurrence of fire from this cause. In the practice of fire protection, brush-burning fires are easy to detect, but are rather difficult to control unless precautions have been taken as a "prevention" measure after a study of fire hazards has noted possible danger from this source.

(vi) Incendiary fires - cause 25·4 per cent of all fires on protected areas of forest - particularly in the South (see Table No. 10) where 42 per cent of all fires are of incendiary origin. The most notorious State in this respect is Oklahoma (83·5% of all fires) while Louisiana (58·5%), Florida (55·4%), Mississippi (54·2%) are also outstanding. Incendiarism also causes the majority of fires in Georgia, Arkansas, Kentucky, Tennessee, and Alabama.

Despite the excessive tendency towards incendiarism shown by Southerners, it is probable that few of these fires are due to any malicious or vindictive spirit. The motive is rather a selfish one, e.g., the burning of the forests to improve grazing prospects. The continued practice of burning Southern Forests, extending as it has for a century or more, has aroused convictions in the minds of many residents that fires also "improve the forest". Checking the incendiarist is thus often a matter of tact as well as law enforcement. Much incendiary action in the South is also said (42) to be traceable to burning by operators who attempt to safeguard their turpentine production, and also to the virtual abandonment of much "tax-delinquent" land by owners who do not care to persevere with same. Unfortunately this large extent of such "tax-delinquent" land, which often carries forest regrowth, is denied protection under State co-operative schemes.

Psychological researches into the motives actuating Southern incendiarists indicated that the problem was closely related to both economic and social conditions among these people, many of whom were deficient in intellect and in worldly wealth. In some cases incendiary habits were found to be nothing but an outlet for emotion and for repressed excitement in the absence of any normal outlets such as entertainment, sport etc. Although the incendiarist may be a simple minded soul, he has sufficient cunning to use elaborate "sets" to avoid his detection. These "sets" may comprise an ingenious arrangement of two boards, matches, black powder, rubber bands and wax, so arranged that sunlight melted the wax allowing one board holding the matches to rub against another board holding the sandpaper and powder, this in turn igniting a neat pile of shavings and brush some hours after the set had been arranged.

In a (confidential) report to the U.S. Forest Service, the psychologist engaged on the abovementioned researches in Southern U.S.A. stressed the importance of alleviating the recreational and social needs of incendiarists, followed by efforts to improve their economic position and standards of education. The investigator claimed, with some apparent justification, that law enforcement among such people succeeds only if it follows the above steps. To prevent the destructive forest practices which are deeply rooted in the "culture" of such people, it is necessary to go back to the source of these practices and divert them at their source.

There is likely to be continued difficulty in reducing fires of incendiary origin, both as regards their number and the extent of their damage to forest areas. Incendiarists are notoriously difficult to apprehend, and can rarely be subdued with threats of law-enforcement or with efforts at education, while their burning efforts often coincide with the worst possible fire weather conditions, thus resulting in extensive damage. The use of bloodhounds, while not successful in actually apprehending many incendiarists, has been found a very useful deterrent.

(vii) Lumbering fires - once considered a material source of danger to forests, are now almost negligible in importance. The recent expansion of tractor and motor-truck use in place of steam haulage in logging operations, will result in still further decreases in the damage to forest areas, while lumbermen generally are now quite active in preventing or combating any fires on or near their holdings.

(viii) Miscellaneous fires - In several States a large proportion of forest fires is classified under this heading - notably Georgia (25% of all fires on protected areas), Massachusetts (21%), Minnesota (20%), Louisiana (19%), but with better protection and detection methods such proportions should be greatly reduced.

(ix) Unknown fires - States notorious for being unable to ascertain origin of many of their forest fires are New Jersey (46% classed as of unknown origin), Rhode Island (31%), Florida (27%), Tennessee (20%) and Mississippi (20%). Until fire control organisations in those States improve their capacity for determining fire origin, the general study of the causes of fires in these areas will still be confused, and the material reduction of fire occurrence will not be planned on a proper basis.

CHAPTER II.

EFFECT OF FIRES IN THE FOREST.

A. Harmful Effects.

(1) Injury to Merchantable Trees.

(a) Immediate Mortality. Few of the coniferous species of U.S.A. escape immediate death if subjected to severe crown fires, especially in the case of large burns such as that at Tillamook (Oregon) in 1933. Greeley (65) and others have indicated that the Tillamook fire killed standing timber having a volume of 10,257 million super feet, on an area of 244,700 acres. This volume of timber would have supplied material equivalent to the total cut of sawn timber in the entire country during the preceding year (1932). The loss in lumber values was estimated at $275,000,000, stumpage values lost being estimated (70) at $20,000,000.

Smaller trees under merchantable size are rarely consumed even by the most severe fires, death being due to penetration of heat through the bark to the cambium tissue. Baker (11) found that a temperature of 129·2° Fahr. (54° Cent.) was sufficient to kill the cambium of young trees. Complete killing of the cambium causes instant death to the trees, whereas partial injury on a section of the tree's circumference causes a fire scar. The cambium is much more sensitive to fire injury early in the summer when growth of the tree is normally at its maximum. Resistance of trees to cambium injury by heat varies according to the thickness and texture of the bark. Hofmann(86) found that the cambium of 15 year old Douglas Fir, with bark 0·25 inches thick, was killed in 11 minutes by applying a heat of 900° Fahr. to the outer bark for 11 minutes. On the other hand old trees of the same species, with bark 4 inches thick, sustained no injury despite an equivalent application of heat for a period of four hours.

Trees which secrete resin in the outer bark or which commonly exude resin are more liable to immediate mortality.

Salvage of timber stands killed outright by fire is not always possible, except where the fire has been restricted to a small area. Varying climatic conditions, the tendency of the species to hold its bark easily after death, or to be rapidly attacked by insects etc., are factors which hasten the detioration of fire killed timber.

(b) Delayed Mortality. The lapse of time before the death of trees after fire is particularly common when surface fires have swept an area of forest without leaving much sign of visible activity. In hardwood sample plots, Stickel (178) found that fire damage was not readily apparent until the following growing season, by which time 47 per cent of the trees (ranging from 2 - 10" D.B.H.) were found to be dead. In the Lakes States it was found necessary (213) to wait at least four months after firing before a reasonably accurate assessment of mortality was possible, especially in the sapling

(Photo by U.S. Forest Service)

Showing effect of repeated burnings on Longleaf Pine regeneration - Kisatchie National Forest - Lousiana.

growth and larger trees - smaller regrowth having been killed outright. Folweiler and Brown (51) have indicated that delayed mortality occurs in Douglas Fir stands, following heat injury to the shallow root system of the tree.

Connaughton (32) found that appraisals of fire damage in the growing season following a 45,000 acre fire in an Idaho stand of P.ponderosa, revealed extremely heavy losses in contrast to what appeared to be comparatively minor damage shortly after the fire.

Maclay (124) tagged 100 trees damaged on Olympic National Forest in 1927 and found in 1930 that 60% of the lightly burned Spruce and 83% of the heavily burned trees of the same species had died. By comparison none of the lightly burned Douglas Fir, and only 32% of those heavily burned, had died.

A study made of surface fires (160) in the Coast Range areas of the Pacific North West region showed that, in trees of 15" D.B.H., 13% of the Douglas Fir, 71% of Hemlock, 90% of Spruce and 100% of the Balsam Fir were killed, by supposedly innocuous surface fires, after an interval of one year.

Wood (220) records studies made after a 1926 New Jersey fire in a mixed hardwood stand, which showed an increase in mortality from 19% in 1930 to 34·3% in 1936.

The influence of delayed mortality in forest stands is to some extent inter-related with the facilities created by fire for subsequent injury by insects or fungi, such as bark injury, or reduced vitality of the tree as a result of defoliation by fire.

In California Show and Kotok (166) also found that mortality could be delayed until the effect of fires became cumulative, direct mortality being most frequent in forests previously injured by fire, the lightest of surface fires being often a direct menace to the forest.

(c) Loss in Growth. Material loss of increment, more marked in the case of pole stands than with saw-log stands, may follow fires which cause defoliation (either partial or total) of forest stands, but which are not sufficiently severe to cause mortality. Data recorded by MacKinney (123) on Longleaf Pine sapling areas show the loss in growth following comparative measurements made both on unburned areas and on other areas burned over annually. During 13 years the recorded loss on burned areas amounted to 9% of the diameter growth, 19% of the height growth and 22% of the volume growth shown by unburned areas.

Such tendencies become less marked as tree height increases, and as live tree crowns become less liable to damage from surface fires.

(ii) Injury to established regrowth.

This form of injury to forests is perhaps more apparent than any other. As in the case of older stands the actual injury may take the form of early or delayed mortality, while the more fire-resistant

(Photo by U.S. Forest Service)

Showing development of Longleaf Pine regeneration with protection from fire - Kisatchie National Forest - Louisiana types of regrowth may suffer only loss of increment. The reduced height of the crowns of regrowth stands above ground not only renders these crowns more liable to defoliation, but also facilitates "crowning" of forest fires. This is particularly the case in coniferous stands where dead branches and dry needles persisting in the base of the crowns are a ready source of fuel to ground fires. Increased susceptibility of regrowth stands to major injury, is also partly due to the reduced bark thickness of the trees, enabling the cambium to be more readily killed by surface fires. The dense nature of certain regrowth, coupled with the presence of slash still present from previous logging operations, or burning, often causes the development of severe fires in these areas. The destruction of regrowth which had established itself after a previous fire in Douglas Fir types, may cause serious difficulty in further natural re-stocking (93). In some such instances Western White Pine stocks the area after the first fire, but when the latter is destroyed by a second fire, further re-stocking was found to be markedly deficient (110).

In the Southern Pine region, MacKinney(122) has reported a loss of 93% in all reproduction of P.taeda by a slow burning night fire in early winter. An apparent mortality of 58 per cent seven weeks after the fire had increased to 93 per cent after another nineteen weeks had elapsed. Folweiler and Brown (51) furnish a table (see Table No. 13) illustrating the growth of various Southern Pines at Urania on plots, each 0·25 acres in extent, which had been burned over annually for 20 years, as compared with that shown on unburned plots.

(iii) Injury to the regeneration of forests.

The effect of forest fires on the natural regeneration which may follow these fires is dependent on the characteristics of the various species likely to regenerate there. Fires cause increased air and soil temperatures on forest sites, and cause intensified effects from insolation, frost, evaporation and soil desiccation. Other effects increased by fires are insect and fungal activity in the upper soil horizons together with accelerated denudation and erosion of upper soils.

All of these factors exert some influence on the regeneration of forest tree species. Repeated or severe burning generally reduces the survival of such regeneration and favours occupancy of the site by weed species. A single severe burning may provide conditions necessary for the regeneration of a particular species, as recorded by Haig (72) who noted that seedling regeneration of Western White Pine was much greater on heavily burned areas than on unburned or lightly burned sites. On the other hand Parkins and Whitaker (147) estimate that in the Western White Pine forests of Northern Idaho, some 25 per cent of cut over land is non-productive due to subsequent repeated burning.

The unfavourable effect of burned areas on regeneration of other species is most marked during the

TABLE NO. 13.

Rate of growth of Southern Pines on unburned and burnt Sample Plots.

PLOT	1915			1920 (Heavy seed crop) (in 1919)			1935		
	NO. OF TREES	AV. D.B.H.	AV. HEIGHT	NO. OF TREES	AV. D.B.H.	AV. HEIGHT	NO. OF TREES	AV. D.B.H.	AV. HEIGHT
UNBURNED									
Longleaf Pine	3,708	NIL	NIL	6,836	NIL	1·1ft.	1,668	3·4"	24·6ft.
Loblolly & Shortleaf	12	NIL	NIL	136	NIL	4·2ft.	152	6·1"	30·2ft.
BURNED ANNUALLY									
Longleaf Pine	3,240	NIL	NIL	6,052	NIL	0·4ft.	1,656	2·3"	14·0ft.
Loblolly & Shortleaf	8	NIL	NIL	-----	NIL	NIL	-----	NIL	NIL

early survival (or failure) of small seedlings. Isaac and Hopkins (94) made studies of Douglas Fir regeneration on burnt and unburnt areas in Washington, where burning of slash accumulations usually causes severe ground fires. The investigators found that such fires destroyed the duff layor and blackened the mineral soil, thus greatly increasing the capacity of such soil for heat absorption. The additional heat on the surface of burned soils killed all seedlings, while those on unburned soils sustained few losses.

In laboratory tests Fabricius (44) found that both seedling germination and survival of European coniferous species (and hardwoods) was seriously affected when sowings were made in wood ashes. Only a very small proportion of the limited number of seedlings to germinate in ashes survivod at all.

Light surface fires, provided they can be adequately controlled, may actually assist the establishment of regeneration where same is impeded by accumulated duff or grass layers in such a way that tree seeds find difficulty in contacting mineral soil essential for their germination. Similar light burning may assist the development of seedling growth by reducing the stocking of seedlings or by at least temporarily eliminating strong competition from surface rooted grass or low brush. Wahlenberg (217) states that periodic light burning is indicated as a means of assisting Longleaf Pine seedlings to emerge from the grass, although one year seedlings have been killed by creeping fires in light grass cover. On the other hand it is generally conceded that fire protection in the Southern region has materially assisted in the establishment of extensive areas of P.taeda regrowth, often on areas which would formerly be classed as Longleaf Pine types.

Severe burning over large areas, resulting as it does in destruction of both seed and of seed trees causes long delays in their effective re-stocking. On the Coeur d'Alene National Forest in Idaho, regeneration has only very recently become evident following the Great Idaho fire of 1910.

(iv) Injury to forest composition and succession.

A general picture of the influence of fire on the succession of tree types in American forests is given by Haig (71) who states that almost every forest climax of North America has its fire subclimax, usually over a considerable area. In the Northern forests of Spruce-Fir, the fire types are Jack Pine, Aspen and Birch, while Eastern White Pine stands in this region have been greatly reduced in area by fire. In the Coastal Plain of the South - fire has perhaps been beneficial in maintaining a Pine sub-climax, at the expense of a Hardwood mixture. Further West fire has maintained a prairie sub-type along the borders of a mesophytic Hardwood Type. In the far West, such types as Douglas Fir, Western White Pine and Lodgepole Pine have been perpetuated by fire in more or less pure stands at the expense of Spruce-Fir, Hemlock and other mixed Conifer types. In California either Chaparral or Monterey and Knobcone Pines are poor fire types which have extended over large forest areas following repeated burning. In many other cases, fire has not been succeeded by tree species, but has resulted in occupancy of forest area by weeds or useless brush.

There are numerous references to the effect of fire on succession of tree species in various parts of U.S.A. Lutz (118) and Harshberger (75) concluded that fire was chiefly responsible for the dwarf Pitch Pine (P.rigida) or "Plains" association of New Jersey, where areas of severe fire hazard are periodically burnt. Continued fires limit the development of the Pines to dwarf dimensions and prevent any change in succession. Parkins and Whitaker (147) point out that two million acres in Pennsylvania, formerly carrying good mixed Hardwoods, have been reduced by continued burning to poor Aspen and Scrub types.

For these Hardwood areas in Pennsylvania - Brouse (19) stressed, inter alia, the following ecological relationships:-

(a) The normal change from temporary to climax types takes place naturally unless some artificial agency, such as fire, intervenes.
(b) Frequent fires prevent any normal progression to climax types.
(c) The vigour of temporary fire types reaches a maximum 5 years after burning.
(d) A single fire will not halt the general scale of plant succession but will result in a fire type that, with subsequent protection of the area from fire, will be eliminated within 20-25 years. Repeated fires also seriously retard normal succession of types elsewhere.

In the Lake States, fire is responsible for large areas of Aspen stands on sites capable of supporting better Hardwoods (212) and also for extensive areas of Jack Pine (P.banksiana) (112). White Pine (P. strobus) stands, on areas where they are not climax types, in the Lake States and North East regions, may have been assisted in their establishment by fire (28) and (126) Eyre (43) has reported that Jack Pine requires fire to ensure its regeneration, as the species must have bare mineral soil for a seed bed, while the high temperatures of forest fires are necessary to open the seed cones.

Korstian (104) states that the depletion of Spruce forests in the Southern Appalachian Region is due chiefly to fire, following destructive logging. He states further that fires must be controlled if the cut-over and burnt Spruce areas are to be reforested even artificially.

Quite a number of foresters and ecologists - notably Chapman (31), Greene (67) and Harper (74) hold that the Longleaf Pine Forests of the Southern regions are climax associations resulting from prolonged periodic burning at 3 - 5 year intervals, and that the continuance of such burning is essential to the perpetuation of the species. At the same time burning of many Longleaf Pine areas would involve the destruction of the more vigorous Slash and Loblolly Pines now present on such areas.

(v) Injury to the protective influence of forest cover.

Forest cover shelters the soil from extremes of temperature, soil moisture and other factors, and generally provides a secondary cover of litter on the soil surface. Even the lightest of fires destroys the soil covering of litter. The influence of severe burning on deterioration of tree cover and on denudation of forest soils is universally known and needs no recapitulation here. Preservation of watershed cover is particularly important in the South West - where large scale irrigation and urban water projects depend on uninterrupted supplies of water. The general influence of forests in safeguarding watersheds has been described by Toumey and Korstian (184), Zon (223), Connaughton (33) and Munns and Sims (139).

Lowdermilk (116) found that preservation of the litter covering the soil under vegetative types was more important in controlling run-off than was the preservation of actual canopy. He found also a great increase in run-off on burned areas of Chaparral as compared with protected areas, the rate of erosion being better determined by measuring soil particles in suspension with the run-off, than in actual velocity of streams.

Preservation of litter not only hinders run-off, but prevents the forest soil becoming impervious as it does after fires. MacKinney (121) found that removal of litter facilitated the freezing of forest soils, thus further increasing the impermeable nature of burnt over soils. In the Oak forests of the Mississippi, Meginnis (131) found that run off on repeatedly burnt Scrub Oak forests was possible after 0·25 inches of rain, whereas 0·77" of rain was necessary to cause any run-off in unburned Oak forests.

Auten (9) came to similar conclusions respecting the water absorbing capacity of soils when studying the burning of forests in the Ozark Mountains. The drying out of the soil surface in burned areas, prevented rapid absorption of moisture by the soil, whereas with protection the damp layer under forest litter preserved the soil in a condition for ready absorption of rainfall, thus checking run-off and increasing percolation.

Run-off in relation to burning was also studied by Bennett (15) who reports that in plots prepared in a Post Oak stand, the unburned plot showed a run-off of 250 gallons of water, as compared with 27,600 gallons on the burned plot. The loss of soil by erosion, per annum, was 0·01 tons per acre on the protected plot as against 0·15 tons per acre on the burned area.

Heavy rains which have followed burning of the Chaparral slopes in Southern California have been notable in causing tremendous erosion, while neighbouring areas which have escaped burning have shown only limited run-off. Such an instance is recorded by Haig (71) as occurring on 1st January, 1934, on which date 34 lives were lost and damage was caused estimated at millions of dollars. Following exceptionally heavy rains, burnt areas gave an extremely high run-off which carried a heavy load of eroded debris, while an unburnt watershed receiving almost as much rain had only a light flow and a minor silt load.

Details of the varying run-off on the burnt and unburnt areas of these watersheds have been furnished by the U.S. Forest Service, and are graphically illustrated hereunder:-

WATERSHED	(1)	(2)	(3)	(4)
"Verdugo" 33% Burnt Two Months Before	12·5"	19·30	320	30,700
"San Dimas" Unburnt " " "	10·8	16·85	53	56
"Pickens" 100% Burnt " " "	12·5	0·48	1,000	50,000
"Fern & Bell" Unburnt " " "	12·4	0·30	25	52

(1) "Rainfall in Storm"
(2) "Watershed Area." Square Miles.
(3) "Peak Run-Off". Cubic Ft. per second.
(4) "Eroded Material". Cubic yds per square mile of watershed.

A study of these figures makes it more easy to understand why such intensive fire protection is planned for the brush covered slopes of Southern California, where watershed management must embrace both water conservation and the prevention of erosion.

Nelson (141) describes how the Henshaw Reservoir in San Diego County in Southern California was entirely filled with debris after a series of fires on its watershed, while the Gibraltar Reservoir built in 1924 has already lost more than one-third of its capacity as a result of a few watershed fires.

The importance of maintaining forest cover has been recognised by such an important body as the Tennessee Valley Authority which is taking active steps in protecting its areas of watershed forest from fire.

As described by Parkins and Whitaker (147) the most serious injury caused by fire to the protective influence of forest cover in U.S.A. is to be seen on the steeper slopes of the Appalachian Mountains, in the vicinity of Lake Superior and in the New England "Uplands".

(vi) Injury to recreational and scenic values.

The increased use of American forests by city and country people has already been mentioned, and fire of any sort can have no place in the management of areas which are used for recreational purposes. Tourist resorts find that their trade languishes when fires occur in their vicinity. The State of Florida lost considerable tourist traffic in the winter of 1931-32 owing to the abnormal fires which followed prolonged dry weather in that State, making even road travelling by tourists a very risky proceedure. Visitors to National Forests have increased in number from 4,600,000 in 1924 to 33,500,000 in 1939 (172) and (195), and in the latter year it was estimated that visitors spent $200,000,000 at nearby tourist resorts. The number of visitors to State and other public forests is much greater owing to their location near concentrations of population. After making due allowance for visits made repeatedly it has been estimated (218) that 30 million people enter National Forests, Parks, Monuments or other recreational areas in the State of California each year. It is obvious that protection of forests from uncontrolled fires, as well as the restricted use of fire for management purposes, must be the aim on areas of forest so popular with the general public. The Forest Service has endeavoured to assist visitors, and to control fires, by providing fully equipped camping grounds on National Forests for tourists and in making available "group camps" for Youth organisations or for persons of limited financial means.

(vii) Injury to grazing values.

The importance of fire control to the grazing industry can best be gauged when one considers that some 340,000,000 acres of forest land in U.S.A. are used for grazing purposes. On the comparatively limited area of National Forest land the number of stock grazed annually includes:- 1,300,000 cattle; 5,500,000 sheep; 30,000 horses; 7,000 goats. In the Southern States it is estimated that some twelve million cattle and eleven million hogs roam through private forest land, while little attempt is made to improve their grazing conditions except for indiscriminate burning.

On many Western forests range preservation and management is at least as important as timber production, and fire control on such areas aims primarily at the protection of grass lands. Range research projects include investigations into the effect of continued burning on both forage and soil values of ranges. Aldous (3) describes burning experiments made on the famous Kansas Blue Stem pastures when the soil was moist. It was found that burnings decreased the yield of forage, failed to control the spread of weeds and brush, reduced soil moisture, stimulated early spring growth etc., but caused no decrease in the organic matter or nitrogen content of the soil.

(viii) Injury to the Naval Stores Industry.

As this industry is concentrated in the South, it suffers greatly from the widespread burning, common to Southern forests, which has already been described. Losses in the Naval Stores region of the South have been revealed in figures quoted by Wackerman (216) and made available by the National Forest Survey which completed its field work in the South in 1934. The Survey figures fixed the annual increment for the naval stores region, an area of 35 million acres, at 658 million cubic feet of Pine. The annual cut was calculated at 313 million cubic feet and the annual losses from various causes (mostly from fire) at 406 million cubic feet. There is thus an annual deficit of 62 million cubic feet, to which must be added the tremendous annual loss in young growth of non-commercial sizes. These figures readily indicate the danger of fires to the future of the naval stores industry (and other wood-using industries) of the South.

There is general agreement that the defoliation, complete or partial, of Pine stands being managed for turpentine, results in at least a temporary check to the growth of the tree and to its "gum" production. The Southern Forest Experiment Station (214) has reported that the gum yielding capacity of Longleaf Pine, burnt over in March, declined rapidly until June and recovered to about normal in the following November. The loss in gum yield was roughly proportional to the extent of the defoliation. Even light fires, which cause the minimum of defoliation, are said to depress the yield of gum to some extent, but it is generally conceded that defoliation of trees large anough (9" D.B.H) to be worked for gum, causes no permanent injury to such trees unless bark injuries result.

(ix) Injury to human life, property and activity.

Injuries of this nature by forest fires, are no longer as serious as they were during the enormous conflagrations of last century. The most serious deathroll within recent memory was a total of 438 on the Cloquet fire (Minnesota) in 1910. Fire protection and suppression measures have greatly reduced the risk of wholesale losses of both life and property. In recent years deaths from fires have been practically confined to the ranks of fire-fighters - the most serious recent toll being on the Blackwater Canyon fire in 1937 when 15 men lost their lives.

The Cloquet fire, abovementioned, obliterated a thriving sawmill town with a population of 12,000 and thus resulted in losses of timber and property estimated (70) at $30,000,000 but losses of this nature have been mainly restricted in recent years, to the investments of logging and lumbering interests which are actually situated within, or nearby, the forest boundaries. At least temporary loss of employment is caused by many such fires - The Tillamook burn (Oregon) in 1933 caused damage to timber stands that would have given employment to 14,000 men for a period of 6 years.

(x) Injury to wild life.

The North American forests are noted for their wildlife, and the preservation of game is important as a conservation measure and also to provide sportsmen with opportunities for hunting, fishing etc. During 1938 over four million people were hunting and fishing on National Forests, while on other forest areas throughout the country another thirteen million persons were similarly occupied. On National Forests some 660 wild life sanctuaries covering over 36 million acres, are rigidly preserved from all hunting. It has been estimated that almost 75 per cent of the big game in Western States is dependent on National Forests for forage during summer seasons. The number of game present on all National Forests is estimated to include nearly two million big game animals, some two and a half million fur-bearers, and indefinite numbers of game birds such as grouse and turkey, while there are some 70,000 miles of fish carrying streams and hundred of thousands of lakes and ponds also carrying fish. It is extremely difficult to assess the actual damage to wild life which results from uncontrolled fires, but it is certain that tremendous numbers of all kinds of game are obliterated by fire. Many other animals such as those living underground or under water, may survive the actual flames only to starve subsequently in the absence of food supplies. Surviving animals are usually so weak that they fall easy victims to their natural predators. Kipp (102) describes the loss of wildlife after a 120,000 acre fire in Wisconsin in 1930. Although many deer survived the actual flames at least 60% of this number had badly burned feet. Bird losses were considerably fewer - in the case of grouse being estimated at only 25 per cent. Large numbers of fish died owing to increased temperatures and alkaline content of the water and the decreased oxygen content of the streams.

Similar losses of fish are recorded by Ludwig (117) in Pennsylvania after streams had become affected by forest fires.

Controlled or "early" burning may also seriously threaten the lives or food supplies of game - particularly ground birds and waterfowl. If wild life are valued at all in a particular area, the effects of any burning should be fully considered before being adopted as a regular practice.

Gabrielson (55) describes the effect of regularly firing dead grass on areas adjacent to streams and marshes. The burning period usually coincides with the nesting time for wild fowl - nests may even be a mile from water and the fires not only cause loss of life among the birds, but ruin the nesting seasons. Gabrielson also stresses the fact that areas burned over by forest fires are virtually useless for the upkeep of game for a period of many years afterwards, particularly in drier regions, owing to the destruction of natural foods.

(xi) Injury to the physical and chemical properties of the soil.

(a) Physical properties.

In discussing the effect of fires on the protective influence of forest cover it has already been shown that the water-absorbing capacity of forest soils is decreased by the burning of the litter covering such soils. The burning of this litter also exposes the forest soil to much more severe extremes of temperature, and generally decreases its porosity. Heyward and Tissor (85) showed that the porosity of soils under unburned Southern forests, as compared with those of regularly burned areas, was due to the existence of five times as much micro fauna in the Ao horizon of soils in protected regions. Repeated burning, on the other hand, may mean the virtual destruction of the Ao horizon on soils subjected to the practice. Protection from fire, for a period of only 10 years, may restore the Ao horizon to a condition equivalent to that found on soils protected for very many years. The presence of a well developed Ao horizon may actually mean that tree roots are so close to the soil surface as to be readily damaged if a fierce fire destroys this horizon.

Heyward (84) made a comprehensive study of soil temperatures during forest fires in the Southern Pine region, from which he concluded that the heat generated from the majority of fires was insufficient to cause any losses in soil fertility. The slight increases in temperature on light textured soils, such as those of the South, may actually benefit plant nutrition. The temperature experienced by artificially piling debris on the site before burning was only 274°F. at ¼" depth, and 195°F. at ½" depth, while the temperature required to char dry organic matter was 350°F.

After another study of the effects of fire on soils of Southern Pine forests - Wahlenberg (217) states that the exclusion of fire benefited the soil physically, but that burning at frequent intervals benefited it chemically.

(b) Chemical properties.
Opinions differ somewhat as to the effect of burning on the chemical properties of soil, which is readily understood when one considers that Soil Science itself is a new development.

Alway and Rust (4) concluded that fires in Minnesota might cause some loss in soil fertility, due to destruction of Nitrogen when the forest litter was burned, but that there was little change in the chemical composition of underlying soils.

In Idaho, Flint (80) came to the conclusion that heavy burning of forests caused the forest soil to become alkaline instead of acid, and resulted in the reduction or loss of many soil organisms. Heyward (83) found that frequently burned soils showed much higher ignition loss, due to the presence of charcoal. They contained more replaceable calcium and (probably) other ash constituents and are thus less acid than protected soils. Burned over soils also contained a higher percentage of total nitrogen. Heyward's general conclusions were that fires in Southern forests do not cause undue soil degradation, but do not, on the other hand, materially benefit forest soils.

(xii) Injury from subsequent attack by fungi or insects.

(a) Forest fire injury and fungi attack.
The relation between fire injury in U.S.A. and attacks to living trees by fungi is best summarised by Boyce (17) who states, inter alia - "The most prolific cause of wounds (to trees) is fire, and fire scars are responsible for extensive decay in many species". Among concrete examples, quoted by Boyce, of the association between fires and fungi are the following:-

The Cytospora Canker (Stereum subpileatum) of Douglas Fir, Poplars and Willows
" Nectria Canker of the hardwood species of Northern U.S.A.
Butt rot (Polyporus schweinitzii) of Douglas Fir, Eastern White and Red Pines etc.
" " (Polyporus frondosus) of the Oaks.
" " (" amarus) " Incense Cedar.

All of the above fungi are stated to owe their origin to the fire scars left on the various species mentioned. Boyce states also- "The bottom-land Hardwoods of the South would be largely free from disease except that ground fires have led to heavy losses from decay".

In a more specific instance Boyce (18) stated that 81 per cent of the total cull volume of Incense Cedar trees studied was caused by dry rot through fire-scar infections.

From forest fire damage studies made in the North-East, Stickel and Marco (179) estimated that from 28 to 45 per cent of fire scarred living trees became infected with fungi within three years after burning.

The general relation between fire scars and fungi expressed by Boyce above, is also echoed by Hubert (91) who states:- "Fire scars are responsible for most of the heart rot in our standing timber, ranking higher than any other wound factor".

From specific studies made on various species the general statements of both Boyce and Hubert have been borne out by other investigators. Meinicke (132) found that over 40 per cent of White Fire culls were due to initial fire wounding. Fritz (52) has blamed fires for more than 90 per cent of butt rot in Redwood, and has indicated the relation between repeated fires, butt rot, enlarged wounds etc. and windthrow of Redwoods.

In the hardwood areas of the Atlantic region - Hepting and Hedgecock (80) and Hepting (81) examined 2900 merchantable Hardwoods of seedling origin, and found that 94 per cent of all butt rot was due to scars. From areas being logged it was estimated that 97 per cent of all basal wounds were due to fire.

Similar damage, on a slightly reduced scale, has been reported by Lentz from the extensive Hardwood area of the Mississippi Delta.

(b) Forest fire injury and insect attack.

The attacks by insects on living trees in the forests of U.S.A., are almost invariably assisted by the presence of fire scars from previous fires. In his recent publication on Forest Entomology, Graham (63) instances several insects which attack timber trees through fire scars. Notable among these are the Golden Buprestid (Buprestis aurulenta) on Western conifers, the Turpentine Borer (Buprostis africans) on Southern pines, and the Carpenter Ants (Campanotus pennsylvanicus) on Western Cedar. Graham also asserts that unregulated exploitation and uncontrolled fires are mainly responsible for the devastation of the Spruce-Balsam Fir forests of Eastern U.S.A. and Canada.

Several authors, including Jaenicke (95) and Miller and Patterson (133) have described the temporary infestation by the Western Pine beetle (Dendroctonus brevicomis) which follows the burning of Western forests. Jaenicke emphasises the fact that even carefully controlled light fires may cause an increase of 1,000 per cent in the normal beetle population - especially where some defoliation of the pines has resulted from the fires.

Similar attacks by Ambrosia beetles on severely scorched Oak stands in New York State, have been also recorded by Stickel (177).

B. Beneficial Effects of Fire.

(1) The use of fires may have compensations.

While uncontrolled fires may have no place in modern management methods it is obvious that such fires have, many years ago, resulted in some of the forest timber stands in U.S.A. (notably the pure stands of Douglas Fir and White Pine in Western Regions), while repeated burnings over an indefinite period have probably been the main factor in the establishment of extensive areas of Longleaf Pine in the South.

The influence of fire in the establishment of Western White Pine (P. monticola) types in the North West of U.S.A. is described by Huberman (90) and Larsen (109). The latter describes the development of a fire succession after the burning of a climax type consisting of Western Red Cedar (Thuya plicata) - Western Hemlock (Tsuga Leterophylla) and Fir (Abies grandis). The first stage in the succession is a "fire type" comprising Lodge Pole Pine (P. murrayana) and Western Larch (Larix occidentalis). The latter species are supplanted by Douglas Fir or Western White Pine unless second burns occur, and continued fire protection will result in a return to the original climax type. With repeated burnings, only Lodge Pole Pine and Western Larch have any chance of succession.

The future composition of forest stands, even in cases where the use of fire is necessary to favour the regeneration of more fire resistant types, or to provide seed of a desired species some contact with the mineral soil, will probably be just as suitably governed by man's use of controlled burning, as it has been done in the past by the uncontrolled fires of nature.

A more clear conception of what constitutes "controlled burning" seems necessary even among foresters, particularly so in regions such as Southern U.S.A. where total elimination of fire from the forests is at present too much to be expected from a protection viewpoint, and where the use of a certain amount of burning may actually be silviculturally desirable. There is need in the first place to clarify the issue between "Controlled" burning from a silvicultural standpoint, and what has been defined (169) as "Light" burning. The objects of light burning are the periodic removal of fire hazards, by burning the forest, at short intervals, in "safe" weather conditions. Since the inception of forest management by public authorities in U.S.A. there has been a continual controversy between foresters and others concerning the use of fire in forest management. In the early part of this century this controversy was centred in California - the foresters seeking to impose the total exclusion of fire from forest areas, and the protagonists of burning pressing the claims of periodic fires as a protective measure. The ultimate victory of the foresters in California was due to the fact that evidence accumulated to demonstrate the harmful effects of even light fires to merchantable and immature timber and to watersheds.

The scene of the controversy has now moved to the South where complications exist owing to the admitted preference of Longleaf pine for light periodic fires prior to, and following, seedling regeneration. With a tremendous fire risk prevailing in the Longleaf region, and the comparative resistance of larger growth of the species to fire damage, there is also a very strong argument for the use of "light" fires to periodically reduce the fire hazard.

The respective uses of "light" and controlled fires require exhaustive study, and some attempt is made hereunder to evaluate the merits and demerits of these forms of burning.

(ii) "Light" fires as a protective measure.

The protagonists of light fires in the California region made definite claims which were answered by foresters after a Forestry committee had investigated these claims. Bruce (22) reviewed the arguments of both sides as follows:-

The use of light burning as practised and advocated by lumberman assumed -

(a) That little or no damage resulted to standing timber in the forest
(b) Any fire damage that did occur was due to the presence of excessive fuel hazards, and light burning would effectively minimise the seriousness of these hazards
(c) That general control of forest fires was quite impracticable without period light burning of the forest at times when the least possible damage would ensue.

Foresters opposed the above arguments in the following manner -

(a) Light fires inevitably damage the forest and particularly the regrowth therein
(b) While accumulations of brush and litter constitute hazards - temporary accumulations occur only after logging for a period of 4-5 years - after which period, decay of litter etc. will offset its accretion.
(c) Complete fire protection of forests is practicable and has been proven.

After a general review of claims made for light burning, a Committee of foresters finally came to these conclusions:-

(1) Light burning in spring is unsatisfactory. By that time forest litter will carry a light fire - it is also possible for such fire to readily constitute a real hazard to forest growth
(2) Light burning in summer achieves better results, during limited periods of "safe" weather; but it is both economically unsound and impracticable on any large scale.
(3) Light autumn burning is very patchy owing to variable moisture content of the litter, and is generally useless in the following summer.
(4) The costs of light burning are not commensurate with the gain derived, irrespective of the season in which burning takes place.
(5) All burning damages reproduction, and most burning injures older and mature trees.
(6) Light burning on extensive areas is impracticable owing to varying fuel conditions, different moisture contents of fuels on various slopes etc.

These findings have been supported in numerous statements by other foresters - notably by Ayres and Hutchinson (10) and Show and Hammatt (163). While inclined to agree that light burning appears correct in theory these observers condemn it as inefficient and uneconomical in practice.

As light burning has been the practice of individuals, rather than trained employees, there is no standard technique associated with its use. Too often the light fire on the property of its advocate becomes an uncontrolled outbreak on adjoining areas. Those who practice light burning are too often concerned more with the continuity of the actual

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(Photo by U.S. Forest Service.)

Showing Douglas Fir regrowth following burning of mixed coniferous stand - Johnson Mountain - Siskiyou National Forest - Oregon.

burning process than with the severity of the burn or the damage associated therewith. It therefore seems apparent that any planned use of fire in Southern forests must be associated with "controlled" rather than "light" fires.

(iii) Controlled fires and their uses.

Evidence is accumulating that the intelligent and careful use of fire may have a major place in modern forest management - provided always that "controlled" fires are used instead of haphazard "light" burnings. As foresters gain a mastery over uncontrolled fires by means of improved fire protection they are able to take a more dispassionate view of the uses of fire in forestry practice.

Considerable research is still necessary, however, before the extent to which controlled burning is desirable or practicable can be fully gauged. Some possible uses of fire in the forest may nevertheless be enumerated:-

(a) To assist silvicultural practice.

Fire has long been used as a preliminary step in artificial reforestation, and increased knowledge of the silvicultural characteristics of indigenous tree species is dictating the use of fire in establishing natural regeneration of at least some species. Davis (38) has advocated broadcast burning after clear cutting to perpetuate Western White Pine at the expense of Western Hemlock. Similar treatment is also required to obtain the best possible regeneration of pure Douglas Fir, in what were previously mixed stands. Broadcast burning also assists in the regeneration of Northern White Pine, provided always that subsequent fire protection is effective. Davis and Klehm (37) believe that controlled burning, applied intelligently and with discretion, has a permanent place in Western White Pine silviculture.

As previously mentioned, Eyre (43) has suggested the use of fire as the best means of regenerating Jack Pine stands in the Lake States in order to open the seed cones and to provide a mineral soil seedbed. Similar treatment of Jack Pine has been recommended by Watson (218). In Pine stands in California, Show and Kotok (169) suggested the use of controlled fires in the thinning of dense regeneration or in the killing of undesirable advance regrowth so as to obtain subsequent stocking by a more favoured species.

Although the problem of raw humus as a detriment to adequate regeneration is not yet a serious problem in U.S. forests - controlled burning may later be found necessary in eliminating such humus and in providing improved seed bed conditions.

Burning of this nature during the spring months has been long advocated by Chapman (29) and (3) for the Longleaf Pine region to remove pine litter, broomsedge grass and vegetation prior to seedfall of the the Longleaf Pine. Subsequent to establishment of seedling growth, careful winter burning is also recommended for seven or eight years to assist the

Pine seedlings in suppressing the ground vegetation abovementioned. Other investigators, including Roberts (155) and Osborne and Harper (145) have shown that both germination and survival of Longleaf Pine seedlings have been markedly improved by the burning of "rough" vegetation.

Widespread use of controlled burning in the South is not, however, favoured by Howell (89) and Mattoon (130) who point out that fire must be excluded where there is a likelihood of Slash (P. caribaea), Shortleaf (P. echinata) or hoblolly (P. taeda) Pines being regenerated owing to the sensitiveness of these species to fire.

Other investigators point out that too rigid an exclusion of fire from forests of the Southern coastal plain may lead to the elimination of Pine species by the more vigorous Scrub Oak-Hickory type.

Caution in the silvicultural use of controlled burning in Southern regions is also urged by Demmon (39) who concludes that no single set of recommendations for controlled burning can be laid down for any area.

(b) To minimise subsequent damage by fire.

As Longleaf Pine seems resistant to damage from carefully controlled fires, it is possible that increased use will be made of controlled burning in order to dispose of the accumulated "rough" of ground vegetation, hazards from thinnings etc. as a means of countering more severe damage from the serious fire risk which normally prevails in the South during most of the year. For the present, and until the full effects of controlled burning are known, such fires can be regarded as a palliative in dealing with the serious fire problem which persists in this Region.

Controlled burning as a means of checking or minimising futuro damage from fire must be carefully planned to cover "key" parts of the forest, but for most areas of forest in U.S.A. is confined either to roadside or trail edges, green firebreaks etc., or to poorer or unmerchantable tree types, cranberry bogs etc. which border valuable timber stands. Burning is also limited to those areas where high risks cannot be effectively minimised by any other means - eg. Along the rights-of-way of railways.

(c) For slash disposal.

Burning of slash usually accomplishes the double task of improving conditions for natural regeneration, and of reducing at least temporarily, the firo hazard on the area to be regenerated. Slash disposal is regarded as a strictly local problem, the technique varying with the demand of the species in question for a clear mineral soil seedbed, the necessity for preventing erosion, the fire hazard prevailing, and the economics of slash disposal. A study along these lines has been made in Western Yellow Pine forests by Munger and Westveld (137). Pearson (149), who studied the problem in the drier P. ponderosa forests of the South West, favoured piling and burning of slash only on areas of high hazard, of high value, or where abundant advance growth was present. On areas of low hazard, or on sites where erosion is likely, slash disposal should be restricted to firebreak edges. Slash disposal after logging in the South West, must be confined to definite areas to reduce damage to either fallen seed or seedtrees, whether such disposal should be in broadcast strips or blocks, or by piling and burning in rows or small heaps, depends wholly on the local conditions, season of year etc.

In the Douglas Fir region broadcast burning is recommended (7) provided the burn is confined to pre-determined boundaries, and takes place just prior to rain. During burning every care should be taken to restrict the fire to the area selected, by lighting in late afternoon, studying weather and topographical conditions etc.

(d) <u>In improving soil conditions.</u>

In discussing the harmful effects of fires on the physical and chemical properties of forest soils it has already been noted that periodic burning of ground vegetation, particularly on the porous soils of the Southern region, may improve rather than injure the chemical properties of such soils. This is an interesting departure from old ideas, but the results obtained by investigators must for the present be classed as tentative. As the technique of soil science improves, and as prolonged and exhaustive investigations are made into the effect of burning on forest soils, more reliable data should be gathered.

In the Southern forests, Heyward & Barnette (82) have indicated that forest soils subjected to many periodic fires are less acid, have more replaceable Calcium, and have a higher total Nitrogen content than soils protected from fires. While these conclusions may not be shaken following further investigation in the South, they should not be accepted as universal for all types of forest and soil, although somewhat comparable deductions were made by Alway and Rust (4) on forest soils in Minnesota.

If further experiments prove that even periodic burning is the reverse of harmful to forest soils, the forester will feel more justification in applying controlled burning to forests for silvicultural purposes, as already discussed.

(e) <u>In Wild-life management.</u>

While there is general condemnation of the uncontrolled forest fire by wild-life protectionists, it has been demonstrated by Stoddard (182) that controlled burning of game ranges within forest areas in the South-East is of considerable benefit to quail and wild turkey. Such burning removes tangled forest litter, grasses and sedges and thus assists the birds to scratch for foods, while it does not harm the forest cover or the understory of shrubs etc. which is essential for protection of the game.

(f) In Range Management.

While uncontrolled fires are as destructive to forage as they are to timber there is evidence that some controlled burning of grazing areas on forests may be necessary to preserve forage values. This burning is directly beneficial in removing accumulations of old grass of low forage value and of high fire hazard. Greene (68) found that during eleven years of burning on comparable areas of rough pasture in the South, cattle raised on burned areas were much superior in condition to those on unburnt areas while soil samples from burned areas revealed more organic matter and nitrogen. Leopold (113) was of the opinion that protection of the Southern Arizona foothills from fire, coupled with overgrazing, has led to "brush" taking over grasslands long used by cattlemen. Pearson (148) has indicated the decline of grazing values and the increased stocking of regrowth which has followed fire protection and control of grazing in many Regions, and particularly in the South West Region.

(g) In controlling insect or fungal attack.

Controlled burning is now accepted as the best means of reducing the virulence of Brown Spot Needle Blight (Septoria acicola), a fungal infestation which affects the growth of Longleaf Pine regrowth by reducing the green leaf surface. Carefully controlled burning, while destroying or damaging a small proportion of seedlings, will effectively minimise Blight infestation for an ensuing period of two years. Without burning, defoliation by the Blight may actually check height growth of the regrowth. The use of fire in this connection is described by Chapman (29) and Siggers (171).

Another use for fire in controlling fungal pests is mentioned by Munger and Westveld (137) who describe the burning of Western stream "bottoms" to destroy plants of Ribes, one of the hosts of the dreaded Blister Rust.

Graham (63) advocates the use of fire against the Pine Tube Moth (Eulia pinatubana) in the Lodge Pole stands of Idaho and Wyoming by the controlled burning of infested areas when the insects were pupating on the forest floor.

In California, similar use of fire has been suggested to control the Western Pine Beetle (Dendoctronus brevicomis), but results to date are inconclusive.

P A R T II.

F I R E P R E V E N T I O N A C T I V I T I E S.

CHAPTER III.

THE STUDY OF FOREST FUELS.

A. Classification of Fuels.

The volume, size and arrangement of forest fuels, coupled with other factors such as aspect, degree of slope, character of tree vegetation (or Cover-Type as it is known) are relatively constant factors which affect the fire danger on any particular area at a given time. Other factors such as fire risk, meteorological conditions etc. are variables which result in different fire behaviour with certain fuels and topographical features.

Of the relatively constant factors fuels are the most important, being the most tangible and most easily tested elements of fire danger on any area. It is obvious that fires will either not burn at all or will burn at a slow rate of spread unless fuels are present in quantity and in a combustible condition. Topographic features while regarded as relatively constant, really influence the combustible condition of fuels either before or during an actual outbreak. While fuel can be regarded in itself as a constant factor, its moisture content is decidedly variable and needs detailed consideration.

Almost all vegetable products of the forest serve as forest fuels - chief among them being humus, litter, peat, ground vegetation, underscrub, fallen limbs or trees, crowns of felled trees, and standing trees whether alive or dead.

The volume and character of potential fuels in the forest are fairly uniform for long periods of time, but their moisture contents vary both separately and individually in a short space of time. Growth over long periods, exploitation, damage by wind, fire or other agency may vary the volume and character of fuels, but there is little seasonal or daily variation in volume as compared with moisture content.

The lighter types of ground fuel in the forest are readily hygroscopic and because of their wide variation in moisture content within short periods are the most definite indices of ignition and rate of spread of forest fires. In dense coniferous forests this type of fuel is usually a loosely compacted layer of dead needles, twigs, herbs etc. known as the duff layer. Its composition and inflammability vary according to the species present. Wright (222) has pointed out that the inflammability of Red Pine duff is much greater at a given moisture content than that of the mixed softwood types (such as Red, White and Jack Pine in varying proportions) as the heavy dry needles of Red Pine are very loosely arranged, and allow free movement of air through the duff layer.

In hardwood or mixed forests the duff layer is a mixture of dry leaves, needles, twigs etc. and the flat leaves become definitely compacted during winter months into a peaty mass, more especially if the winter is marked by heavy snow. In this way the duff layer in mixed or hardwood forests retains its moisture content much longer, and is subjected to less rapid variations in moisture content than is the case with coniferous duff. In open areas of either Coniferous or Hardwood forest there is an accumulation within a single season of dry herbaceous

(Photo by U.S. Forest Service).

Stand of Yellow Poplar - Liriodendron tulipiferum - typical Hardwood Fuel Type of Southern Appalachian Region - Eastern - U.S.A.

vegetation which has proved a troublesome source of surface fires in the spring before new growth commences, and in the late summer or autumn when this vegetation is either drought or frost killed.

Duff layers vary in their seasonal inflammability according to the forest composition. In hardwood areas, or where the latter species predominate, the most serious fuel hazard conditions may occur in the spring, or in the autumn, when meteorological conditions dry the duff layer to a serious extent in the absence of a forest canopy.

In coniferous forests where the amount of canopy and duff varies only slightly with the season, the actual moisture content of the duff layer remains a uniformly satisfactory index of fire hazard conditions, and as such has been widely investigated.

Accumulations of other material such as slash, dead timber or limbs add materially to the dry fuel present in forests but large dimension fuels of this character are not subject to rapid changes in their moisture content as are the lighter fuels.

The total amount of fuels present within forests is classified
(76) as follows:-

(a) The living trees present on the area. They may be variable as regards species size etc.
(b) Underbrush - comprising the living plants in the understory and including small regrowth of the tree species. In the case of coniferous regrowth, or during long drought periods, the underbrush may be extremely inflammable and may then assist fires in "crowning". Dead underbrush, comprising plants killed by suppression, or by previous fires, is a serious fire hazard.
(c) Ground cover - herbaceous plants, grasses etc., are usually much more inflammable in character than the rest of the forest species, particularly in the case of annuals and perennials which become most inflammable at the height of the firo season.
(d) Forest litter and undecomposed humus, including dead organic material such as leaves, twigs, needles. This litter may be in the form of a definite duff layer as already described, and as such is subject to sudden changes in moisture content depending on combinations of atmospheric agencies such as rain, temperature, relative humidity etc.

(e) Dead branches, needles, moss etc. on living trees which in certain forest types constitute a great source of danger.
(f) "Snags" or standing dead trees of the present crop or relics of previous stands. They are usually most inflammable, and when in a decayed state are capable of scattering "spot" fires ahead of any outbreak. They are especially abundant in Western coniferous forests, or in Eastern Hardwood forests where the Chestnut has been killed by blight.
(g) Slash - or logging waste which may have accumulated in considerable quantity. It acts both as a ready source of "heavy" fuel, and as a serious impediment to fire fighters. Its actual inflammability varies greatly with species, climate, season, etc., but it is often a serious problem as a primary fuel on cut-over areas.

In general, the quantity and inflammability of forest fuels is reduced by maintaining density of tree cover, or by management on selection lines.

(Photo by U.S. Forest Service).

Pinus Ponderosa cover type showing light undergrowth needle and grass litter - a favourable fuel type for fire suppression - Eastern Oregon.

(Photo by U.S. Forest Service).

Typical mixed coniferous forest (virgin stand) in the Pacific North West Region - a heavy fuel type for fire suppression.

B. The Influence of Forest Fuels on Fire Behaviour.

(i) Fire occurrence.

It may be argued that the presence or absence of fuels is immaterial if the majority of fires are man caused, but it is important to realise that fires could not progress through any forest, irrespective of atmospheric conditions, if suitable fuels were not present therein. Furthermore the existence of a particular type of fuel may in itself be one of the principal reasons for the origin of fires, as in the case of loggers burning slash, or the burning of either underbrush or ground cover by adjacent landowners.

Fires normally commence in the lighter types of ground fuel such as grass or dead herbaceous growth, duff layers etc. when these fuels have a moisture content below a certain percentage because of certain weather conditions. Dry fuels of this nature provide conditions suitable for the occurrence of fires, and the planning of fire control must be based on the extent and character of these light, hazardous ground fuels.

In areas where lightning fires occur frequently the presence in the forest of a large number of snags may not only increase the number of lightning "strikes", but will provide conditions suitable for the rapid early development of fires of this nature, even during "wet" storms.

The influence of fuel types on fire occurrence is illustrated by Abell (1) who records the fact that fire occurrence followed definite trends in fuel types - approximately one-third of all fires occurring on two fuel types, and approximately 80 per cent occurring on only four types.

(ii) The rate of fire spread.

This rate is governed by the character of the fuels, as in the case of fire occurrence, and also on the continuity of such fuels throughout the forest. A uniform extent of light and inflammable fuels such as ground litter or vegetation, dry moss or needles on the trees, allows an extremely rapid rate of spread. Heavy fuels do not cause a fast rate of spread except in the case of uncontrolled fires of unusual severity which create tremendous heat and draughts, progressively drying all fuels in their advance. If the continuity of fuels is broken as in the case of firebreaks cleared of all vegetation, roads, fire lines bared to the mineral soil etc. the rate of fire spread is abruptly checked except in the case of severe fires fed by large quantities of heavy fuels.

"Spotting", or the lighting of small fires in advance of the main outbreak, is also influenced by the character of the fuels present. The presence of numerous "snags" in a decayed condition, will cause severe risk of spotting, and a consequent acceleration in the rate of spread.

(iii) Resistance to control.

Resistance to control can be expressed as the severity of the fire, which is more dependent on the density or volume of available fuels than on any other factor. The worst possible conditions are large accumulations of heavy dry fuels - once a fire has been provided with such conditions for its early development it can be a serious menace to adjoining areas of forest having little or no dry fuels.

For this reason extensive areas carrying heavy slash are sources of considerable anxiety to any forester engaged on protection work. If a sufficient volume of heavy fuels is not available, an outbreak may never develop beyond the stage of being a surface fire, and serious damage to old growth may thus be avoided.

The extent of the damage from fires is influenced by the density of the fuels present on the area, even when burning conditions mitigate against rapid spread.

Under such circumstances fires will generate intense heat by burning for a prolonged period among an accumulation of fuel - thus greatly increasing fire damage without necessarily defoliating the standing trees.

C. Cover Type and Fuel-Type Mapping.

It has long been the practice of foresters in U.S.A. to prepare maps of each forest showing the location of various types of fuels therein in relation to the nature of such fuels, the cover type (= vegetative type) occupying the site, and topographical aspects which influence fuel inflammability. With all this information assembled, and with the evaluation of fire risk for various sections of the forest (based on a study of the origin and frequency of previous fires) the forester can plan his protective efforts so that the worst risk areas are effectively safeguarded, and the expenditure on protection concentrated on sections of the forest most in need of same.

Some of the earliest work on fuel type mapping was that of Show and Kotok (165) in California. They attempted to correlate fuel types directly with the cover types present and concluded that crown fires occurred in Chaparral or Brush cover types; Surface fires in grass, woodland, P.ponderosa, mixed coniferous or Douglas Fir types; and Ground fires in the Sugar Pine-Fir or pure Fir types. Show and Kotok also prepared a table showing the average rate of fire spread in the Northern California region, based on a study of past fires in various cover types.

Subsequently, Hornby (88), in the Northern Rocky Mountain Region, did not rely at all on Cover types when formulating a scheme for the mapping of fuels. Hornby based his classification of fuels on (a) Their relative rates of spread
(b) " resistance to control
under conditions which could be expected in forest areas after one month of midsummer drought. Hornby's objective was to fix a figure of so many chains per hour for the spread of fire perimeter for a certain fuel type. By estimating the "resistance to control" of the same fuel type he could then fix another figure for the number of chains of fire-line which one man could construct per hour in fighting fires in the type. It was then a simple matter to ascertain the number of men required to suppress any fire occurring within the type, in a period of one to three hours. Estimates for a period beyond 1 to 3 hours were not made - as any fire not suppressed within such period would be dependent more on climatic factors for its subsequent spread than on the fuel conditions. For both "Rate of Spread" and "Resistance to Control" fuel types were classified generally as Low, Medium, High and Extreme.

Hornby asserted that the kind, volume, arrangement, continuity and exposure of "fine" fuels were far more important in classifying

TABLE NO. 14.

COVER TYPES AND RATE OF FIRE SPREAD.
FOR NORTHERN CALIFORNIA (165).

COVER TYPE	RATE OF FIRE SPREAD ACRES PER HOUR
Fir (Abies)	1·07
Mixed conifers	3·79
Sugar Pine-Fir	4·33
P. ponderosa	8·18
Douglas Fir	8·20
Woodland	12·58
Brush	13·79
Grass	23·73
Chaparral	55·00

these fuels than was the existing cover type, as he found that fuel characteristics within types exerted 3 to 15 times as much influence on initial rates of fire spread, as did cover type characteristics. Considerable importance was attached to the effect of aspect - fuels on North and East aspects classed as Medium in rate of spread would be classed as High if occurring on West or South aspects.

Although the classifications adopted by Hornby for rate of spread were admittedly arbitrary - when compared with "going" fires experienced during the 1934 season it was found that the ratings adopted showed uniformly consistent trends with actual fire behaviour.

It was stipulated that fuel conditions which changed conspicuously be then re-mapped, but as the mapping of fuels formed one of the bases for the entire fire control plan - it was necessary to predict any immediate changes in fuel conditions to ensure future co-ordination of control measures, the planning of permanent road systems etc.

Considerable attention was paid to the density of timber or brush cover,-experiments at Priest River Forest Experiment Station (Idaho) having shown that moisture content of fuels was higher, and wind velocities were lower in fully stocked stands as compared with clear or partially cut areas. In cleared areas and to a less extent in open stands, drying winds have more influence on forest fuels, while during forest fires wind is able to furnish increased supplies of oxygen to the flames and carry more hot air to unignited fuels. Although ground measurements of wind velocity in dense forests show greatly reduced figures as compared with open areas - it must be remembered that the wind velocity above the tree tops is unchecked so that inflammable fuels at that level such as moss, dead needles, rotten bark or wood require mapping as well as ground fuels.

Prevailing wind direction must be considered, together with aspect, amount of slope, etc., while any marked influence of local topography on wind movement must also be considered as affecting fuel inflammability. Aspect is important as regards the amount of sunlight (and consequent increased temperatures) experienced there - steep Northern slopes may actually receive no sunlight. The effect of shading by mountains etc. during part of the day must also be assessed. On steep Northern slopes the effects noted by Bates (12) were that cool and moist conditions at the base of these slopes become progressively warmer and drier on the upper parts of the slope.

Although Hornby (88) found a marked difference in the rate of fire spread in various local timber types, this difference was due almost entirely to the varying density of these types - or to some special characteristic of the timber type which caused changes in fuel types. Any comparison to be made between the fuels of various tree types should naturally be confined to fully stocked stands above sapling size which are free from any abnormalities such as insect epidemics, burns, logging or windthrow. Previous fires were not considered to influence rate of spread unless burning conditions were critical. In considering snags as potential fuels it is important to note their spacing, exposure to wind, fuel around their bases, and the fire fuels present on the snags themselves. On cut over areas, rates of spread were found to coincide more clearly with method and extent of slash disposal than with timber types. If slash is continuous and is located in an open stand, it provides a serious fire hazard.

In calculating the resistance of fuels to fire control - Hornby considered both the volume and type of fuels present, and the effect of roots, soil, rocks, slope etc. on the possible smothering of fuels with soil during average midday burning conditions, and by an efficient force of fire fighters. Not only was the volume of fuels considered in relation to practical difficulties of clearing fire-lines, but the extent of fuels in increasing the severity and spread of fires had also to be remembered.

Hornby finally listed a classification of 43 types of fuel conditions for the typical conditions, as discussed above prevailing in the Northern Rocky Mountain region.

The procedure adopted by Hornby is now largely followed in the various Regions administered by the U.S. Forest Service - detailed instructions (198) having been issued by each Regional Forester regarding the aims and technique of Fuel Type Mapping.

An attempt will be made hereunder to summarise the various Regional instructions so issued:-

Specifications and Instructions for Fuel Type Mapping.

(i) Purpose - Fuel type inventories are basic to forest protection just as timber inventories are basic to forest management. Fuel type maps are one of the basic sources of information required in fire control planning, administration and suppression action etc. In conjunction with fire occurrence maps, they will determine the placing of fire guards, lookouts etc. and the location of transportation facilities.

(ii) Definitions - Rate of spread is measured in terms of chains of fire perimeter increase per hour.
Resistance to control is measured in terms of chains of "held" fire line per man hour to the time the fire is "corralled".

(iii) General specifications for maps - Usually one inch scale maps are used for field mapping - the information from such field maps being later transferred to Office Maps on a ½" scale. In the field, the mapper usually carries an up to date reference map showing all the latest information regarding roads, trails, topography, grazing types, timber types etc. Persons selected for mapping fuels have an intimate knowledge of the area and considerable local experience in the early suppression of fires, so that they can readily classify the fuels on any area. Each mapping unit should comprise an individual forest and each forest fuel map should be suitable for reproduction. In Region No. 4 of the Forest Service it is suggested that fuels outside the forest boundary be also mapped, where practicable, within a distance of three miles.

In Region No. VIII this distance is extended to the limits of the fire suppression action necessary to protect National Forests on average bad days. For high hazard forests, fuels should be mapped on the basis of "average bad" summer conditions but in low hazard forests the most dangerous season should be used as a basis. On areas where slash is to be disposed of - fuels should be mapped as they will appear after such slash disposal.

The most intensive mapping is done in areas of highest fire occurrence which have the most dangerous fuels. In Regions Nos. I and IV the minimum area classified as a Fuel Type is - Extreme class - 40 acres, High - 80 acres, Medium - 160 acres, Low - 320 acres.

In Regions V and VI the same unit areas are used except that both Medium and Low classes are restricted to 160 acres. In Region VIII no types less than 160 acres in extent are mapped.

(iv) Fuel Type Specifications - After considering what would be "average bad" summer conditions the fuel types are divided into 4 arbitrary classes viz:-

Extreme = E or X (In some cases E is used only in exceptional cases)
High = H
Medium = M
Low = L

The same classifications are used in gauging both rate of spread and resistance to control - each Fuel type being thus classed with two letters. For instance grass areas with high rates of spread and low resistance to control would be shown as H.L, the classification for rate of spread always appearing first. The following factors are considered in studying fuels in the various Regions:-

(a) Rate of Spread - Generally two local types are selected as extremes, such as dense Douglas Fir forests on North slopes, and dry Cheat grass on open hillsides (Region 4) and the various local types graded between these extremes.

As previously stated, rate of spread should be based on "average" bad summer conditions and the fuel type is graded on these factors:-

1. Volume of fine fuels (In Region No. VI the "fineness" of fuels is also specified)
2. Arrangement of fine fuels
3. Slope of ground under fuels
4. Degree of fuel exposure to summer sun and to average-strength prevailing winds
5. Presence of snags, tree moss, dead trees, slash, wind-thrown trees etc. that would affect fire spread.

In Region No. I special emphasis is also placed on the size of fuels and on their continuity. Mappers have to rate fuels in terms of a fire actually occurring within an area, and not in the case of a fire spreading to the area from elsewhere.

(b) Resistance to control - In assessing fuels on this basis, mapping must note all items which may occupy the time of fire-fighters, or may hinder their movements. A standard "low" local assessment should first be decided on and all fuel types mapped in comparison with this "low" type. A typical "low" type is an open stand of P.ponderosa, with a light ground cover of needles or grass, on a slope up to 10%.

A "high" type would be represented by a dense "bug"-killed Lodge Pole Pine stand on a steep and rocky Southern slope. Resistance to control is assessed on these main factors:-

1. Presence of brush, slash, weeds, heavy types of grass, musk e.g., regrowth, vines, etc., that would slow up the rate of fire-line construction.

2. Number and size of snags, dead trees, logs, windfalls to be cut or felled.

3. Depth of duff, litter, rotten wood before mineral soil can be exposed.

4. Presence of rocks, roots etc. as they affect clearing a fire line to the mineral soil.

5. Slope as it affects man-power and fatigue.

In Region No. I, Resistance to Control is assessed on slightly different bases, viz:-

1. Size of fuels (light, medium, or heavy.)
2. Volume and arrangement of fuels (light, medium or heavy - down or standing)
3. Fuel continuity to a relative extent
4. Slope and soil conditions as they affect working of fire fighters
5. Size, density, and quantity of other material such as green brush, roots, reproduction etc. which affects control work.

(c) Photographs of fuel types, standardised for a Region are now commonly supplied for the use of fuel mappers in order to effect visual comparisons with Regional standards.

(d) Preparation of data on maps - varies greatly between Regions as indicated by examples hereunder:-

Region No. IV. After boundaries of fuel types have been sketched on the map - a set of symbols will be shown on each type, or on every square inch of type in the following order:-

The double letters representing Rate of Spread (first) and Resistance to Control e.g.,	H.L
From a prepared list of numbers is shown the factor most responsible for rate of spread (say grass) or No. 16 -	S. 16
From a prepared list of numbers is shown the factor most affecting the resistance to control (say brush - No. 5) -	R. 5

Region No. VI. Commencement is again made with the double letters representing Rate of Spread and Resistance to Control e.g. High and moderate respectively

Control e.g. High and moderate respectively	H.M.
Beneath this is inserted the local Type No. (from Forest Survey Types) e.g. No. 6 -	T.6.
Beneath this is the most important factor affecting Rate of Spread e.g. Brackenfern -	B/fern
Beneath this is the most important factor affecting Resistance to control e.g. Vine Maple -	V.M.

Beneath this is the average prevailing slope per cent expressed as one of the four following classes e.g. Extreme -+75% slope; High - 50-75%; Moderate 25-50%; Low 0-25% - Take for example a 50-75% slope - | H%

In Region VI the first two symbols e.g. H.M. may remain constant while the others are changed by local variations of vegetation and topography.

Region No. VIII. In Southern forests there is close correlation between cover types of vegetation and fuel types so much so that various vegetative cover types can be grouped under any single combination of Rate of Spread and Resistance to Control. Thus both Shortleaf-Loblolly and Yellow Pine - Hardwood types are classed as H.M. To this is added any outstanding factor affecting either Spread or Control (or both) e.g. Heavy Shade to give a symbol - $\boxed{\frac{\text{H.M.}}{\text{H.S.}}}$

In Region No. I lists have been prepared showing 6 factors chiefly affecting rate of Spread and seven others which mainly affect Resistance to Control. Apart from the general indication of extremes of Spread and Resistance characteristics of fuels which is shown in all Regions by variously coloured hatching (described hereunder), the mappers in Region No. I select the dominating factors which affect both Spread and Resistance. If these are Numbers 4 and 3 on the respective lists of such factors - they will be superimposed on the hatched areas either as $\frac{4}{3}$ or 4 - 3, the rate of spread factor appearing either above or in front of the Resistance to control factor.

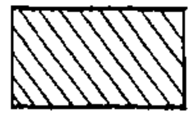
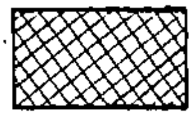
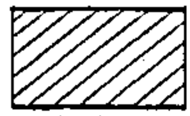
In Region No. II the two major letters, such as H.H., are used to indicate respective rates of spread and resistance to control. If local experience indicates that the fuel type is severe enough, under average bad conditions, to cause a crown fire within an hour of a fire starting in Douglas Fir or Ponderosa Pine forests - this is shown by an initial "C" - e.g. C/HH. or $\frac{\text{C}}{\text{H.H.}}$. In addition, other symbols are added to show the number of the forest type, with a small letter a,b,c, or d, respectively the result of cut-over land, unthinned regrowth, thinned regrowth, or uneven-aged stands. Thus 1a would be cut-over Lodge Pole Pine, 2c would be thinned Spruce regrowth etc. 1b-2b would be used to represent mixed unthinned regrowth of Lodge Pole and Spruce. The full number of symbols to be used might appear on the map as $\frac{\text{1b-C}}{\text{H.H.}}$

(v) Standard Hatching and Colouring to be used in all Regions:-

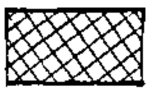
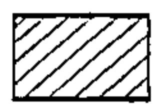
(i) Rate of Spread - shown by Colours e.g.:-

BLUE	EXTREME	GREEN	MEDIUM
RED	HIGH	YELLOW	LOW

(ii) Resistance to control - shown by type of hatching

SOLID COLOUR	EXTREME		MEDIUM
	HIGH		LOW

(iii) Sample combinations as illustrations:-

Red Lines		(High rate) (of spread) (High resistance)	Yellow Lines		(Low rate of spread) (Low resistance)
Green Lines		(Medium rate of spread) (Medium resistance)	Blue Lines		(Extreme rate of spread) (Low resistance)

As previously indicated, each of the Regions makes some reference to tree or ground vegetation in describing various fuel types, in some cases listing a series of different types of such vegetation from which numbers or symbols can be taken for illustration on the Fuel Type Map. Regional Instructions issued to Fuel Mappers also list a complete set of fuel types for the Region with illustrating photographs from which mapping can be easily done.

The following numbers of Fuel Types have been delineated in each Region:-

Region No. I	30 Types	Region No. VI	20 Types
Region No. II	32 Types	Region No. VII	--------
Region No. III	-- Types	Region No. VIII	10 Types (Based on cover types)
Region No. IV	48 Types	Region No. IX	38 Types (Lakes States Section)
			11 Types (Central States Section)

D. Factors Governing Fuel Moisture Content and Their Measurement.

Quite apart from the volume, texture and arrangement of forest fuels it is necessary to study their moisture content - since it is obvious that the inflammability of fuels in the forest depends, above all, on such moisture content.

This moisture content is one of the most elusive of all conditions of fire hazard to measure representing as it does the combined effect of general meteorological factors, which are themselves closely interdependent, and the edaphic factors of a particular site, which are really the expressions of local climate. A knowledge of the moisture content of fuels enables the forester to study present and impending weather conditions and so obtain a precise determination of the extent of the fire hazard prevailing, or likely to occur.

Although for many years U.S. foresters have studied the correlation between weather data and fire records - it is only during recent years that successful efforts have been made to define the factors governing the moisture content of forest fuels.

(i) Climatic or meteorological factors.

To appreciate the relationship between major climatic factors and the varying moisture content of forest fuels - the duff layer should be regarded, as described by Stickel (181), as a tension zone between the moisture vapor of the atmosphere and the water vapor in the soil air. Precipitation alone contributes to the elimination or reduction of water loss from the duff layer and is the only climatic factor which completely checks fire danger, if only for a short period. The hygroscopic action by which duff absorbs moisture from the atmosphere under conditions of high humidity, is quite insufficient to render dry duff safe from ignition. Both the atmosphere and duff can absorb large quantities of moisture - in the case of the former the air temperature controls this capacity. In tests made by Stickel (180) it was found that litter and duff from North Eastern mixed Hardwood and Coniferous forests were capable of absorbing up to 100 per cent of water, based on their dry weight. There is a constant exchange of moisture between the atmosphere and the duff in an effort to reach a state of equilibrium, a state which is reached only when both are fully saturated or are both "bone" dry. Numerous meteorological factors assist in this exchange of moisture, except for rainfall, most of these factors work in their own particular fashion towards the dissipation of duff moisture. While the general effect of weather factors on fuels is known, it is necessary to study individual factors to determine which single factor, or group of them is so intimately associated with duff moisture content as to be worth measuring as a guide to forest fire hazard. Difficulty immediately arises in endeavouring to separate the vital weather factor - as each is interdependent with the others, and it is difficult to gauge the sole influence of any single factor.

Duff layers are used to study the effects of weather on fuel moisture content, as it is the duff layer which is most sensitive to rapid weather changes and which acts as the initial burning agent before fire is carried to the heavier forest fuels.

(a) Precipitation.

This factor has long been regarded as an indication of fire danger, particularly so when precipitation records over long periods showed a cumulative deficiency. Loveridge (115) attempted to use cumulative rainfall records to determine a forest fire hazard on a nationwide basis and showed that current records revealed a marked deficiency. Perhaps more important than total rainfall is its intensity over a definite period. Rains extending over long periods are of more value in increasing fuel moisture content than those of short duration - especially so in the case of light rainfalls. Pearson (149) showed that such factors as distribution of rain, character of succeeding weather, topography, amount and nature of forest fuels were to be considered as well as the total precipitation. A fall of 0·50" of rain would, under average conditions in the South-West, minimize fire hazard for a period of approximately two weeks. In Minnesota, Mitchell (134) noted the seasonal effectiveness of rainfall, - 0·50" being less effective in summer than in the spring or autumn due to greater evaporation and to more interception of summer rain by Hardwood trees in full leaf.

Mitchell and Richman (135) showed that there were considerable local variations in the total fall experienced in Lakes States regions for 10 day periods during summer months - such areas as Northern Wisconsin being more likely to show a deficiency than other areas.

In Canada, Wright (222) found that light rains over 0·12" falling over a period greater than 4 hours, were much more effective than for periods under 4 hours, but traces of rain amounting to less than 0·12" were more effective over the shorter period. Wright also noted the varied effectiveness of rain under different types of canopy or of duff - the nature of the duff varying with exposure as well as with tree types. He also prepared empirical curves showing the effectiveness of 1·20" of rain in varying types of duff, and stressed the relation between moisture content of duff and its absorption of rains - dry duff being much more absorbent than duff of high moisture content. Stickel (181) stressed the greater value of frequent light rains in the North-East as against short heavy showers more especially as heavy summer showers are usually succeeded very quickly by dry, warm weather and/ or bright sunshine.

In Montana and Northern Idaho, Larsen and Delavan (108) estimated that two inches of rain per month would effectively preclude the development of a fire hazard, but admitted that such a rainfall was seldom experienced during summers in that region.

Stickel (181) stresses the importance of stand density to rainfall effectiveness - he found that after measurable rain, duff in clearings was hazardous within 20-36 hours while in mixed Hardwood - Coniferous forest, no hazard is experienced for a period of 200 hours.

While Stickel admitted appreciable interception of rainfall by forest canopy, he suggested that any such loss was more than offset by the condensation of fogs and mists by forest trees, and the draining of such condensation from tree branches or down their stems.

Gisborne (58) estimated that in the Rocky Mountain region heavy rain might increase the moisture content of dead branchwood to 80%, that of small twigs to 100%, and that of duff to 300%.

The view of Larsen and Delavan (108) that two inches of rain per month is required during the summer to reduce fire hazard is supported by a similar estimate made recently by Lansing (107) for New Hampshire. This investigator also estimated that 0·60" of rain might cause fuel saturation, but this would be quickly diminished by subsequent hot sun and, or dry winds. A fall of 0·20" - 0·25" of rain may check burning fires and give purely temporary relief, while 0·10" may be counted on only as assisting fire suppression. Lansing was another to stress the danger from cumulative deficiencies of rain over a period of twelve months or more unless heavy recent rains had occurred. He also stressed the value of light and frequent rains in conserving fuel moisture. In the Rocky Mountain area Brown and Davis (20) have stressed the importance of the interval since the last rainfall, especially since falls exceeding 0·75" of rain. They also found that 0·10" of rain had little or no effect on burning conditions due to rapid local evaporation, particularly in heavy fuels.

It is obvious that under an extremely wide range of fuel and weather conditions, there must be marked differences in the effect of varying amounts of rainfall on the various forest fuels available in U.S. forests while the periods for which such rainfall is effective must likewise show tremendous differences.

Investigators agree that because rainfall is the source of all moisture to forest fuels it is an all important factor, particularly because it is easily measured.

The various viewpoints above-mentioned differ mainly in laying stresses on local modifications of the general effect of rainfall and indicate the need for intensifying local research into weather conditions as they affect local fuels.

Precipitation from snowfall is an important factor in many forests - marked deficiency in normal snowfall being just as important as rainfall deficiency.

Heavy snow compresses duff layers in coniferous and/or hardwood forests, thus materially reducing the drying effect of summer temperatures and wind. Snow is also stated to replenish and conserve soil moisture and thus furnish additional moisture to the duff layer. In Canada, however, Wright (222) claimed to have disproved the alleged increase of duff moisture by saturated underlying soils. If extremely low temperatures during early winter freeze the soil before a heavy snowfall is experienced, moisture from melting snow may not reach the soil at all - the soil remaining frozen until the following spring. Delayed thaws of heavy snow may be beneficial in delaying the development of green herbaceous vegetation until the summer season is well advanced, thus temporarily diminishing the fire risk in the early part of the summer.

Measurement of precipitation does not offer serious difficulties except where daily or hourly recordings are required and gauges are unattended.

The standard U.S. Weather Bureau rain gauge is a container about 30 inches high, recordings being made by inserting into this container a measuring stick 24 inches long, 0·56 inches wide and 0·1 thick, graduated to give direct readings to the nearest point of rain. Owing to the high cost ($11·00 each) of Weather Bureau gauges, the Forest Service commonly uses a cheap ($1·25 each) but efficient gauge, 10 inches high, which gives readings having no significant difference to those made in Weather Bureau gauges. If a recording rain gauge is required, the most common type used is a tipping-bucket device which makes a recording each time a "bucket" of rain is registered.

Apart from care in levelling and exposing rain gauges, it is suggested by Gisborne (58) that the top of rain gauges should be 3 to 4 feet above ground level to prevent debris from collecting therein.

In cases of yearlong precipitation measurements careful recordings of snow fall are made by means of standard snow stakes and "boards".

(b) Relative Humidity.

Humidity has long been regarded as of major importance in the development of "fire weather" conditions. As pointed out by Gisborne (58) it is theoretically incorrect to speak of the "humidity of the air" - water vapor being only one of other gases such as oxygen, hydrogen, etc. which constitute air. If the water vapor in a cubic foot of air space is increased, the volume of air within that space is correspondingly reduced, provided that air temperature and pressure remain constant. With a rise in temperature the water holding capacity of the air space is increased, with a corresponding reduction in moisture capacity if air temperature is decreased. Thus the humidity of a given volume of air varies with temperature, even though air itself does not actually absorb or lose moisture.

Relative humidity is a measure of the ratio between the actual quantity of moisture in a unit of air space and the maximum quantity which the same unit of air space could contain at the existing air temperature and pressure. Only when Relative humidity is 100 per cent does evaporation of moisture from forest fuels cease. Once these fuels have been dried to moisture contents of ten per cent or less, even the finest types of fuel require several hours of high relative humidity to absorb any appreciable moisture from the air, while heavy fuels like snags etc. would require from twelve to twenty-four hours to change materially in moisture content. Gisborne (58) instances a going fire which spread over 54,000 acres on an afternoon when the relative humidity was 43 per cent after an extended period of low humidities had dried out forest fuels. He states further that low humidity may not necessarily produce great fire danger, and that humidity alone is not a satisfactory index of inflammability in the coniferous forests of the Rocky Mountain region.

Relative humidities below 15-20 per cent are, however, considered potentially dangerous by Gisborne, while a figure of 10 per cent is classed as definitely dangerous. He records actual readings of five and six per cent in the Rocky Mountain region, and a figure as low as two per cent in California on ten occasions between 1927 and 1933. Even during rainstorms, humidity readings have been as low as 40 per cent in the Rocky Mountain region, and 18 per cent in California.

In Eastern Areas of U.S.A. a relative humidity less than 16 per cent rarely occurs, but in Western regions low humidities may be both common and prolonged.

Tables prepared by Folweiler (50) and Stickel (181) on the relation between fire occurrence and relative humidity in New Jersey and New York, and by Show and Kotok (170) to show a relation between fire spread in California and relative humidity, are reproduced here in Tables Nos. 15,16,and 17. Although these tables are from widely varying regions, they serve to indicate that relative humidities of 50-55 per cent, with low wind velocities, result in limited occurrence and spread of fires. Wind velocity is important not only in assisting fire spread, but also in also accelerating the drying effect of low relative humidities on forest fuels. In the Pacific North West, Hofmann & Osborne (87) emphasised the relation between relative humidity and fire hazard - at 60 per cent humidity in that region they estimated that fires would not spread but at 25 per cent humidity, fires would "crown."

T A B L E NO. 15.

Influence of Relative Humidity on Forest Fire Occurrence - Central New Jersey -1926.

RELATIVE HUMIDITY (PER CENT) DURING DAY PERIOD	NUMBER OF FIRES	RELATIVE HUMIDITY (PER CENT) DURING DAY PERIOD	NUMBER OF FIRES
24	18	38	4
26	15	40	3
28	13	42	2
30	11	44	2
32	8	46	1
34	7	48	1
36	5	50 plus	0

T A B L E NO. 16.

Relationship between Relative Humidity and Forest Fire Occurrence - New York State-1926-1929 inc.

% RELATIVE HUMIDITY IN OPEN - 2 P.M.	% SURFACE DUFF MOISTURE IN OPEN - 2 P.M	FIRES OCCURRING	
		NUMBER	PERCENTAGE
21-30%	8%	16	17·8%
31-40	13	21	23·3
41-50	15	15	16·7
51-60	19	19	21·1
61-70	23	8	8·9
71-80	25	7	7·8
81-90	25	3	3·3
91-100	41	1	1·1

TABLE NO. 17.

Influence of Relative Humidity on Rate of Spread of Fires - California Region.

RELATIVE HUMIDITY (PER CENT)	AVERAGE FIRE AREA FOR VARYING WIND VELOCITY			AVERAGE OF ALL FIRES
	MINUS-1 M.P.H.	1-20 M.P.H.	PLUS-20 M.P.H.	
20-25%.	57 acres	314 acres	478 acres	292 acres
26-30	80 "	244 "	---	218 "
31-35	57 "	31 "	663 "	47 "
36-40	16 "	81 "	420 "	76 "
41-45	19 "	27 "	80 "	21 "
46-50	12 "	40 "	---	36 "
51-55	11 "	82 "	80 "	78 "

TABLE NO. 18.

Daily variations in Surface Duff Temperatures - Mixed Forests - New York State.

DATE	SURFACE DUFF TEMPERATURES- IN OPEN °(Fahr.)				SURFACE DUFF TEMPERATURES - IN FOREST °(Fahr.)			
	8 a.m.	11 a.m.	2 p.m.	5 p.m.	8 a.m.	11 a.m.	2 p.m.	5 p.m.
8/5/28	39°	72°	85°	75°	39°	61°	66°	60°
21/7/28	54	95	116	95	53	78	68	68
15/8/28	64	106	134	110	62	86	76	72
10/9/28	47	94	104	73	43	74	76	66
13/5/29	56	84	97	77	48	63	60	56
17/6/29	67	96	107	95	59	79	77	70
22/8/29	65	102	123	90	57	77	66	65
27/9/29	58	104	113	73	55	82	79	68

Jemison (97) conducted an analysis of weather factors which influenced the moisture content of light fuels in the Northern Rocky Mountains over a long period. He claimed that the analysis showed definitely that of all weather elements and related factors examined, relative humidity and current air temperature had the most important effect on the moisture content of surface duff.

The majority of investigators stress the importance of relative humidity as a practical index of general fuel hazard. Such importance has hardly been lessened by modern tendencies to make direct readings of fuel moisture content. As well as meaning the evaporation of moisture from duff, relative humidity serves to regulate such evaporation whenever a state of equilibrium is approached between the water vapor in air space and that present in the duff. It is important to remember that due to the more rapid diffusion of water vapor through gases as compared with solids, moisture changes in duff layers (especially compacted duff) lag behind those of the atmosphere, particularly with rapid fluctuations in humidity. This lag is more pronounced in the lower layers of the duff or in the duff layer of densely stocked stands. To some extent the greater lag in dense forests is due to impeded movement therein of drying winds. Cumulative low humidities are most important of all as they result in the rapid dissipation of duff moisture which accumulated in the last rainfall. Repeated low humidities during day periods are not measurably compensated for by intervening high humidities at night. There is a normal daily variation in relative humidity as follows:-

Midnight to 5 a.m.	- High humidity	
5 a.m. to Noon	- Falling "	(Day transition phase)
Noon to 4 p.m.	- Low humidity	
4 p.m. to Midnight	- Rising "	(Night humidity phase)

These changes are actuated mainly by the trends of temperature during the periods indicated. In cases where the humidity does not rise during the early night phase - extremely low readings and serious fire damage may follow on the ensuing day.

Various experimental studies have been made (58) and (107) to determine the probable readings of humidity in the early afternoon (when the humidity is usually at its lowest) from the 8 a.m. readings. The results show that a drop of 20 to 30 per cent in humidity can be anticipated during the period in question on an average summer day.

Because of the importance of recording cumulative low humidities, measurements of humidity recorded by hygrothermographs are much more valuable than the usual dry and wet bulb readings made in the mornings and late afternoons by psychrometers. But as the costs of these instruments are $150 and $7 respectively it is obviously impossible to equip all forest meteorological stations with hygrothermographs.

There are several types of Psychrometer in use, preference now being given to the Whirling Fan type evolved by the Pacific North West Forest Experiment Station. In the latter type a small hand-rotated fan is used to generate an air current which blows on to the wet bulb to give comparative dry and wet readings. The latter readings are referred to Psychrometric tables which give the relative humidity for the elevation at which readings are made. The cost of Whirling-Fan Psychrometers ($6.73)

(Photo by U.S. Forest Service).

Instrument Shelter at Fire Weather Station showing (from left) - Whirling - fan type psychrometer, Byram Fuel-Moisture Scale, Connection to Buzzer-type Anemometer. Nemo Ranger Station - Black Hills National Forest - South Dakota.

General view of Fire Weather Station (in clearing) at Priest River Experimental Forest. Forest Service staff being instructed in the use and care of instruments - Priest River - Northern Idaho.

is slightly less than the commonly used Forest Service Sling type, which costs $7·25 with case. In the Sling type the dry and wet bulb thermometers are mounted together on a small base, which is rotated swiftly by hand by means of a short chain and handle.

It has been pointed that only clean water and clean cotton should be used in contact with the "wet" bulb if accurate readings are to be obtained.

The use of Psychrometers is not wholly confined to weather recording stations as recent use has been made of these instruments at or near forest fires to furnish readings of relative humidity to fire suppression crews.

(c) Air temperature.

In meteorology, air temperature is probably the most important of all weather elements. Quite apart from its thermal effect on terrestrial objects, it has an indirect influence on almost all other weather factors. Temperature determines the amount of moisture which a given quantity of air can hold - rising temperatures allow an increase in water vapor for a given air space so that evaporation from fuels is increased and relative humidity decreased. With lower temperatures there is an increase in Relative Humidity. For instance a cubic foot of air at a temperature of 60°F will hold 5475 grains of water vapor at saturation point (100 per cent humidity), but at a temperature of 90°F it will hold 14,790 grains of water vapor. Thus if air at 60°F and 50 per cent relative humidity (2872 grains of water vapor per cubic foot) is heated to 90°F, the relative humidity will be reduced to $\frac{2,872 \times 100}{14,790}$ or 19 per cent.

Temperature also plays a large part in the daily variation of atmospheric pressure, and the variations in temperature created between two areas influence wind direction and velocity. Surface winds commonly blow from colder to warmer areas, because the latter generally have a lower air pressure than the former. As condensation occurs when air is cooled below saturation point temperature also exerts a major influence over precipitation and cloud formation. It is these indirect influences of temperature on other weather factors that make it important to foresters - although not all of the influences mentioned can be easily measured, or correlated with fire hazard conditions.

High temperatures, and particularly direct sunlight, exert a marked influence on the temperatures of fuels. As the inflammability of duff is directly dependent on its moisture content, and the rapidity with which this can be evaporated, the temperature of the duff is an important consideration. Quite apart from accelerating evaporation, high duff temperatures are important because much less additional heat is necessary to start and maintain combustion. By reason of its colour and opaqueness, duff reflects very little of the insolation which reaches it, transmits pratically none, and absorbs nearly the whole quantity. This absorption of heat is particularly marked in the thin surface layer of duff when the latter has a low moisture content.

The influence of surface duff temperatures on fuel inflammability is much more marked in clearings than in dense forest stands. The duff layer in the forest never attains the same temperature as in the open, while even the same degree of duff temperature in the forest does not produce the same moisture conditions. The comparative temperatures at different times on summer days are well illustrated by Stickel (81) and reproduced here in Table No. 18. Stickel mentions the fact that surface duff temperatures of 78°F, and also a temperature of 93°F one inch below the duff surface, indicate a serious condition of fire hazard in mixed forests in the North-East.

Wright (222) mentions the recording of duff temperatures as high as 148°F on areas without any shade, while under similar conditions in N. Idaho a figure of 181°F has been recorded.

In N. Idaho - Hayes (77) stresses the effect of insolation in greatly increasing duff temperatures. For readings taken throughout August in three successive years on cleared areas in a mixed forest of conifers, Hayes found that the average maximum duff surface temperatures exceeded the mean maximum air temperatures as follows:- On a Southern aspect by 73·3°F, on a fully exposed valley bottom by 53°F, on a northern aspect by 36·8°F. Further investigation into low moisture contents of the duff layers showed that they could not be correlated with the general factors of air temperature and relative humidity and that both low moisture content and high surface temperatures of duff were due to direct insolation. On all clear days during the month of August, insolation had the effect of reducing duff moisture content to the same figure each day, irrespective of air temperatures and/or relative humidity. While the investigations made were in small clearings and may not be generally applied to areas under dense canopy - the trends shown indicate the conclusion by Hayes that insolation, where it was allowed to act on duff surfaces, exerted a drying influence which dominated all other climatic factors.

In studying duff temperatures, Gast and Stickel (56) also showed that the greater the amount of solar radiation which came into contact with surface duff, the lower was the duff moisture content. Most U.S. investigators have noted that high temperatures are associated with the most dangerous fire weather. While such high temperatures are usually associated with strong drying winds, as in the case of the Lake States and the North West, comparatively calm hot weather is also very dangerous, particularly in mountain areas, because of the strong convection currents set up by surface heat and from outbreaks of fire.

Larsen (111) has shown that the length of the fire season in the various altitudinal forest zones of Northern Idaho and Montana is governed largely by the number of days having a mean daily air temperature of over 50°F. Brown and Davis (20) found in the Rocky Mountain Region that while the influence of air temperature on fuel moisture content is theoretically accounted for by changes in relative humidity and in rates of fuel moisture evaporation, variations in burning conditions on 312 fires were only explained when consideration was also given to air temperature fluctuations. They point out the great effect of air temperature on relative humidity readings, and when preparing a correlation of the major weather factors which influence fire hazard, they gave a definite proportional weight to air temperature changes.

In New Hampshire, Lansing (107) has shown that one of the main weather factors preceeding periods of major fire occurrence, was the occurrence during the previous week of mean daily maximum temperatures, and hours of sunshine, consistently above average readings.

As in the case of other fire weather factors, investigators have found that temperature readings must either be taken during the most severe conditions of hazard in early afternoon, or some relation must be established between early morning readings and the probable temperatures later in the day.

Among the points to be watched in obtaining true temperature recordings are:-

(a) Proper exposure of thermometers in standard Weather Bureau shelters or in cheaper shelters of equally sound design, with the door or opening of the shelter facing North (in the Northern hemisphere).

(b) Correct mounting of instruments away from walls of the shelter, the minimum thermometer to slope slightly towards the bulb and the maximum thermometer sloping slightly away from the bulb.

(c) Careful readings to be made, the hands of the observer to be kept away from thermometer bulbs. Checks to be always made to ensure that mercury columns in the instruments are not broken. The minimum thermometer is read by holding it vertically upside down while the maximum thermometer should be read only after being lowered gently to a vertical position.

For most weather stations a pair of good maximum and minimum thermometers is sufficient but if automatic recordings are required to give a complete log of temperature changes either thermographs or hygrothermographs must be installed. If the latter are used, any readings made during the day from thermometers should be used as checks against the readings shown at such times on the charts of the recording instruments.

The cost of standard types of maximum and minimum thermometers is approximately $3·50 each as against a cost of $150 for a hygrothermograph.

(d) Wind Movement.

Wind movement as it affects the fuel moisture content, and the development of fire hazards and fire outbreaks, needs to be discussed in detail, both as regards the velocity and the direction of winds which occur generally in any region, and locally in any part of a forest.

1. Wind Velocity - High wind velocities may be of paramount importance, as instanced by Gisborne (61) who mentions the occurrence of a crown fire in a very strong wind when the forest floor was actually snow-covered, and of serious "blow-up" days during periods of high humidity. In the Northern Rocky Mountain Region, Gisborne rates wind (velocity and direction) as almost equal in importance to fuel moisture content and investigators generally are now agreed on the importance of assessing wind action, particularly its velocity. Both the velocity and direction of wind are dictated by large scale atmospheric movements of air pressure and temperature, but local variations due to topographical features are of almost equal importance when the effects of wind on forest fire hazard are studied.

Wind velocity is important not only as it affects the drying rate of forest fuels but also in affecting the rate of fire spread. Wind currents carry away the layer of air in contact with drying fuels before this layer can show any tendency to become saturated. By introducing a continuous supply of non-saturated air to the fuels, wind movement greatly accelerates the process of evaporation and the loss of fuel moisture content.

When a forest fire is burning, wind currents carry fire horizontally to adjoining fuels, introduce necessary oxygen to the flames in large quantities, create the necessary draught for fierce burning, and intensify the danger from "spot" fires ahead of the main fire. In a forest fire under still air conditions Wright (222) points out that about 84 per cent of the theoretical heat generated by a forest fire passes off vertically by convection or radition without aiding the lateral spread of the fire. The effect of wind currents is to drive at least part of this escaping heat horizontally against adjacent fuels, and thus make a fire less amenable to control. With a plentiful supply of ground fuels, and the development of crown fires, high winds caused a rapid fire spread in the green foliage of tree crowns, particularly in coniferous forests. Such foliage may have a moisture content of 160 per cent but intense heat liberates sufficient resinous and volatile matter to overcome the high moisture content and thus allow burning.

The effect of increased wind velocity is particularly serious once fuel moisture content has reached a hazardous percentage. Even in cases where only the lighter fuels are inflammable, strong winds will carry sufficient heat to moister heavy fuels, cause their rapid combustion, and create uncontrollable fires. Under calm conditions with similar fuel moisture content, fire spread might be practically impossible.

In California, Show and Kotok (170) estimated that "rate of spread, as governed by wind velocity, may be stated to vary as the square of the wind velocity", and that wind velocity was fully as important as relative humidity in governing the rate of fire spread.

To illustrate this equation, one man might be able to corral a fire with a wind strength of 5 M.P.H. but if the wind increased only to 15 M.P.H. a gang of 9 men would be required to corral the same fire. The same investigators also estimated that wind velocity in front of a forest fire might be at least 40 per cent greater than that prevailing velocity outside the fire. In the same region Curry and Fons (35) have indicated that the effect of wind on the rate of fire spread on level ground is likely to be a proportional, rather than a logarithmic relationship, as previously supposed.

In the Rocky Mountain Region, Brown and Davis (20) strongly emphasise the importance of wind - which they assert "had been the universal contributing factor in every uncontrollable fire that had occurred in the Region". They state further that strong winds account for most of the freak fires which at times occur under "otherwise unburnable conditions". Regional evidence also indicated that there was a big increase in uncontrolled fires from calm to light winds, but not a proportional increase from the effect of a 15 M.P.H. wind to that of a 25 M.P.H. wind. Brown and Davis also emphasises the importance of gauging local wind velocity, as well as the general velocity, for a certain region.

The local effect of wind on fuel moisture content and fire spread is to intensify the variable effect of topography. Thus on slopes exposed to strong winds severe hazards will be prevalent. If wind direction is fairly constant, the extent of the local influence of wind can be estimated after due consideration of such topographical features as aspect slope, direction of valley drainage. With variable wind direction the true estimation of the cumulative local effect of wind movement becomes extremely complex.

Table No. 17 shows the effect of general wind velocity on the rate of spread of Californian fires, and more information of this nature could no doubt be supplied after due investigation. Brown and Davis (20) assert that rapid local fluctuations in fire behaviour which resulted in the disastrous Blackwater Canyon fire in 1937 were directly related to changing wind velocity.

While the standard 3 or 4 cup anemometer provides the only means of accurately measuring wind velocity, the cost of these instruments ($75 - $80) precludes their general use at all forest meteorological stations. Even the great majority of Weather Bureau stations are not equipped with wind-recording instruments, and observers have found it necessary to estimate wind velocities from an empirical scale known as the "Beaufort Scale" - see Table No. 19. When forestry investigation into wind movement became intensified it soon became apparent that the Beaufort Scale was not descriptive, and that observers were inclined to over-estimate actual velocities. As a result the Northern Rocky Mountain Experiment Station produced their own wind scale in 1933 (see Table No. 20) and this has proved so successful, as to become generally adopted in Western U.S.A. and in Eastern Canada.

The same Station has also produced a handy modified anemometer, of an inexpensive type, costing $3, the revolutions of which can be counted to give wind velocities up to 30 M.P.H.

The various classifications of wind velocity used in the Northern Rocky Mountain Wind Scale have also been used by Jemison (98) in evolving a Wind Scale for use in Eastern U.S.A. Jemison varied the descriptions in the Northern Rocky Mountain Scale so that Eastern observers could estimate wind velocity from a study of the effect of wind on nearby vegetation, especially during seasons when Hardwood species were without leaves (See Table No. 21)

Foresters interested in measuring wind velocity by means of instruments have sought to interest manufacturers in the design of cheap but efficient types of anemometer. The most reliable of these cheaper instruments is the Stewart type which uses a pair of dry cells to provide an electrical contact and a buzzing sound when the arm of the anemometer revolves sufficiently to record 1/60th part of one mile per hour of wind. By counting the number of "buzzes" during a period of one or two minutes the velocity in Miles per hour can be determined. For example if "10 buzzes" are counted within a two minute period the wind velocity is five miles per hour.

The Stewart type, which costs $6·00, is in wide use by the Forest Service in many parts of U.S.A. and attempts are now being made to produce an inexpensive type of dial recording anemometer. Jemison (98) describes an attachment that can be fitted to the Stewart instrument to give a continuous record of wind movement.

No general agreement has been reached by foresters in regard to the height above ground at which anemometers should be exposed. Many observers prefer to record the lower wind velocities experienced close to ground level as such wind is in contact with ground fuels. In some Regions a standard height of 20 feet is insisted on, Jemison (98) suggests a height of 8 feet above ground under tree canopy in the Appalachian Region, while in California the Regional practice is to mount anemometers in the open at 9 feet above ground.

II <u>Wind Direction</u>. Direction of wind is important in fire weather studies, as within certain broad limits it serves to indicate general weather trends. This is particularly the case when a change of wind direction is usually associated with a definite change in relative humidity or in wind strength. The direction of wind may not be important in all regions of U.S.A. but it is of particular interest in the Western region. In the Pacific North-West region, Easterly winds are dry and hot after blowing over the semi-arid areas of Eastern Oregon and Washington. When they occur, a fire hazard is created which is only relieved when winds veer to the West or North. This relation of wind direction is perhaps more pronounced than anywhere else in the United States, with the possible exception of Southern California. In Eastern U.S.A. Stickel (181) has prepared a table, reproduced here in Table No. 22, showing the influence of various winds on fuel moisture content in New York State, North and North-West winds being most dangerous in this region.

Folweiler and Brown (51) publish another table (see Table No. 23) showing the relative effect of various wind directions on fire weather development in New Jersey which shows that North West winds are as dangerous there as demonstrated by Stickel for New York State.

In California, Munns (138) found that winds from a Northerly direction were conducive to considerable fire danger, as they were experienced in the case of 75 per cent of all fires more than 500 acres in extent and for 93 per cent of all fires of more than 1,000 acres.

While foresters can obtain reasonably accurate Weather Bureau, or local, forecasts of general wind direction in their locality they have to study the local influence of marked topographical features on wind direction. In some cases it is found that a combination of such local effects results in sweeping draughts along narrow valleys, or a local wind current quite different from the general direction. The regularity of local wind movement also needs further study. In New Hampshire, Lansing (107) showed that the movement of wind direction on mountains was more or less uniform by day and night - whereas during clear weather the valleys showed an updraught during the day and a down draught at nights.

T A B L E N O. 19.

Beaufort Wind Scale used by U.S. Weather Bureau.

BEAUFORT SCALE	EXPLANATORY TITLES	SPECIFICATION FOR USE ON LAND	M.P.H. (statute)	TERMS USED IN U.S. WEATHER BUREAU FORECASTS
0	Calm	Calm-smoke rises vertically.	-1	
1	Light air	Wind direction shown by smoke drift but not by wind vanes	1-3	LIGHT
2	Slight breeze	Wind felt on face, leaves rustle, ordinary vane moved by wind	4-7	
3	Gentle "	Leaves and small twigs in constant motion, light flag extended by wind	8-12	GENTLE
4	Moderate "	Wind raises dust and loose paper, small branches are moved	13-18	MODERATE
5	Fresh "	Small trees in leaf begin to sway, crested wavelets form on inland waters	19-24	FRESH
6	Strong "	Large branches in motion, whistling of telegraph wires heard, umbrellas used with difficulty	25-31	STRONG
7	High wind	Whole trees in motion, inconvenience felt in walking against wind	32-38	
8	Gale	Twigs broken off trees, progress generally impeded	39-46	GALE
9	Strong gale	Slight structural damage occurs (chimney pots and slates removed on roofs	47-54	

TABLE NO. 20.

Northern Rocky Mountain Scale of Wind Velocity.

EFFECT OF WIND	WIND VELOCITY M.P.H.	TERMS USED IN U.S. WEATHER BUREAU FORECASTS
Smoke rises vertically, no movements of leaves or bushes	-1	Calm
Leaves of quaking Aspen in constant motion, small branches of bushes sway, slender branchlets and twigs of trees move gently, tallgrasses and weeds sway and bend with wind, wind vane barely moves	1-3	Very light
Trees of pole size in the open sway gently, wind felt distinctly on face, loose scraps of paper move wind flutters small flag.	4-7	Light
Trees of pole size in the open sway very noticeably; large branches of trees, in the open, of pole size toss, tops of trees in dense stands sway, wind extends small flag, few crested waves on lakes	8-12	Gentle
Trees of pole size in the open sway violently, whole trees in dense stands sway noticeably, dust is raised on roads.	13-18	Moderate
Branchlets are broken from trees, inconvenience felt in walking against wind	19-24	Fresh
Trees are severely damaged by breaking of tops and branches, progress is impeded when walking against wind, structural damage, shingles are blown off	25-38	Strong

TABLE NO. 21.

Appalachian Mountain Scale of Wind Velocity.
(A guide for estimating wind velocities in the Appalachian Mountains during Fall, Winter and Spring when trees are leafless)

EFFECT OF WIND	WIND CLASS VELOCITY IN M.P.H.	TERMS USED IN U.S. WEATHER BUREAU FORECASTS
Smoke rises vertically, no movement of trees, bushes, leaves or grass	-1	Calm
Dead leaves on Oaks rustle, Tallgrasses and weeds sway slightly; Leaves and twigs of Laurel move very gently, Wind vane barely moves	1-3	Very light
Stands of Broom Sedge sway and bend with wind, Twigs of hardwood trees and slender switches move very gently, Small branches of Pines move noticeably, Wind flutters small flag, Wind felt distinctly on face	4-7	Light
Dry leaves on ground are blown about, Twigs of Hardwood trees move distinctly, Branches of Laurel shake and toss; Large branches of Pines in the open toss, Wind extends light flag	8-12	Gentle
Tops of large Hardwood trees sway noticeably, Pines in the open sway violently, Dust is raised on roads	13-18	Moderate
Entire Hardwood trees sway, their tops whip violently, Small twigs are broken from Pines, Inconvenience is felt in walking against the wind	19-24	Fresh
Branches broken from Hardwood Trees, Progress is impeded when walking against the wind	25-38	Strong

TABLE NO. 22.

Showing relation between Wind Direction and Average Surface Duff Moisture Content. All readings taken 2 p.m. New York State - 1928-9.

ORDER OF RELATIVE DRYNESS	WIND DIRECTION	AVERAGE MOISTURE PER CENT OF DUFF SURFACE	WIND FREQUENCY	ORDER OF WIND FREQUENCY
1	N.W.	32.7%	430	1
2	N.	34.6	141	5
3	W.	37.1	259	2
4	N.E.	37.1	60	8
5	S.	37.7	164	4
6	S.W.	38.4	232	3
7	CALM	40.1	113	7
8	S.E.	40.7	115	6
9	E.	45.0	17	9

TABLE NO. 23.

Showing relation between Wind Direction and Forest Fire Weather - New Jersey - 1926.

PREVAILING WIND DIRECTION (2 p.m. Readings)	NO. OF FIRE DAYS	PER CENT
North	13	7%
North-East	11	6
East	1	0.5
South-East	18	9
South	16	8
South-West	30	15
West	42	22
North West	63	32

(e) Atmospheric pressure.

Air pressure is more of a guide to future weather conditions, than to the current fire hazard, especially in assisting the prediction of wind direction and velocity, relative humidity, temperature, precipitation etc. Foresters find their own meteorological recordings capable of much greater interpretation and significance if such recordings are used in conjunction with daily weather maps showing barometric pressure in their region, or approaching their region. While admitting that local influences, particularly in mountain areas, have an upsetting influence on the normal development or direction of pressure systems, foresters often find that there is a particular arrangement of these systems for their own region which means the development of very serious fire hazard.

For instance in New Hampshire, Lansing (106) found that on 80 per cent of days on which fires occurred in a particular forest, there was an arrangement of pressure systems which placed a "High" to the South of the region and a "Low" to the North-resulting in a flow of warm air from South to North.

Daily maximum and minimum air pressures were found by Stickel (181) to occur at about 10 a.m. and 4 p.m. in each case, being a few hours later than the opposite extremes of air temperature. Evaporation was also found to vary directly with barometric pressure, while relative humidity varied inversely with it.

Up to the present, research into fire weather has been directed chiefly towards allocating values for the major elements which constitute such weather. Once reasonable certainty exists as to the identity of the most important factors, barometric pressures, as expressed in daily Weather Bureau maps, will be of considerable importance in the attempted forecasting for local regions of the most important weather trends.

Even now, foresters observing fire weather require barometric readings - if these are read from self-recording barographs showing the trends of pressure, and the rapidity of pressure changes, these readings are of immediate and practical importance. As with other instruments of a self-recording nature the cost of barographs (£65 or more) is an obstacle to their general use - although mercurial barometers may cost almost as much.

Following barometric readings and other fire weather recordings, foresters in Western U.S.A. have a great opportunity to localise the Weather Bureau forecast issued between 6 a.m. and 7 a.m. each morning. As this general forecast is for a 24 hour period commencing at 5 p.m. on the same day, forest observers have ample notice of general pressure trends, on which to base their local review of fire-weather conditions.

(f) Cloudiness.

The respective amounts of sunshine and cloudiness during or preceding fire weather have recently attracted some attention from foresters. Even light cloud layers will modify air temperatures and reduce the rate of evaporation shown by duff layers, but little statistical data is available to indicate the extent to which cloudiness is of value. Cloudiness may improve or hinder visibility from lookouts and will thus affect fire control practice. During fire weather, cloudiness is of more importance in conserving fuel moisture content when it occurs during the day. Clouds at night tend to minimise the normal reduction in air temperature, especially near the surface of the forest floor, which under clear skies may increase humidity to near saturation point.

The study of clouds has further interest for observers of forest fire-weather - as a knowledge of cloud types and cloud movement enables the observer to predict probable wind movement, precipitation, humidity etc. If observers have high peaks of known elevation, or other means of measuring the height of the cloud bases during thundery weather, meteorologists may be able to predict the extent and severity of lightning storms.

(g) Evaporation.

This factor is not now commonly used in studying fuel moisture content - the principal reason being the difficulty in correlating the measured loss from free-water surfaces, in evaporimeters or atmometers, with the loss of duff moisture in a similar period. This view has been expressed by such investigators as Show and Kotok (170) and Gisborne (59).

On the other hand, Stickel (181) experimented with twin atmometers, and found that for New York State, the hourly rate of evaporation from these atmometers closely followed the loss of duff moisture content over 8770 paired observations. Under widely differing conditions in California, Munns (138) found that evaporation measurement was the best means of anticipating loss in fuel moisture content.

In Canada, Wright (222) found that a high relationship existed between duff moisture content and atmometer evaporation figures - but this relationship ceased to be effective once duff fuels reached the inflammable stage (19-23 per cent for mixed conifers, 24-34 per cent in Red Pine). Below this stage relative humidity had to be considered as well as evaporation rates.

Evaporation is actually a reflection of the combined effect of wind movement, air temperature, relative humidity and solar radiation. If the particular importance of these four factors can be emphasised independently of evaporation tests, greater precision and accuracy should result from fire weather studies.

In any case the use of porous cup atmometers can hardly be recommended for field observations except in the case of a few experienced observers.

(ii) Edaphic factors.

When discussing climatic factors it has been indicated that there are a number of local factors, mainly topographical, which have a distinct bearing on fuel moisture content by either retarding or intensifying the general influence of climate. No study of fuels or of their moisture content should ignore the most apparent of these local factors, although it is admitted that lengthy experience is needed in any particular locality if a full knowledge is to be obtained of their influence.

(a) Elevation.

This factor is mainly considered important in its effect on prevailing temperatures and relative humidity - both of which affect fuel moisture content to a major extent. Any great local range in elevation undoubtedly introduces more complexities than ever into the study of fuel moisture content, especially where topographical features are so extensive and variable as to affect the normal movement and development of barometric pressure systems and to nullify the value of regional forecasts. The very limited application of such forecasts in the rough topography of the Rocky Mountain region was long ago stressed by Beals (14).

Where marked variations in topography are marked by alternating and steep-sided ridges and valleys, the shading of lower slopes by morning or afternoon shadows may check to an appreciable extent the loss of fuel moisture on such slopes.

Elevation has a marked effect on relative humidity, readings of humidity being lower at high elevations for the same temperature recording, particularly during daylight hours. This has been pointed out by Hayes (77) in N. Idaho, and by Bauer (13) in California. The latter published comparative readings in the Chaparral zone in the Santa Monica Mountains which showed a relative humidity shortly before noon of 45 per cent at an elevation of 2,819 feet as against a reading of 72 per cent at 747 feet elevation.

Precipitation also tends to increase with elevation up to what is known as a "zone of maximum precipitation", after which it tends to decrease. These differences are more marked with heavy rainfall, and in the local wet season. Price and Evans (154) found that winter precipitation at 8850 feet elevation in Utah was three times that at the 5575 feet level, while the summer rainfall at the higher level was twice as great as that at 5575 feet.

In regions where prevailing winds blow fairly constantly, increases in elevation are usually associated with increased exposure to wind, with consequent increases in fire hazard. Hayes (77) found that the maximum daily velocity of wind occurred between 2 and 4 p.m., wind velocity being greater at the higher elevations both day and night, particularly on Southern aspects. Increased elevation is usually associated with decreased temperatures, but several studies have recently shown that it it by no means the case in every instance. Bates (12) found that on steep Northern slopes the cool and moist conditions at the base of such slopes became progressively warmer and drier as the slope was ascended.

In Northern California, Show (162) found that comparing forest litter at elevations of 4,000, 5,000, 6,000 and 7,000 feet, the litter on a Northern aspect was driest at 6,000 feet and wettest at 4,000 feet. On a Southern aspect, driest conditions were met at 7,000 feet and wettest at 6,000 feet. In Northern Idaho, Hayes (77) has carried out comprehensive studies on the influence of altitude and aspect on climatic factors which govern fuel moisture. These studies were made by comparing records of weather and fuel moisture at a valley station (2,300 feet elevation) with those at elevations of 2,700, 3,800 and 5,500 feet on Northern and Southern aspects on each side of the Priest River valley. All recordings were made during the clear and hot conditions which prevailed in the month of August during 1936, 1937 and 1938. One interesting feature was that mean temperatures of the "duff layer" on the S. slope, at the respective stations, were 150°, 164° and 148°F. as compared with a mean temperature of 139°F. for duff on the valley bottom. On the Northern slope much cooler duff tem-

T A B L E   N O. 24.

Showing Number of hours on an average day in August (from studies in August 1936-38 inc.) in which Forest Fuels were placed in various Moisture Content classes.

SITUATION AND ELEVATION	FUEL MOISTURE CLASS					ORDER OF INFLAMMABILITY
	VERY LOW 18·6-25% Moisture	LOW 13·5-18·5% Moisture	MEDIUM 10·6-13·4% Moisture	HIGH 7·5-10·5% Moisture	EXTREME 0-7·4% Moisture	
(i) BRANCHWOOD ([illegible] "diameter) FUELS.						
North Aspect						
2700' Elevation	0	0	11½	12½	0	7
3800' "	0	0	0	16½	7½	4
5500' "	0	0	5	19	0	6
Valley Bottom (2300')	0	1	7	7½	8½	3
South Aspect						
2700' Elevation	0	0	2½	13½	8	2
3800' "	0	0	0	7	17	1
5500' "	0	0	0	24	0	5
(ii) DUFF LAYER.						
North Aspect						
2700' Elevation	7½	6	4	5	1½	7
3800' "	0	14	4	3	3	6
5500' "	1½	8½	3	4	7	4
Valley Bottom (2300')	7½	3½	2½	3½	7	5
South Aspect.						
2700' Elevation	0	7½	4	4	8½	3
3800' "	0	2	8	4½	9½	1
5500' "	0	7½	4	3½	9	2

peratures prevailed throughout than that in the valley, the respective stations recording 119°, 121°, and 111°F. The general effect of elevation and aspect is summarised in Table No. 24, where the respective hazards experienced at the various stations are recorded for two types of forest fuels. From these tables it can be noted that the three stations on the Southern aspect were all more hazardous than the valley bottom, while the Northern aspect stations were generally less hazardous than the valley. The most striking feature is the respective dryness of the various elevations on each aspect On the Southern aspect - the degree of hazard was in the following order - Mid slope, Upper Slope, Lower Slope, while on the Northern aspect there was little difference between the Mid slope and Upper slope but the Lower slope showed easily the least hazard. The main feature which emerged from Hayes' study was his discovery of a nocturnal inversion of temperature in the 2300-3800 feet zone, the temperature increasing at night from the valley bottom to the top of the "inversion layer" at 3800 feet. Between 2300 and 3800 feet there existed on practically every night from July to September during the three consecutive years 1936-38, an altitudinal zone where the air at night was 15-18°F warmer than that either above or below the zone. Not only was the temperature greater, but relative humidity was less, duff temperatures higher, and the moisture contents of fuels was lower. This discovery explodes the commonly accepted theory that mountain slopes are less hazardous from a protection viewpoint, during the night hours, than the valleys and immediate slopes to the valleys. In Hayes' own words - "The level of highest fire danger (which is at the lower elevations during the day), mounts the slopes after sunset, comes to rest during the night some 700-1000 feet above the valley floor, returns to the foot of the mountains after sunrise, and by 9 a.m. is fairly uniform for all elevations on both aspects".

(b) Aspect.

Owing to their greater exposure to solar radiation, Southern aspects in U.S.A. are usually marked by lower moisture content of ground fuels and by more xerophytic types of tree or ground vegetation.

As indicated by Lansing (107), Southern aspects dry out much faster than those facing North after any appreciable rainfall. This has also been demonstrated by Hayes (77) in his comprehensive investigation into elevation and aspect modifications of the N. Idaho climate, already described. Hayes found that after any appreciable rain, the duff layer on Northern aspects remained non-inflammable (when above 10% moisture content) for an average period of 1·6 days, as compared with 0·8 days on Southern aspects, and 0·9 days in the valley bottom - these figures being for small clearings in the forest.

The mean temperature of the duff surface during the month of August was found by Hayes to vary from an average for several elevations of 117°F on a Northern aspect, to 139°F in the valley bottom, and to 154°F for the same elevations on the Southern aspect. While these variations might not be so marked under forest canopy, they at least indicate the wide influence of aspect on drying conditions. Another interesting result obtained by Hayes was an indication that the comparatively cooler and moister conditions in evidence on Northern aspects became less marked as elevation increased. In fact, day-time temperatures at the 5500 feet level were 0·7°F cooler on the Southern aspect than they were on the opposite side of the valley at the same elevation, while at lower levels of 3800

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feet 2700 feet, the Northern aspect was found cooler by 1·1°F and 4·3°F respectively.

Aspect must also be considered in reference to local prevailing winds, or to the most dangerous winds occurring during the fire season. As shown on Tables Nos. 22 and 23 the most serious winds experienced during the summer in the North Eastern region are those from the North, North West and West. As shown on Table No. 22 such winds greatly influence fuel moisture content, and it is reasonable to assume that steep slopes exposed to such winds would show an accelerated loss of fuel moisture.

It is difficult to generalise on the influence of aspect throughout the country, except to observe that it is most important to study local aspects if a detailed knowledge of forest fuels and their moisture content is to be obtained.

In Northern Idaho and Montana, Larsen and Delavan (108) have indicated the effect of topography in checking extensive outbreaks of fire where the general trend of aspect is at right angles to prevailing Westerly summer winds. On the other hand, the incidence of main topographical features parallel to such winds in Central Idaho intensifies their drying influence on forest fuels and also the "fanning" effect of wind on the rate of fire spread.

(c) Slope.

The greater the amount of slope, the greater influence will convectional and general winds exert in the drying of forest fuels and in assisting the rate of fire spread. Steep slopes also directly influence the degree of exposure to solar radiation - as an illustration it might be found that a precipitous slope might receive no direct sunlight during midsummer, and might yet be exposed to strong prevailing winds. Other steep slopes might receive the full force of both sunlight and wind velocity.

Generally speaking, it has been found that steepness of slope intensifies the influence of aspect, particularly where prevailing winds combine with aspect in either building up or mitigating conditions of hazard among forest fuels.

In fire protection studies, the steepness of slopes has so far been considered more in respect of its influence on rate of spread of fires. Fires rapidly become uncontrollable on "up-slopes", and the fatigue of fire fighters is greatly increased among steep slopes. Even steep "down-slopes" may be troublesome owing to the need for trenching fire lines to catch live embers or burning debris which rolls down these slopes.

(d) Vegetative cover.

All investigators agree that the density and general effectiveness of the cover provided by trees and other vegetation greatly influences the effect of general climate and of local topography on the moisture content of fuels. The nature of the forest cover type has a primary influence in determining the nature of fuels and their exposure. Thus Stickel (181) found in the North East that coniferous and mixed types of forests produced a loosely compacted duff layer, while hardwood areas yielded a layered type of litter that retained its moisture to a much greater extent.

Stickel also points out that the end of the spring fire season and the beginning of a similar season in the autumn are determined largely by the respective appearance and disappearance of hardwood foliage. The ameliorative influence of hardwood canopy on fuel moisture content is so marked as to confine the North-Eastern fire season in Hardwood forests to the spring and autumn months when the deciduous trees are not "in leaf". The effect of various Cover Types elsewhere on the rate of spread of fire is graphically illustrated in Table No. 14.

The lesser vegetation on forest areas, and particularly annuals or perennials which are likely to dry off and form dangerous fuels in themselves, is also of particular importance in studying the general inflammability of forest fuels. During recent years there has been a growing realisation by investigators of the retardant influence of green herbaceous vegetation on the drying of forest fuels and on rate of fire spread. While such fuels as grasses are usually at their lowest moisture content during the height of the summer, droughts at other periods of the year may so dry these fuels as to cause serious fire hazard during the spring or autumn months. The importance of studying the moisture content and inflammability of herbaceous growth has been stressed by Gisborne (61) Brown and Davis (20) and Jemison (98), the latter in particular emphasising the moisture content of lighter fuels such as grass, weeds and duff as controlling the start and spread of fires in the Appalachian Mountains.

Another important influence of vegetative cover on fuel moisture content is the completeness with which it effectively covers the forest floor and thus shelters the duff layer and other litter from drying agencies. Lansing (107) points out that in New Hampshire high hazards may occur within 36 hours of effective rainfall on open sites, but under closed forest canopy, subject to the same general weather influences, a similar hazard may not exist until 200 hours have passed.

As shown in Table No. 25, Stickel (176) found that of four forest types in the North-Eastern region, only White Pine-Hemlock and Red Spruce - Balsam Fir duff became dangerous over a long period, the former type being hazardous on twice the number of occasions. The other two cover types, Mixed hardwoods and Conifers, and mixed regrowth of Red Spruce Balsam Fir and Cedar, did not show a duff moisture content low enough to become dangerous. As a contrast Stickel shows the degree of hazard resulting from loss of duff moisture in cut over areas of each of the four types - the White Pine-Hemlock type being then the most dangerous, and the Red Spruce - Balsam Fir duff showing the least loss of moisture.

In another investigation, Stickel (181) traced the relationship between duff moisture contents of a Mixed Hardwood-Coniferous stand in New York State, compared to the moisture of the duff in the open, and in the closed sections of the forest, under various influences of weather. This relationship is illustrated in Table No. 26.

Elsewhere Simson (173) found marked differences in the duff moisture content and relative humidity prevailing in clear-cut lands and mature forests in the Douglas Fir cover type of the Pacific Northwest. The moisture content of litter on cut over lands was very low (13-25 per cent) in the early summer, but after early summer rain, fresh herbage greatly increased this moisture content and little hazard was experienced throughout the summer. On the other hand the moisture content of duff under mature forest was high (200 per cent) in the early summer, (end of April) but then decreased rapidly to reach 35 per cent at the end of June and 23 per cent in mid-August.

In Idaho, Gisborne (62) made tests of the degree of inflammability (as expressed by duff moisture content) experienced on three sites situated within a circle less than a mile in diameter, and classified as:-

1. Moist site on a fully timbered N.W. aspect
2. Medium " " " partially cut over knoll
3. Dry " " " clear cut full exposed flat.

As shown in Table No. 27 the fully timbered area showed the lowest inflammability.

At the same Experiment Station, Jemison (99) compared similar effects of varied meteorological conditions and of duff moisture percentages experienced under (1) Dense virgin timber (mixed conifers); (2) Under approximately half the original canopy and (3) In the open with only scattered regrowth. The comparative results obtained by Jemison are illustrated in Table No. 28 and are sufficiently comprehensive and consistent to be regarded as noteworthy illustrations of the effect of forest cover.

(e) Soil moisture.

This factor was long thought to directly influence the moisture content of duff but close investigations made recently in Canada by Wright (222) showed that even in the case of soils where the moisture content was artificially maintained at 5 and 40 per cent respectively, the difference in readings of duff moisture content on the respective sites was only 1 or 2 per cent. In the forest, Wright found a variation in soil moisture ranging from 3 to 23 per cent with little change in duff moisture content. Stickel (181) obtained a significant correlation between duff moisture and the moisture content of mineral soils in New York State beneath a 12" layer of organic material. Both Wright and Stickel, however, determined the effect of soil moisture on the daytime moisture content of duff. Hayes (77) points out that the influence of soil moisture on that of the duff layer is mainly felt during the night and may assist in reducing duff hazard in cases such as were found to exist in Idaho, where the conditions of fire hazard increased at night on the middle slopes of a valley.

E. Methods for Measuring Fuel Moisture Content.

Research workers studying summer weather, and its influence on the moisture content of forest fuels, agree that no combination of meteorological or edaphic indices can be used to determine the exact moisture content of forest fuels at any time. Even the lightest types of fuel, such as surface duff or dry grass, only follow the trends of climatic and topographical factors as regards their moisture content. For instance,

TABLE NO. 25.

Showing the relation between Cover Types (and their crown density) and Duff Moisture Content for 2 p.m. readings taken daily during fire season - June 6 to September 22, 1927.

COVER TYPE	LOCATION	TOTAL NO. OF DAYS	STATION IN OPEN				STATION IN THE FOREST			
			DUFF MOISTURE %	DAYS No.	DAYS %	AVERAGE RELATIVE HUMIDITY %	DUFF MOISTURE %	DAYS No.	DAYS %	AVERAGE RELATIVE HUMIDITY %
White Pine-Hemlock at 850' elevation	Petersham, Mass.	109	15 or less	74	67.9	52	15 or less	14	12.8	39
Mixed Hardwoods and Conifers at 1800' elevation	Cranberry Lake, N. York	109	do.	49	45.0	55	do.	0	0	--
Young mixed stand of Red Spruce, Balsam Fir and Cedar	Elk Lake, N. York	109	do.	38	34.9	57	do.	0	0	--
Second growth Red Spruce and Balsam Fir	Smyrna Mills, Maine	109	do.	35	32.1	41	do.	7	6.4	40

TABLE NO. 26.

Showing Relation between important Weather elements and Fire Hazard development in Open and Under Forest - New York State-1926-29.

WEATHER ELEMENT	HAZARD COMMENCES IN		ELEMENTAL DIFFERENTIAL PRODUCED BY INFLUENCE OF FOREST CANOPY
	OPEN AT	FOREST AT	
Air Temperature	68°F	Seldom sufficiently high	---
Duff Temperature	78°F	" " "	---
Soil Temperature	64°F	" " "	---
Relative Humidity	62%	26%	36
Depression of dew-point	14°F	34°F	20
Hours since last measurable rain	35	195	160
Evaporation rate per hour	1·25 c.c.	2·23 c.c.	0·98

TABLE NO. 27.

Showing percentages of time, from June 12 to August 30, on which various degrees of inflammability occurred in N. Idaho.

INFLAMMABILITY	EXTREME	EXTREME & HIGH	EXTREME HIGH & MEDIUM	EXTREME HIGH MEDIUM & LOW	EXTREME HIGH MEDIUM LOW & VERY LOW	NIL
Dry site - Clear cut, exposed flat	76	83	86	89	93	7
Medium " - Partially cut over knoll	57	74	79	83	85	15
Moist " - Fully timbered N.W. slope	5	43	59	68	75	25
A V E R A G E	46	67	75	80	84	16

TABLE NO. 28.

Showing average readings of weather etc. and fuel moisture for variable stocking of forest. Priest River Forest Experiment Station - N. Idaho.
(Readings taken during July & August -1931,32, & 33)

FACTOR MEASURED	FULLY TIMBERED AREA	HALF-TIMBERED AREA	CLEAR-CUT AREA
Maximum Air Temperature	79.3°F	81.7°F	84.1°F
Soil Temperature at 12" Depth	51.4°F	53.9°F	59.6°F
Maximum Surface Duff Temperature	77.0°F	91.6°F	126.9°F
Relative humidity - 4.30 p.m.	35.8%	29.0%	27.3%
Absolute " - "	3.343 grains per c/ft.	2.886 grains	2.817 grains per c/ft.
Wind Movement during day	3.8 miles	18.8 miles	32.6 miles
Evaporation rate (1931 & 1932 only)	40.0 grams	77.0 grams	163.0 grams
Duff moisture content	18.8%	16.5%	8.2%
2" Branchwood moisture content	11.1%	9.5%	6.4%
Highest duff temperature measured	94°F	122°F	158°F
Lowest " " "	8.5°F	8.0°F	3.5°F
Lowest 2" Branchwood moisture content measured	7.5%	7%	3.5%
Average % of days with duff moisture below 10%	8.1%	32.3%	88.7%

(90)

temporary increases in relative humidity of the air do not greatly affect the summer loss of fuel moisture, as it requires either 100 per cent humidity or rainfall to check the evaporation of wet fuels. Once dried to a moisture content of 10 per cent (oven dry weight basis) light fuels will remain almost equally dangerous despite any temporary increase in relative humidity. Fuels of varying dimensions and density require various periods to become dangerous after being wet, thus preventing any simple correlation between Relative Humidity and Fuel Moisture Content, while different fuels lag for varying periods behind major weather changes. In a dense forest stand such fuels as duff, branchwood, windfalls, snags etc. may each act independently as regards rate of drying and absorption of moisture under identical conditions of weather, topography and canopy.

The determination of duff moisture content has been usually attempted, as it is realised that this fuel is most susceptible to climatic fluctuations for any given locality. Methods attempted include:-

(i) Direct measurement of Duff Moisture Content.

(a) Sampling method.

This method as suggested by Show (162) consisted of selecting a representative sample of duff, weighing the sample, drying it in an oven to eliminate moisture, re-weighing to ascertain the oven-dry weight of the sample, and finally computing the moisture content of the sample on an oven-dry weight basis. The method had the following serious disadvantages:-

1. It was extremely slow, requiring several days for each moisture determination
2. It required sensitive and expensive apparatus for both drying and weighing
3. It was extremely difficult, if at all possible, to select one truly representative sample of duff.

(b) The wire basket method.

Simson (174) used a wire basket of one cubic foot capacity, suspended 4½ feet above ground, in which to place samples of such fuels ad dried bracken fern etc. and subject them to atmospheric drying. By taking daily moisture determinations of the fuel suspended in the basket he obtained a very close correlation between their daily moisture content and relative humidity readings.

Nichols (142) used a similar basket placed in direct contact with the ground, in which to place samples of duff from a layer 1" thick on the forest floor.

As pointed out by Stickel (181) both these methods are open to considerable criticism, in that the fuels were subjected to an unnatural intensified influence of all drying factors. The methods ignored the correlation which is thought to exist between the dryness of the surface duff and the moisture present lower down in the duff and in the soil itself. In Nichols' method the use of duff to a depth of 1 inch, would give higher average moisture content than that of surface duff.

(c) The breaking test method.

McCarthy (120) devised a simple and empirical method for determining the moisture content of dead hardwood leaves by the degree of cracking and breaking exhibited by them. He found that Oak leaves with 20-40 per cent moisture content cracked when creased but did not break; with 14 to 20 per cent moisture the leaves cracked if folded more than a right angle, but did not break freely, especially at the veins; with 10 to 14 per cent moisture they broke entirely if bent at a right angle; and with 10 per cent moisture they broke but did not crumble if crushed in the hand.

Stickel (181) used this method on dead Yellow Birch and Sugar Maple leaves and obtained practically identical results. Burning tests also made with leaves of various Hardwoods showed that leaves could not be readily ignited with a match when containing more than 40 per cent moisture. Ignition with a match was possible with moisture ranging from 20 to 40 per cent, and was easy with moisture contents of less than 20 per cent.

(d) The duff hygrometer.

This instrument was invented by the U.S. Forests Products Laboratory and was developed with the co-operation of the Northern Rocky Mountain Experiment Station, Priest River, Idaho. In brief it consists of a piece of rattan about 12 inches long and a sensitive dial-gauge. These are housed in suitable frames consisting of a slender, perforated metal tube for the rattan, in which the rattan expands and contracts with changes in duff moisture content, and a heavier metal case for the dial-gauge. One end of the rattan is attached to the spike point of the duff hygrometer and the other to one end of the dial-gauge spindle. The opposite end of the dial gauge spindle is hooked into a wire spring, which in turn, is fastened securely to the housing of the hygrometer. In this way the contraction and expansion of the rattan caused by the decrease or increase of the water vapor in the interstices of the duff layer, are confined to a single horizontal plane, and such motion is transferred directly to the dial gauge.

In the field, the spike end of the instrument is thrust horizontally through the duff layer at the depth for which measurements of moisture content are required, usually just under the duff surface. The dial-end of the instrument should be slightly higher than the spike end (to prevent water from entering the dial-gauge) and the spike end should be carefully covered with duff of the desired depth for its entire length.

It is admitted that carefully calibrated duff hygrometers do not give satisfactory readings when fuels are above 30 per cent moisture content, due to fibre saturation of the rattan at this percentage. But as few forest fuels are inflammable at this percentage, the instrument provided a valuable measure for low percentages of fuel moisture content.

Use of the instrument in the forest had the distinct advantage of enabling observers to gauge duff moisture content without introducing unnatural changes in the duff layer. The instrument responded rapidly to fluctuations of duff moisture content, particularly the downward trends, and has been widely used by all regional observers of fire hazard throughout U.S.A.

Each instrument is carefully calibrated before each fire season in laboratory tests. These tests are summarised in a "calibration curve" of duff moisture content, and the dial gauge of the instrument is then adjusted to give readings which will correspond with the curve. In the field, readings of the hygrometer are made in conjunction with those of meteorological instruments, and have been found to give quite a good indication of the fluctuations experienced in the moisture content of duff fuels.

One of the most serious disadvantages of Duff hygrometers is the great care necessary each season in their calibration. This work is not only tedious, but requires the employment of skilled laboratory workers on an extensive scale. Another serious drawback is that few observers can be relied upon to place the hygrometers in the duff in the correct fashion, to ensure that the spikes of the instruments are effectively covered to the right depth. Experienced meteorologists have found that it was easier to cover the spike with a double layer of hessian, to ensure a continuance of comparable readings among a number of observers. The hessian layer gave a covering equivalent to that used if the hygrometer was carefully placed within the upper half inch of the duff layer.

Yet another disadvantage of the duff hygrometer as a standard gauge of fuel moisture content is the fact that it was of limited use in hardwood or mixed forests owing to the absence of a "bed" of needle litter.

Despite the extensive use of duff hygrometers throughout U.S.A. during the last few years, it now seems inevitable that they will be generally replaced by other (indirect) methods which permit a greater standardisation in actual readings at a single weather station, or between various stations. These indirect methods involve the exposure of wooden sticks, changes in the weight of these sticks being used to indicate actual changes in the moisture content of local fuels.

Danger Rating of Duff Fuels.

Investigators nevertheless agree that the determination of duff moisture content by means of the duff hygrometer has enabled them to define the inflammability of various fuels at various moisture contents. The greatest advance in determining such inflammability has been made by Gisborne (58) and Stickel (181). Despite the fact that these investigators were working on

TABLE NO. 29.

Gisborne's (58) Hazard Table based on Percentages of Duff Moisture Content.

INFLAMMABILITY RATING	MOISTURE CONTENT OF SURFACE DUFF
Nil	+ 25%
Very Low	19 - 25%
Low - Camp fires become dangerous	14 - 18%
Medium - Matches " "	11 - 13%
High - " always "	8 - 10%
Extreme - All sources of ignition dangerous	2 - 7%

TABLE NO. 30.

Stickel's (181) Hazard Table based on Surface Duff Moisture Content and Ignition Tests of Fuels.

INFLAMMABILITY RATING	MOISTURE CONTENT OF SURFACE DUFF	EFFECTIVE FIRE BRANDS
GENERALLY SAFE	30% or More	None - generally safe from all
VERY LOW	23-29%	Camp Fires - duff at edges of fires will smoulder but not spread much
LOW	17-22%	Matches and Camp Fires
MEDIUM	11-16%	Pipe heels, matches and camp fires
HIGH	6-10%	Locomotive sparks, pipe heels, matches and camp fires
EXTREME	Below 6%	Cigarettes, locomotive sparks, pipe heels, matches and camp fires

entirely different fuel types and on opposite sides of the American continent, the "zones of inflammability" which they defined are remarkably consistent as will be seen from reference to Tables Nos. 29 and 30.

Stickel illustrated his various "zones" by indicating their inflammability to such common agencies as matches, locomotive sparks, camp fires etc. on the basis of actual ignition tests.

(ii) Indirect Methods.

Experience in several regions in U.S.A., particularly those Western areas of forest carrying a large volume of heavy inflammable fuels, demanded that some measurement be made of the fluctuating moisture content of such heavy fuels. Attempts were first made to measure the moisture content of selected pieces of branchwood, but it was soon found that differences between sample pieces such as bark thickness, straightness, cracks, knots etc. gave results of little comparative value.

Following the poor results obtained it was decided to use selected pieces of clear lumber, of uniform density and moisture content, as "Indicator" or "Hazard" Sticks, in efforts to demonstrate the varying moisture contents of heavier forest fuels. Different forest Regions developed different types of these sticks in efforts to approximate the heavy fuels in their locality. As described by Matthews (129) the use of branchwood in the Pacific North West was followed by the use of wooden (Douglas Fir) cylinders having a diameter range from ½ an inch to 4 inches. In 1931 the use of cylinders was abandoned in favour of square sticks, the latter being easier to manufacture on an extensive scale. In the Northern Rocky Mountain Region Gisborne (58) and others also developed the use of single cylinders of wood, half an inch and two inches in diameter respectively.

To conform with modern tendencies towards standardization of fire weather recording, all Forest Service weather stations in Western U.S.A., together with many other protective agencies such as the National Park Service, State Forest Departments etc. are now adopting the use of half inch diameter wooden cylinders. Three of these cylinders, made from selected sapwood of Pinus ponderosa, are matched and joined together by wooden dowels to form a set of sticks. The length of the three sticks is approximately 18 inches, this length being gradually reduced in preparation of the sticks until the exact weight of the set of sticks, on an oven dry weight basis, is 100 grams. In the field each set of sticks is supported on a bracket of No. 9 galvanised wire in a horizontal position usually 10 inches above ground level in an unshaded position. A bed of pine needles approximately two inches thick and at least four feet square is placed underneath the sticks to prevent undue radiation of heat from the soil surface. Care is taken to orientate the sticks in a North-South direction, and one end of the sticks is tabbed to ensure that this end faces North each day and that daily exposure is thus uniform.

When sticks of this type were first used they were weighed at each reading and the actual weight recorded was referred to a conversion table which in turn indicated the moisture content of the sticks. This procedure introduced the chance of a mathematical error, which was, howevor eliminated when Byram at the Appalachian Forest Experiment Station developed his "Fuel Moisture Scale".

This scale as described by Byram (26) consists of a brass plate mounted on throo angle brackct supports, and a beam pointer which rests on bearings fastoned to the brass plate. The brass plate is graduatod in such a manner that when the set of sticks is hung on the loop markod 100 on the beam arm, the pointer indicates directly the per cent moisture content of tho sct of sticks. The scale is calibrated to measure most accurately when the moisture content of sticks is lowest, and costs approximately $8. It is most important that the sticks be handled with care and that they be kept quito free of oil, paint, dirt or grease. It is preforable to use a new sct of sticks for cach fire season owing to the effects of cumulative leaching and to changes in hygroscopicity of various sticks after a season's use. Owing to the care taken in manufacturing the sticks to a definite woight of 100 grams it is not nocessary for them to be calibrated prior to use in the field.

It is hoped before very long to have all stations recording fuel moisture content in Western U.S.A. equipped with the Byram "Fuel Moisture Scale" as well as the standard "sets" of 100 gram sticks. This will mean that well over 1,000 stations will be recording fuel moisture content on a comparable basis and in a uniform manner.

Measurement of the moisture content of tho sticks is usually made late in the afternoon at which time readings normally ropresent the daily minimum. In some cases as in California, further readings are made in the morning and at midday in conjunction with other fire weather observations.

In Eastern U.S.A. where forests are mainly of a hardwood type (puro or mixed) Jemison (98) has evolved the use of Hazard Sticks made from flat slats of Basswood similar to those used in Venetian blinds. Use of those sticks is advocatod owing to the more rapid fluctuation of their moisture content following atmospheric changos. Unliko the exposure of the wooden cylinders in Western regions in unshaded positions - tho flat sticks used in the East are exposed under the average forest canopy for the locality. This is done because changes in tho canopy of hardwood forests, have a direct bearing on the moisture content of tho forost floor. In these forosts the ground fuels are at their driest during the spring and lato autumn when hardwood trees are without leavos. By comparison, the summer conditions in these stands are much safer, because the full canopy of the hardwoods conserves the moisture content of the ground fuels.

Still further improvements in the technique of determining fuel moisture content are to be expected. In order to assess the cumulative drying effect which occurs during tho dry summer months in Western coniferous forests, attempts have been made to show the gradual loss of moisture from the outer sections of logs 2 or 3 fect in diameter. This involves the use of electrical (Blinker) Meters and is not a suitable method for use in hundreds of field stations. It may, however, indicate the effect of a continued drought period on the fire hazard, this effect not being fully demonstrated by half inch diameter cylinders, which are likely to show a uniformly low moisture content throughout such period.

Other efforts made to improve the measurement of fuel moisture content include the development of recording instruments such as the "anemo-hygrograph" at the Northern Rocky Mountain Experiment Station, Priest River, Idaho. This ingenious instrument makes a continuous measurement of the fuel moisture percentages of both duff and the half inch sticks, as well as recording the wind velocity registered by a standard 3 cup anemometer.

F. Preparation of Fire Danger Meters.

(1) The development of fire danger rating methods.

Forest administrators must appraise correctly from day to day the probability of fires starting, and the prospects of any such fires becoming uncontrollable, if fire protection planning is to combine efficiency with economy. While the prevalence or activity of fire causing agents is an extremely elusive factor to predict, it can be determined, at least within reasonable limits of probability, once certain conditions of fire hazard are known to exist. The appraisal of existing fire hazard is chiefly concerned with:-

1. The amount and character of forest fuels - This factor is the most tangible and most easily tested element of fire hazard and once it can be accurately assessed, the relative danger of various combinations of fuels can be easily determined, provided they have been accurately mapped, as already discussed.

2. The state of burning conditions - An elusive factor to assess correctly as it involves the multiple effect of climatic and edaphic factors on the inflammability of fuels, and on the rate of fire spread, as discussed in previous pages.

   Research into the state of burning conditions has proceeded under three main headings:-

   (a) Investigating the relation between weather and site factors, and the forest fire hazard
   (b) Determining current conditions of forest fire hazard by meteorological recordings.
   (c) Applying fire-weather data and weather forecasts to fire control plans.

The effect of various weather and site factors on fuel inflammability has already been discussed, but the use of such data in estimating fire hazard for a forest area is difficult for several reasons. Firstly, weather is the net result of numerous inter-related forces, none of which provides an infallible index of the others. Secondly, current fire hazard is just as much the result of past weather factors as of those prevailing at any time. Finally, weather conditions are usually in a constant state of flux.

So far investigators have not agreed as to which weather element, or combination of such elements, is most indicative of fire hazard. While admitting that any controlling element of weather might vary between different climatic and fuel types, a closer approximation of ideas on the subject of the most indicative weather element appears possible. Recent investigations into the determination of fuel moisture content by comparatively simple methods, as already described, should assist research workers in specifying those factors which chiefly influence such moisture content.

Determination of fuel moisture content is not however the whole story, as the dryness of forest fuels is mainly the result of past weather conditions in any given fuel type and topography. Foresters are realising more and more that they need accurate local weather forecasts, before the measurement of fuel moisture content can be used to give an up to the minute rating of fire hazard. The development of fire danger rating has been sponsored by H. T. Gisborne of the Northern Rocky Mountain Forest Experiment Station, many of the research men associated with him at the Station having since assisted in the formulation of danger rating schemes in other forest regions. As previously mentioned, and as pointed out by the Californian Fire Danger Rating Committee (207), the rating of forest fire danger embraces:-

(a) Recognition of those factors which influence fire danger
(b) Measurement of such factors
(c) Practical combination of these measurements so as to indicate the class of fire control organisation required under any condition of danger.

While most danger rating schemes consider the same contributing factors, they differ to a great extent between various forest regions. This difference is due to local variation in the importance of any factor or to variation in the measurement of factors, but the main reason is that fire danger rating is essentially empirical.

Fire danger rating has become such an invaluable aid in fire control practice that administrators are continually pressing for improvement in local rating schemes.

Actually the standard of rating schemes is already high especially when one considers that these schemes have only been in general operation during the past few years. They have mainly been concerned in assessing the probabilities of fire behaviour for a given area of forest rather than for individual cover or fuel types.

It has been stressed (192) at a recent conference of Fire Control specialists that further progress in fire danger rating requires fundamental knowledge of the physics and chemistry of combustion, of the effects of fire itself on convection currents and on other meteorological elements, of the effect of topographic types on wind currents, and the influence of certain weather elements on fuel moisture and fuel condition. The same conference stressed the uses of fuel moisture content and current weather conditions as the bases of rating schemes, and the need for incorporating these factors into a nationally applicable index of fire hazard.

The first attempt made to evolve such a national index was that of Loveridge (115) who attempted to utilise trends of precipitation as a basis.

In the following pages a review will be made of the various fire danger rating schemes evolved in the principal forest regions of U.S.A.

(ii) Types of fire danger meters.

(a) Stickel's Hazard Tables - (Region No. 7)

These tables were devised in 1931 by Stickel (181) for use in New York State. This investigator first plotted all factors affecting fire weather hazard, in accordance with the practice used by others, but soon found this method had certain inherent weaknesses which could only be overcome by statistical analyses of all the data available. Analyses were directed at any pair of variables which were apparent from graphical presentation of the data, and it was found that the following factors, in order of importance, showed the highest degree of statistical association with fuel (duff) moisture content:-

1.	Evaporation per hour	-	Alienation	Index	0·730
2.	Duff Temperature	-	"	"	0·779
3.	Hours since last measurable rainfall	-	"	"	0·815
4.	Air temperature	-	"	"	0·830
5.	Depression of dew-point	-	"	"	0·837
6.	Relative Humidity	-	"	"	0·846

The differences between the various alienation indices were not large but were nevertheless significant. For instance when relative humidity was used to estimate duff moisture content, 84·6% of the variability in such moisture content could be correlated with elements other than relative humidity.

When the same factors were also subject to statistical analyses according to various times during the day, the relation between them remained approximately the same.

Since the water vapor in the atmosphere and that in the duff layer is in closest equilibrium during early afternoon, which is also the peak of daily fire hazard, 2 p.m. was selected as the best hour for meteorological recordings.

In a multiple correlation of the various factors indicated above, evaporation rate per hour took into account the influence of such psychrometric factors as time since last rain, air temperature, solar radiation, and duff temperature. The results of Stickel's multiple correlations are best presented in the form of alinement charts, which when translated on to cardboard slides present a compact and easily manipulated means of expressing the complex relation between weather and hazard. Separate alinement charts were actually prepared to show inflammability from 11 a.m., 2 p.m. and 5 p.m. recordings.

(b) Northern Rocky Mountain Fire Danger Meter - Region No. I.

As developed and described by Gisborne (58) this Meter was developed, after a close study of local conditions, by a system of weighting and integrating measurements of seven main factors which were selected as significant in their influence on current fire hazard. By testing the weights given to these factors during three consecutive fire seasons on thirteen National forests in the region, the correct contribution of each of the seven factors was eventually assessed. The assessments of the various factors were then embodied on a pocket cardboard device, which has two slides which can be set to show the fire danger resulting from measurements of each of those seven factors:-

1. Season of year, and section of the summer period, as affecting hours of sunshine, herbaceous vegetation etc.
2. Lightning occurrence within past two days - lightning causes 72 per cent of all fires in the region
3. Land clearing fires in progress on nearby properties
4. Visibility distance - for distances of one, four, eight, or more than eight miles - additional detection to be provided for if poor visibility coincides with severe conditions
5. Relative humidity
6. Fuel moisture - as measured with duff hygrometer and/or half inch hazard sticks
7. Wind velocity - during the afternoon in accordance with the Regional Scale (see Table No. 20).

The allocation of various weights to these factors, and the use of the sliding scales of the meter to record their measurement, gives direct readings of fire danger as classified in seven different numerical ratings.

Each of these ratings signifies specific rates of fire spread which warrant the specific control measures illustrated in Table No. 31.

The fire danger meter developed by Gisborne is now used at the 150 Fire weather recording stations of the U.S. Forest Service in the Northern Rocky Mountain Region (Region I.) The various factors which are integrated into the meter in order to rate the fire danger at each station are measured late in each afternoon during the fire season. Each station forwards to the forest headquarters details of all the weather recordings made, together with the assessed fire danger rating. The weather information is forwarded to the regional Weather Bureau officer responsible for fire weather forecasting in order to assist this officer in the preparation of a series of local forecasts for each station. The assessed fire danger ratings are collected by administrative officers at forest headquarters in order to indicate what action is necessary to keep the fire control plans for the forest abreast of local burning conditions.

It is also the practice in the Region for administrative officers in charge of a forest, or of a Ranger District therein, to keep a "Fire Danger Chart" posted. On this chart the daily fluctuations of the most important fire danger factors, and of the daily fire danger rating, can be studied. From the chart officers can be warned of any trend or "build-up" of factors which may result in the approach of critical conditions. The charts have also proved of practical use in providing comparable information for the use of inspecting officers and for later compilations.

One of the Fire Danger Meters used in Region I is appended on Page 328 for illustration purposes.

(c) <u>Central Rocky Mountain fire danger Meter - Region No. II.</u>

As indicated by Brown and Davis (20) a meter of this type, to automatically correlate burning conditions and fire risk, is of particular value in the Central Rocky Mountain region where local conditions such as various combinations of fuel,

TABLE NO. 31.

Showing the association between various ratings of Fire Danger in the Northern Rocky Mountain Region and probable fire behaviour, necessary administrative action etc.

FIRE DANGER RATING	PROBABLE FIRE BEHAVIOUR	ADMINISTRATIVE ACTION NECESSARY
CLASS I	Brush burning and other fires do not spread enough to require any trenching	No men specially detailed for fire control
CLASS II	No fire spread under dense timber or on North slopes. On open areas and on South slopes fires spread slowly during the heat of the day	Man positions covering special hazards such as dangerous slash (or brush) disposal operations. Man key lookout stations following lightning storms in June
CLASS III	Fires spread slowly and hold overnight on North slopes and under dense timber, make short runs in the open and through slash. Running Crown fires are very rare except with fresh and strong winds	Man key detection positions. Commence placing "minimum" protective organisation.
CLASS IV	Fires crown in single trees and groups but do not make long runs in full timber on North slopes. Occasional Crown runs on South slopes and flats with moderately fresh winds	Any probability of continuance warrants placing of "average season" protective organisation
CLASS V	Occasional runs in dense timber on North slopes but seldom crossing pronounced topographic divides. Fast spread certain on South slopes, cut over areas, and on heavily fuelled old burns	After 1 day finish placing full "average" organisations. After 2 consecutive days commence filling "first overload" positions. After about 7 consecutive days complete the "first overload"
CLASS VI	Big runs common on all exposures within a single drainage but only occasionally crossing pronounced topographic divides or barriers	After 1 day complete "first overload". After 2 consecutive days commence filling "second overload". After 4 days complete "second overload"
CLASS VII	Explosive conditions, with fires spreading at rates up to 1500 or 2000 acres per hour including densely timbered North slopes during afternoons and evenings. Topographic and other usual barriers such as rivers and large cultivated fields are ineffective during daytime peak conditions.	If occurring or predictable mobilise supplemental overhead and take other action specified by "third emergency call" in the overload plan.

topography, lightning risk, intense local human risks render ordinary personal judgment of the fire hazard wholly unreliable.

Fire danger meters from four various Regions were tested against the meteorological records for the actual burning periods of 312 major outbreaks of fire dating back to 1920. This examination showed wide variations due to the arbitrary weights given to changes in "fire risk" and in atmospheric visibility, and to the attempts made to correlate these two factors.

The 312 fires selected were in the nature of catastrophes so that they furnished good examples of the "build-up" of severe burning conditions. The worst of such burning conditions revealed in the study showed:- Air Temperature 92°F, Relative Humidity 5 per cent; Wind Velocity 25 M.P.H., Fuel Moisture Content probably below 5 per cent. These conditions caused a fire to spread 8,000 acres in a few hours. In rating various burning conditions on an arbitrary percentage classification, the severe conditions enumerated above were assessed at 97 per cent only, as even more severe conditions are possible. The arbitrary division into danger ratings was defined so as to narrow the classifications as extreme conditions were approached.

The first major contributing factors considered were Wind Velocity, Relative Humidity, and Elapsed Time since last rain. As the study progressed it was found necessary to include other factors and to make progressive adjustments in the weighted values given to each until there were no apparent inconsistencies remaining. Fuel Moisture content of Hazard Sticks also replaced Elapsed Time since the previous rain, as a determining factor - these moisture percentages being combined with those of relative humidity in the proportion of 4 to 1. This composite factor was found to follow very closely the actual moisture content trends of the important lighter forest fuels. The factors which were finally adopted as being indicative of prevailing fire hazards in Region II are classified hereunder in order of their importance:-

(1) Wind Velocity - from 0 to 35 miles per hour which was found to be the universal contributing factor in every uncontrollable fire experienced in the Region.
(2) Air Temperature - from 56°F upwards
(3) The combination of Atmospheric and Fuel Moisture based on actual (percentage) readings of Relative Humidity and of Hazard Stick moisture content, twice as much weight being given to the latter percentage.
(4) Cumulative effects - being the cumulative sum of the percentages expressed by Factors (1), (2), and (3) since the last general rain or since thawing of the last snow cover.
(5) Vegetation hazard - from Factors (1) to (4) above a deduction is made when "annual" vegetation in the forest is green or partly so.

The various percentages assigned to the factors enumerated above have been carefully assessed and are shown on boards for ready reference as illustrated in Table No. 32. To facilitate reference to these boards the graduations thereon are plainly coloured. The various classes of Fire Danger Day, namely Extreme, High, Moderate, Low and Dormant are derived from the graduations assigned to the various factors already enumerat

(103)

TABLE Nº 32

FIRE DANGER METER - CENTRAL ROCKY MOUNTAIN REGION

R-2

CLASS OF FIRE DANGER DAY

PERCENT		
100–90	EXTREME	ALL AVAILABLE FORCES
90–75	HIGH	PRIMARY EMERGENCY FORCE
75–65	(HIGH MODERATE)	NORMAL PROTECTION FORCE
65–50	MODERATE	
50–25	LOW	FIRST PROTECTION FORCE
25–0	DORMANT	NO SPECIAL ARRANGEMENTS

WIND VELOCITY

Percent	0	4	8	12	15	18	20	22	24	26	27	28	29	30	30	31	31	32	32	33	33	33	34	34	34	35%
M.P.H.	0	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 UP

TEMPERATURE

0%	2%	4%	6%	8%	11%	13%	15%
BELOW 56°	56°–62°	63°–69°	70°–76°	77°–83°	84°–90°	91°–97°	98°–UP

ATMOSPHERIC AND FUEL MOISTURE

RELATIVE HUMIDITY

0%	2%	4%	6%	8%	11%	13%	15%
ABOVE 70	70–61	60–51	50–41	40–31	30–21	20–11	10–0

FUEL MOISTURE STICK %

0%	2%	4%	6%	8%	10%	12%	14%	16%	18%	20%
COMPLETE SNOW COVER OR ABOVE 25	25.0–21.1	21.0–17.1	17.0–14.6	14.5–12.1	12.0–10.6	10.5–9.1	9.0–7.6	7.5–6.1	6.0–4.6	4.5–0

CUMULATIVE EFFECTS

CUMULATIVE SUM OF PERCENTS OF ALL ABOVE FACTORS SINCE LAST GENERAL STORM OF .25" OR MORE OR SINCE SNOW LEAVES GROUND

0%	3%	6%	9%	12%	15%
GENERAL STORM OR COMPLETE SNOW COVER	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 – UP

VEGETATION HAZARD

DEDUCTION FOR HERBACEOUS STAGE

FINAL METER READING SHOULD NOT BE LESS THAN 0

ANNUALS DRY	ANNUALS GREENING			ANNUALS GREEN	ANNUALS CURING			ANNUALS CURED
−% 0	1 2 3	4 5 6	7 8 9	10	9 8 7	6 5 4	3 2 1	0

UNDER CONDITIONS OF A COMPLETE SNOW COVER METER READING IS AUTOMATICALLY 0 UNTIL SNOW LEAVES GROUND

For example, on the first day after a precipitation of 0·25" or more, Class of Fire Danger Day is determined as follows:-

Wind Velocity	- 9 M.P.H.	= 26%
Temperature	- 79°	= 8%
Relative Humidity	- 33%	= 8%
Fuel Moisture of Sticks	- 7·5%	= 16%
Cumulative Effect	- 6%	= 6%
Total		64%
Deduction for "annuals being green		10
Class of Fire Danger Day		= 54% - Moderate

If, for example, on the next day the total percentages of Wind Velocity, Temperature, Relative Humidity and Fuel Moisture was 59% giving a cumulative effect for that day of 6%, plus the previous day's cumulative effect of 6%, or a total of 12%. Readings would then be recorded as follows:-

Wind Velocity	- 10 M.P.H.	= 27% on Scale
Air Temperature	- 76°	= 6%
Relative Humidity	- 31%	= 8%
Fuel Moisture Sticks	- 6%	= 18%
Cumulative Effects	- 12%	= 9%
Total		= 68%
Less Deduction for "Annuals"		= 10
Class of Fire Danger Day		= 58% = Moderate

This method of Rating Fire Danger has the great advantage over certain others in that it gives due weight to the cumulative drying effect over any protracted period since measurable precipitation.

To compute Fire Danger, meteorological readings are made at most stations at 8 a.m., 10 a.m., 1 p.m., 3 p.m., and 5 p.m. Where it is not possible to take all these readings, those at 8 a.m. and 3 p.m. are insisted upon. After continuous readings for some time, the 8 a.m. reading becomes quite a good indicator for the rest of the day. The 3 p.m. readings are necessary, however, as they alone are used in computing the daily fire danger for record purposes.

Special sheets are used for the daily recording, at the times abovementioned, of the various factors which are the basis of Fire Danger rating. The computed rating for each day is charted at each recording station, a corresponding entry being made on the chart for each day to show the number of fires of various sizes occurring in the locality. Recording stations are so located as to be typical of the greatest area of forest having a relatively high fire danger, areas of purely local climate being largely ignored. The occurrence of high danger ratings over a large part of any National Forest, or of extreme ratings at any individual recording station, is immediately telegraphed to the Regional Office of the Forest Service.

The Central Rocky Mountain Danger Rating Method has been adapted for use in the adjoining South Western Region of the U.S. Forest Service.

(d) <u>The California (Region 5) Method of Fire Danger Rating</u>.

In California, fire control specialists are interested mainly in the ignition conditions for fires, and in their rate of spread under any set of weather conditions. It is also considered that there is now sufficient knowledge to enable indices to be derived so as to show the relative number of fires to be expected and their relative rates of spread.

(a) The Ignition Index has been derived from extensive fire research and has been found to consist of two main variables e.g., Fuel Moisture content of half inch sticks and Wind Velocity. The experience of previous fire seasons indicates the number of fires to be expected from a given amount of risk, and for normal weather conditions, and the abovementioned variables indicate a proportionately greater or lower hazard. No calculation can of course be made for any incendiary fire which may be started - especially so when such fires are usually started under the worst conditions of hazard.

(b) The Spread Index - was derived from extensive tests and shows the relative rate of spread under various conditions of fuel moisture and wind velocity for an average (10 per cent) slope in a certain fuel type.

(c) The Lightning Index is derived from a special lightning meter which is based on statistical averages of some 10,000 lightning fires. As it includes some theoretical assumptions, it is not intended to wholly supplant individual judgment in respect of probable lightning occurrence. The lightning meter is used to convert the local fire weather forecast into an index of the probable number of lightning fires.

The integration of the Ignition Index with the Lightning Index gives an estimate of the probable number of fires, while the Rate of Spread Index gives a separate estimate of their probable size. By adding the Lightning Index to the Ignition Index and by multiplying the result by the Rate of Spread Index - an estimate is obtained of the total amount of fire perimeter which may develop. This latter estimate is referred to as the Fire Load Index. To obtain an accurate Fire Load Index it is necessary to restrict the range of such Index to a comparatively limited area - owing to varying climatic and fuel types. Individual judgment is permitted to amend the Fire Load Index in such cases as arise when the condition of annual vegetation is of importance in classifying fuel conditions, or when local difficulties are experienced in securing average visibility from lookout towers.

In compiling fire weather data, readings are made of various meteorological and other instruments at 8 a.m., 12 noon, and 4.30 p.m. but only the latter observation is used in the compilation of fire danger indices or ratings.

A summary of the late afternoon observations is forwarded from the forest headquarters each evening to one of the three special fire weather forecasters in the Region who later in the evening (8.30 p.m.) broadcasts his forecasts to the different parts of his territory.

Some seven classes of fire control organisation are used in applying the fluctuations of the Fire Load Index to administrative action. These organisation classes are as follows:-

Class I — "No Fire Danger" - Fire control staff confined to yearlong personnel

" II — "Skeleton" - Fire organisation includes yearlong personnel, some key lookouts, and some dispatchers.

(Photo by U.S. Forest Service).

Fire Danger Rating board used in Pacific North West Region (U.S. Forest Service) to illustrate daily derivation of prevailing fire danger rating.

CLASS III	"Subnormal" - The organisation is increased to allow the employment of from 50 to 75 per cent of the normal summer force - e.g. key lookouts, key guards, suppression foremen.
CLASS IV	"Normal" - The full regular fire season organisation is employed.
CLASS V	"First Emergency" - Additional guards and lookouts posted where necessary while initial suppression crews are strengthened.
CLASS VI	"Second Emergency" - All forces available on the administrative unit are assigned to Fire Control
CLASS VII	"Full Emergency" - All facilities available on the forest are supplemented by help from other forests.

(e) <u>The Pacific North West (Region No. 6) Fire Danger Rating Methods.</u>

In this case actual use was made of the Ignition and Rate of Spread Indices developed in California, these two indices being multiplied together to give a "Burning Index" for use in Region 6 (the States of Oregon and Washington). This latter Burning Index was divided into percentages for simplifying its use, and these percentages were grouped into ten different classes. These classes are then used with assessments of both visibility and the activity of fire starting agencies, to arrive at what is called the "Class of Day Index" for Administrative action.

The "Burning Index" values express the basic physical relationship of weather factors to fire behaviour under an assumption that all other factors are constant. As in California, easily recognisable local differences in fuel, topography etc. are used as a correction factor before applying Burning Index values to administrative action plans.

The inclusion of estimates of fire danger (visibility and degree of risk) in methods of fire danger rating is peculiar to the Pacific North West Region and requires considerable judgment on the part of the District Ranger, or his assistant. It also necessitates the provision of a large number of stations to record fire weather observations if the great variation in topography, fuel types, visibility distance, fire risk, is to be effectively minimised. It is not therefore surprising to find some 550 fire weather stations in use throughout the Region, or an average of five or six stations within each administrative unit (Ranger District). Each Ranger District is divided into zones in which Fuel Moisture content fluctuates more or less uniformly (based on past records and on fuel type maps), and efforts are made to make fire weather stations representative of these zones.

(f) <u>The Cumulative Relative Humidity Scale of Hazard - Region No. 4 - Intermountain Region.</u>

In Region No. 4 all forest weather stations on high hazard forests are equipped with - Psychrometer (or hygrothermograph); ½" wooden cylinder Hazard Sticks; Wind gauge and Rain gauge.

In the Region any deficiency of relative humidity, occurring either generally or over a definite period of time, is used to determine the relative seriousness of the forest fire hazard. Use of humidity tables was first concentrated at the "base station" at Boise, Idaho. For this station a "base humidity" of 21 per cent was fixed, and once seven days had elapsed which showed shade temperatures of 83 degrees or more at 6 p.m., a daily record of humidity readings was commenced, all such humidity readings being also recorded at 6 p.m. This record of humidity readings is then carried on throughout the fire season, and afterwards, until all danger has subsided. When the humidity on any days is higher than the "base humidity" of 21 per cent - a plus sign is recorded for the excess percentage. Minus signs are similarly registered when humidity falls below the "base" of 21 per cent. If at any time the cumulative record shows a plus sign, followed by a single day with a minus sign - a new set of cumulative values starts from zero. When plotted on curves, any minus value will be shown as beginning at zero if it follows a period of plus values. The procedure adopted is best illustrated in Table No. 33.

Daily cumulative values are plotted for each forest, once "base humidity" for each weather station has been fixed by correlating daily humidity readings with those at the "Base" station at Boise. These "base humidities" range for the various regional stations range from the 21 per cent at Boise up to 36 per cent at several locations, and down to 19 at one station.

The use of hazard sticks, wind and rain gauges is building up meteorological records so that a check on "cumulative humidity" as a hazard index will be available.

For each station "cumulative humidities" are classed into the following Fire Hazard Periods.

PERIOD I	-	All periods showing excess humidity
" II	-	Cumulative deficiency of humidity from 0 to minus 60
" III	-	" " " " " minus 61 to minus 120
" IV	-	" " " " " " 121 " minus 180
" V	-	" " " " " " 181 or less

Information from past records (37 years at Boise) shows the average number of days for which each "Period" usually lasts. Definite administrative action is assigned to each "Period", and as the daily records show a more serious "Period" approaching, preparations can be made for suitable administrative action to be taken. Past records show that the chance of a Period IV occurring are only about once in three years, and Period V about twice in every nine years, but all administrative action is ready for their occurrence.

Once the daily humidity readings show an accumulated excess of 100 or more after September 1st the fire season is usually counted as being ended.

Cumulative humidity is used chiefly as a guide to definite administrative action, such action having already been planned in accordance with such varying local factors as:- (a) Area seen by detection units; (b) Fire occurrence; (c) Values at stake; (d) Fuel types; (e) Resistance to control; (f) Available reserves of man-power. For Humidity Period II the number of fire guards on duty is approximately 70% more than for Period I, while the number of fire guards employed for Period IV is nearly five times as many as for Period I.

TABLE NO. 33.

Showing Cumulative Humidity Record - Boise, Idaho
(Base Humidity = 21 per cent)

DATE	6 P.M. HUMIDITY READING	DIFFERENCE FROM BASE (21 per cent)	CUMULATIVE HUMIDITY
June 21	16	-5	-5
22	18	-3	-8
23	19	-2	-10
24	25	+4	-6
25	30	+9	+3
26	35	+14	+17
27	18	-3	-3
28	13	-8	-11
29	10	-11	-22
30	30	+9	-13
July 1	35	+14	+1
2	27	+6	+7
3	14	-7	-7
4	10	-11	-18

(g) Appalachian Forest Fire Danger Rating Scheme (Region No. 7)

As explained by Jemison (98) the scheme evolved at the Appalachian Forest Experiment Station, North Carolina, stresses only a limited number of factors viz. - Fuel Moisture Content, Wind Velocity, Season of Year, Condition of vegetation, and Precipitation Interval.

In the mountains of the Eastern region, fluctuations in fire hazard are mostly rapid, and they occur frequently. Short periods, or single days, of severe hazard are often interspersed with wet days or with unsettled weather of low hazard.

1. Fuel Moisture Content - as previously explained (in discussing fuel moisture determination) the method adopted is to expose thin flat strips of Basswood to natural conditions of forest cover. For instance if surface hardwood litter is to be measured for its moisture content the sticks are exposed to natural shade in such a stand. If dead grass fuel in an "old field" is to be rated the sticks are exposed there in the open. The lowest afternoon reading is recorded.
2. Season of Year - Reflects the effect of solar radiation both as regards angle of the sun's rays and the number of hours of possible sunlight. Comparatively safe North aspects are much less so under the drying influence of the mid-summer summer sun.
3. Wind Velocity - Largely controls the rate of spread and is of paramount importance once fuels are inflammable. Measurements are made either with standard anemometers or with buzzer type instruments.
4. Condition of vegetation - as reflected by the stage of dryness reached in the case of grass, weeds, shrubs etc. during the summer, hardwood leaves in the autumn etc.
5. Precipitation interval - since the last fall of 0·50 inches of rain. As the fuel hazard sticks abovementioned are calibrated to record only moisture changes in surface of fuels they do not indicate any drying out of deep litter. For this reason the precipitation interval since the last effective rainfall is included.

It has been found necessary to establish a network of stations to record the above factors which is fully representative of geographical and topographical variations in any single forest. The number of stations is controlled according to available personnel, location of past fires, compactness of a forest unit, variations in topography, cover or fuel types etc.

Daily recordings are made at 7 a.m.; 1 p.m.; and 4 p.m. - except in the case of precipitation which is measured only at 7 a.m. and 4 p.m. when it occurs near one of these times. After integration of measurements, and the most satisfactory weighting of the various factors, a fire danger meter has been prepared in the standard "pocket" type - e.g. a Cardboard envelope with "slide rule" insertions to record any combination of assessed factors, and for summing up these assessments to place the existing fire danger into one of five numerical classes. (Class I represents "no danger"). "Classes" of fire danger are determined and charted daily so that either administrative action in fire suppression, or forecasting of further local hazards in the immediate future, is facilitated. It has also been found useful for recording stations to measure "visibility range" so that additional detection may be arranged when poor visibility is combined with conditions of serious hazard.

Owing to the varying conditions of hazard experienced in truly mountainous areas of South Eastern U.S.A. and in the Coastal Plain along the Atlantic Coast it has been found necessary to use separate meters for each of these localities. While there is practically no difference in the factors used to prepare each of these two meters, different weights are given to the various factors in each case, based on their importance in the locality.

A specimen of the Fire Danger Meter prepared for use in the Eastern Mountains of U.S.A. is appended on Page 329.

(h) A Tentative Fire Danger Meter for the Southern (Longleaf-Slash) Pine Type (Region No. 7).

In this Pine Type, fire danger changes rapidly and frequently, and the "fire season" if it can be called such, occurs at intervals throughout the year, interspersed only with wet or unsettled weather. Changes in fire danger in this timber type are directly associated with changes in the "burning condition" of the herbaceous undergrowth. In preparing a tentative fire danger for the type, actual rates of fire spread in the type were used. The most important factors having a bearing on the rate of spread were found to be wind velocity and fuel moisture content. In the absence of any adequate basis for defining the limits of the danger classes, these classes were equally divided in accordance with the rate of spread index, but experience may indicate the necessity for some revision of these divisions.

To measure fuel moisture easily and accurately, flat strips of Basswood are used as indicator sticks (as used in the Appalachian Fire Danger Rating Method.)

A movable slide rule, set for a certain condition of herbaceous vegetation (e.g. green, drying or dry) is used to indicate the danger class, and the rate of spread index, for any readings made of wind velocity and fuel moisture content.

The new fire danger meter is now being extensively tested in the field, and until the conclusion of such tests no instructions or plans have been laid down for administrative action based on the different danger classes.

It is hoped to prove that a definite percentage of the total number of fires may be expected to occur within various danger classes and that the average potential size of such fires may be estimated so that a certain strength of suppression forces will be required for a certain danger class. The evolution of this meter has been explained in detail by Bickford and Bruce (16).

(i) Fire Danger Meters used in the North Central Region (Region No. 9).

In this Region two separate meters are used - one known as the "Lakes States Meter" being utilised in the forests of Michigan, Wisconsin and Minnesota, while the "Central States Meter" is used in Missouri, Illinois, Indiana and Ohio.

Both of these meters are based on days elapsed since rain, current relative humidity, current wind velocity, prevailing conditions of vegetation etc., but the Lakes States Meter also specifies the amount of the last rain. These factors are subsequently combined with fuel moisture content, (from readings made of duff hygrometer or half inch diameter sticks), and visibility distance, to determine the "Class of Fire Danger".

Each fire danger station makes daily observations (at 8 a.m., 12 noon and 5 p.m.) of Precipitation, Relative Humidity, Wind Velocity and Direction, Fuel Moisture, Sky conditions, and Visibility. Each observer reports to the forest headquarters after 8 a.m. readings each morning, giving for his locality:-

(a) The previous day's fire danger rating - the worst rating calculated from the three observations made each day
(b) Precipitation for the 24 hours ended 8 a.m.
(c) Current (8 a.m.) readings of fuel moisture content, visibility, relative humidity and wind movement
(d) The number of fires and area burnt for the preceding 24 hours.

The forest headquarters arranges for telegraphic transmission by code of these fire weather data to one of the two special fire weather forecasters assigned to such work by the U.S. Weather Bureau, and before 10 a.m. the same morning each forest receives back a detailed local fire weather forecast for that day.

The Hazard Indicator sticks used are half inch or two inch diameter sticks of clear Northern White Pine - the smaller size being joined in a set of five to give an oven dry weight of exactly 100 grams while the larger sticks are in pairs having a net dry weight of 400 grams.

Visibility is measured only from lookout towers while reports on the condition of (herbaceous) vegetation are based on determinations by the District Ranger whether it is green, curing or dead.

A tentative classification of Fire Danger for Region 9, interpreted into terms of Fire Behaviour and essential organisation changes is shown in Table No. 34.

(iii) <u>The use of Fire Danger Meters in Fire Control Planning</u>.

The main objective of fire danger rating is to gauge the existing or impending danger from fires to any forest area, given any set of local conditions. If danger is accurately gauged, administrative officers can plan and adjust their fire control organisation to meet the fluctuating fire load, so as to make the best use of funds available for fire protection. Officers can also classify forest units on the basis of total fire danger, thus ensuring the most effective allocation of available funds to those forests or other units most urgently demanding protection. At the outbreak of fire, experienced officers can calculate the size of the suppression job and can place most effectively heavy reinforcements which have been planned for extreme conditions of danger. During the fire season, a knowledge of existing and impending fire danger also facilitates the working of the permit system for brush-burning, smoking, camping etc. and dictates the placing of

T A B L E N O. 34.

REGION NO. 9 - FIRE DANGER RATING.

Showing classification of fire danger, probable fire behaviour, and the necessary administrative action.

FIRE DANGER CLASSIFICATION	PROBABLE FIRE BEHAVIOUR	ADMINISTRATIVE ACTION REQUIRED
CLASS I (No danger)	Fire will not start from a match or spread beyond the heat of a campfire or burning brush pile. Fires in peat, rotton logs and snags will continue to smoulder	No men specifically needed on fire control except for mop up of any smouldering fires
CLASS II (very low danger)	Fires will start from an open flame and from un-trenched camp and brush pile fires but spread slowly and tend to go out themselves	Lookouts needed for areas of special danger such as slash areas, land clearing operations intensively used recreation areas etc.
CLASS III (Low Danger	Fires will start from a lighted match and will spread (rapidly in dead grass, more slowly in heavier fuels) until extinguished	Men needed on primary lookouts. Regular protection force should be within call
CLASS IV (Moderate)	Fires start readily from a match, burn briskly and tend to spread rapidly as they increase in size. Peat fires tend to develop into surface fires at the higher wind velocities	Men needed on secondary lookouts when visibility is low. Regular protection force should be available for immediate action on fires as reported Secondary force should be within call
CLASS V (High Danger)	Fires start readily from a match or glowing cinders, spread rapidly and tend to crown in young growth	Regular and secondary protection force should be available for immediate action on fires as reported. Reserve force should be available if needed.
CLASS VI (Very high)	Fires will start from a cigarette butt or sparks, spread rapidly and tend to crown generally. Spot fires common	Men needed at emergency stations. Entire protection force ready for immediate action, additional over-head required if conditions remain bad. Volunteers or supplemental help may be needed
CLASS VII (Extreme Danger)	Explosive Conditions. Fires start readily from sparks, burn fiercely, crown and spot generally and are all but controllable.	Emergency conditions prevailing. Maximum effort called for.

(Photo by U.S. Forest Service).

Mobile Fire-Weather Forecasting Unit used by Fire Weather specialists of U.S. Weather Bureau in close proximity to major outbreaks of fire- Western Regions - U.S.A.

regular or additional patrols and detection units. Detailed discussion of the use of fire danger meters and fire weather data generally can be best summarised as follows:-

(1) To anticipate critical fire danger occurrence
(2) To rate current danger dependably
(3) To gauge the severity of the current fire season

(1) <u>To anticipate critical fire danger occurrence.</u> This really means the preparation of effective local forecasts for 24 or 36 hour periods by the correlation of local "fire-weather" records with the regional forecasts of fire weather furnished by the U.S. Weather Bureau. As far back as 1928, definite fire-weather units of the Weather Bureau organisation had been established for use by various forest regions at the following centres:-

California	San Francisco
Oregon	Portland
Washington	Seattle
Montana, N. Idaho	Spokane
Southern Idaho	Boise
Minnesota, Wisconsin, Michigan	Duluth
New England, New York	Boston

Meteorologists at each centre supervise the collection of fire weather recordings from each weather station in the forests, and endeavour to improve the detail and accuracy of all local forecasts throughout their region. For a number of years efforts were made to transmit fire weather reports from major fire outbreaks, and it was finally found advisable to adopt a mobile forecasting and weather recording unit in the form of a truck specially equipped with necessary meteorological instruments, radio (two-way) equipment etc. So successful was this truck in actual service that seven special trucks of this nature, with trained staffs are now available. Three of these are located in various parts of California, the others being situated in the States of Oregon, Washington and Montana.

In the Western regions the greatest amount of study has been given to the accurate local prediction of the occurrence, and fire risk characteristics, of lightning storms. It has also been found possible to determine after intensive local study of cloud heights, the direction travelled by storms and the number of fires possible at various elevations.

While the progress made in bringing fire-weather service by the Weather Bureau to the foresters, in the form of accurate forecasts either once or twice a day, is a tremendous advance, there remains the necessity for rendering these forcasts more effectively local. With the continued development of fire danger meters, it should become progressively easier for foresters to provide themselves with accurate local forecasts based on their own recordings <u>and</u> on the daily forecasts from the Weather Bureau. It has been thought advisable in most

Regions for forest officers to transmit their local weather data to Regional or Ranger headquarters, so that local forecasts for every unit can be prepared at such headquarters by an experienced officer, who correlates Weather Bureau forecasts with the detailed local recordings supplied to him.

As fire danger meters become even more reliable, and officers more experienced in their use, it will probably be found more advantageous for each officer to sum up for himself the local conditions likely to exist in the near future.

Whatever the local means adopted to produce accurate forecasts of local burning conditions, such forecasts will ensure the maintenance of fire control organisation at a standard commensurate with predictable conditions, and will obviate that element of surprise which has too often resulted in fires becoming uncontrollable.

Anticipation of danger has been found particularly useful in:-

(a) Locating patrols at danger points, manning detection units, and holding reserve labour forces in readiness when hazardous conditions are predicted.
(b) Control of the issue of permits (and of the conditions of issue) for brush-burning adjacent to forests, camping or smoking within forests etc. At times of exceptional hazard, foresters have concrete data on which they can logically base their refusal to issue permits or to even allow visitors to enter forests, in place of the unsatisfactory method of fixing calender dates for the control of permit issues.
(c) Employment of "key" protection men, on other remunerative work during safe periods in cases where these men are retained throughout the fire season
(d) Control of the reinforcement action necessary in the case of fire outbreaks to ensure the effective "corralling" of such fire in the shortest possible time. Similarly, with the conditions of hazard suddenly reduced or "blanketed" entirely by imminent rain, preparations can be commenced for the withdrawal of heavy and costly reinforcements from fires.

(2) To rate current danger dependably

While the results obtained in determining "anticipated fire danger" may not always prove satisfactory, fire danger rating schemes should at least allow observers to accurately gauge the current danger, either daily, or at any time throughout the day, when thought necessary. The objectives set down for anticipation of fire danger and its administrative application are still aimed at, and it should be possible to approach these objectives more closely once a knowledge of existing danger is available.

If regional or other protective organisations were set in motion according to the date of the earliest "probable fire occurrence" the expense involved would be unwarranted in most seasons. Similarly if a commencement were made in accordance with a calendar date, the start would be found to be either too early or too late for effective functioning. Careful assessment and rating of fire danger is the only justification for maintaining protective organisations at either low or high strength. The personal judgment of the local officer may be either good or bad - fire danger rating seeks to standardise, or to eliminate, this personal judgment. The rating of fire danger into defined classes, each of which involves definite administration action, is also a material advance on past methods of assessing danger according to the lurid nature of adjectival descriptions.

In a review of fires in Southern States, Bickford and Bruce (16) state clearly that many large fires were not controlled, while still small, through failure to recognise current fire danger. While ability to recognise dangerous fire conditions will not prevent fires from starting or spreading, officers are in a much better position to take effective prevention and suppression action once they have a sound estimation of current fire danger. The ultimate size of any fire indicates not only the seriousness of burning conditions, but also the promptness and efficacy of prevention, detection and suppression measures. Many fires which have been controlled during extremely hazardous conditions were potentially larger fires than many that "got away" during less severe conditions. Apart from any other consideration of its usefulness, fire danger rating demonstrates its efficiency by reducing the number of fires either under manned or over-manned.

(3) <u>To gauge the severity of individual fire seasons</u>
Statistics showing the annual occurrence of fires, areas burned over, causes of fire, have little significance unless they can be definitely correlated with an index of the fire danger conditions existing for that particular year. Comparisons need to be made between the fire danger of various seasons, or that existing in various regions, before any assessment can be made of the following factors:-

(a) <u>The comparative severity of the current or past fire season.</u>

(b) <u>" " efficiency of fire control organisations in any forest or administrative unit.</u> The objective of efficient fire control organisation is to follow the narrow path between acceptable expenditure and the too risky exposure of the forest to undue risk. The extent of unjustifiable expenditure, and unnecessary losses, can only be assessed when performance of the fire control organisation is checked with the seasonal or periodic occurrence of specified fire danger.

(b) <u>The need for increased allocations of expenditure for the protection of any individual forest unit.</u> Definite deficiencies can only be revealed where the existence of certain classes of fire danger has proved too much for efficiently conducted organisations and has thus furnished indisputable justification for increased expenditure allocations.

Consideration of these aspects postulates the efficient keeping of daily weather records in order that periodic or seasonal trends can be identified at any time, and any further emphasis made on any factor, so as to improve either fire control organisation or to modify the system of rating fire danger. Fire danger meters, as they exist to-day, could not have been evolved without accumulated records of past fire weather and of fire behaviour under any set of weather or burning conditions. The extension of necessary local studies into the effect of edaphic factors is only possible once comprehensive past records have failed to account for the behaviour of fires. In stressing the need for comprehensive records of fire weather it should perhaps be stipulated that all the significant daily variables of fire danger should be recorded, and such recordings should be fully representative of local cover types, fuel types, topographical divisions etc. If a full series of recording stations cannot be manned, greatest weight should be given to those stations which may be counted as truly representative.

Gisborne (58) gives a useful method for determining the average fire danger for a season by enumerating the number of days for which each class of danger existed, viz:-

(1) Class of Danger -	(2) No. of days - such danger existed	(1) multiplied by (2)
I	NIL	0
II	NIL	0
III	10	30
IV	16	64
V	29	145
VI	7	42
VII	0	0
	62	281

The average Class of Danger for the Season is thus $\frac{281}{62} = 4 \cdot 5$ - Previous averages (for several seasons) may be 5·5 so that the current season was below average.

(iv) <u>The trends of Fire Danger Rating Methods.</u>

The future trend of Fire Danger Rating methods was discussed (192) at a recent meeting of Fire Control specialists, at which meeting it was agreed in the first instance that "administrative practices have already overhauled and surpassed the original objectives of any or all existing systems of danger measurement". It was further agreed that the diagram shown hereunder was a logical representation of the conditions that should be measured and of the indices or ratings which should be produced:-

Fuel Condition (Moisture content and/or greenness) plus weather

= <u>Relative Danger Index</u>

Relative Danger Index plus Risk and Visibility
= <u>Preparedness Index</u>

Relative Danger Index plus Fuel Type (Fuel size, volume and arrangement, plus topographic slope and aspect)
= <u>Fire Behaviour Rating</u>

Fire Behaviour Rating plus Travel time, Soil or Rocktype, fatigue element etc. =
<u>Fire Despatcher's Meter</u>

Fire Behaviour Rating plus Weather Forecast =
<u>Fireline Meter</u>

It was admitted that no Forest Service Region has yet advanced beyond the preparation of Preparedness and (very general) Fire Behaviour Meters, while no Region has yet evolved a separate Fire Behaviour Meter for each of its distinct cover or fuel types.

The recommendations of this Committee (192) are worthy of repetition:-

1. "It is of first priority that fuel moisture (or condition), and weather be recognised as the basic elements that should be incorporated, as soon as possible, into a nationally applicable scale of relative danger.
2. That the ultimate objective of fire danger rating development should tend towards a system based on universal principles susceptible of national application.
3. That the fire research project leader should follow the concept that the same basic measurements of fuel and weather conditions will serve all administrative uses, both locally and nationally, through the application of fire control management devices.

4. That the immediate job is to correlate obtainable fire danger measurements to suit the needs of the fire control executive. In general, those needs are the correlation of fire behaviour basic elements to assist the executive in handling those prevention, pre-suppression and suppression activities that vary with the variable factors of fire danger. Specifically, the administrator wants measurements which he can use as a guide to determine, for example:-

   (a) When to close specific areas to entry or to smoking, or to take other preventive steps, because of high ignition and spread danger
   (b) When and to what degree more lookouts are justified, because of ignition and spread alone, because of reduced visibility alone, or because of combinations of ignition, spread and visibility.
   (c) When and to what degree more smoke chasers and/or contact men are justified, by increases in presence of causative agencies, by increased danger of ignition alone, by increased rate of spread alone, and by any combination of these three
   (d) When and to what degree speed and strength of attack should be changed by the fire despatcher, because of rate of spread alone, because of resistance to control alone and because of any combination of these
   (e) When the "fire boss" should change tactics and/or strategy, because of any combination of probable rate of spread and resistance to control resulting from size of fire, position of fire front, with respect to topography and fuels, existing and probable rates of spread."

CHAPTER IV.

THE STUDY OF FIRE HISTORY.

A. The location, origin and time of occurrence of past fires

The importance of studying the nature and extent of forest fuels, together with weather and other conditions which influence their inflammability, has already been discussed in detail. It has also been shown (see Table No. 8) that the great majority of fires originating on protected forest areas are the result of man's carelessness or wilfulness. When administrative officers have commenced the preparation of local fire planning, they have found that an urgent necessity exists for detailed records of past fires on a particular forest or administrative unit. Such records have been found even more useful and illuminating when it has been found possible to correlate them with fire weather records for a corresponding period and for corresponding days. Administrators in U.S.A. have long realised that fire control planning and expenditure must be concentrated on areas of greatest hazard and/or of greatest economic importance. They also have realised that such planning is impossible without analyses of fire history, for individual forest units, which reveal the sources of past fires, the responsible agency, and the predominance of any period or time in their occurrence. With this information available, officers have been able to allocate expenditure to the best advantage, and to seek the elimination or reduction of the most serious fire risks and fire hazards. Without this information, other officers have found their suppression efforts to be very largely wasted effort, particularly during the critical periods which occur occasionally to test all efforts at fire control.

Systematic fire planning includes the location and manning of detection and suppression units and the keynote of such planning is the speed and efficiency of initial attack on all fires. Only when administrators have a full knowledge of past and probable fire risks can they most effectively "route" their transportation systems, and locate their labour forces and equipment to the best advantage.

It has already been shown that lightning fires are a serious risk only in Western Regions so that foresters in the East no longer plan intensive protection from such fires. On the other hand Western foresters realise the necessity for closely following the path taken by severe storms, and for distributing detection and suppression forces throughout areas of probable "strike". Smokers and campers have also been indicated as serious fire risks throughout the country (see Table No. 10) so that nation-wide efforts to cope with such risks are being taken. The systematic patrol of travel routes and camping sites, the "fire-proofing" of such areas, the check up on all forest visitors, followed by insistence on permits to enter, or even total exclusion from the forest, are some of the steps taken to minimise the fires caused from these agencies. The details of such preventive effort will be found in later pages. In cases where debris burning is proved from past experience to be a serious and prolific source of fire risk, effective "fire-proofing" of adjacent forest land, and intensified patrols in the vicinity, have been adopted as counter-measures. Where legal facilities exist for the limitation of debris burning to those times approved, under a permit system, by forest officers, still more progress against this type of fire origin has been made.

Apart from acquiring detailed knowledge of fire origin, foresters have also found it necessary to study the season of the year or the time of day when local fires can be expected to be most serious. Even the general trend of the U.S. fire season is lacking in uniformity. In the Southern areas fires are more numerous, if not actually more severe during the winter months from December to March. In the mixed and/or hardwood forests of the North East the most serious hazard exists during the late spring, before the forest floor is shaded by the new season's canopy. The fire season in the North East continues throughout the summer, but is usually tempered by frequent summer rains or generally favourable weather. Another minor peak of the season may occur during the autumn, when the freshly cast hardwood leaves are in their most inflammable stage. In Western regions, severe fires are almost wholly confined to the peak of the summer, but in studying past fire seasons, which show variations in the length of this summer fire period, foresters have been able to avoid being taken by surprise, during recent years, when inflammable conditions suddenly return after the supposed "dying-out" of all fire hazards. In cases where foresters have found that the most severe risks coincide with the periods of worst hazard, they have profited from past experience in planning for heavy reinforcement of all suppression action.

The actual day or time of the day when fires originate is a more elusive factor to determine from any study of fire history. Weekend fires, occurring just after meal periods have been found a very common source of fire origin on areas open for recreational use, calling for intensification of patrol activity at such times. Railroad fires have, in some cases, been found to originate at regular times or on regular days, according to the passage of heavy freight trains. Incendiary fires have been found to follow the logical period for their occurrence - the advent of "worst possible" burning conditions.

Foresters agree that even the comprehensive records kept during recent years may not be sufficient for future studies of the fire problem. Such records include extremely detailed reports on fire outbreaks, lightning occurrence, reviews of seasonal or large outbreaks, fire weather data etc., in tabulated form. Other important records include charts of weather trends, fuel inflammability, classification of fire hazard and annual or periodic maps showing the occurrence and intensity of all outbreaks.

B. The possible elimination or reduction of causative agencies

Effective elimination or reduction of these agencies will not only relieve the pressure on fire control organisations but should effect major economies in expenditure on protection. Until very recently most attention, in the problem of fire control, had been given to the organisation and improvement of suppression efforts - comparatively little planning or expenditure having been concentrated on the prevention phase of fire protection. Now that foresters have been able to reach a certain standard of efficiency in suppression work, they are turning to the prevention field with hopes of similar success. They have found already that anything constructive in the way of fire prevention can only be accomplished by efforts to eliminate the underlying causes of the numerous fires for which man is responsible. Detailed efforts now being made to overcome ignorance with education, apathy with co-operation, and negligence with law enforcement will be discussed in later pages, together with the code of restrictions imposed on the movements and actions of forest visitors during the fire season peak. These latter restrictions include the compulsory registration of all visitors, the necessity for them to carry fire tools and to report to fire guards, and even total prohibition of entry to forests during periods of extreme fire hazard. Smoking while travelling through forests or other inflammable areas may also be forbidden - Forest Service employees setting a good example in this respect by refraining from smoking, except at permanent forest stations or fireproofed camp grounds throughout the fire season.

Comprehensive instructions are issued by Regional Foresters to their staffs explaining the benefits resulting from tactful efforts to obtain co-operation and assistance in fire prevention from visitors to the forest, or from adjoining residents or landholders. In the first place, officers and employees must maintain a satisfactory standard in their personal appearance and attire. They must treat all visitors or neighbours with tact and courtesy, and avoid all appearance of officiousness, without tolerating lawlessness. Realising that forest visitors have a right to the recreational use of these areas, any errors or neglect on the part of visitors must be explained tactfully in order to develop and cultivate the hoped-for co-operation of all forest users. When hazard conditions necessitate the imposition of restrictions or of prohibition to entry, even more tact is required in explaining the necessity for such restrictions by demonstrating boards or charts which show the "build-up" of severe current hazards.

It is admitted by administrators that while the origin of man-caused fires can still be traced to such divergent motives as maliciousness and "pure cussedness" there is a great deal of ignorance, apathy, negligence and prejudice to be overcome or broken down before any success can be claimed.

A more direct effort at eliminating fire origin is the contacting of railroad officials, followed by persistent efforts to obtain written co-operative agreements with such railroads in fire protection of rights of way and other railroad property. Considerable success has attended efforts to obtain the co-operation of lumbermen and of organisations representing forest-industry employees, in the reduction or elimination of fires.

On those areas where debris burning is to be feared, responsible officers personally inspect those properties known to present serious risks. Even if efforts made to enlist the landowners' co-operation, or attempts to warn him of the hazards prevailing, are unsuccessful, the officer at least succeeds in estimating the extent of the risk presented by any fire originating there. In districts repeatedly exposed to danger from incendiary action, it has been found advantageous to delegate a small force of forestry or police officers to the task of apprehending the "fire-bugs," and of securing their conviction. In such districts, it has been found that a limited number of convictions can be counted on as a deterrent to future incendiarism, especially if such convictions are made sufficiently severe, and are given adequate publicity in the right quarter. The introduction and maintenance of bloodhounds in those districts noted for past incendiarism has also proved an effective deterrent, not so much from actual activities of the dogs, but in implanting a genuine fear in the minds of would-be incendiarists.

C. <u>The reduction of major fire hazards</u>.

It has already been indicated that all dead (and living) material within a growing forest can be classified as fuel for forest fires. Attempts to reduce the volume of dead material must be concentrated on the principal sources of such fuels - logging slash, snags, insect-killed trees etc. The strong advocacy in Southern regions for the periodic burning of the forest in order to keep all fuel to a minimum, may succeed to some extent if it can be proved that such work can be done efficiently, effectively, and economically from a protection standpoint. The general experience has been, however, that even the burning or removal of localised accumulations of danger litter is an expensive procedure which does not always attain its objective. In fact there is a strong school of opinion to support the theory that money spent in reduction of slash, or other hazards, could be more efficiently spent by leaving these hazards in situ, and intensifying general protection from fire, for a period of several years, over the area in question.

The active steps taken to reduce or eliminate existing fire hazards, after their annual location by "hazard surveys", are as follows:-

(i) <u>Disposal of slash</u> - The nature and extent of slash accumulations varies tremendously with species, locality, silvicultural practice (if any), amount of cull present on any logging area, intensity of logging practice and utilization etc. The problem reaches its most acute form in the Pacific North-West, and in one State, at least (Montana) special State laws have been enacted to deal with the problem. Under these laws, Federal and State foresters, working in co-operation, direct the disposal of slash on private lands, timber sales areas within, or adjacent to, areas of reserved forest, or to areas subject to fire protection. Land-owners or logging operators may be required to spend 15 cents per 1,000 super feet of logged timber on slash disposal on any area being logged. In the case of sales on National Forest lands in North-Western regions, operators may be required to pay an additional stumpage of up to 30 cents per 1,000 board feet - this money being then spent in top disposal on the sale area. Foresters discuss disposal plans with the landowner or operator, "follow up" any proposed action along these lines, and exercise full supervision over actual burning operations to ensure safe and efficient methods. Despite the nature of the advice, or of instructions, given him by forest officers, the responsibility for any escape of top disposal fires remains with the operator. Refusal or neglect to execute top disposal on logged areas often renders the operator also liable to penalty under State Laws.

In several other States, local laws enforce the disposal of all slash along highways or railroads, and in strips along property boundaries. In the North West region, lumbermen have become more interested in the subject of slash disposal since they have obtained a better conception of the fire protection problem. They are now most active in formulating the best methods for slash disposal or for the most efficient protection of areas carrying extensive accumulations of slash. Slash disposal may proceed in a variety of ways viz:-

(a) Piling and burning - including well stacked piles of "green" tops which are burnt, after drying, in safe weather - such as early winter when the intervening ground is too damp to carry a fire. The method is costly and is rarely justified for this reason.

(b) Swamper burning - tops being burnt or scorched as logging proceeds, either before or after actual log extraction. The method is even more expensive than piling and burning and is obviously impossible during the fire season.

(c) Broadcast burning - This is a cheap method (1-2 cents per 1,000 super feet of logs cut) but its application is limited to small areas of clear cutting, owing to the injury inevitable to trees standing in the slash and to the great risk of a widespread fire developing. The method is advocated particularly in the Western White Pine type both to reduce slash, unmerchantable old growth etc., and also to perpetuate the White Pine type. The usual precautions must be taken to prevent spread of the burn - one of the latest suggestions being initial centre-firing of the area, with subsequent lighting near the edges, to utilise a strong centre draught as a deterrent against spread. "Spot burning", or the burning of only the dense slash accumulations, is sometimes used as an alternative.

(d) Lopping with or without Scattering - Allows easier construction of fire lines and may assist more rapid decay, being used in the case of selective logging, or other partial cuttings, or in cases where any burning is impracticable.

(e) Partial Disposal - as suggested (137) for the P. ponderosa stands in Eastern Oregon consists of piling and burning "gridiron" strips of slash, with additional strips cleared along roads, camps, railways etc - supplemented by intensive fire protection of the areas for some 15 years subsequently - the total cost being estimated at 22 cents per 1,000 super feet of logs cut, or only half the estimated cost of piling and burning.

In a later discussion of slash disposal for the same species, in the South West region, Pearson & McIntyre (150) did not favour any standard method, owing to variable conditions of stocking, fire hazard etc. Where serious fire hazards were thought to exist, they favoured piling and burning - elsewhere less expensive methods of scattering or lopping were suggested - decision as to methods etc. being entirely a local one.

An illustration of the effectiveness of State legal provisions for top disposal is that made in 1931 by Wisconsin State. It was realised that total disposal would be too heavy a burden for loggers, but the latter were required to take the following action:-

(a) Disposal of all slash under 4 inches diameter within 50 feet of roads or railways.
(b) Disposal of all slash etc. on strips 50 feet wide (along logging roads etc.) so that no area of slash would exceed 640 acres
(c) Disposal on strips 66 feet wide along adjacent property boundaries if the latter areas carry valuable forest growth
(d) All slash under 4 inches diameter to be burnt or removed unless special permission for lopping or scattering is obtained.
(e) Clearing all hardwood slash within 110 yards and coniferous slash within 220 yards of any building.

All disposal to be completed within a year otherwise it will be done by local authorities and costs charged to the operator.

(ii) Precautions in respect of other hazards -

(a) Snags - require elimination where fire risk is unduly high. Foresters agree that a single burn on an area of green forest produces a large number of snags, especially in the case of mature stands. A succession of forest fires is required to eliminate snags from any area, by which time the area will be beyond re-stocking with adequate regrowth. It is therefore necessary to fell snags, if not on the entire area, at least in close proximity to roads, trails, firebreaks etc. on which safe suppression effort is based. Felling may also be concentrated along such topographical features as well defined ridges, large streams etc. which offer some assistance in fire control. Action in this connection is largely confined to the hazardous areas of the North West region and the Pacific Coast, where the size and number of snags on a particular area often presents a serious problem. Despite the high cost of their removal, many foresters insist on the elimination of snags as being the most economical practice in the long run. The recent introduction of power saws for tree-felling has considerably cheapened previous high costs of the work. As outlined by Ferguson (47) the snag-felling law enforced in the State of Oregon requires felling of all snags in green timber. After exploitation of merchantable timber on any area snags more than 25 feet high and 16 D.B.H. must be felled, provided that the number per acre so felled need not exceed the average number per acre present in surrounding old growth stands.

Concentration of snag-felling is also practised on areas subject to severe periodic lightning risks, owing to the propensity of lightning for rapid spread of fire after "strikes" among snags. Lightning may strike an equivalent number of green trees, but the effects of the latter "strikes" are not usually felt so seriously.

(b) Industrial hazards - Industries within forests which are normally associated with fire risk include sawmills, quarries, naval stores, mines or even petrol filling stations on roads. Foresters usually carry out accurate surveys of all fire risks associated with such enterprises, and proffer advice and instructions as to protection measures necessary under Federal and State laws. Safe burning methods are demonstrated, if necessary by forest employees, and managers are given a clear understanding of the risks and penalties associated with indiscriminate burning. The co-operation of managers and of all employees is also sought in the careful use of fire at camps, power plants etc. and in the local laws which specify the fire-proofing of all building and/or industrial sites in forest or protected areas.

Sawmills and naval stores operators in forest areas are usually subject to specific restriction in, or total prohibition of, the use of fire under the sales agreement clauses of State fire laws etc. Naval stores operators usually take steps to protect their own field of operations by burning of surrounding areas. Provided such work is done when approved by foresters, and in the manner prescribed by regulation or permit system, the operator may actually be assisting in the general reduction of fire hazards. Mills are required to clear all inflammable material within a radius of 100 feet or more of mill or other buildings, and must also post a watchman when slab or sawdust fires are burning, and the mill plant is not in operation. Where mills have occasion to use fire as a precautionary measure, burning must be done under special permit or not at all. In North Western areas logging operations may be shut down completely when severe hazards exist, while lumbermen may even arrange to start field operations at dawn during the summer and complete the day's work prior to the dangerous afternoon period. Spark arresters of an approved type are standard for all locomotives or other engines generating steam power which are used in or near protected areas.

Forest officers take the initiative in constantly inspecting all industrial risks, insisting on all due precautions required by permits, regulations and laws. Breaches of regulations on National Forest areas involve cancellation of operating permits or agreements, and liability for all damage and suppression costs. Where the industrial concerns are operating on other lands, foresters will lay information regarding neglect of or non-compliance with regulations, with the State authorities responsible for law enforcement.

(c) Railroad rights of way - Foresters make themselves well acquainted with risks and hazards existing along railroad rights of way both before and during the fire season. Railroad companies can not usually be compelled to execute

(Photo by U.S. Forest Service).

Exterior view of Public Registry - National Forest Campground.

prevention measures under State fire legislation, but foresters usually contact the responsible local official, and furnish him with estimated costs of fuel and hazard reduction, pointing out that the cost of the work may be lower than future claims for damages to protected areas, fire suppression costs etc. Where real danger exists and fires occur from the operation of railroads - both patrols and suppression forces are concentrated in the vicinity and prompt claims submitted to the railroad company for damages and costs of suppression. Where railroads co-operate with foresters in fire protection measures they may furnish valuable assistance in the form of labour forces, suppression equipment and transportation of emergency forces.

The efficient operation of spark arresters, and ash pans, together with the dumping of hot ashes only on "safe spots" is mandatory in most regions, and the careful observance of these regulations is generally facilitated by approaching engine crews through local railroad officials. On certain National Forest areas, railroad companies arrange with forest officers for the elimination of hazards along their right of way to be executed by forestry employees at the expense of the companies.

(d) Power line rights of way - In certain areas power lines constitute a far more serious fire risk than railroads due to insufficient clearance of high voltage lines above vegetation, damaged insulators or poles, inflammable material along rights of way. Agreements with operators of power lines usually insist on remedial measures for the abovementioned defects. Not only must rights of way be kept clear, and the line itself maintained in safe condition, but it is also stipulated that a circle of 10 feet radius be kept clear around poles or towers carrying up to 11,000 volts and a circle of 20 feet radius in the case of poles carrying higher voltages.

Foresters usually inspect all rights of way and, as in the case of railroads, present a statement and estimates of of necessary maintenance and improvement work to the engineer in charge. Such inspection is followed up to ensure that necessary action has been taken - if not, the operating company is liable to claims for damages for noncompliance, or for any resultant costs or damage.

(e) Hazards resulting from recreational use of the forest. As previously explained, foresters endeavour to welcome visitors of all kinds to forest areas, and to tactfully explain and insist on the need for certain definite precautions against the neglected or careless use of fires. They also seek to obtain registration of all visitors to forest areas during periods of hazard, even when conditions prevailing do not dictate the issue of permits governing the movements or actions of such visitors.

Detailed attention is given to various classes of visitors, as follows:-

(Photo by U.S. Forest Service).

Public Registry at National Forest Campground - Interior View -

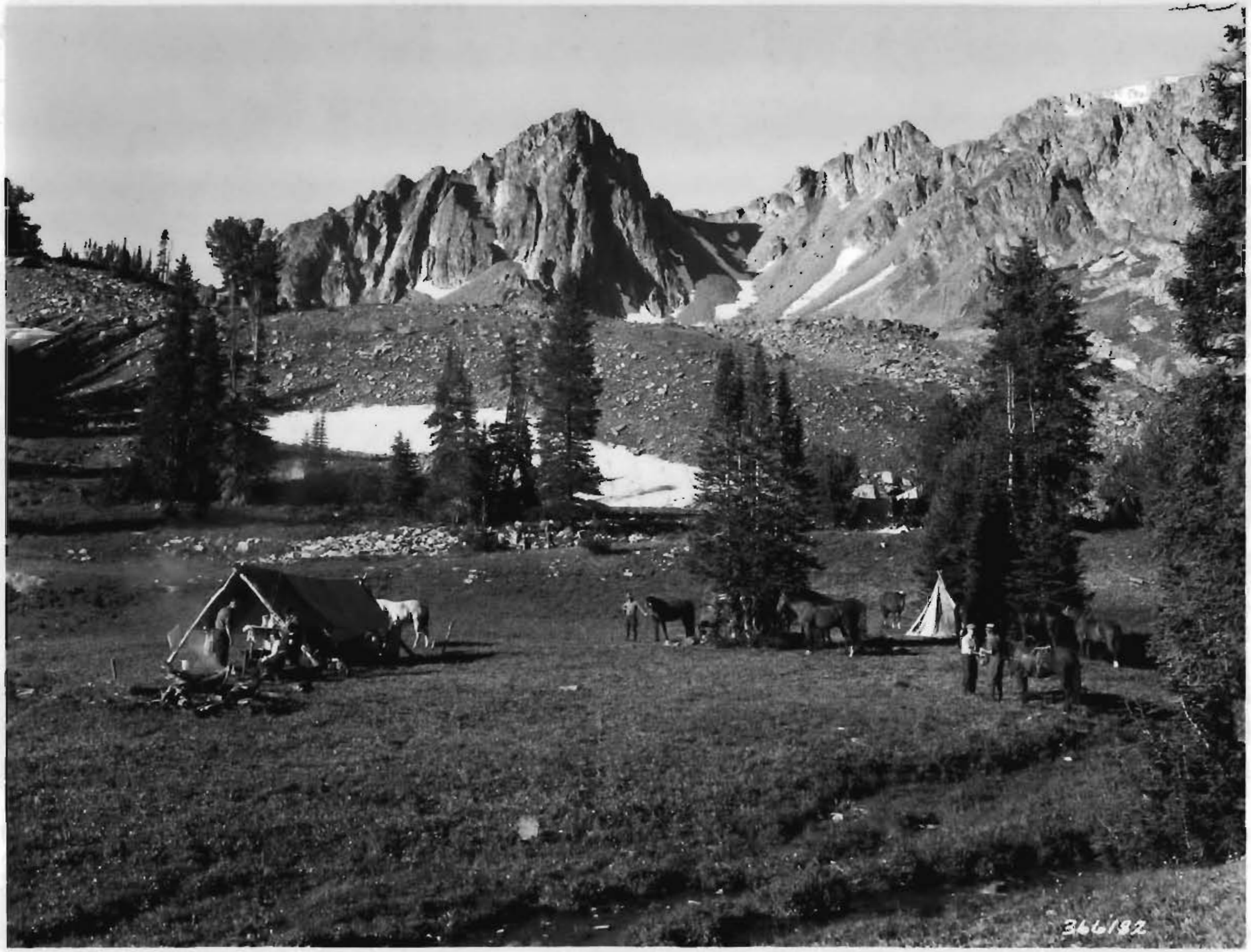
Note - (from left) - Signature Book, Fire Poster, Camp Ground Rules - Southern Region.

1. Smokers - During severe hazard conditions, smoking may be forbidden, except in fireproofed camp or building areas, or at specially designated "fag stations", under National Forest regulations or State Fire laws, whichever area is concerned. Forest officers are responsible for reducing smokers' fires to the best of their ability by means of persuasion, exercise of authority etc. Their personal habits in smoking must conform with the general regulations prevailing for the district. All Forest Service cars and trucks, or vehicles operated by Service employees, must be equipped with suitable ash-trays. Oil companies issue warning "stickers" to be placed on the windscreens of cars, while the companies also instruct attendants at their service stations to clean out the ash-trays of cars while they are cleaning windscreens etc. Certain States, e.g., Washington, have enacted laws which inflict severe penalties ($250 fine or 90 days' imprisonment) on any person found guilty of throwing away any lighted or burning material during the closed season in any protected area.

2. Campers - Major forest camps and other intensively used Recreation Areas are "fireproofed" for an effective radius of 500 feet, or more, around these sites, prior to each fire season. Minor picnic spots, or camp sites used by other travellers, are surrounded by a clean fireline up to 6 feet wide, and all debris inside this line is kept in check by spring burning or summer collection. Largely as a result of C.C.C. activities, thousands of improved recreation areas are now available for public use on National Forests, or Parks, and in other tourist regions. On these improved areas, campfire permits are not required, and during severe fire weather, camping elsewhere on the forest may be forbidden. In any case, camping on other areas is subject to the issue of special annual permits, which specify the conditions under which the permit is issued, and under which fires may be lighted. Permits also indicate the location of high hazard areas, closed areas, telephone numbers to call for the reporting of fires, and are issued either by forest officers, or by specially selected co-operating individuals or agencies.

   Persons found building fires without permits, or neglecting all reasonable precautions, are not at first subjected to law enforcement, efforts being first made to seek their co-operation by explaining the nature of precautionary measures, the technique of building and extinguishing camp fires etc., and by cautioning the culprits against further violation of regulations.

3. Hunters and fishermen - An endeavour is made to ensure the registration of all hunters and fishermen on their entrance to forests or protected areas, even at times when such registration is not prescribed as mandatory. Foresters may further their contacts with sportsmen by arranging for the "policing" of those hunters and sportsmen who are authorized by the State laws, or by the regulations of the Department of Agriculture, or the Director of Emergency Conservation Work. Sportsmen are welcomed to protected areas with the usual tactful approach, and are given advice regarding game or fish movements. They are also issued with camp fire permits, after the necessity for such permits has been explained. Their movements within forest areas are kept under surveillance, owing to the high risk usually associated with their presence in inaccessible areas. When individual field contacts are impossible,



(Photo by K.D. Swan - Courtesy U.S. Forest Service).

Conducted party of Trail Riders camping on a Mountain Meadow - Northern Rocky Mountain Region.

literature regarding local sporting conditions, fire prevention measures etc. may be left in their automobiles or arrangements may be made for "pep-up" talks to sporting clubs prior to, or during fire seasons. By recording the presence and behaviour of various sportsmen or sporting bodies, thanks may be extended by foresters for precautions taken, and the visitors may be communicated with by letter prior to the following summer, and invited to return.

4. Motorists - During conditions of fire hazard all motorists travelling through National forest areas are stopped at special checking stations, by neatly dressed and intelligent guards, for registration, and are advised to equip their car with a shovel, an axe and a gallon canteen of water. Restrictions on smoking and use of campfires are explained to them and their co-operation is sought. Movements of all motorists are checked either by patrols, or by other checking stations some distance away. During severe conditions of hazard, the carrying of fire tools is made compulsory, and driving on forest roads or highways may be either restricted to safe and well patrolled routes, or prohibited altogether. The need for such restrictions has of course to be tactfully explained.

Prior to the opening of each fire season, district officers may arrange for the effective fire-proofing of roadside strips for a minimum distance of 15 feet from each water table, this work being followed by maintenance of strips in clean condition throughout the fire season. Maintenance or construction employees working on roads must also arrange for the removal of debris from those strips, burning not being allowed during the fire season except at night, or under special conditions approved by the local Forester. In California, State highway authorities arrange for the spraying of roadside edges with fuel oil while the grass etc. is still green. In a very short period the sprayed strip of grass is dead and can be burnt before other grass on the road dries off.

5. Hikers and Horseback riders - Control of these visitors is practised in the same way as with motorists, and the same restrictions are applied except in the matter of carrying tools. As this class of forest visitor is more mobile in his movements, additional care is necessary to ensure effective contact and patrol of these movements. The co-operation of "dude" and other ranches supplying horses is always sought, and visitors to such ranches or to trail camps are asked to co-operate, and are provided with literature.

In the case of large parties on organised summer tours the Forest Service or other Governmental agency may not only prepare special camps, but also provides a guide or party escort for the double purpose of intensifying interest in forest areas and of preventing any careless use of fire.

6. Casual or transient visitors - This class usually includes berry pickers, "small time" salesmen, picnickers and others, whose movements are uncertain even in their own minds, and

who constitute a serious problem for patrols and checking stations, especially when they fail to confine themselves to main routes of travel or to camping sites. As previously mentioned, special provision in the matter of camping sites is made for this class of people, but it has been difficult to control their movements or habits even by careful contacts.

There has been greater justification for restricting the movements of this type of visitor, during severe conditions, than in hampering the movements of others genuinely interested in the recreational values of the forest.

(f) Hazards from construction and other camps.- Rigid control of campfire and smoker risk in labour camps, or in working gangs, is mandatory on all National Forest land during the fire season. Forest Service employees, C.C.C. camps, and other agencies are placed under definite restrictions regarding camp and lunch fires, smoking only at "fag stations" etc., while fireproofing around buildings, camp sites etc. is also compulsory.

Explosives may be entirely barred, or their use restricted to electric detonators instead of caps and fuses. Burning of debris involved in the construction of highways, railways, power lines etc. must either cease during the summer, or be done under the supervision of forest officers during night hours in favourable weather. Co-operative efforts with the local engineer or camp officer must include the use of all labour forces for prompt reporting and for suppression work in the vicinity of the camps, while an adequate supply of fire tools, pumpers etc. must be kept on hand. Motor trucks working within protected areas must always be equipped with an axe and shovel - other trucks carrying explosives, gasoline etc. must also carry a chemical fire extinguisher of 1½ quarts capacity. Welding or other similar jobs must not be done in protected areas in the absence of fire extinguishers, knapsack sprays etc., the latter equipment being also compulsory in all camp or other buildings. Building flues are checked to make sure they are not defective, while approved spark arresters are required on all buildings, tractors etc.

The field operations and camps of construction jobs are subject to continual inspection by patrolmen and other forest officers to ensure that all precautionary and co-operative action is being taken on the lines indicated above.

(g) Debris burning - The location of each farm or habitation, within the boundaries of protected areas, where careless burning of debris or brush constitutes a serious fire risk is shown on risk and hazard maps after risk surveys are made prior to the fire season in question. Property owners are contacted by forest officers with a view to co-operation, owners being simultaneously warned, or instructed, regarding prevailing or expected fire hazards. Protection of owners' properties from fire is promised if they will co-operate by reducing hazards around buildings or common boundaries or by being careful in the disposal of ashes, garbage etc. Foresters usually insist that any burning be done before, or after the fire season, or at least during safe weather, and then only under burning permit and in compliance with all precautionary and restrictive conditions of such permit.

Intelligent and tactful approaches to neighbors, made by foresters interested in the control of debris burning operations, supported by co-operative assistance to these landowners, has often resulted in close future co-operation by the latter in district fire protection problems. Quite often, adjoining landowners act as reliable agents in the reporting and suppressing of forest fires which occur near their boundaries - this form of co-operation being greatly desired by forest officers.

(h) Incendiary hazards - Incendiarism is always a shifting risk, and can rarely be defined into anticipated zones of occurrence. In some cases repeated personal contacts with persons residing within or near forest boundaries have lessened incendiary efforts, but any material reduction in this class of fire hazard can only be effected when special officers or police are delegated for intensive investigation of all fires which are suspected as incendiary efforts. When a case has been formulated against any individual, criminal or other legal action is promptly taken and severe penalties pressed for - the legal approach being sometimes facilitated by pre-season contacts with local justices and other law enforcement officials. Even in cases where material damage does not result, heavy penalties are sought as a deterrent and demonstration to other residents in the vicinity.

In zones where incendiary fires occur, no local labour is employed on fire fighting and no local supplies of stores, pack-horses etc. are obtained - the reasons for such action being openly stated to responsible citizens, storekeepers etc. in the hope of using them to break down local hostility to fire control.

Presentation of the situation to local business men or civic leaders may often cause a revulsion of local feeling against a minority of persistent "fire-bugs", and at least assists in the future apprehension of law-breakers.

(i) Grazing and other forest permittees - In cases where reasonable, if not conclusive, evidence exists that a grazing permittee, or his employee, has caused fires on the permit area either carelessly or wilfully, or has failed to take suppression action as prescribed under the conditions of the permit, immediate steps are taken for the cancellation of the permit and/or of "grazing preference". This cancellation may, in serious cases, be extended to all grazing areas in the district so that the former permittee is unable to obtain any consideration in future allotment of grazing areas. In Region No. 5, the minimum requirements of grazing permits in respect of fire control include the provision of tools at camps, notifications to foresters re location of camps, restriction of smoking and of using unprotected camp fires, proper instructions to employees re care of fires, reporting and suppressing all fires in the vicinity of the permit area etc. Holders of special permits for summer residences are bound by conditions of their permit which force them to take prescribed action under Forest regulations, or other local fire ordinances, to prevent spread of fire from buildings, accumulation of hazards around residences etc.

If inspections by foresters, and instructions issued regarding necessary precautions are ignored, prompt legal action is taken and publicity is given to any convictions made.

CHAPTER V.

EDUCATIONAL EFFORT.

The growing importance of fire prevention activities has already been stressed, and considerations of the importance of educational effort immediately arise. Education must not be confined to any class of people, or to any particular generation, otherwise the much-desired cumulative improvement from any campaign will not materialise. It is obviously useless to improve adult appreciation of the fire problem, while the younger generation is allowed no chance of acquiring a "forest conscience". As an illustration of the success which attends patient and planned educational effort, Folweiler and Brown (51) cite the results obtained on the Ozark National Forest since 1923. The introduction of fire protection to a region where woods-burning had developed into a routine, aroused a strong resentment among the inhabitants. Gradually this feeling of hostility has been broken down, and although passive resistance to fire protection still persists, forest officers are no longer regarded as interlopers, and fire occurrence has dwindled. Table No. 35 shows this reduction in the occurrence of man-caused fires, and although much of this reduction may be due to more active patrol and other measures, the real improvement lies in the changing attitude of local residents.

It is almost impossible to approach educational projects with the idea of dealing with individuals, owing to the enormity of such a task. It becomes necessary to formulate a programme that will achieve results by making contact with groups representative of influential public opinion, or with classes of people in a receptive frame of mind. School children fall naturally into the latter classification.

A. Juvenile Education.

Many foresters interested in prevention work are convinced that money expended on such work is productive of much better results if concentrated in schools. Discussion of fire origin has shown that most fires are due to the degree of carelessness, malice or prejudice which is ingrained in the adult population. Even if patient and time-consuming efforts are made to counter these origins of fire, the best that can be expected is slight improvement over long periods. Meanwhile another generation or two grows up to furnish a further field of patient endeavour. School children are admittedly receptive to influences which will have a future effect on their character and habits. Even if children can not be made to grasp the ethics and economics of the entire protective problem - a foundation of appreciation and care of forest areas can generally be established in juvenile minds, so that future attempts at their education and co-operation will be greatly facilitated. Another factor greatly in favour of schools work in prevention efforts is the organised group discipline of schools, which exerts a forward movement despite the inherent objections of certain students. Attendance at schools of the great majority of children is another favourable feature and it can at least be said that facilities exist at schools for enlisting co-operation among almost all of the coming generation.

TABLE NO. 35.

Showing reduction in the occurrence of Man-caused Fires-
Ozark National Forest.

YEAR	GROSS AREA PROTECTED	DEPARTURE FROM NORMAL OF ANNUAL RAINFALL	NUMBER OF FIRES PER 100,000 ACRES
1923	530,000 acres	+11·5"	44
1926	530,000 "	+0·9"	21
1929	634,000 "	-2·2"	19
1932	634,000 "	+2·8"	21
1935	886,000 "	+8·7"	13

Forest officers in various regions either attend schools to give illustrated or special talks or they enlist the aid of the teaching staff. Once the latter are convinced of the importance of fire protection, and are supplied with basic information or literature on the subject, they usually co-operate in working the subject into teaching programmes. Only those foresters who have a bent for attracting the sympathetic attention of juvenile audiences attempt the special task of schools talks, as educational work of any nature requires special presentation to be effective. It is just as important for youthful minds to realise the importance of forest and other natural resources, as it is for them to learn systems of Government, particularly in regions like the South or North West where the practice of forestry is integrated into the entire economic structure.

Some states have made progressive moves in placing conservation of resources on school curricula, but owing to the lack of experience, or interest, on the part of teaching staffs, little benefit has accrued. State forestry organisations are anxious to assist in schools' work, but are rarely able to finance any comprehensive programmes, while foresters can rarely agree over the essentials of any educational project. As education in U.S.A. is essentially a State or County function, it obviously requires strong inspiration and financial assistance from local Governments before material progress can be made. No real benefits can be anticipated unless a sustained effort is made, as any education is only temporary in its effect if attempted only at certain periods. It is admitted that many States have been hard pressed in their efforts to organise fire suppression and that they have overcome many difficulties in achieving material progress along those lines. Various States are gradually realising the wisdom of spreading their efforts and expenditure on protection, by closer attention to educational problems. In the absence of educational effort much administrative energy must necessarily be wasted, and at least a proportion of annual expenditure will be mis-directed year after year. Efforts at education have perhaps achieved greater success in those States which do not have extensive areas of State forest, and where the local government has not a heavy administrative task in organising suppression measures.

School educational efforts are either:- (i) Direct and (ii) Indirect.

(i) Direct Methods - Fire prevention is the only topic discussed, the case for protection being put forward in as attractive a way as possible, while effort is concentrated on a group of students intelligent enough to realise the logic attempted.

Methods of this kind are particularly useful among senior students of high schools, when these students are commencing to take an intelligent interest in general problems.

It has been proved a successful approach at Vocational Agricultural schools, due mainly to the following factors:-

1. The education and experience of teachers gives them a sympathetic interest in the subject
2. Students are from agricultural areas and understand a few of the elementary concepts of forestry. Their response is more certain if such aspects as the importance of farm woodlot protection are stressed
3. The information imparted to them will probably be put to practical test after their departure from college, particularly in regions where there is close geographical association between farms and forests, or where farm forestry may be a profitable investment.

The method has also wide scope among such semi-educational groups as Boy Scout organisations. The latter are more highly developed in urban areas, but even there they are attracted to the enjoyment and benefits of outdoor life. Boy Scout and similar organisations, may in fact, well prove to be the urban counterpart of agricultural colleges in so far as they foster juvenile interest in forest protection.

The general success of direct education on fire protection in schools hinges largely on the knowledge of the responsible teachers. Without such knowledge, teachers cannot be expected to approach the subject with either the interest or enthusiasm which is so necessary to success. The expression so often used - "Educate the educators to achieve education" appears particularly suitable in respect of fire protection, and efforts in this direction are already being made.

Between 1926 and 1928, the U.S. Forest Service co-operated with the States of Oregon and Washington in producing Fire Prevention Handbooks suitable for local schools, and also publishing similar literature for a wider circulation. The Forest Service of the State of Florida has more recently (1934) published literature for use in both Agricultural and High Schools.

(ii) Indirect Methods. - These methods make an indirect approach to the subject of protection by embodying the latter discussion in talks, moving pictures etc. which foster the "human interest" spirit. In discussing or portraying the beauties of the forest, or the glory of its recreational facilities, apt reference is made to the need for general support in the tremendous problem of protection. Many foresters insist that educational efforts should first endeavour to capture the interest of children or of students, especially when so many of them are entirely ignorant of the need for forests and have no conception of what is entailed in their management or protection. As indirect methods seek only to make an impression on basically ignorant minds, it follows that the application of these methods should be so timed as to create more than momentary interest in forest protection. The use of these methods involves more difficulties than a direct approach, as the speaker or lecturer must make a tactful approach to the task of "putting-over" certain points, at the same time making his talk or lecture both amusing and interesting. Perhaps the best approach to the subject was made some years ago (1928) when the American Forestry Association's "Southern Educational Forestry Project" commenced a three year campaign in Southern States. The aim of the project was to localise protection education in a Region where indiscriminate burning of forests has always been prevalent, efforts being concentrated in the most notorious States in this respect viz. Georgia, Florida and Mississippi.

Visual education and personal contacts were aimed at through the medium of:-

1. Travelling motor trucks as mobile propaganda units
2. Educational exhibits at fairs and other public gatherings
3. Enlisting local co-operation through the leaders of each rural community.

Newspapers were provided with news items concerning fire protection, and regarding the movements of the publicity trucks. Essay contests for special prizes on the effects of forest fires were held in schools. Co-operative pledges for future fire prevention were obtained from adult members of audiences. Pictorial leaflets, prepared in an attractive manner, were distributed, together with rulers carrying fire slogans for use by children.

Communities were placarded and bombarded with posters and leaflets. Motion pictures, however, proved the great drawcard, particularly when Departmental films of an educational type, which had little action or humor and abundant moralizing, were replaced by specially produced films. The latter were noted for local color and contained the right mixture of romance, drama, humor and educational features to be appealing and entertaining to all types of audiences.

The Project undoubtedly stimulated much local interest in forestry, the extent of which was extremely difficult to gauge, but which undoubtedly strengthened the State forestry administrations in their efforts to obtain public support. Pioneer educational efforts of this nature can not be expected to achieve lasting results, unless there are numerous local organisations to follow up the primary interest created, and to maintain public interest and foster enthusiasm.

B. Adult Education.

Extensive efforts to educate adults are not highly regarded by foresters, as they are too often an insult to the intelligent man, who is the object of the methods, and they generally fail to interest the ignorant types. Local foresters have a true appreciation of the origin of fires, and the persons mainly responsible for them, and they prefer the more direct methods of contacting responsible parties or persons. Some of the contacts made with visitors, sportsmen, employees etc. in forest areas have already been described - general instructions regarding the making of necessary contacts, and the approach necessary to successful effort, are issued by all Regional foresters to local officers, fireguards, patrols etc.

All Forest Service employees are expected to consider themselves agents of goodwill for the service they represent, and for the advancement of protection. Every contact made with outsiders, whether casual or deliberate, is expected to leave the impression with such persons that their assistance and co-operation in forest protection is being sought. Local administrators are in frequent touch with those persons responsible for local risks. Forest visitors and others may be rated as low fire risks individually, but owing to their numbers they constitute a high collective risk - as figures showing general origin of fires have already demonstrated. Proper approach to personal contacts has proved that uninstructed people can be made to discard neglectful or careless habits and become interested in fire protection. If these persons can be moved even further in their interest to the stage when they feel personally responsible for protection, or become active allies of forest service employees, real success can be claimed.

Such results can only be achieved by what is really salesmanship on the part of the forester or ranger. Rangers with likeable personality and a capacity for friendly interest in the other fellow, secure a reciprocal interest by the visitor in the officer's worries about fire protection. Those officers who can secure the goodwill of visitors, without any display of partiality or abjectness, may really count on the assistance of these visitors. Business men can be interested in the economics of fire protection, "recreationists" can be approached through their attachment to a "living landscape", and sportsmen can be convinced of the fact that game conservation and fire protection go hand in hand. Even incendiarists are in some instances reached by indicating to them the provisions and penalties of the law. While officers do not hope to reach all forest visitors, the effort is worthwhile if the methods adopted are sound and a cumulative interest is maintained among those actually contacted. It has never been the policy of the U.S. Forest Service to impose its comprehensive protection regulations and activities on local residents or visitors without giving "the other fellow" a chance to learn what the aims of the Service are. Only by such means can the apathy and antagonism of outsiders, at first aroused owing to seeming interference with local customs or beliefs; be overcome to any great extent. Foresters agree that such an approach to an already difficult administrative problem makes heavy demands on their tact, courtesy and good nature, but they are unanimous in stressing the need for such methods, and the achievements which are slowly resulting from them.

The approach to adult education by means of contacts is usually made as follows:-

(1) <u>Casual contacts</u> - These are frequently made by officers during the course of their duties, particularly during the fire season, when augmented staffs of selected guards and patrolmen are constantly moving through these sections of the forest where they will probably contact visitors,

sportsmen, employees etc. No opportunity is lost for enlarging on the need for public assistance, and the value of such assistance, but officers are warned against being over-zealous, and thus becoming a nuisance instead of an acquaintance.

(ii) Specific contacts - These contacts are usually the most productive - foresters direct their efforts at particular persons or agencies, according to a well prepared plan, and concentrate their endeavours until some success has been achieved. Neighbouring settlers are more valuable as potential co-operators than transient motorists, while construction managers or community leaders are far more important than the rank and file. Officers find that the quickest results are achieved by selected contacts of key individuals, although no opportunity is lost to enlist the aid of others, or to continue general propaganda.

(a) Individual contacts with settlers, permittees, visitors, logging superintendents etc. are best made at the centre of activities of the particular individual. Thus settlers are interviewed in their own homes, and forest permittees on their own areas. Other important contacts with individuals are those made with Federal, State, County or Municipal officials who are in a position to use the influence of their official positions for the advancement of fire protection. These individuals include local justices and prosecuting attorneys; superintendents of State or Town fire departments; law enforcement, highway, school and other officials. Other "key individuals" worth noting for special contacts are influential local residents, scoutmasters, newspapermen, hotel and resort owners or managers, private owners of timberland or of adjacent valuable property.

Mention has already been made of steps taken to register all forest visitors, issue them with necessary permits during the fire season, or even bar their entry to forest areas, by means of checking stations on forest roads or highways which traverse protected areas. At these checking stations men specially selected for their intelligence and personality, and correctly attired, obtain information from tourists regarding their identity and movements, and issue necessary warnings or advice concerning restrictions imposed. These men are specially instructed to cause the least possible interference with the travelling public, commensurate with the fire hazards prevailing. Checking stations are made attractive in appearance and are located in pleasant surroundings, where the stopping of car traffic causes least inconvenience to drivers. Elsewhere on the forest other individual contacts are sought by patrolmen, who may or may not combine the duties of camp custodians.

(b) Group contacts - Numerous organisations exist in both rural and urban areas, which are potential allies in the cause of fire protection provided the right approach is made. Foresters first approach the leaders of such organisations, stating the aims of fire protection and pointing out how their particular organisation could assist in a certain direction. Once these leaders can be induced to to take a definite stand, and to acquire a special interest in the forester's problem, it is usually an easy matter to convince the members that they can be of material assistance. Efforts are not made to secure the interest of individual members, but rather to foster powerful and organised goodwill groups who have the means in their power to increase public interest and support in fire protection efforts. Many of the organisations are only too willing to demonstrate their interest in public affairs, while many of them are found to welcome a new incentive or interest. Among the many local or community associations and groups which are regularly contacted are:-

1. Sportsmen etc. - Hunters or fishermen's clubs, Hikers' clubs, Motoring associations and clubs
2. Social service etc. - Churches, Women's guilds, Youth Movements, Boy Scout movement
3. Organised groups - Men's clubs, Rotary Club branches, Men's or Women's Service Clubs
4. Conventions or unions - Teachers' or Farmers' conventions, Labour Unions
5. Business men - Chambers of Commerce, Commercial Travellers, Hotel and Resort managers or associations, Lumbermen's organisations.

(c) Letter campaigns - A successful practice adopted by many district officers, prior to the opening of each fire season, is the sending of special letters to a carefully selected list of "desirable contacts" residing in and around the district in question. Many of these individuals cannot be easily contacted in person, but their assistance, or co-operation, may be earnestly desired. In simple, direct fashion the forester makes a statement of fire protection aims as they affect, or are of interest to, the recipient of the letter. It is also explained in tactful language, how assistance is particularly desired from the recipient in respect of his own habits or actions, or those of his family or employees. Letters have to be individual in their approach and in their message, as any feeling by the recipients that they are stereotyped or mass produced has to be strictly avoided. If thought advisable, letters are flavoured with the right mixture of flattery or gravity, and in every case they must carry a topical and local message in a readily appreciated way. In some cases it is thought advisable to have letters forwarded from superior officers such as Forest Supervisors, in the hope of impressing an individual most susceptible to unconscious flattery - but usually the letters are of a "man-to-man" type.

Some foresters forward letters of thanks to forest visitors who have shown exemplary conduct in their movements through protected areas - using the addresses obtained when such visitors registered at checking stations. The pleasant surprise which such letters bring to the recipients often extends the measure of co-operation evinced by them on future visits to the forests, and assists in spreading the goodwill efforts of foresters to the visitor's friends.

C. General efforts at Education.

While foresters usually maintain that greatest progress and most lasting benefit is obtained from contact methods of adult education, they admit that well conceived and original publicity of a general nature will also achieve some results. These publicity efforts are usually concentrated in the form of (i) Posters and Signs, (ii) Press and Radio messages, (iii) Fire Prevention Exhibits.

(i) The use of Posters and Signs.

Permanent wooden signs usually serve a double purpose in providing tourists or travellers with information regarding their location, routes of travel, mileages etc. as well as carrying a topical message on the subject of fire protection. Considerable ingenuity and artistry has been displayed in producing rustic signs which have an original and pleasing appearance, and yet harmonise perfectly with a charming forest scene or background.

Posters are supplied in a diversity of designs and carry a variety of messages. Small posters, 12" X 15" and 15" X 18" are most commonly used, the larger type of Forest Service poster measuring 44" X 17". The small posters are mounted on cardboard and are neatly displayed on standard types of signboard. The large poster is mounted on one of two standard designs of rustic bulletin board.

Extreme care is taken to ensure that posters are not only placed where they will be seen, but that they will carry a message suitable to that particular area, or to the class of person likely to visit such area. The indiscriminate placing of posters, or their too frequent scattering around the Forest, is carefully avoided.

Most of the posters carry messages of a seasonal type or of a temporary nature, so that even greater care is necessary in their location, and in ensuring that they are always topical by the prompt replacement of out-moded types. The general practice adopted in poster display may be summed up as follows:-

1. Posters attract attention and convey information in simple, direct terms, or in brief phrases which cannot be misunderstood.
2. Posters should conform to existing risks, local hazards, and correct season of the year, if they are to convey any message at all.
3. They should be promptly removed when no longer applicable, owing to changed hazards, or to varied classes of restrictions.
4. The number of posters used should be confined to the absolute minimum necessary to state the facts - they must not appear with monotonous frequency.
5. Large print and plain messages are necessary if fleeting motorists or others are to catch messages. Thus only the large size poster is used on highways.

Warning posters, such as those informing motorists that they are required to carry fire tools or have camp-fire permits, are carefully placed near towns, service stations, turn-offs, from highways etc. where motorists cannot fail to read the notification contained on the poster before they actually reach the forest.

Along main forest roads or highways, additional care is taken that posters or signs do not mar the landscape, and that they are strategically placed at right angles to the line of vision on straight roads, or on the outside tangents of curves. They are not placed outside actual curves unless the latter are safe at speeds of 40 M.P.H. or more. Posters are also placed at forks leading off highways, but in such a position as to be easily seen without marring either the landscape or directional boards. Along side roads and trails within forest boundaries, posters are confined largely to intersections or to special areas under notifiable restrictions, so that the forest landscape is not repeatedly dotted with signs. All fire posters and signs erected specially for the purpose are withdrawn after each fire season, especially in regions where the fire hazard exists only during the summer. Steps are taken to ensure that all necessary posting is completed well in advance of the following fire season, if at all possible a change is always made in the sign erected annually, or for shorter periods, at any particular location.

Foresters maintain records of the location of all posters, and such location is shown by special symbols on large scale maps reserved for the purpose. Requisitions for new display boards are usually accompanied by illustrations of the general layout of posters. As the policy of renewing styles and types of poster each year is followed by the Forest Service, officers requisition annually for their estimated requirements among the many different types available.

Postmasters are authorised to allow the erection of fire display posters in Post Office lobbies, the posters so displayed being of topical interest, and are frequently replaced if no longer applicable, or if at all unsightly.

Other posters are displayed on those private lands which are under co-operative protection agreements, while "general message" types of posters are also shown at hotels, resorts, camps, tourist areas, service stations etc., with the aim of attracting interest in forest protection.

(ii) Press and radio publicity.

It has been found that newspapers and broadcasting stations are only too ready to utilise news items concerning fire occurrence or hazard, and also the notifications of seasonal restrictions. Officers are specially allocated to the task of providing news items that are truly descriptive of fire outbreaks, or which plainly state the need for care, and the reason for any restrictions imposed on forest visitors. These officers also contribute a carefully planned series of longer newspaper articles for publication, either before or during the fire season, these articles being made as informative as possible in a popular fashion.

All of the above efforts are strictly local in their use, and application - if any nation-wide presentation of the situation is thought necessary, it is usually handled through Service headquarters as Washington.

Any successful efforts at law enforcement following incendiary fires are given the most intensive publicity in local circles, not with the intention of further injuring the culprit, but in order to exhibit the result of his action to others who may feel disposed to incendiarism.

All news items are checked for accuracy, and are supplied in such a manner that there is no possibility of the inaccuracies and exaggerations common to those fire reports usually furnished by reporters or by radio announcers. Where possible, officers arrange for newspapers and radio stations to obtain prompt and exclusive versions of the events of the fire season, particularly in the case of going fires, so that there is no uncertainty or conflicting data conveyed to the general public from irresponsible sources.

(iii) Other forms of publicity.

1. Miscellaneous printed matter, on the relation of various types of forest use to the problem of protection, is distributed to those individuals whom it particularly concerns, when permits are issued on contacts made. This literature takes the form of prevention pamphlets, map folders, circular letters of various types, strip maps, cards of introduction, or identity cards. This material is also exhibited at schools, hotels, service stations, forest headquarters etc., while arrangements are sometimes made for its distribution by State authorities when motor, fish or game licenses etc. are being mailed. Every officer has a small supply of such literature, together with a summary of local forest statistics, for distribution as the opportunity or occasion arises.

2. Fire Prevention Exhibits - at district fairs or conventions, or in store windows are often arranged, when a suitable arrangement of material can be displayed with a prospect of attracting interest. Literature is also available at those exhibits, which are distinct from general forestry exhibits in being quite local in their "set-up" and appeal.

   Minor exhibits are also arranged at those lookout towers which possess a "tourist" attraction for visitors - the lookout operator being instructed to demonstrate the detection phase of fire protection provided that the public will not interfere with his work during periods of special hazard.

3. "Show-boats" - These are portable motion picture units mounted on suitable trucks which visit rural areas in and around forest boundaries to show films of a special "semi-entertainment" value. The greatest success is achieved in "backwoods" centres where entertainments of any sort are not plentiful, and where films of the type specified hold the interest of the audience. The use of films as an educational measure in larger towns has not achieved any great success.

4. Illustrated lectures - Lectures are given to clubs, conventions or meetings of youth organisations, and the use of slides undoubtedly increases interest in any such lectures. Lantern slides also furnish a valuable media for holding the attention of children during lectures given at schools by teachers and visitors. Collections of suitable slides are available from Forest Service headquarters, but foresters are urged to make good photographs of local forest scenes or forest fires to further interest in any particular region. Such photographs can be used for exhibition at forest headquarters, exhibits etc., or incorporated in literature which describes local forest conditions.

CHAPTER VI

ORGANISATION OF CO-OPERATIVE AGENCIES.

A. Forest ownership as it affects co-operation.

The latest figures available (193) which summarise the position regarding ownership of forest lands in U.S.A., are summarised in Tables Nos. 36, and 37.

It will be noted at once that 69 per cent of a total area of 630 Million acres of forest land, and 74 per cent of the area of 462 Million acres classed as capable of producing timber, is under private ownership. Of the remaining areas which are under Public ownership, approximately two-thirds are included within National Forests, leaving other areas which are held under no less than six different titles. This multiplicity of ownership renders any broad system of management extremely difficult, especially when the objects of management are so variable, and these difficulties are echoed when a uniform system of forest fire protection is attempted. Multiple ownership would be a serious enough obstacle to fire protection were all forests under various titles segregated, but when most types of Public forest ownership are found intermingled in a single County with areas of forest belonging to a host of private owners, the difficulties become even more stupendous. The situation is by no means eased when one finds the enactment and enforcement of fire legislation, and the administration of forest fire protection, in the hands of State organisations. While protection of forests has improved under these latter organisations, there is a notable lack of uniformity in the nature and the vigour of their efforts. It is not difficult to imagine the conflicting opinions between public agencies concerning their individual interests, responsibility, authority etc. in formulating and executing any planned fire protection, but when there are numerous private owners, many of whom are loth to co-operate at all, or to a varying extent, the real extent of the difficulties which may occur can be readily understood.

The above-mentioned proportion (74 per cent) of the total area of productive forest land which is held by private owners, carries approximately 60 per cent of the remaining yield of saw-timber in U.S.A. These private areas include the more easily logged and accessible forest areas which will thus always remain the principal potential sources of timber supplies. Another important reason for conserving these private areas of forest, is that they embrace approximately two-thirds of the 465 million acres of forest areas which have a protective influence on watersheds.

Some consideration of the above factors indicates the need for a strong policy of co-ordination between various classes of ownership before protection can be really efficient. It is significant that real progress in protection has only been achieved since the provisions of the Weekes Law, and the Clarke-McNary Act, provided a means of co-operation between Federal, State and private owners of forest, and facilitated the provision of necessary finance. This has already been discussed to some extent, together with the great assistance rendered since 1933 by the C.C.C. and similar youth or relief organisations, but the task is by no means completed.

A glance at Tables No. 26 and 27 shows that 423 million acres of the total area of 462 million acres classified as Productive forest land, is owned by private individuals or is included within National Forests, but only 26 per cent of such area is under any form of forest management. It seems safe to assert that systematic fire protection of these "commercial" or productive forest lands has much progress to make, when even broad bases of forest management are in such a minority.

From a practical viewpoint, it is admitted that the degree of co-operation possible in fire protection is largely governed by provision of financial assistance. If regulation of the private owner is necessary in the national interest, it follows that financial assistance to private owners is a quid pro quo of such regulation, and an incentive to such owners in overcoming inherent difficulties or handicaps in their ready co-operation. Prior to the passing of the Clarke-McNary Act of 1924, when protection was still more preached than practised, there had been a strong feeling that co-operation would achieve little success and that some form of public regulation of private forest land was essential. The passing of the subject Act, which has been described (193) as the Magna Charta of Public Aid, meant that a trial was to be given to co-operative efforts as follows:-

(a) By the Federal Government directly, or through the States
(b) By the States themselves.
(c) By smaller political or geographical subdivisions.

B. Co-operation by U.S. Forest Service with other Federal Agencies.

(a) Inter-regional co-operation.

Where the boundaries of Forest Regions pass through forested areas, it is necessary to have co-operative agreements between these administrative divisions, so that there is no cause for misapprehension or mishap in the case of fires which threaten the forests of one or both Regions.

Arrangements are made, in localities like the Rocky Mountain Regions, to prepare for any such eventualities. These arrangements go so far as to be formulated into written agreements, between any two Regions, concerning the following:-

1. Technical (Regional) boundaries are disregarded, when any planned improvements such as communicating or transportation systems are being considered, so that completed works will be equally useful to both Regions, and so that duplication of effort and cost is avoided.

2. Similar action is taken in the development of Fire Control Plans - the aim being to provide a service to both Regions that will be the most efficient and most economical. In this connection detection unit location, exchange of "smoke-chasers" etc. is arranged for in a plan clearly understood by both parties.

3. It is the policy of either Region to attack a fire on the other side of its boundary, if such an attack will control the outbreak. If not, an attack should still be made, but re-inforcements should be requested from the other Region, or taken to the fire by the first Region, whichever appears to be the most effective in the circumstances. Officers

TABLE NO. 36.

Showing the ownership of Forest Land in U.S.A. (exclusive of Alaska)

OWNERSHIP CLASS	COMMERCIAL FOREST LAND (Suitable or available for timber production)		NON-COMMERCIAL FOREST LAND		TOTAL	
	AREA (Millions of acres)	%	AREA (Millions of acres)	%	AREA (Millions of acres)	%
PRIVATE OWNERSHIP						
FARM WOODLANDS	138·8	30·1	46·7	27·7	185·5	29·4
INDUSTRIAL	202·1	43·8	46·2	27·4	248·3	39·4
TOTAL	340·9	73·9	92·9	55·1	433·8	68·8
PUBLIC OWNERSHIP						
COMMUNITY FORESTS	7·1	1·5	0·7	0·4	7·8	1·3
STATE FORESTS	16·9	3·7	2·1	1·3	19·0	3·0
INDIAN RESERVATION FORESTS	6·4	1·4	5·6	3·3	12·0	1·9
NATIONAL PARKS & MONUMENTS	---	---	6·5	3·9	6·5	1·0
PUBLIC DOMAIN	4·7	1·0	19·3	11·5	24·0	3·8
NATIONAL FORESTS	81·5	17.6	40·5	24·0	122·0	19·4
OTHER FEDERAL FORESTS	4.2	0·9	0·8	0·5	5·0	0·8
TOTAL	120·8	26·1	75·5	44·9	196·3	31·2
GRAND TOTAL	461·7	100·0	168·4	100·0	630·1	100·0

TABLE NO. 37.

Showing extent of forest management on Private and National Forests of U.S.A. ("Commercial" Forest Land only).

EXTENT OF FOREST MANAGEMENT	PRIVATE FORESTS				NATIONAL FORESTS		TOTALS OF VARIOUS OWNERSHIP	
	INDUSTRIALLY-OWNED FORESTS		FARM FORESTS					
	AREA	%	AREA	%	AREA	%	AREA	%
	(millions of acres)		(millions of acres)		(millions of acres)		(millions of acres)	
Under intensive Sustd. Yield Managt.	3·9	1·9	1·6	1·2	3·4	4·2	8·9	2·1
" extensive " " "	7·5	3·7	9·7	7·0	33·3	40·8	50·5	11·9
" " managt. (not on a sustd. yield basis)	17·2	8·5	30·0	21·6	3·5	4·3	50·7	12·0
Additional forest - partially productive & $\frac{2}{3}$ under forest protection. No assurance of future management	136·8	67·7	76·2	54·8	35·9	44·0	248·9	58·9
Poor and (not restocked) forost	36.7	18·2	21·5	15·4	5·4	6·7	63·6	15·1
TOTAL	202·1	100·0	139·0	100·0	81·5	100·0	422·6	100·0

TABLE NO. 38.

Showing classification of area included within National Forest boundaries in U.S.A. (including Puerto Rico and Alaska).

(ALL FIGURES IN MILLIONS OF ACRES).

Area of productive forest under management	41 M.ac.				
" " " " not "	46·7 M.ac.				
Total area - Productive forest land		- 87·7 M.ac.			
Area of partially productive forest (not under management)		- 46·3 "			
Area of forest land - TOTAL -			134·0 M.ac.		
Grass and Alpine areas			41·0 "		
Net area within National forest boundaries - TOTAL -				175·0 M.ac.	
Private and other holdings within National forest boundaries -				52 M.ac.	
Gross area within National Forest boundaries.					227 M.ac.

(146)

TABLE NO. 39.

Showing classification of "Commercial" Forest land in U.S.A. (excluding Alaska) according to existing timber stands.

1. AREA

Areas of old growth saw-timber	- 101	Million acres
" " second " " "	- 112	" "
" carrying cordwood "	- 101	" "
" " fair to satisfactory regrowth	- 71	" "
" where regrowth is poor or absent	- 77	" "
TOTAL	462	Million acres

2. VOLUME

Standing volume of old growth saw-timber	- 1267	Billion super feet
" " " second " " "	- 497	" " "
Total volume of Saw-Timber	1764	Billion super feet
Estimated Total volume of all stands	519	Billion cubic feet

in charge of suppression in another Region should remain in charge until a local officer is available to take over. Officers and employees who have to proceed to another Region are always relieved and sent back to their own territory at the first opportunity.

4. District officers make sure that key employees and themselves are sufficiently familiar with areas in adjacent Regions, and with all fire control plans for that locality, by exchange of plans, and of visits, each Spring. In Region No. 4 - conferences between Supervisors and Rangers of various Regions are held every 2 to 4 years.

5. Whole hearted co-operation is required from both Regions - any local differences in policy, in "appropriateness" of action or in results obtained, being referred to the main Regional Officers.

(b) Inter-Forest Co-operation.

In this case the action taken, before and during the fire season, between adjoining or adjacent National Forests is even more inter-dependent than that described between Regions. Additional arrangements are made for the calling for help by one Forest if men and equipment on other areas can be spared. When help is requested, the fullest possible information is given concerning the location and seriousness of the fire, the action taken and proposed for its suppression, and the staff already employed. If necessary, guides are made available to fresh forces from other forests, these forces to be answerable to the officer in charge of the home forces but to be released at the earliest opportunity.

There is a daily interchange, by telephone or telegram, of advices concerning fire weather, and/or hazard conditions, prevailing on any pair or group of forests situated in close proximity to each other. This is particularly the case where one forest serves as a base for fire-weather investigations, or has better facilities for recording hazard fluctuations than is the case with other forests in the neighborhood.

Agreement on the exchange of advice also assists in warnings given, or plottings made, of the direction and severity of lightning storms in Western Regions.

(c) Co-operation between Forest Service and Indian Service.

In Western Regions the existence of Indian Reservations and of National Forests in close proximity renders co-operation necessary between the Forest Service and the forestry officials of the Indian Service.

A co-operative agreement which has existed since 1913 between the Department of Agriculture (Forest Service) and the Secretary of Interior (Indian Service) includes the following provisions:-

1. Detailed co-operation in fire protection will be worked out, preferably through conference, between employees of the Indian Service and Forest Supervisors of the Forest Service.
2. Field officers will remain under the jurisdiction of their respective Services.

3. The primary control by lookouts for a given area of timber land or brushland will be worked out by the Indian Service and Forest Service as far as possible without regard to boundary lines and departmental jurisdiction.
4. Primary (permanent) lookouts maintained by the Indian Service will be furnished by the Forest Service with fire control maps of adjacent National Forest areas, and lookouts maintained by the Forest Service will likewise be supplied with maps of adjacent areas of Indian Reservations. All lookout stations will be furnished with necessary equipment as agreed on between the two Services.
5. Local employees of the Indian Service and Forest Supervisors will exchange fire control plans and maps for adjacent areas under their respective control.
6. Patrol services will be organised and maintained separately by each Service, but patrol routes will be so arranged as to provide the most efficient patrol without unnecessary duplication.
7. Wherever practicable, telephone communication will be established and maintained between National Forests and Indian Reservations.
8. Fires discovered by Forest Service officers on an Indian Reservation will be reported, as promptly as National Forest fires, to the Indian Superintendent or nearest forest officer of the Indian Service. Forest officers of the Indian Service will act similarly in the event of discovering fires on National Forest areas.
9. Any officer of the Forest Service will take suppression action against fires discovered on Indian Reservations, until relieved by an officer of the Indian Service, provided such fires are within reasonable distance of National Forest boundaries, and endanger such National forests, and also provided that the action taken will not expose to danger other areas under the control of the Forest Service officer. Reciprocal action of this kind will be taken by Indian Service officers.
10. National Forest officers will render assistance in fire suppression to Indian Service officers, on being so requested, provided such action will not endanger areas of National Forest. Indian Service officers will reciprocate in the event of their requiring reinforcements.
11. If National Forest officers cannot communicate with Indian Service officers before any outbreak of fire discovered by the former on Indian Reservations is liable to assume serious proportions, the National Forest officers will take charge of the fire and employ all necessary assistance in its suppression. The salaries of regular Forest Service employees engaged on such fires shall not be considered, but the Forest Service will meet the cost of other necessary labour and seek re-imbursement of such amount from the Indian Service, provided that no claim for costs shall exceed $500. A similar procedure will follow in the case of National Forest fires suppressed by the Indian Service under similar circumstances.

On the basis of the general agreement described above, local officers of each Service work out the best practical methods of close co-operation prior to each fire season. Particular attention is paid to the interchange of fire control plans, and the utilisation of employees or equipment from the opposite Service in the event of serious emergency. Written agreements are drawn up each season to ensure successful co-operation - copies of the essential parts of such agreements being forwarded to local rangers etc. of each Service. Local officers of each Service also confer when costs have been incurred by one Service on areas administered by the other, in order that unanimity may be reached regarding the responsibility for such costs.

As the Forest Service has officers specially delegated to the systematic training of lookouts, guards etc., arrangements are often made for such officers to be utilised in the training of Indian Service employees engaged in similar protection duties.

(d) Co-operation with the U.S. National Park Service.

While there is no general agreement drawn up between the two Services, local Forest Service officers prepare written agreements with the Superintendents of National Parks in the vicinity of National Forests. Such agreements may cover a period of years, mutually agreed upon, but are subject to financial appropriations, or to review, prior to any particular fire season.

A complete exchange of Services in fire control is provided for in agreements, no charge being made when any particular Service renders assistance in detection or "smoke-chasing" to the other. Heavier costs of fire suppression are either reimbursed, or paid direct, by the Service on whose area the fire in question has occurred. Preliminary arrangements made in agreements, also prevent any misunderstandings regarding the supervision of fire-fighting - the ultimate supervision of all fires resting with the officers on whose territory it is being attacked.

(e) With General Land Office.

The General Land Office has under its control the area of unallotted "Public Domain" owned by the Federal Government, and its field officers have standing instructions to watch for fires on Domain and other areas, and report them to the responsible authorities. They are also instructed to respond promptly when called to fire duty by Forest officers, provided that such calls are to be made only in real emergencies and that men are to be relieved as soon as possible. The Forest Service may request such assistance on its own areas, and in such cases will meet all costs except the salaries etc. of permanent Land Office employees. Forest Service officers are empowered to initiate suppression action in the case of fires occurring on Public Domain lands which threaten National Forests.

In some instances, as in the case of Region No. I in 1938, the U.S. Forest Service is allotted special funds for the fire protection of forested areas of Public Domain within, or immediately adjacent to, the boundaries of National Forests or of forest protective associations. Many of such lands are to be found in Western regions, and they are not ordinarily under any organised fire protection. If the funds allotted for the purpose are insufficient for the prevention, pre-suppression or suppression of these fires, the work is continued if necessary, and the costs charged to Forestry funds.

Where special allocations of this nature are not made, Forest officers incur only such expense on Public Domain areas as is necessary to prevent damage to National Forests.

When Survey crews engaged by the Land Office are working in any National Forest, or adjoining area, they are given a clear understanding of their responsibilities in preventing fires and in reporting any detected outbreaks immediately.

(f) With the U.S. Biological Survey.

Officers or hunters employed by the Biological Survey on or near National Forests or protected areas co-operate in the detection, reporting and suppression of forest fires. Quite a number of hunters are employed in the elimination of predatory animals, and at the suggestion of the Survey administrators these men will work in close association with forest officers on fire protection measures.

Hunters are instructed to take the following action:-

1. Extinguish neglected camp fires or other small outbreaks. If fires get beyond their control, they will notify Forest officers and continue to render assistance.
2. Report all visible fires where same are believed to be on or near National Forest lands.

In cases where hunters spend less than 8 hours on fire suppression their regular salary will still be paid by the Survey Office, but when they spend 8 hours or more on fighting fires which threaten National Forests, their salary payments for such period will be made by the U.S. Forest Service in accordance with the usual rates of pay for fire-fighters.

Hunters are also advised to make efforts to identify the person or agency responsible for any particular outbreak, and to generally assist foresters in any law enforcement or admonitory action taken.

Inspectors employed to supervise hunters, or the hunters themselves, advise forest officers of their intended movements on National Forest areas, and arrangements are then made for the most effective means of conveying messages concerning fire occurrence or spread.

(g) With the Federal Bureau of Public Roads.

Because of past confusion and misunderstandings - Regional officers, usually state, very clearly, the policy governing the use of road construction or engineering crews in fire protection. The following general agreement has been reached between the Forest Service and the Bureau concerning reporting and suppression of fires etc:-

1. Responsibility for action - All agents, employees and contractors of the Bureau must take immediate action by every means in their power towards the suppression of any fires for which they are responsible, within, partly within, or threatening National Forests. All such fires must also be reported immediately to Forest officers. Contractors

must suppress all fires in accordance with the "forest fire" provisions of their contracts with the Bureau (through the Secretary of Agriculture). Salaries or wages of Bureau employees engaged in fire fighting, except in the case of fires caused by contractors, are paid by the Bureau up to the time that the Forest Service takes charge of the fire. Expenses incurred by the Bureau in employing extra labor, or in purchasing supplies and equipment expressly for the purpose of fighting fires, whether employees of the Bureau are responsible or not for the fires, are paid from the fire suppression appropriation of the Forest Service.

Fires within, partly within, or threatening a National Forest and on, or reasonably adjacent to, the rights of ways of Forest Highways, and for which the agents, employees or contractors of the Bureau are not responsible, will, nevertheless be reported immediately to the nearest known Forest officer. Such officer, on receiving notification, will proceed to take charge of the fire, but until his arrival all such fires will be handled by the available forces of the Bureau.

2. Calling out of labour crews - In the absence of other sufficient or available help, crews and employees of the Bureau within National Forests may be called on by Forest officers to assist in suppressing fires regardless of their origin, and when so called on must promptly comply, as in the case of fires for which the Bureau is responsible, until other suitable fire fighting forces are available. All expenses in such cases are handled as in Paragraph 1 above.

Forest officers may call on road crews only as emergency help in the following circumstances:-

(a) When the fire can be reached faster by the road crew than by any other adequate force.
(b) When the delay incidental to securing other fire fighters would necessitate heavier expenditure
(c) When no other forces are available.

In each of these circumstances the Forest officer's judgment will govern necessary action, he should carefully consider other practicable sources of help and also arrange for the earliest possible release of road labour forces. There should be no opportunity given for criticism that Forest officers neglected the rights of contractors or road engineers, and/or hampered the progress of road construction. For this reason local Foresters and Engineers usually arrange for pre-season discussions on mutual difficulties which may occur, and reach agreement on definite courses to be taken in emergency action. Local staffs of each administration are given a clear understanding of the procedure prescribed for each season.

The above arrangements apply to roads being constructed by day labour or contract under the supervision of the Bureau of Public Roads, and not to new roads or maintenance work under the direction or supervision of the Forest Service.

3. The Forest Service must furnish warning signs for all road workers' camps on or near National Forests, these signs to be posted by Bureau officers. In large camps a special appointment as Fire Chief of Bureau labor forces is made. When and where possible telephone systems used by the Forest Service are temporarily connected to road camps.

4. During the dangerous fire season, from May 15 to October 31 in the Western States, and elsewhere as designated by Regional Foresters, all employees, agents or contractors of the Bureau shall secure brush burning permits from the nearest Forest Officer before burning brush in connection with Forest Highway operations. The following special arrangements are also made respecting slash or brush disposal on the roads abovementioned:-

(a) Special Requirements re Equipment etc - Local Forest officers are empowered to take action with the Bureau engineer to ensure provision for:-

(i) An approved type of portable power pump, where water supplies are available and where hazard conditions necessitate such equipment, to be maintained.
(ii) A specified number of men to be present at all burning operations.
(iii) A specified number of tools, the quantity and location of which are to be determined by Forest officers, are to be provided for fire suppression at all times.
(iv) All burning to be executed strictly in accordance with forest officers' instructions. These are specially issued in writing for each occasion and are presented by the Engineer to any contractor employed. The instructions cover the time, place and method of brush disposal, man-power and equipment requirements etc. In cases or in seasons where State fire laws do not require the issue of Brush-Burning permits, the instructions of the forest officer still hold authority for burning on or near National Forests.

(b) Contract clauses - Standard road contracts between the Bureau and its contractors include these specific conditions regarding brush burning in forest areas:-

(i) The contractor must communicate with the responsible Forest officer before lighting fires.
(ii) The contractor must abide by any rules or instructions prescribed by forest officers regarding the time and place of any burning.

The above conditions of contract still hold, irrespective of the existence or application of any State fire laws requiring the issue of brush burning permits.

(c) Effective brush disposal - Forest officers are to work out adequate plans for debris disposal on all road projects, and must use their judgment in not insisting on unnecessarily harsh restrictions which would hamper progress in, or greatly increase the costs of road construction.

(d) Patrolmen - During or after brush burning, patrols deemed necessary by the Forest officer are provided and paid for by the Bureau, and work under the Forester's instructions. Foresters must ensure the provision of adequate patrols, and should fully inform the Bureau Engineer as to the extent of necessary patrols, the cost of which should be estimated so that Regional foresters can advise the Bureau of the financial provision necessary.

(h) With the U.S. Post Office Department.

The extent of the co-operative assistance rendered by the U.S. Post Office Department is best explained by quoting the following instructions which appeared in the Official Postal Guide in September, 1938:-

1. In accordance with the request of the Secretary of Agriculture, this Department has arranged a plan of co-operation with the State and National Forest officers whereby rural and "star-route" carriers (of mail) shall report forest fires discovered by them along their route to persons designated by the State and National authorities to receive such intelligence.
2. Co-operation with State officers shall be given in all States which have established by law a system of forest fire protection.
3. Co-operation will be furnished National Forest officers in all States containing National forests.
4. The State and National forest authorities will inform postmasters as to whom the discovery of fires should be reported, and each rural carrier should be directed to co-operate to the fullest extent with such authorities in the manner agreed upon, namely, that the carrier shall report a fire to the nearest State Fire Warden or National Forest officer on his route, or, if no such warden or officer lives on the route, to arrange through some responsible citizen to have him notified by telephone, if possible. "Star-route" contractors and carriers are included in the plan of co-operation and should be requested to report the discovery of fires in the same manner as will be done by the rural carriers.
5. Postmasters in or near National Forests are also directed to report fires to the nearest Forest Officers.

Both State Fire Wardens and Forest Service officers make necessary pre-season contacts with local postal employees to ensure the fullest possible co-operation along the lines indicated in the above agreement.

(i) With other Federal Departments of Agencies.

(a) Following representations made to the Departments of Commerce, Navy and War, respectively, these Departments have promised to make aeroplanes available for (limited) scouting activity during periods of serious emergency. As the Forest Service make its own plans for chartering commercial transport or passenger planes as the occasion arises, limited use is made of the above-mentioned Departmental planes, but facilities exist for their requisition when the forest officer experiences unusual difficulties.

(b) Army Co-operation in so far as it affects the co-operation required from C.C.C. Camp labour forces is always arranged for as detailed in a later discussion of C.C.C. activity.

(c) Soil Conservation Service - Co-operation with this Service is also usually in respect of the most suitable disposition or regimentation of C.C.C. forces under its control, so that such forces will be available in emergency and where possible, to Forest officers. Any such agreements reached are made fully reciprocal.

(d) U.S. Weather Bureau - As already mentioned in discussing fire-weather research, Forest officers assist the Weather Bureau in gathering basic weather data for use in improving and localising forecasting services. Officers of the Weather Bureau furnish special local forecasts to Forest Officers when so requested. Emergency plans may also cover the use to be made of special or mobile forecasting units, such as those used in Western areas on actual fires, or in centres of most severe hazard.

(e) Canadian Agreement - In Region No. I which impinges on the Canada-U.S.A. boundary line for a considerable distance of forested area, a gentlemen's agreement exists with the Canadian authorities by means of which lookout service is exchanged, "smoke-chasers" work freely across the border from either side, and either party crosses the border to suppress threatening fires. No charge is made for lookout or smoke-chasing services but re-imbursement is made to either party for actual costs of fire suppression services, rendered on its behalf. One lookout structure administered by the U.S. Forest Service is actually situated on the Canadian side of the border, but it still flies the U.S. flag.

C. Co-operation by U.S. Forest Service with State Agencies -

In previous Chapters it has been shown that co-operation by the Federal Government with State organisations on the subject of forest fire protection dates from the enactment by Congress of the Weekes Law of 1911, and the Clarke-McNary Act of 1924, particularly the latter Act, which laid down the following broad principles for Federal aid:-

1. Assistance given only to those States which legislate a protective system.
2. Assistance not to exceed the sum of State and accredited private expenditures.
3. Assistance to be rendered through appropriate State officials.

It is also understood that financial provisions made by the Federal Government are to be expended on capital improvements, prevention of fires etc., and are not to be used to meet suppression costs. The Chief of the U.S. Forest Service has indicated (195) that during the financial year 1938-39, 40 out of 48 States co-operated, under the provisions of the Clarke-McNary Act, with the Federal Government in protecting approximately 308 Million acres.

The cost of such protection was contributed as follows:-

Federal Government	$ 1,736,201 =	(21·7 per cent)
State Governments	$ 4,322,011 =	(53·9 " ")
Accredited private expenditure -	$ 1,952,341 =	(24·4 " ")
TOTAL	$ 8,010,553	

Previous expenditures of a similar nature have been mentioned in an earlier discussion of the history of organised fire protection in U.S.A. (Part C of Introduction). It will be noted that during 1938-39, contributions were not made in strict accordance with the proportions fixed by the Clarke-McNary Act (e.g. 25% each by Federal Government and Private forest owners, and 50 per cent by the State Governments.) The apparent deficiency on the part of the Federal Government is, however, more than compensated for by a contribution of approximately $17,000,000 per annum during the last six years for fire control improvements effected in forest areas by the C.C.C. (and similar) organisations. Estimates made (193) of the cost of extending fire protection to an area of approximately 162 million acres still lacking protection, involve a further expenditure of $18,500,000 in contrast to the above-mentioned current expenditure.

It is recommended by the Forest Service (193) that early protection of this additional area can only be achieved by increasing the Federal appropriation to approximately half the total requirements, or about nine million dollars per annum. Increases are also recommended in Weather Bureau appropriations, to maintain fire-weather research at a satisfactory standard of efficiency and usefulness.

The whole question of Federal assistance in fire protection, and in forest management generally, was raised in Congress on March 14, 1938 by President Roosevelt, and a Joint Congressional Committee was appointed to study the entire forest problem in the United States. This Committee has not yet completed its investigations, the results of which will probably be a review by Congress of the entire situation, with particular reference to the amount of financial assistance or regulation required to ensure conservation of the nation's forest lands.

In view of the small area of forest in State ownership (approx. 17 Million acres, see Table No. 36,) the progress achieved by the States in organising fire protection within their boundaries must be generally commended. Of their total area of forest land the States actively manage approx. 11 million acres as State Forests or Parks, this latter area being protected from fire, while approximately 50 per cent of same has been intensively developed for recreation purposes. It thus becomes obvious that State forest land is not of great value from a timber production standpoint, and that any material returns obtained therefrom will be those from recreational use. C.C.C. and other emergency labor forces have greatly assisted in the management and protection of State Areas.

The forestry activities of various States have been summarised (193) as follows:-

1. Timber Management - principally in Connecticut, Pennsylvania, New Jersey, Vermont, Arizona, New Mexico and Idaho.
2. Planting activity mainly concentrated in New York, Pennsylvania, Connecticut, New Hampshire, Michigan, Wisconsin, Minnesota, and Washington.
3. Recreation developed mainly in New York, Pennsylvania, Indiana, Connecticut, Massachusetts, New Hampshire, Ohio and Vermont.
4. Wildlife cared for chiefly in Michigan, New York, Pennsylvania and Indiana.
5. Acquisition - Although the 40 States contributing to the

Clarke-McNary co-operative scheme have large areas of State Forests or Parks, approximately 90 per cent of such areas is concentrated in ten States - viz -. New York, Pennsylvania, Minnesota, Michigan, Montana, Idaho, Washington, New Mexico, Wisconsin and Massachusetts. In these ten States the areas have been acquired either by State purchase, from Federal Grants or Grant Areas combined with the acquisition of tax-delinquent land.

The Southern region, which has at least one-third of the total forest area in U.S., has only 3 per cent of the State Forests or Parks.

The U.S. Forest Service has at its Washington headquarters a division known as the Branch of State and Private Co-operation, among the activities of which are included the relations with State forestry administrations under the provisions of the Clarke-McNary and other Federal Acts which relate to State forestry. The relations between this Branch of the Forest Service naturally vary to a great extent owing to the different types of State administration set up. Some fifteen State organisations function in full control of all fire protection within their boundaries, while in other cases the States administer only a small area of forest, and may be active either in an educational, preventive or law-enforcement capacity. The only States without any local forestry administrations are those of the Central Plains Region where forests are practically non-existent.

The Federal Government, through the Forest Service, is constantly endeavouring to extend the scope and activities of State forestry, and is making special efforts to galvanise the Southern States into a realisation of what practical forestry means to the economic welfare of that region. As previously mentioned, the difficulty lies in convincing Southerners that fire protection of forests is either necessary or practicable, or both.

In a concise review of the activities of State forestry administrations in forest fire control Allen (3A) has enumerated the achievements of the undermentioned States:-

1. Arkansas - Co-operative fire control extends over 11,250,000 acres of forest within seventeen protection units, each in charge of a district forester who is required to have a technical forestry training.
2. California - The main duty of the well organised State Division of Forestry is fire control on 32,000,000 acres of land, half of which is timber and watershed land. A full time labour force of 100 men is maintained but the regular force during the fire season exceeds 500 in number, excluding C.C.C. labour which is also available in emergency.
3. Florida - has 3,300,000 acres of private forest land protected by State forestry authorities under financial agreements made with landowners on a co-operative basis.
4. Georgia - The State Division of Forestry protects some 4,000,000 acres of private forest land by arrangement with the owners, who contribute an assessed (voluntary) payment for such protection.
5. Indiana - A co-operative fire control system organised by the State Division of Forestry (Conservation Department) and utilising some 25 towers, 75 fire wardens and 750 fireguards.
6. Kentucky - Fire control on private lands is supervised by the State Division of Forestry through five fire-protection associations, covering one million acres within 14 counties.

A compulsory payment of one cent per acre per annum by private timberland owners is required, where adequate fire control is initiated by the Division.

7. Louisiana - Timberland owners, by co-operation with the State Division of Forestry, contribute two cents per acre per annum for fire control on about one-third of the whole area needing protection (2,500,000 acres). On the remaining area of 7,500,000 acres protection is financed directly by the State and Federal Governments.
8. Maine - The Forest Commissioner, who is answerable direct to the Governor, has charge of forest fire control within the State, protection being financed by a special tax. Protected areas include some 15,000,000 acres.
9. Minnesota - The Division of Forestry is one of seven divisions in the State Department of Conservation and its Director supervises fire control on some 20,000,000 acres of forests, peat land tracts etc. Fire protection is the paramount activity of the Division.
10. Mississippi - In 1936 the State Forest Service had almost 4,500,000 acres of forest land under fire protection and the acreage burned over is being steadily reduced.
11. Montana - Fire control is the main activity of the State Forester. The compulsory "fire patrol" laws of the State require private owners to protect their timberlands and co-operative fire protection associations are most active on these private lands. Further improvements in State fire laws are expected to give 100 per cent fire protection to all private forest lands.
12. North Carolina - The Division of Forestry (one of six Divisions of the State Department of Conservation and Development) protected some 13,675,000 acres of forest land in 1937, this area representing some 67 per cent of the area needing fire protection. Some 58 Counties and 53 large owners of timberlands co-operated financially in the same year and a force of over 1,000 forest wardens, under fairly adequate overhead, was maintained.
13. New York - State Forestry Authorities exercise forest fire control on some 17,000,000 acres of forest including a considerable area of State Forests.
14. Ohio - Under the Forestry Division, some 1,250,000 acres of land, approximately one million acres of which are forested, is receiving organised fire protection.
15. Oklahoma - The Division of Forestry, under the Oklahoma Planning and Resources Board, protects 1,400,000 acres of privately owned commercial timber land under co-operative agreement.
16. Oregon - The State Forester has little State owned forest land to administer but his organisation is particularly active in fire control. Vigorous educational activity is sustained with a lecture force and equipment adapted to putting on a programme "in any place at any time". Oregon is one of the five Western States requiring forest fire patrol of its timberland owners, and the State Forester controls the use of fire and power driven machinery on lands bordering State Forests. He may require the closing down of logging operations during periods of high hazard. In general, the fire prevention provisions of the State laws are unusually strong.
17. Pennsylvania - In this State, one of the first to inaugurate a real forestry programme, fire control is handled by a well organised fire warden force under district foresters - co-operating with organised private owners.

18. Rhode Island - In this tiny State each town is empowered to appoint a fire warden and is required to share half the expense of fire control within its territory.
19. South Carolina - More than 4,200,000 acres of the timbered area within the State were under co-operative fire control in 1932. Some 50 lookout towers in the coastal counties are manned on a "subsistence farm" basis. The towerman has to be a good farmer and lives on a ten acre farm adjoining the tower, being paid from $180 to $240 per annum for their lookout duties.
20. Tennessee - The Division of Forestry in the State Department of Conservation protects more than 6,500,000 acres of forest from fire with a well organised system of district, deputy and local forest fire wardens, the suppression staffs numbering in all more than 7,000 men.
21. Texas - The Division of Forest Protection in the Texas Forest Service is maintained at Lufkin and supervises the protection of 11,000,000 acres of forest land. 90 per cent of this area is under patrol and the balance is included within protection units in which the forest owners contribute half the protection costs. An educational programme is conducted throughout the area by two motorised motion picture units using locally produced films.
22. Virginia - Forest Fire Control organisations are maintained in 77 of the 100 counties within the State. Each county organisation is in charge of a chief fire warden, who has local wardens under his supervision. The total forest area under protection is approximately 10,620,000 acres, while some 980,000 acres of non-forest and abandoned farm lands must also be protected. The extensive fire control organisation developed by States despite the limited area of State-owned forests is well exemplified in Virginia, where there are only State forests having a total area of 988 acres!
23. Washington - The State Forester has extensive powers under the State fire laws and has full power to close down logging operations during hazardous conditions. Only 0·16 per cent of the 12,000,000 acres of State and privately owned lands under co-operative fire protection was burned over during 1937.
24. West Virginia - The Division of Forestry, under the State Conservation Commission, undertakes to protect from fire some 7,300,000 acres of private forest land within 37 Counties. To do this, the Division co-operates closely with two organised protection associations of private landowners, employs five district foresters permanently, and during periods of fire hazard operates a ground force of more than 200 rangers, wardens and lookout men.
25. Wisconsin - The Chief Forest fire Warden of the State has an extensive field force engaged in supervising fire control over more than 12,500,000 acres of forest in eleven districts.

It is obviously impossible in these pages to traverse the relationships existing between all of the 40 States co-operating and the Forest Service, but an indication will be given to the types of co-operation existing in various Forest Service Regions, each of which is a self-contained administrative unit:-

REGION NO. I.

This Region embraces only the State of Montana, and the Northern part of Idaho State. The State of Washington adjoins the Western boundary of one (Kaniksu) National Forest within the Region.

1. State of Idaho - By agreement with the State, the State Forester contracts with the Forest Service for fire control within regularly created Forest Protection Districts, in which are located all the National Forests in N. Idaho. The local Forest Supervisor is appointed Fire Warden of the Forest Protection District. The State Forester deposits each year in the Co-operative Work Fund an amount sufficient to cover the agreed costs of fire control on all State Lands within each F.P. District. Further, he makes an advance deposit to cover the part of the cost of fire control on private lands within the various districts. Sums collected through State fire protection assessments on landowners are ultimately paid to the Forest Service when the private lands are within a F.P. District controlled by the Forest Service.

   National Forests within these same Districts follow a rather complex procedure in connection with collection of funds under the State agreement.

   (i) All National Forests must certify to the State Forester, as at September 1st, of each year, giving particulars of all privately owned lands which should be placed on the County assessment rolls for collection of protection assessments under State Law. These particulars must be submitted in duplicate on special forms procured from the State Forester. Any necessary revisions of a previous year's list will be made annually by the Forest Supervisor.

   (ii) Foresters must closely examine the record of exemptions made by the State Protection Board, and keep their "land lists" corrected accordingly. They must also check lists of State owned land, and report any necessary corrections therein.

   Many Counties within the State of Idaho (and other States in the Region) have acquired lands within or near National Forests and this land requires listing for fire protection with a qualified agency. Forest Service officers, after consultation with heads of protection agencies, decide which lands should be listed with the Forest Service for protection. In such cases forest officers will list the lands in question, compute fire control assessments, and advise County officials.

   Similar efforts are being made to list for protection by a responsible agency, hazardous areas of County-owned rights of way, which traversed private lands within National Forest boundaries.

2. State of Montana - An agreement exists with the State of Montana similar to that described for N. Idaho. Under the terms of this agreement, the State Forester deposits

each year in the Co-operative Work Fund an amount covering the annual costs of fire control on all State lands listed with the Forest Service. It is the responsibility of Forest Supervisors to secure from the State Forester, a record of all lands within or adjacent to the National Forest under their control, that are classified by the State as forest lands. Fires occurring on any non-listed State areas of forest land will be suppressed as usual, and a claim submitted to the State Forester for the entire amount, reports giving details of such fires, costs etc. to be also forwarded to the Regional Forester.

Supervisors must also forward to the Regional Office an annual statement covering the individual fire reports for each fire that occurred on State lands listed with the Forest Service for the purposes of protection.

Each Supervisor has a district map charted to show (each fire season):-

(i) Boundaries of Territory for which the Forest Service has undertaken protection.
(ii) Boundaries of Territory for which the Forest Service has undertaken the responsibility of issuing burning permits.
(iii) Boundaries of territory for which the Forest Service has undertaken the supervision of slash disposal.

These boundaries may vary from year to year, and the different territories enumerated above will also be variable in any single year. Burning permits may be controlled over a wide area, while the responsibility for protection, and/or slash disposal, may be confined to an area only several miles outside National Forest boundaries.

The Forest Service also seeks to include landowners, miners etc. situated within or adjacent to National Forest boundaries, in co-operative protection agreements - but this will be discussed later.

3. State of Washington - Although the State of Washington touches only the Western part of one National Forest in Region No. I, an agreement has been reached between the Regional Forester and the State, whereby the Forest Service assumes control of protection service on State owned or private lands. As in the case of other States, Forest Supervisors are appointed State fire wardens in charge of fire control on all territory, within designated boundaries, in the vicinity of National Forests.

REGION NO. II.

In this Region the State of Colorado embraces most of the National Forests, with several such forests in Wyoming, and a few in the States of South Dakota and Nebraska.

In the State of Colorado a long standing agreement, first promulgated in 1912, exists between the Forest Service, and the State Forester of the State Board of Agriculture. The full conditions of this agreement are given hereunder:-

1. "The agreement in no way intends to restrict the officers of the State, or of the Forest Service, in, or relieve them of, the performance of any of their duties imposed on them by law, with respect to the prevention and extinguishment of forest fires.

2. This agreement relates to all lands within the State of Colorado, including lands held in private ownership, lands owned by the State, and lands of the United States, both reserved and unreserved.
3. The use of the term "fire warden" throughout this agreement is for the sake of convenience in designating the officers of the State, and includes County Sheriffs, under-Sheriffs and deputies, and all other State and County officers whose duty it is under the laws of the State of Colorado to prevent and extinguish forest fires.
4. Whenever any fire warden discovers a forest fire, he shall if possible proceed at once to extinguish it, and shall thereafter, as soon as possible, report the occurrence of the fire to the nearest officer of the Forest Service and to the State Forester. If, however, he is unable to control the fire without assistance, he shall immediately report the fact to the nearest officer of the Forest Service, and to the County Sheriff. In like manner any officer of the Forest Service discovering a fire outside of National Forest land shall extinguish it, if possible, and thereafter, as soon as possible, report the occurrence of the fire to the County sheriff. If he be unable, however, to control the fire without assistance, he shall immediately report the fact to the sheriff of the County where the fire occurs.
5. Whenever a forest fire is discovered by a fire warden upon National Forest land, the extinguishment of such fire shall be in charge of the fire warden until an officer of the Forest Service arrives. Whereupon the said Forest Officer shall assume charge, and may call on the Fire Warden for assistance, and in such case the fire warden shall render all assistance possible to the said officer of the Forest Service, and a like procedure shall be followed where the fire is upon lands other than National Forest land and threatens National Forest land. The officers of the Forest Service shall determine whether or not the fire threatens N.F. land.
6. All forest fires upon lands other than N.F. land shall be in charge of the fire wardens except as provided in the preceding paragraph. However, whenever a fire is discovered by a Forest Officer on lands other than N.F. lands which does not threaten N.F. land, he shall assume charge of such fire until the arrival of the fire warden, whereupon the said wardon shall assume charge, and thereafter the Forest Officer shall render no further assistance unless in his opinion, his assistance is necessary. Whenever such fires are discovered by a fire warden, the officers of the Forest Service shall upon request of the fire warden render assistance whenever the performance of their official duties will permit. Provided that, whenever such assistance is rendered by Forest officers, the expenses exclusive of salary, incurred by them shall be defrayed by the county or counties in which the fire is located.
7. Whenever fire wardens aid or assist in the extinguishment of fires upon a N.F., they shall be paid directly by the Forest Service at the rate of not less than 35 cents per hour, except the county sheriff who shall be paid at the rate of 50 cents per hour, for such time as they may be engaged in fighting said fires.

8. Whenever fire wardens aid or assist the officers of the Forest Service in the control or extinguishment of fires upon land other than N.F. lands, and which threaten N.F. lands, they shall be paid by the Forest Service at the rates prescribed in the preceding paragraph, unless the fire is located on the unreserved public domain and arrangements can be made with the U.S. General Land Office to defray the expenses, or unless such fire is located on State or private lands and arrangements can be made with the proper officials of the State or of the county or counties within which the fire is located, or the private owner or owners of said lands, to defray the expenses or any part thereof.
9. Whenever a fire on N.F. land or threatening N.F. land, is discovered by a fire warden, he shall, before incurring any expense to be paid by the U.S. for the purpose of extinguishing the fire, report the fire to a properly authorised forest officer, who will authorise such expenditure as is necessary to control the fire; not exceeding, however, the amount which may be available from any appropriation, then subsisting, made by Congress for that purpose.
10. It is further agreed and understood that for the purpose of this agreement, all Forest officers who have been, or who may hereafter be, appointed fire wardens by the Governor of the State of Colorado, as provided for in the Laws of 1909, Section I, Page 394, shall be considered officers of the Forest Service and not officers of the State of Colorado, and all provisions of this agreement applying to other Forest officers shall apply equally to them.
11. It is further understood and agreed that the responsibility of the respective parties hereto shall not in anywise be extended beyond the express or necessarily implied provisions of the laws of the State of Colorado and of the U.S.A., and the respective rules and regulations made pursuant thereto. This agreement shall be and remain in effect until the 30th day of June 1913, and in the event that adequate authority is conferred, and sufficient appropriation is made available by Congress, shall be automatically renewed for the period of each fiscal year thereafter, unless sooner revoked by either party upon thirty (30) days notice in writing to the other".

All forest officers are conversant with this agreement and have standing instructions to see that its provisions are followed.

In the cases of Counties which do not assume liability and costs, and it is necessary for the Forest Service to fight fires on State lands, the Regional Forester will endeavour to obtain reimbursement of costs (except Forest officers' salaries) from the State Board of Land Commissioner of Colorado. Complete fire report forms of such outbreaks, together with a brief report of the circumstances, are forwarded by officers to the Regional Forester for this purpose.

The control of fires on private and State lands which do not threaten N.F. lands, rests exclusively with the Sheriff. Under Article 6., of the above agreement, forest officers must render all possible assistance when the performance of official duties will permit. Authority for allowing any claims against the County for fire suppression costs rests with the County Commissioners, and in some cases claims made by the Forest Service for expenditures incurred for fires on private and State owned lands have been disallowed by the Commissioners. Before incurring any such expenditure, it is thus necessary to obtain approval from the Sheriff, whose duty it is to suppress fires. Fires threatening N.F. lands are controlled by Forest Service employees without any delay.

County Commissioners cannot contract, in advance, to authorise fire suppression on the part of persons other than duly constituted County officers such as the Sheriff. It is necessary to keep these local County officers interested, so that if fires occur on lands where the Forest Service has no authority to expend funds, the County Commissioners will authorise or instruct the Sheriff to take the necessary suppression action.

Wyoming and South Dakota - Neither of these States has laws authorising County Commissioners to expend money on fire suppression.

REGION NO. V.

This Region, except for a small section of the State of Nevada, is wholly situated within the State of California, a situation which has lead to extremely close co-operation between the Forest Service and the State Division of Forestry, Department of Natural Resources, California.

An agreement has existed since 1932 between the respective organisations, which inter alia, provides as follows:-

1. Reimbursement from the State of Forest Fire funds expended.

(a) For State fires not threatening National Forest areas - reimbursement will only be made when the Forest Service takes suppression action on such fires in conformity with the local fire plan and local agreement between the two organisations, or upon special request of a State officer.
(b) Joint fires along National Forest boundaries - Each agency pays its own costs of suppression, but where this is not equitable or practicable, an adjustment is made on the ground, on as fair a basis as possible considering the relative areas burned, relative value at stake, and the special agreements in the fire plan, or in those entered into during the course of the fire. If the adjustment cannot be handled by having each agency pay the determined share of the cost directly, the adjustment claim is filed promptly with the agency concerned.

To obtain re-imbursements in (a) or (b) above, Forest Supervisors submit claims, in triplicate to the State Forester with substantiating evidence of payment by the Forest Service. Claims for purchase of equipment are not included except for tools used and worn out on the fire. All claims should first be discussed with the State Ranger in order to reach agreement on details.

2. Appointment of State Voluntary Fire Wardens.

The State Forester governs all such appointments in accordance with a policy of:-

(a) Holding appointments to a minimum
(b) Appointing either men for a year-long term or members of short-term forces required to enforce State fire laws
(c) Primary (permanent) lookouts, emergency guards, persons not employed by the Forest services, supervisors of C.C.C. work not directly concerned with fire duty or law enforcement are not recommended for appointment as Wardens.
(d) The appointment records of all Wardens are held in Supervisors' offices while they remain current. Men appointed for the duration of the year hold their badges of office and their status while employed by the Forest Service, but badges of short-term wardens are handed in to the Supervisor after each fire season is completed. In case of other Forest service employees replacing wardens, the number of the badge to be transferred is reported to the State Forester. Badges must not be issued or transferred until written appointment or authority for any individual is received from the State Forester. In cases of "year-long" Wardens transferred by the Forest Service to other parts of the region, efforts are made for them to continue as Wardens in their new location. Any wardens who are transferred to other Regions do not, however, retain authority as Wardens.
(e) Before December 15 of each year a list is submitted for each National Forest to the State Forester, showing the number of voluntary fire wardens appointed, transferred, cancelled etc. during the fire season.

3. Co-operative Fire Plans with State Rangers.

These are drawn up and put into service before each fire season - and provide for:-

(a) Determination of boundaries of areas to be protected ="protection boundary"
(b) Determination of co-operative fire collection boundary which conforms as closely as possible to the "protection boundary" in (a) above
(c) Assistance to the Forest Service for State fires not threatening National Forest zones of responsibility
(d) Assistance to the Forest Service for fires along any "protection boundary"
(e) Payment of fire suppression costs by the State as outlined in (1) above
(f) Determining the distance from National Forests to which the Forest Service will despatch "second line of defence crews" for the suppression of State fires.
(g) Best means of despatching suppression labour forces to fires, and the responsibility for such despatch
(h) Definition of responsibility in the case of the first forestry officer arriving at a fire
(i) Supply by the Forest Service of tools and equipment with all labour forces, and the release at the earliest opportunity from State fires of all Forest Service employees tools etc.
(j) The handling of fires classed as joint State and Forest Service fires.
(k) The most efficient use of C.C.C. or other emergency labour crews.
(l) The replacement or reconditioning of equipment used by the Forest Service on State fires.

State of California - Fish and Game Commission.

The Forest Service has a separate agreement with the Fish and Game Commission, Department of Natural Resources of California, respecting fire protection, the principal clauses of which are:-

1. Deputies of the Division of Fish and Game will pay strict attention to the enforcement of State fire legislation; familiarize themselves with and obey the regulations governing the use of the National Forests, and by personal actions and attitude assist in creating the right public reaction and sentiment towards these laws and regulations.
2. On request from the Regional Forester that any Deputy of the Division of Fish and Game be appointed a State fire warden, the Fish and Game Commission will forward this request to the State Forester of California, accompanied by a recommendation that such appointment be made. The Fish and Game Commission will instruct all its Deputies who receive such appointments as wardens, to co-operate fully with the Forest Service in the prevention and suppression of forest fires. When such Deputies are actually engaged in the work of suppressing or preventing fires the State Fish and Game Commission will pay their salaries and the Forest Service their expenses. The calls made for the services of such men will be limited to cases of actual emergency.

California State Highway Patrol - Since 1935, District Inspectors, Captains and Traffic officers of the California Highway Patrol have been instructed, by their Chief, to seek to prevont fires and to co-operate fully in work of this nature. Officers are particularly instructed to enforce State regulations which forbid the throwing of burning materials from moving vehicles, also the use of motors and trucks, without spark arresters, near grain or grass.

Counties - California State.

Forest Service Supervisors also enter into co-operative agreement with those Counties of the State of California which maintain forestry departments. Such agreements are broadly on the same basis as State agreements, but are much more local in their application. The most intensive instance of co-operation with Counties is to be found in Southern California where the extremely efficient Forestry administration of Los Angeles County and local U.S. Forest Service officers maintain an intensive protection over the Chaparral covered mountains overlooking Los Angeles and its environs.

REGION NO. VI.

In the Pacific North West Region, the U.S. Forest Service co-operates actively with the States of Oregon and Washington, both of which States levy taxes on all forest land where the owner lives more than a mile distant. For convenience, the U.S. Forest Service protects some 8 Million acres of State and Private forest land, in addition to its own protection area of 22 Million acres, receiving from the States of Oregon or Washington the sum of 2½ cents per acre per annum for all State and Private land so protected. On some 600,000 acres of forest land owned by the Northern Pacific Railroad Co., the U.S. Forest Service is responsible for fire protection, receiving an annual return of 4 cents per acre for such protection. The above per acre protection charges are hardly sufficient in average seasons, average annual appropriations by the U.S. Forest Service in Region No. VI for Prevention and Pre-

Suppression being $1\frac{3}{4}$ cents per acre, while Suppression costs range from 3 to $5\frac{1}{2}$ cents per acre per annum depending on the season experienced.

REGION NO. VII.

This Region embraces no less than thirteen States in the North East of U.S.A. in which there is a marked diversity of forest ownership and where there are perhaps more individual classifications of ownership than in other Forest Region. Co-operative agreements between the Forest Service and various public agencies can thus only be described in very general terms.

Forest Service officers are instructed to establish close working relationships between fire control organisations on National Forests and those organisations of public agencies which are also concerned with forest fire control. Such agencies may include State, County, Town or Municipal organisations. Prior to each Spring fire season, the Supervisor of each National Forest in the Region confers with the State forester, or head of the State Fire Control forces, and enters into written agreements concerning co-operative prevention, detection, reporting and suppression methods. Such agreements are circulated to local representatives of State organisations, district (Forest Service) Rangers etc. District Rangers, in their turn, contact local State, County, Town or Municipal officers involved and perfect local co-operative understandings, if necessary through supplementary written agreements.

These special contacts are repeated prior to the dangerous Autumn fire season. Forest Service officers are instructed to attend meetings of State Forest Fire control organisations and officials of such organisations are invited to group meetings of Forest Service officers. Forest Service officers also invite State, County and other fire control personnel to special tours of inspection which demonstrate National Forest Fire control organisation, standards, equipment and methods etc.

REGION NO. IX. (Lake States Region)

In this Region it is made clear that the U.S. Forest Service is obliged to co-operate fully with State, County and Municipal organisations concerned with conservation, and also to exercise leadership and initiative wherever necessary. Forest Supervisors are expected to maintain close contact and co-operation with State officials in those States having an active administration concerned with fire control. If there is any likelihood of a misunderstanding regarding fire control on adjoining areas under the control of either Federal or State administration - written agreements are executed prior to each fire season detailing the responsibilities and duties which, it is mutually agreed, shall be accepted by either organisation. Such written agreements include the following main points:-

1. Each agreement is to be illustrated by a map showing clearly the area which each agency agrees to protect. Agreements may provide that either agency will, under certain circumstances take initial action over its protection boundary on land controlled by the other agency.

2. Tho agreement must show clearly the towers or other protection points to be mannod by each agency, and the approximate period of such manning. Each agency must notify the other when significant changes take place in their organisation and manning.
3. Action which either agency agrees to take in the case of fires outside its own boundaries, but within the jurisdiction of the other agency, must be clearly defined. Similar definitions are made regarding action to be followed when fires cross the boundary botween areas under different jurisdiction.
4. Agreements must be clear as to which fires will be included in the annual statistics of each agency, at the same time ensuring that no fire will escape recording.
5. Agreemonts should indicate clearly the responsibility for paymont of hired fire fighters and for rented oquipment on fires in which both agencies are involved.
6. The responsibility of each agency over the enforcement of fire laws, issue of burning permits, maintenance of telephones etc. is clearly set forth.

All such agroements are submitted to tho Regional Forester both before and after thoir execution. Exchange of visits between State and Federal officers at fire control moetings of either administration is actively advocated and practised. U.S. Forest Service officers also assist the States of Michigan Minnesota and Wisconsin in furnishing prompt reports of any detected breachos of State laws governing the use of inefficient spark arresters, grates etc. which are usually rosponsible for tho occurrence of railroad fires.

In cases where State and Federal protection units adjoin, it is usual for each agency to agree on taking initial action on fires within a strip one mile wide outsido its protection boundary and within the protection unit of tho other agency.

D. Co-operative use of the C.C.C. and other "Relief" labour..

(i) Co-operation with the Army.

Tho Army authorities control C.C.C. camps and the working conditions, commissariat etc. of tho camp occupants. No formal agreoment exists between the Forest Service and tho Army (or its District Commanders) respecting the responsibility to bo assumed by the Army in the use of C.C.C. forcos for fire suppression. In some Regions, Army District Commanders prepare annual fire plans for their C.C.C. District, which set forth the linos of action to bo followod for assistance in fire suppression. Forost Service officers sook the co-operation of Army Commanders, even in the absenco of any Army fire plan, to ensure efficient organisation when C.C.C. men aro to be used on fires, according to varying local conditions.

Details of the occasions for which C.C.C. labor is to be employed on fires, the conditions of working, and the organisation of definite fire crews of varying labour strength and equipment standard will be discussed later in describing the use of labour forces of all types.

Detailed arrangements of a local nature are necessary in respect of messing arrangemonts for all C.C.C. labour called out on fire duty from their usual camps. Such arrangements include provision for:-

POISONOUS

Not to be taken

"SILVER-DEATH"

BAIT CARD

For Destruction of Silverfish

1. Maintenance of prepared lunches of sufficient quantity, or of lunch supplies to avoid delays, during periods of fire hazard
2. Ration units prepared for a certain number of men, to be ready for instant conveyance with the addition of some perishable items
3. Follow-up with field kitchens, bedding etc. when C.C.C. men are required to be absent from their usual camp more than 12 to 16 hours
4. Establishment of a special C.C.C. - "fire camp" in cases when men will be absent from their usual camps for a considerable time and will travel long distances.
5. Company Commanders to also have sole charge of messing arrangements on fires where both C.C.C. and other labour is engaged. After such fires the Commander itemises those meals partaken by Forest Service officers and employees and the Forest Service arranges payment for these meals at an indicated cost, which is based on the allowance of $1\frac{1}{10}$ daily rations allowed to Army officers for C.C.C. labour etc. engaged on fires. If the actual food costs exceed this augmented daily ration, increased costs are reported to the War Department which Department will probably meet the increase - if not, it will be paid from Forest Funds. The Forest Service officers usually check food prices and the number of meals for which payment is claimed.

In some cases the Army appoints a Company Commander, on or near a National Forest, as a special Fire Officer, to supervise immediate dispatch to fires of men, field kitchens, cooks, blankets, ambulance, medical officer or supplies etc. in cases where C.C.C. men from several camps are sent to a single fire. He also maintains a record showing location of all C.C.C. details, arrival and departure of men and equipment etc., and is in charge of all supplies to C.C.C. field forces. In Region No. I, this officer is known as a Fire Marshal, and has additional duties throughout the fire season such as supervision of all precautions against fire in Camps or on C.C.C. works, authority to proceed as law enforcement officer, training of labour in fire suppression methods etc.

(ii) <u>Co-operation with Public Agencies employing C.C.C. Labour.</u>

United States agencies in this category include the Soil Conservation Service, National Park Service, Bureau of Reclamation, U.S. Division of Grazing, Indian Service, Biological Survey etc., while State administrations such as those supervising Forests, Parks etc., are also included.

Pre-season co-operative agreements are prepared, following consultation between Forest Service officers and those representing one or more of the agencies mentioned, which make provision for:-

1. Services to effect an interchange of maps showing protected areas, location of C.C.C. camps within or adjacent to such areas, with information as to officers in charge of various areas or labour forces
2. Each co-operating Service to report the discovery of fires, and their location, to the authority responsible for their suppression

3. Superintendents of C.C.C. Camps situated on areas controlled by either Service, are authorised and obliged to dispatch fire crews promptly, when called on by responsible officers of either Service, to assist in suppressing fires in (or threatening) areas administered by the other co-operating Service in those cases where fires occur within a reasonable distance from the Camp. (This distance does not exceed 50 miles except in special or severe circumstances).
4. Each C.C.C. camp will furnish its own transportation, equipment, tools, food supplies etc. unless other arrangements are more expedient. No charge is made by any Service for the use of any C.C.C. equipment, tools or supplies, or for repairs or replacement of damaged, destroyed or lost equipment etc. used by C.C.C. Labour forces.
5. A reasonable reserve of man-power and equipment must be retained at all Camps in case of any threat to the security of the areas where such Camps are located.
6. Each Service is in charge of fire suppression within its territory unless some other arrangement is necessary, and is mutually agreed upon.
7. Any Service despatching labour forces to the territory of another Service will also despatch "crew bosses" and other supervisory staffs for such forces, to work under the local "Fire-Boss".
8. Initial attacks on fires are made by the first crew arriving - if the co-operating agency crew arrives first, the officer in charge of such crew will remain in charge of the fire until the arrival of an officer responsible for the territory in which the fire has occurred, after which time the latter officer will direct the use or withdrawal of the co-operative force.

E. Co-operation by Forest Services with Private persons and Agencies.

The necessity for such co-operation can best be indicated by the fact that owners of "small" forests are more than four million in number. The participation of landowners, or other private agencies, in plans for co-operative fire protection naturally varies according to the control exercised, or fire legislation enacted, by State organisations charged with fire control responsibilities and activities. As already mentioned, the Federal Government assists private owners financially only through such State organisations, so that general co-operation in any district is usually effected by the three parties concerned - Federal, State and Private. Local co-operation between Forest Service officers, and private individuals or agencies, is, however, frequently effected to the mutual advantage of both parties.

It has been thought advisable to discuss the co-operation with private individuals etc., according to the practice within several Regions of the Forest Service administration, owing to differences in principle, or in detail, which are found between such Regions.

REGION NO. I.

All possible efforts are made to enlist the general co-operation of forest users, local residents and others, so that the interest of those persons will cause them to act promptly, and without any instructions, when they detect fires. From the most outstanding co-operators, men are chosen at strategic points to act as voluntary fire wardens, or as "per diem fire guards," because of the respect and confidence in which they are held by other local residents.

In cases where land owners are not in a position to protect their holdings from fire, persistent effort is made to secure the owner's permission to have such land "listed" for inclusion in protected areas, at a small charge for such protection. Complete records are kept posted to show the ownership of all private lands within National Forest boundaries, and extending outside such territory for distances with "protection limits" of any National Forest. Apart from contacts made with all resident landowners to secure the "listing" of their land, all non-resident owners of more than 150 acres of land, on or near National Forests, are requested to pay their pro-rata share of fire control costs to the Forest Service, except in the following cases:-

1. When private land is within areas for which protective Associations have already contracted protection, in which case the Association will seek collection of costs
2. Where the State Law in Idaho provides that habitation, within certain limits, shall be considered adequate protection.
3. Areas of special hazard, which cannot be expected to participate in fire protection plans at the usual rates of contribution. These would include:-

    (a) Areas logged, or those where logging railroads operate, throughout the fire season.
    (b) Areas within a radius of 20 chains of a sawmill.
    (c) " of undisposed slash, or of improperly disposed slash of high hazard.

If necessary, tracts less than 150 acres in extent may also be admitted.

All co-operators of this nature are listed in proper records each year to avoid confusion as a result of changing ownership, transfer of local forest officers etc. Local foresters handle the entire supervision of small agreements covering areas up to 5,000 acres. For larger areas, and for co-operation with State or Federal agencies, Railway companies etc., all agreements are handled by the Regional Forester.

Reimbursements to co-operators. - Repayment to co-operators of costs of fighting fires may legally include such items as State Industrial Accident Insurance, Social Security, State and Federal Unemployment Compensation, where these are added to wages paid and have not been mentioned specifically in agreements. Co-operators may also be compensated for the loss of time by teams etc. when labour forces have been called to fires and the forest officer doing so has promised the compensation claimed for. In cases such as timber-sales etc. where the co-operator is required to assist in suppression to a certain extent as fixed by agreement - he can only be paid for any services in excess of contract stipulations.

Exchange of co-operation with residents - In regard to the supply of men, tools, transportation etc., or for assistance in detection, by any residents, the cost of such services rendered may be accepted by Forest officers in lieu of ordinary payments, on a per acre basis, by such residents for the cost of protection. Owners of areas less than 160 acres in extent who are unable to pay protection costs, may be employed, if suitable, at ordinary rates of "pay" to "work out" these costs.

Flat rate agreements - As fixed costs for suppression of fires may not be adequate in years of serious hazard, officers do not bind the Forest Service for the suppression of extensive areas at these fixed costs. In the Western part of the Region an area of only 1500 acres, at fixed costs, may be accepted from a single owner. In the Eastern section of the Region, up to 3000 acres may be accepted from one owner.

Larger areas are accepted, in each instance, only on the condition that payments made are for estimated prevention and pre-suppression costs. The owner or company undertakes to also pay suppression costs, which are determined by the percentage ratio which areas burnt on lands listed by the owner under the agreement, bear to all areas of National Forest, or other protected lands burned during the fire season.

The forms used in soliciting the co-operation of land owners, and in preparation of agreements with both small and large landowners are reproduced in Appendix "C".

Nothing contained in the agreements effected with both small or large landowners prevents the Forest Service from claiming the costs of fire suppression and/or damage on National Forests resulting from outbreaks of fire for which any individual co-operator is responsible.

Timber Protective Associations.

These Associations are co-operative organisations which set out to pool the resources of adjacent owners of timber lands in the protection of such areas. Adjacent landowners who may or may not possess timbered lands are also invited to join the Associations on a co-operative basis, annual assessments being made of the per acre payments to be made by all contributing members.

Within Region No. I there are five well organised and well-equipped Associations of this type, the Supervisor of the neighboring National Forests working in close co-operation with these organisations and preparing, before each fire season, carefully checked agreements providing for active liaison between the Forest Service and the Associations. The lines of these agreements follow those, already described, between the Forest Service and various public agencies, and are maintained at a certain standard of uniformity, commensurate with local conditions prevailing.

Maps showing protection areas, information concerning disposition of labour forces, equipment, areas of severe hazard, patrol arrangements etc. are all interchanged between local officers prior to each fire season. The usual arrangements are also made for reciprocal action in detecting, reporting and suppressing fires on all protected areas - whether same are handled by Associations or by the Forest Service. Mutual agreement is reached prior to each season regarding any areas of National Forest to be handled by Protective Associations, and vice versa.

The Forest Service advises the Association concerned, at the end of each year, of all fires which occurred, in whole or part, on "deadhead" (non-contributing) lands, State lands etc. within the area allocated to the Service for protection. Associations advise the Forest Service as soon as any fires occur on National Forest lands under Association protection.

Efforts are made by both the Forest Service and the Associations to collect protection payments in respect of "dead head" under their respective charge, in order that pro-rata allocations of seasonal suppression costs can be reduced or corrected.

The success of at least one successful Association, the Southern Idaho Protective Association, has been outlined (6). This body was organised in 1908 under a "Gentleman's Agreement" and in 1938 embraced territory amounting to approximately 1½ million acres of cut-over, brush and timber lands in Southern Idaho. Of this area approximately 600,000 acres provide regular annual payments from per acre assessments. The State of Idaho and one large Lumber Company together contribute about 40 per cent of the total protection fund. During 1937 members and subscribers contributed some $17,000, non-members $840, and the Federal Government (Clarke-McNary Act)-$4600. The value of equipment, cars, trucks, telephone systems, buildings, lookouts etc. owned by the Association is estimated at $50,000.

The success obtained by this Company in its protective efforts is best gauged from the fact that the area burned over between 1914 and 1937 amounted to only 109,155 acres, or 4548 acres per annum, these figures being all the more impressive in view of the hazards prevailing. The Association also spends money on control of insect attacks, several separate instances of which have occurred.

The area of cut-over lands within the Association territory shows a steady increase viz. - 1·5% in 1914, 9·3% in 1920 and 49·2% in 1937, which immediately raises doubts whether the organisation can continue much longer, or like similar associations elsewhere, fade out of existence when owners refuse payment for cut-over areas.

<u>Northern Pacific Railway Company - (The only company with which definite agreements are current)</u>. Two co-operative agreements exist with this Company, one of which defines action regarding prevention and suppression of fires along railroad rights of way operated by the Company, while the other agreement details the terms under which the Forest Service undertakes protection of lands owned by the Company.

(a) <u>Right of way Agreement.</u>

This provides that the Company take all steps to extinguish fires on or near its rights of way in localities where any fire might reasonably be expected to endanger National Forest lands. The Company is required to take active steps for preventing fire occurrence by removal of hazards (burning grass etc.) prior to or during fire seasons, and active steps in this direction are usually taken following discussions between Company officials and Forest Officers. The onus of placing effective patrols, and reporting fire outbreaks, is accepted by the Forest

Service, while officers make certain that the steps taken by the Company are both active and safe. Suppression costs which exceed wages of rangers, or those of patrols who are employed along or near the rights of way, will be claimed from the Company by the Forest Service, through the Regional Forester. Any costs so claimed may include those of temporary labour, supplies, transportation etc., together with salaries and expenses of forest officers.

(b) Land-owner agreement.

Under this agreement the Company makes assessed payments to the Co-operative Work Fund for the seasonal protection of those of its lands which are listed with the Forest Service for fire control, and not included within areas controlled by Protective Associations. Payments, which do not include any costs of suppression, are in accordance with unit (per acre) rates fixed for each part of the Region by the Forest Service.

Calculation of suppression costs is made, as previously described, on a pro-rata basis depending on the area actually burnt on Company lands, as compared to total areas of listed protected territory which are also burnt. Suppression costs include all labour so engaged (including officers' salaries), together with costs of supplies etc., but do not include costs of regular patrols, which are already met from "prevention" contributions.

Speeder Agreements.

These agreements which operate between the Forest Service of Region No. I and several Railway companies within such Region, allow the Forest Service (special approved officers of such Service) to operate petrol driven "speeders" for emergency transport on railway tracks in cases of fire etc. These "speeders" are owned by the Forest Service, but special arrangements are necessary with the Railroad companies to ensure they are operated, in a safe manner, only by those persons specially approved by the Service and by the Companies.

REGION NO. II.

Efforts are made by Forest officers to effect co-operative agreements with resident or non-resident owners of private land within or near National Forests which provide for annual payments based on the assessed fire protection cost of the National Forest concerned. In consideration for such payments the Forest Service assumes responsibility for both fire prevention and suppression on private lands.

The intermingling of private lands within and surrounding National Forests of the Region, makes it important that such lands be protected, and forest officers are instructed to make every effort to ensure that private owners pay for protection benefits. Co-operation is rarely sought for areas of land less than 160 acres, but at the same time the Forest Service does not assume the protection of unlimited areas of private land which are beyond the capacity of existing administrative forces.

Efforts are being made to enlist as co-operators, without charge, private owners who have limited financial means, but who are willing and trustworthy enough to act as "firemen" on a voluntary basis, or, in the case of larger owners, maintain equipment and man-power for any emergency calls.

As already noted in Region No. I, the Forest Service does not include in financial co-operative protective schemes, areas of land where exceptional hazards prevail owing to industrial operations such as sawmilling, mining etc. In such cases the following areas are excluded:-

(a) Logging or Sawmilling:-

1. A strip 100 feet wide on either side of main spur lines of logging railroads.
2. Within the limits of logging camps and up to 200 feet from any buildings.
3. Within any current cutting area or any area proposed for cutting during the fire season.
4. Within a radius of 20 chains of any sawmill.

(b) Mining operations:-

1. Within the limits of any mining camp (not prospector's camps) and up to 200 feet from any buildings.
2. Areas within 20 chains of wood or coal-using power plants such as hoisting plants, smelters, dredges, concentration mills etc.

Any other special hazards on privately owned areas should be excluded in special clauses of any agreements made for such areas.

Responsibility of co-operators for any fires caused on their areas by them, or with their knowledge, is not affected by agreements reached with them. The Forest Service claims the recovery of suppression and damage costs of such fires, and takes all possible action against the landowner in regard to law enforcement.

Rates per acre for suppression vary from 0·5 to 0·75 cents on the Rocky Mountain areas to one cent per acre in Southern Colorado and Northern Wyoming, and 2·25 cents per acre in Southern Wyoming and 5 cents in the drier regions of South Dakota.

All payments are made one year in advance to a "Forest Service Co-operative Fund" regardless of the National Forest area for which they are collected. The Regional Forester allots necessary funds for payment of "protection guards" from this Fund, allotments conforming as nearly as possible to actual receipts from various areas.

Co-operators' Record - this is kept by means of a card index system which enables instant reference to a particular co-operator, his address, the ranger district, legal description of land included in agreement, total acreage involved etc. also being shown on the card. Particulars of annual payments, changes of ownership etc. are also posted on individual cards.

Voluntary Co-operators. - Strong efforts are made by forest officers throughout Region No. II to enlist for each fire season the aid of settlers, ranch-owners, or others having a permanent location, who can be relied upon to report all fires visible from their homes, camps etc. The areas covered by such voluntary detectors are charted on the ground and shown by distinguishing legend on special "Co-operative detection" maps. This map illustrates the extent of the "Detection by Co-operators" in graphic fashion and indicates readily the need for further volunteers in any particular region. This system is extended, to some extent, by equipping voluntary detectors for the suppression of any fires within their detection sector, on the understanding that they will be employed as temporary "per diem guards" on such fires. The location of this type of volunteer is shown on special "First Attack by Co-operators" Maps, which show the location of all co-operative suppression facilities.

Special attention is paid to keeping up to date the maps showing possibilities of Detection and/or Suppression by co-operators - it being necessary to personally interview all listed co-operators before the current season's maps are charted - only those co-operators having a permanent location during the summer being considered. In cases where co-operators on detection also take initial suppression action, the location of suitable tools, equipment, telephones etc. in relation to such co-operators is most important.

Once each year, preferably in the Spring, efforts are made to arrange meetings of forest fire wardens and local co-operators in order to discuss both the local fire plans and also the latest technique in fire control. Despite the extensive use made of the C.C.C. organisation in fire control, special stress is laid on the necessity for retaining the interest and co-operation of all local individuals who may be expected to be of assistance in any emergency.

While fire wardens have power to supervise suppression crews, and may incur obligations for labor, transportation, supplies etc. - voluntary co-operators act mainly as trustworthy individuals, willing and able to assist in local fire control as the need arises. It goes without saying that special care is necessary in selecting both wardens and co-operators, and also in maintaining their interest in the job. Both wardens and co-operators are paid at an hourly rate for time spent on fire control.

Such organisations as Chambers of Commerce, the American Legion (Returned Soldiers etc.) Employment agencies, mining or industrial companies etc. are also co-opted to assist in fire control - usually through the leadership of some principal of such organisation.

REGION NO. III.

All possible effort is directed (203) towards obtaining the maximum possible co-operation, both financial and in terms of labour, from private landowners within and adjacent to the boundaries of National Forests in Region No. III.

All owners of unoccupied land are listed in efforts to secure annual payments from them, ranging from 1½ to 2½ cents per acre, for both Pre-Suppression and Suppression Costs. When fires occur on non-listed lands, an endeavour is made to collect suppression costs from the owner thereof.

Co-operative arrangements with landowners may not be on a financial basis, but may include the provision by the owner of such services as detection, initial suppression, furnishing men, tools, transportation etc. In cases where owners of areas less than 160 acres cannot finance assessments for fire control, they are given employment with the Forest Service on available or suitable forest work in return for the fire protection afforded to their properties.

The Service may refuse to enter agreements with owners, at flat rates per acre for both Pre-Suppression and Suppression costs, in those cases where hazards are greater than those on adjacent National Forest lands.

Written Agreements similar to those used in Region No. I are used in Region No. III between the Forest Service and co-operating landowners.

REGION NO. VI.

In this Region it has already been mentioned that the States collect taxes for the fire protection of unoccupied forest land. In some cases the State finds it expedient to arrange for the protection of private land to be handled by local Protective Associations - these associations to receive fees for such work from the protection taxes levied by the State. The importance of Fire Protection Associations in the Region can best be gauged from the fact that some 15 of these organisations are actively operating in the State of Oregon, while in Washington State one large Protective Association protects approximately five million acres of all private forest land West of the Cascade Mountains. The fire season strength of labour forces employed by both Protective Associations and the State averages about 600 men, but reserve equipment is available for several thousands of emergency labour forces.

REGION NO. VII.

Local forest officers are instructed to assist State, County and Town officials in organising the co-operation of private individuals. Special agreements are made with private timberland owners within or near the fire boundaries of National Forest, which provide for the extension of Forest Service protection measures to include their lands, on a co-operative basis, in accordance with the local standards of such protection measures.

The local officer of the Forest Service also organises special crews of reliable local residents, under the direction of National Forest Fire Wardens or Voluntary Deputy Forest Guards, for incorporation into the labour forces of his fire control organisation (on a payment basis).

National Forest Fire Wardens are selected from a few carefully selected local men, fitted by their location, ability, position in the community; and their willingness to be active in detection, prevention and reporting of fires. They must also be willing to assume the definite responsibility or organising and maintaining a reliable suppression force, in readiness to serve on call, or on the Warden's initiative, when fire threatens any National Forest. A special list of such Wardens in prepared, giving their names, addresses, telephone numbers etc. and also the fire unit or units on which they will function. Each Forest Supervisor issues proper credentials, in the form of a letter or card, to each Warden appointed by the Forest Service.

Miscellaneous Co-operative Labour - Each Forest Service Ranger, after consultation with local State, County or Town officials, prepares pre-season lists showing the sources and amount of co-operative labour available, including organised labour crews, and also miscellaneous man-power, available during the ensuing season for suppression duty. Advance arrangements are made in writing to show territories served, methods and terms of hire, transportation planning etc. to obviate delays when emergency calls are made. All such arrangements will be listed in local and Regional Fire Plans.

F. General Co-operation between all Agencies.

In discussing various co-operative efforts, attempted and achieved, between Federal, State or Public, and Private agencies etc. in various Forest Regions, the emphasis laid on close local contact and co-operation between all parties will have been noted. The general lines to be adopted so as to achieve the closest measure of co-operation between all agencies are laid down by a Forest Protection Board comprising the following members:-

The Chief of the Forest Service, Department of Agriculture - Chairman Ex-officio
" Chief of the Weather Bureau,
" Director of the National Park Service, Department of the Interior.
" Commissioner of Indian Affairs, " " " Interior
" Commissioner of the General Land Office, " " " Interior
" Chief of the Bureau of Biological Survey, " " Agriculture
" Head of the Office of Forest Pathology, Bureau of Plant Industry, Department of Agriculture.

The above Board formulates general policies and plans for the protection of the forests of the country, especially for the prevention and suppression of forest fires, embracing measures for the co-operation of Federal, State and private agencies in the execution of plans etc.

The Board is authorised to consult with appropriate State and private agencies, to invite authorised representatives of such agencies to attend the sessions of the Board and to present their views on matters under consideration.

State and Private agencies may also be invited to assist in the protection of Federal Forests in order to reduce fire hazards in State or privately-owned reserves adjacent thereto. Without prior sanction of the Chief Executive of the Board, the United States will not be bound by any formal agreement requiring it to assume responsibility for the protection of State or Private forest reserves, beyond that incidental to a reasonable protection of Federally-owned Reserves.

The objective is to secure, from each owner of cut-over or timber lands, his annual share, on a pro rata basis, of the cost of fire control. Four main problems are involved:-

1. Securing deposits from small owners, on a flat rate per acre basis, for fire prevention, pre-suppression, and suppression costs and services, or on the basis of advance

payment for prevention and pre-suppression, with fire suppression service on the same basis as with larger owners.
2. Securing from large owners advance deposits to cover cost of prevention and pre-suppression, with agreement that cost of suppression will be "pro-rated" on the basis of acreage burned or a "per centage of the total unit" basis.
3. Securing agreements with Associations, for the protection of timber or cut-over lands which are intermingled with or adjacent to National Forest lands.
4. Co-operation with other Government Bureaus, with the States, or with corporations such as railroads etc.

Illustrations of the steps taken by various Regions, in these directions, have already been described.

To ensure that officers of the Forest Service have no misconceptions as to the necessity for securing all possible co-operation with State, Private or other agencies, covering Regulations (Nos. A - 11 and 12 F.S.) appear in the U.S. Forest Service Manual and read as follows:-

Regulation - A.11 - "All forest officers will co-operate with State officials, in so far as is practicable, to enforce State Fire, Game and Health Laws. They are authorised to accept appointments, without compensation, as deputy State fire wardens, game wardens, and/or health officers, whenever, in the judgment of the Chief of the Forest Service, the performance of the duties required by these officers will not interfere with their duties as Federal forest officers".

Regulation - A.12 - "The Forest Service shall, whenever possible, and is hereby authorised to, enter into such agreements with private owners of timber, with railroads, and with other industrial concerns operating in or near the National Forests, as will result in mutual benefit in the prevention and suppression of forest fires, provided that the service required of each party by such agreement shall be in proportion to the benefits conferred".

The above regulations are the basis of all co-operative action taken by Forest Service officers towards achieving the degree of agreement between all forest owning agencies which is sought by the Federal Forest Protection Board.

CHAPTER VII.

FOREST FIRE LEGISLATION AND ITS ENFORCEMENT.

A. Federal Regulations on National Forest Lands.

(1) Forest Service Regulations.

The authority for seeking the conviction of a person, or persons, responsible for fires on National Forest lands is usually derived from special Regulations drawn up by the Forest Service, through the Department of Agriculture. The violation of any such regulation pertaining to forest fires is known as a fire trespass, and action against any violator may be taken in a Federal Court, irrespective of the existence or absence of any State fire legislation pertaining to forest areas. Whether the prosecution of violators of Federal regulations is conducted in Federal or State courts of law depends on the merits of the case and on local support. State laws may also be used for any action proposed when the court and the public is considered sympathetic, or State officials willing to co-operate, while it may be preferable to expedite court action by prosecuting in a State court under State laws, although the offence was committed on Federal land. If State laws are inadequate, or if local support and/or co-operation is meagre, it is preferable to take the case to a Federal Court.

The Federal Government offers rewards to those persons who give material assistance in the conviction of incendiarists, or of persons careless in the use of fire, on National Forest lands.

The full extent of the Forest Service regulations prohibiting the use of fire, lighting of fires etc., is set out hereunder (Regulations T. 1 and T. 2 - Section, GA - A3, of the National Forest Manual). The regulations apply only to National Forest lands and have no application to areas of private land within or near National Forest boundaries. Several of these regulations deal with restrictions on visitors to National Forest areas such as prohibition of entry, or of smoking, possession of camp-fire permits etc. on "areas of high hazard". Proclamations restricting public use of National Forests are technically in force throughout the entire fire season of any individual Region, but actual enforcement of regulations is not proceeded with unless the local forest officer has made public any such intentions by means of notices in newspapers, in the restricted areas, or in other conspicuous places. Such notices give details of the periods and areas for which various types of restriction, or any single restriction, will operate.

Forest officers do not insist on such restrictions unless they are clearly warranted by the severity of local hazards, notice of restriction being given as far as possible in advance, except in cases where large outbreaks of fire early in a season force sudden restrictions. Local officers are specially instructed to ensure that restrictions operating in adjoining or adjacent areas of National Forest are uniform in character and severity unless marked local differences in hazard persist (as with isolated occurrence of heavy "wet" thunderstorms). Conditions must be unusually severe before either total closure to entry, or restriction of smoking to defined areas, or throughout National forests, is brought into operation. Smoking can rarely be restricted or prohibited in the case of persons travelling along Public Highways, but Federal or State laws prohibiting the throwing or dropping of burning materials from moving vehicles can be applied in the event of any such careless action along Highways. Prohibition of entry to National forest areas cannot be applied in the case of persons travelling on State or County Highways which traverse such forests.

Prosecution of minor offences, such as repeated failure by a motorist to carry fire tools, is rarely insisted on unless the offender is entirely unreasonable or defiant. Offences against the smoking regulations are, however, classed as serious, and criminal prosecution is insisted on whenever there is a probability of successful conviction in Federal Courts.

(ii) Other Federal Regulations:-

Other provisions of Federal forest fire laws which may be used in law enforcement actions etc. include the following:-

1. Section 106, Title 18, United States Code:- "Whoever shall unlawfully set on fire, or cause to be set on fire, any timber, underbrush or grass upon the public domain, or shall leave or suffer fire to burn unattended, near any timber or other inflammable material, shall be fined not more than $5,000, or imprisoned not more than two years, or both".
2. Section 107, Title 18, United States Code:- "Whoever shall build a fire in or near any forest, timber, or other inflammable material upon the public domain.......without the consent of the United States, shall before leaving said fire, totally extinguish the same; and whoever shall fail to do so shall be fined not more than $1,000 or imprisoned not more than one year, or both".

(iii) Powers of arrest.

All Forest Service employees of a permanent character, and also specified temporary employees, have power to make arrests for any violations of Laws and/or Regulations which relate to National Forests. Arrested persons are taken before the nearest United States Commissioner, and a written criminal complaint is filed with such Commission charging the offender with the violation made. Only those employees having personal knowledge of the facts may swear to a complaint. The Commissioner either liberates the offender for want of sufficient evidence, or holds him for trial in a Federal Court.

Offenders may also be arrested by authorised forest officers, or deputy U.S. Marshals, on the issue of a warrant by a Commissioner after a written criminal complaint is sworn against the offender by a Forest Service employee having full personal knowledge of any violations.

Any assistance required by local officers in the prosecution of offenders, either before or during their actual trial, may be sought through the Regional Forester, to whom all arrests or charges made are reported.

U.S. Forest Service Regulations governing use of fires etc. on National Forest areas.

"Fire Trespass".

Under Regulation T1 of the U.S. Forest Service the following acts are prohibited on lands of the United States within National Forests:-

A. Setting on fire or causing to be set on fire any timber brush, or grass, except as authorised by a forest officer.
B. Building a camp fire in leaves, rotten wood, or other places where it is likely to spread, or against large or hollow logs or stumps, where it is difficult to extinguish completely.
C. Building a camp fire in a dangerous place, or during windy weather, without confining it to holes or cleared spaces from which all vegetable matter has been removed.
D. Leaving a camp fire without completely extinguishing it.
E. Building a camp fire on those portions of any National Forest which have, with the approval of the Regional Forester, been designated by the respective Supervisors thereof, without first obtaining a permit from a forest officer.
F. Using steam engines or steam locomotives in operations on National Forest lands under any timber-sale contract, or under any permit, unless they are equipped with such spark arresters as shall be approved by the Forest Supervisor, or unless oil is used exclusively for fuel.
G. Disturbing, molesting, interfering with by intimidation, threats, assault, or otherwise, any person engaged in the protection and preservation of a National Forest.
H. Smoking during periods of fire danger, publicly announced by the Regional Forester, upon such areas as may be designated by him, which may include roads and trails and improved camping grounds, but shall not include improved places of habitation.
I. Going or being on those portions of the National Forest which may be designated by the Regional Forester as areas of fire hazard, except with permit issued by the local forest officer, but no permit shall be required of any actual settler going to or from his home.
K. Using an automobile not provided with exhaust and muffler equipment in efficient condition on any road over lands of the United States, within National Forests, or any road acquired or maintained by the Secretary of Agriculture for the protection and administration of the National Forests, which shall have been posted by the Secretary of Agriculture as closed to such automobiles.
L. Carrying a firearm, except by authorised Federal or State officers, upon any portion of any National Forest designated by the Regional Forester in time of fire or other emergency.
M. The throwing or placing of a burning cigarette, match, pipe heel, firecracker, or any ignited substance in any place where it may start a fire; and the discharging of any kind of fireworks on any portion of a National Forest closed by order of the Regional Forester to the discharging of fireworks.
N. Going or being on those portions of the National Forests which may be designated by the Regional Forester as areas of fire hazard, unless registered previously to entering

upon such areas, at points designated by the local forest officer, but such registration shall not be required of any actual settler going to or from his home.

O. Going or being upon any portion of a National Forest designated by the Regional Forester as an area of fire hazard, without being equipped with fire-fighting tools, such as axes, shovels, and similar implements of the kind and number prescribed by the Regional Forester, when means of conveyance, such as an automobile or pack outfit, are available for carrying such tools. In the case of a camping party, the person in charge will be held responsible for any violation hereof.

P. Having in possession, or firing or causing to be fired, any tracer bullet or tracer charge onto or across such lands.

REWARDS.

Regulation T2 - Hereafter, provided Congress shall make the necessary appropriation or authorise the payment thereof, the Department of Agriculture will pay the following rewards:-

1. Not exceeding $500, and not less than $100, for information leading to the arrest and conviction of any person on the charge of wilfully or maliciously setting on fire, or causing to be set on fire, any timber, underbrush or grass upon the lands of the United States within or near a National Forest.
2. Not exceeding $300, and not less than $25, for information leading to the arrest and conviction of any person on the charge of building a fire on lands of the United States within or near a National Forest, in or near any forest timber or other inflammable material, and leaving said fire before the same has been totally extinguished.
3. All officers and employees of the Department of Agriculture are barred from receiving reward for information leading to the arrest and conviction of any person or persons committing either of the above offences.
4. The Department of Agriculture reserves the right to refuse payment of any claim for reward when, in its opinion, there has been collusion, or improper methods have been used to secure the arrest and conviction thereunder, and to allow only one reward where several persons have been convicted of the same offence or where one person has been convicted of several offenses, unless the circumstances entitle the claimant to a reward on each such conviction.

"These rewards will be paid to the person or persons giving the information leading to such arrests and convictions, upon presentation to the Department of Agriculture of satisfactory documentary evidence thereof, subject to the necessary appropriation, as aforesaid, or otherwise, as may be provided by law.

Applications for reward, made in pursuance of this notice should be forwarded to the Chief of the Forest Service, Washington D.C; but a claim will not be entertained unless presented within three months from the date of conviction of an offender.

In order that all claimants for reward may have an opportunity to present their claims within the prescribed limit, the Department will not take action for three months from date of conviction of an offender."

(iv) Federal Regulations governing Forest Permittees.

(a) Grazing permittees - Apart from being required to conform with local practice regarding use of debris-burning, camp fire or smokers' permits, as in the case of all other forest visitors and users, those persons holding grazing permits on National Forest lands, are specially bound by fire control clauses which they undertake to observe, along with other conditions of their permits.

These special clauses are:-

1. "I also hereby bind myself, and my employees, engaged in the caring for the animals while on the forest, independently and voluntarily to do all in our power to prevent and suppress forest fires on my allotment, or in its vicinity, and to report promptly to the local Forest officers all fires which I or my employees discover but which we cannot suppress through our own efforts.

   Unless prevented by circumstances over which I have no control, I agree to place at the disposal of any authorised forest officer myself, employees, and transportation facilities for fighting forest fires. Payment for such services shall be at, the current rates of pay prevailing within said National Forest for similar services, unless I or my employees are directly or indirectly responsible for the origin of the fire, in which event no payment will be made for services so rendered." (from - Application for Grazing Permit - U.S. Forest Service Form No. 879).

2. "During the period covered by this permit, the permittee binds himself and his employees while on, or in the vicinity of the National Forest, to extinguish all fires started by him or them. He will further do all in his power, independently, to prevent and suppress forest fires on his range allotment, or in its vicinity, and will require his employees to do likewise. Unless prevented by circumstances over which he has no control, the permittee agrees to place himself, his employees, and his transportation facilities, at the disposal of any authorised forest officer for fighting forest fires. Payment for such services shall be at the current rates of pay prevailing with said National Forest for similar services. If, however, the Forest Supervisor holds the permittee or his employees directly or indirectly responsible for the origin of the fire, no payment shall be made for the services so rendered." - (From - Grazing Permit - U.S. Forest Service Form No. 656.)

In cases where forest officers have definite or convincing evidence that grazing permittees or their employees have deliberately caused the lighting of fires in or near their permit areas, the Grazing Permit is cancelled immediately and the former holder is also struck off the "Preference List" of those who desire to hold National Forest Grazing

Permits. He is also debarred from the issue of grazing permits on other National Forests.

(b) Operators under Timber Sales Permits and Agreements.

The required co-operation between these operators and Forest officers has already been discussed in dealing with prevention and pre-suppression action such as top disposal, taking precautions in respect of hazards existing, making available labour and equipment for fire suppression etc.

Sales agreements now provide for the suspension of logging operations during times of special danger, for the use of oil burning machinery, for fire-proofing around steam machinery, for the effective clearing of all mill sites, engine settings, logging railroad rights of way etc., and for maintenance of fire fighting equipment. Numerous conditions governing the care to be taken by all timber sales operators and their employees etc. are found in Timber Sales agreements, the essential features of which are tabulated hereunder:-

1. Smoking - prohibited in forest during periods specified by Forest officers, except at camps or designated "fag-stations".
2. Fire tools in boxes - are compulsory when five or more men are employed in the forest, unless modified by a Forest officer.
3. Fire tools in woods - as laid down in standard conditions of agreements.
4. Fire tools on steam machinery - as laid down in standard conditions of agreements.
5. Pumps and hose - required on or near steam machinery operating in forests, if so instructed
6. Portable pumps and hose - required if more than 20 men are working in forest areas where water is available, unless waived by Regional Forester in less hazardous forest types
7. Pumps and hose - to be stationed at all sawmills cutting over 20,000 super feet a day, in positions where fires may escape to forest areas
8. Moving patrol - to be stationed on sales area unless waived by Regional Forester
9. Moving patrol - to follow locomotives using wood or coal unless waived by Regional Forester
10. Emergency control of working, or complete closure, as required by Forest Supervisor, on sales areas where steam-using equipment is in operation.
11. Oil burning machinery in forest areas is stipulated - unless waived by Regional Forester
12. Coal or wood burning machinery is allowed only with approval of Regional Forester and then only if adequately fire-proofed from surrounding forest
13. Spark arresters of approved types are mandatory on all steam-using machinery, unless specially exempted on certain locomotives.
14. A tank car of 5,000 gallons capacity, with pump and 1,000 feet of 1½" hose, nozzle etc. is required (e.g. RegionV) on broad gauge logging railways, or a 3,000 gallon car with similar equipment, on narrow gauge lines, where stipulated by the Regional Forester.

15. Purchasers of Government timber are required to do all in their power to prevent and suppress forest fires on their sale area, and in the vicinity of same, and must place their employees at the disposal of any authorised forest officer for fire suppression duty. If employed outside the sale area, on fires not originating therein, forces used in fire suppression will be re-imbursed (e.g. Region No. 5).

(c) Visitors' permits.

After even partial closure of forests, or restriction of movement by visitors, to National Forests has been considered necessary, visitors entering the forests do so only under special permit.

Typical of the permit issued is the one copied below from Region No. IV of the Forest Service:-

.................National Forest Entrance Permit.

Mr......................,of.......................and party

consisting of.........persons, mode of conveyance.............,

auto licence number...............State of.......,......., is

hereby granted permission to enter and be upon..................

...................within...................National Forest

during the period................,to..................for the

purpose of...

This permit is granted pursuant to the order of the

Regional Forester, U.S. Forest Service, dated.............19..,

and is subject to the following restrictions:-

(ENTER RESTRICTIONS INCLUDED IN ORDER)- (e.g. Camp fires limited to cooking only).

It is understood and agreed by the permittee that in consideration of the issue of this permit, he will pay the cost of extinguishing any fire which he or any member of his party may start, and will pay for any damage done to the property of the United States by any such fire.

Failure to comply with the terms of this permit will render the permit null and void and will make the permittee liable to action under the Federal or State Law.

Permit Issued...............19..

Signature of Permittee...................

" " Forester Officer.............,Title......

TERMS OF PERMIT.

If smoking and the building of camp fires is permissible under the Regional Forester's order, the following rules will be observed and are made a part of this permit:-

1. Build no fire larger than necessary for ordinary camping purposes.

2. Build no fires except in places from which all inflammable material (refuse, grass, brush, roots, rubbish, needles, leaves) down to mineral soil has been removed.
3. Start no camp fire until there has been cleared an area large enough to insure that neither the fire nor any spark from it will ignite any inflammable material outside the cleared area.
4. Do not leave, even for a short period of time, any fire without extinguishing it.
5. If enough water is not handy for thoroughly quenching the fire, place the fire in a hole dug in mineral soil and smother it with mineral soil before leaving. In windy weather dig a hole in mineral soil, and build a fire in, and confine fire in, that hole. Stir fire thoroughly in applying water.
6. Restrictions on Smoking - Smoking is permitted:-
   (a) While travelling on roads, provided matches and tobacco are entirely extinguished before being discarded
   (b) In camps and at places of human habitation.
   (c) At any other place free from inflammable material, provided the smoker absolutely stops travelling while smoking, and entirely extinguishes his tobacco before resuming travel.

   Smoking is prohibited elsewhere, or under any other conditions, on National Forest lands.
7. Have in your possession a shovel, an axe of at least 2 pounds weight, and a water receptacle of 1 gallon or greater capacity. These are necessary in order to be able to comply with the above requirements.

B. State Fire laws.

Law enforcement is perhaps the most important part which States may play in forest fire protection - some foresters assert that State activity might profitably be confined to this task alone. The greater percentage of forested land within State boundaries is privately owned, in some States by thousands of small owners. Legislation is sought in some States to assist private owners of forest in the protection of their areas while in other States (as in the South) there has long been strong prejudice against any extension of State powers for forest fire protection. There is thus a tremendous difference in the powers possessed by various States under local legislation, and in the strength of the organisations responsible for enforcement of such legislation. It is significant that in Western regions, where the coincidence of severe hazards and weather conditions has brought a general appreciation of the seriousness of the forest fire problem, the State laws governing fire protection are most stringent. In sections of the North-East, where a concentration of dense population enhances the recreational values of forest lands, several States (such as New York) also possess wide powers and are active in their enforcement. Rarely, if ever, do States possess the sweeping powers conferred on the U.S. Forest Service in National Forest areas by means of the Federal Regulations already listed. Owing to the resistance naturally to be expected from landowners, it is doubtful whether any State could hope to possess equal powers over what are predominantly private areas of forest and other lands. Practically all States now possess legislation conferring power on State or other local authorities in reference to:-

(a) The wilful or careless use of fire during certain seasons
(b) Minimising risks from industrial operations
(c) Reduction or elimination of hazards
(d) Regulation of brush burning by means of permit
(e) Allotment of powers to local public authorities, such as Counties etc., willing to assist in active fire protection

The general extent of State fire legislation has been more specifically defined (101) as follows:-

(i) Restrictions directed towards the Prevention of Fires
(ii) Provisions for the disposal of brush or logging debris
(iii) " " minimising risks from railroads or stationary engines
(iv) Systems of fire control within the States
(v) Liability for fire damage and penalties for violating fire laws.

This broad latter classification will be used in attempting to summarise the position regarding the extent of State powers in fire control. While it is impossible in these pages to describe the whole scope of State legislation - the main offences covered by such legislation, and some typical examples of modern State legislation, will be mentioned.

(i) Restrictions directed towards the prevention of forest fires.

Kinney (101) has pointed out that prohibition of the lighting of fires in the open, at least during part of the year, has been in force since early colonial days in at least nine States. In other States the only insistence by the law in regard to such fires was a notification in advance to adjoining landowners. More recent legislation in practically all States now prohibits the malicious or careless use of fire in the open, during periods prescribed by the State administration; and in some cases offences on private or public lands are specifically mentioned. There has also been a decided tendency to make laws more comprehensive in their application, and more specific in regard to various types of offence, while penalties for violation have been strengthened to a marked extent. Wilful lighting of fires is even classed as a felony in some States (e.g. Nevada, Wisconsin, California and New Jersey etc.) while penalties for incendiarism are now generally severe. Much of the recent extension and strengthening of State fire legislation has resulted from the impetus given to State forestry by the Clarke-McNary Act, and from the insistence by Federal authorities that financial assistance would not be extended to any State that did not possess adequate legislation of this nature.

(a) Setting of fires in the open:-

1. Careless or negligent use of fire.
Anyone guilty of negligence or carelessness in setting or allowing a fire to spread, without taking steps to extinguish it, or who leaves such a fire unattended or fails to assist in its suppression, is liable to a fine up to $100, or imprisonment up to 30 days, or both. (States of Colorado (1937) and South Dakota (1937)). Penalties for a similar offence in the State of California are a fine up to $500 or up to six months imprisonment, or both. Anyone who discovers such a fire burning and fails to give warning of same, extinguish or assist in suppressing such fire, is liable

to a similar penalty (States of Colorado and South Dakota) In the States of Minnesota and Michigan it is unlawful to light fires on or dangerously near forest or grass land, leave them unquenched, or to use other than incombustible gun wads, carry a naked torch fire brand, exposed light in or dangerously near to forest lands causing a risk of accidental fire.

2. Wilful or malicious use of fire.

Anyone wilfully or maliciously causing the burning of fodder or grain (in crops or stacks), fencing, buildings, or timbered areas, which is the property of another, and which is valued at more than $35, shall be imprisoned for a term of 1 to 3 years.

If the damage caused is less than $35 the penalty may be a fine of from 5 to 100 dollars, or imprisonment up to 30 days. (State of Nebraska - (1922). In the State of Indiana any malicious or wanton use of fire is punishable by fines of from $5 to $50 and/or imprisonment up to 30 days. More than $25 worth of damage by a similar wilful or malicious burning in the State of California is classed as a felony - punishable by imprisonment for periods ranging from 1 to 10 years.

"If any person shall maliciously set fire to, or cause to be set on fire, directly or indirectly, in person or by agent, any woodlot or forest; or wildland, property, material, or vegetation being or growing thereon, such person shall be guilty of a felony, and upon conviction shall be sentenced to pay a fine not exceeding $5,000, or be imprisoned in a penitentiary for a period not exceeding ten years" - (State of New Jersey).

The variation in State laws is well exemplified when one compares the heavy penalties quoted above for incendiarism (Nebraska and New Jersey), with those imposed for an identical offence in Louisiana. In this latter State incendiarists may only be fined from $25 to $200, or imprisoned from 10 days to three months, or both.

(b) Closed seasons and burning permits -

Most of those States which have made it a practice to close certain periods of the year to the lighting of fires, have allowed burning during such periods under special permits issued by State officials, fire wardens etc. In some States the issue of permits is also required during these periods for lighting camp-fires.

1. Period covered by closed seasons.

In Eastern areas where conditions of fire hazard exist at different seasons during any calendar year two closed seasons may be designated - e.g. - March 15 - June 1 and September 15 - November 15 (Connecticut) April 1 - May 20 and September 10 - November 10 (Pennsylvania), April 1 - June 15 and October 15 - December 1 (North Carolina). Elsewhere in the East a single season exists e.g. March 1 - November 30 (Ohio) March 1 - December 1 (Massachusetts), April 1 - November 1 (New Hampshire), April 1 - December 1 (Rhode Island). In Western areas, the closed season is mainly confined to the latter part of the year e.g. July 1 - October 1 (Idaho) May 15 - December 31 (Oregon), April 15 - October 15 (Washington), April 15 - December 1 (Southern California) or May 1 - October 31 (Northern California). In the States of New York, New Jersey and Minnesota there is no "open" season at all, while in Georgia the State Director of Forestry may fix definite periods not exceeding 30 days in any single year in which woods burning may be allowed (127). In Illinois Wisconsin and Utah, local authorities may designate any part of the year as a closed season, according to prevailing hazards. In Oklahoma no burning of any kind is permissible without sanction from local authorities, while in Connecticut where the "open" season extends from June 2 - September 14 (see above) burning at any time during this open season is still restricted to the prior issue of permits from State authorities. In Michigan, Wisconsin, Minnesota burning permits, together with efficient firebreaks, are required for all burning in the open at any time when the ground is not snow-covered, while there is total restriction of all burning, by proclamation of the Governor, when special hazards prevail owing to drought etc.

2. Conditions imposed on burning under permit etc.

In Connecticut and Massachusetts, burning of hazards along railroads, or of domestic or agricultural refuse, is permitted at a distance of 200 feet from forest land. In Rhode Island this distance is reduced to 100 feet, while in Indiana permits are only required for burning within 40 chains of forest land. In Oregon, permits may not be required for fires carefully set under strict control, but the escape of any such fire is a violation of State laws. The law in Washington which requires such conditions for burning permits as the felling of all "snags", is also typical of that in other States where many precautions are insisted on to prevent the spread of fires to adjoining territory.

A typical set of conditions governing burning under permit is that included in California (1931) legislation which provides that the burning of inflammable cover, blasting, setting of fireworks either on the permittee's land or on other areas, is forbidden between April 15 and December 1, without a permit issued by the State Forester or his agent. The burning of small piles of debris on rocks, in yards or gardens etc., when 100 feet from any timber, brush or inflammable cover, is not forbidden but at least one adult person must remain in attendance at all times on such burning. (Redwood logging areas and municipalities are exempted from the above conditions - fire being an integral part of Redwood logging operations).

(c) The lighting and extinguishing of camp-fires.

The majority of the States insist on proper extinguishing of camp fires - the offence of leaving such fires unguarded or improperly extinguished being either specified in particular clauses of the State fire laws, or included in general clauses covering any lighting of fires in the open. In most States the emphasis on care to be taken with camp fires is not confined to the closed season of the year. During the closed season, the use of camp fires on any area is usually governed by strict conditions of the camp fire permits issued by U.S. Forest Service officers, local State, County foresters or other specified officials.

The following example is quoted of general control over camp fire lighting:-

"Any person who shall build a camp fire in any woods, or any prairie, or on other grounds in this State, shall, before or at the time of breaking and leaving such camp, totally extinguish such camp fire; and, upon failure to do so, such person shall be deemed guilty of a misdemeanour, and upon conviction thereof, shall be punished by a fine, not exceeding $100, or by imprisonment not exceeding one month, or by both.....(State of Colorado, 1921).

Similar offences are punishable elsewhere as follows:- Up to $500 or up to 6 months imprisonment, or both (California), Fines ranging from $5 to $100 and/or imprisonment for up to three months (Illinois).

(d) - Suspension of the hunting season.

Local officials may suspend all hunting during specially proclaimed periods of severe fire hazard, the carrying of firearms during such period constituting an offence in forested areas included in the proclamation. Some examples are the States of Connecticut, Maine, Massachusetts, New Hampshire, Vermont, Oregon, Washington and New York (part area).

In the State of Illinois it is a punishable offence to set fire to any peat, grass, brush or other inflammable material to assist in hunting, or to hunt around or near a fire set for that purpose.

(e) Setting of fires by combustible gun-wads, dropping of matches or other burning materials.

Anyone offending in the above capacity, who causes fires by the dropping of burning wads, matches, cigars, cigarettes, tobacco or other materials in forest, brush or prairie lands is liable to penalties in quite a number of States. Recent improvements have been effected to such laws in a number of Western States such as California, Wyoming, South Dakota, Montana and Idaho, one example of which is quoted below:-

"Any person who shall drop or throw from any vehicle or other means of transportation, any burning match, cigarette, cigar, ashes of pipe, or other burning substance of any kind, shall be guilty of a misdemeanour, and upon conviction shall be punished by a fine of not more than $50, or by imprisonment ....not more than 30 days, or by both".....(South Dakota, 1937).

The law governing a similar offence in Wyoming (1937) is almost identical, but does not include "dropping" of burning materials.

In South Dakota, Nevada, Wyoming, Indiana and Wisconsin and in the North Western States of Idaho Oregon and Washington the throwing etc. of burning materials of this nature is an offence whether fires are actually caused from such action or not. In Wisconsin offenders who throw or deposit any lighted cigar or cigarette, or empty any unlighted pipe, on any public highway or parkway, are liable to the following penalties:-

(i) Fine of $10 and/or imprisonment of 10 days where damage

resulting is less than $25
(ii) Fine of $100 and/or imprisonment of 6 months where damage resulting is more than $25

(f) Other restrictions on use of fire in open areas.

Special measures to prevent the setting of fires along highways or to facilitate the use of highways as fire lines, have been adopted in California, Nevada, Connecticut, Kansas, Nebraska, Minnesota, New Jersey, North and South Dakota. In Nebraska, road overseers are required to have four furrows ploughed on each side of public or main roads, not less than half a chain from the centre of roads, and the intervening space between ploughing and roadway burned before the end of July each year. (Nebraska, 1922). Minnesota has recently (127) provided for the clearing of all inflammable debris within 200 feet of either side of its public roads.

Several States, such as Minnesota and Indiana, have recently made provision for the closing during emergency periods, by State authorities, of all roads (except State Highways) within State lands and/or forests. Minnesota also insists on provision of fire lines for the protection of cities or townships exposed to forest fire danger. New Hampshire has authority to resume land required for lookout purposes.

A number of States such as Washington, Georgia and Utah have power to declare uncontrolled fires found burning to be a public nuisance, the person responsible for their lighting, or the landowner on whose land they are burning, to be responsible for extinguishing them or for paying suppression costs.

The lighting of fires on lands owned by other persons is also forbidden, particularly in cases (California and Oregon) where the owner of the land has given public notice that he forbids the use or lighting of fires. Such offence involves a penalty of up to $500 fine, or imprisonment up to six months (or both), in the State of California.

(ii) Provisions for the disposal of slash or logging debris.

(a) Slash from logging operations -

Legislation insisting on intensive disposal operations among logging slash is enforced by the States of New York, Minnesota, Washington and Idaho. In the latter State, regulations which insist on disposal of logging slash, include a provision that land owners must spend 15 cents per acre for every thousand super feet of logs obtained from such acre, as already described in "Slash Disposal".

All logging operators in the State of Minnesota must inform State Forestry officials who is responsible for disposal of slash. The actual disposal is then subject to the direction of State forestry officials and if not proceeded with, such work is done by the State administration at the expense of the landowner. Disposal of slash at the expense of landowners is also specified under Wisconsin State Fire Laws.

(b) <u>Slash and debris along highways, railroads</u> -

Proper disposal of all logging slash is required, where same is adjacent to highways, railroads, watersheds, other property etc. in various States e.g. Connecticut (Highways), Massachusetts, Minnesota, Michigan, and Wisconsin (Highways, Railroads in forest areas), New Hampshire (Railroads), Maine and New York (Highways and Railroads), North Carolina (City water supply areas) Pennsylvania (Railroads, Oil or Gas wells). As already described for Minnesota, the disposal of all debris from road construction must be properly attended to along such roads - those conditions also applying in the States of Maine, Oregon, Washington and California. Similar conditions re disposal of "construction debris" are also provided, in the State of Indiana and elsewhere, where roads, telegraph or power lines etc. are constructed through forested areas. In the State of Illinois, failure to dispose of inflammable material along railroad rights of way is punishable by the payment for all damages and costs resulting from such neglect - the fact that any fire was communicated from an engine being accepted as prima facie evidence of neglect.

(c) <u>Treatment of Slash as a nuisance</u>:-

The States of California, New Jersey, Ohio, Oregon and Washington provide that any area of slash not disposed of may be declared a public nuisance, the areas in question may be either patrolled, or slash thereon disposed of, at the expense of the owner or person responsible.

(iii) <u>Provisions for minimising risks from engines etc.</u>

State laws have for many years aimed at minimising the number and extent of fires from moving and stationary engines using steam and burning either wood or coal. Many earlier laws made railroads responsible for fires occurring along their rights of way, irrespective of any proved evidence of negligence. The main efforts made to minimise risks from railroad (and other) fires have been as follows:-

(a) <u>Spark arresters</u> - The use of such arresters, of an approved type, is mandatory on locomotives (excepting electric or oil-burning types) operated through areas of grass or timberlands, at least during the fire season, in at least half of the States of the Union. The majority of these States also insist on similar precautions with stationary steam engines etc. used in logging, portable sawmills etc. Boats using wood fuel are even required to be so equipped in the State of Michigan.

(b) <u>Maintenance of locomotives etc.</u> - While most of the States which insist on spark arresters also require every engine to be equipped with proper fireboxes and ashpans (to prevent escape of burning ashes or cinders) only a comparative few States insist on inspecting other mechanical appliances of engines etc. In the latter States, engines or boilers may be condemned by local officials as unfit for use in forest areas unless all fire-prevention appliances are present and in good working order. Finding engines etc. in such a condition usually results in a fine for the owners thereof.

(c) Deposition of live coals or ashes - The usual practice of depositing live coals and ashes along railroad tracks from moving engines is expressly forbidden, under penalty, in many Northern States. Operators of locomotives must confine such deposits to special "safe" pits or other sections of the right of way, and provision for such safe areas must also be made. In California and Michigan dumping of coals etc. from threshing machines etc., is also forbidden.

(d) Clearing of hazards from rights of way - The majority of States insist on the clearing of all hazards resulting from construction of railroads, highways etc., as already mentioned. Where specific reference is made to railroads, hazards must be regularly eliminated (either once or twice annually). Along lengths of railroad where local officials declare that hazardous conditions prevail, certain States provide for the removal of hazards by the State, or by adjoining landowners, at the owner's cost, if the latter neglects such removal. In Missouri, adjoining landowners are empowered to collect double costs for such work. A minimum width of 50 feet on each side of the centre of the right of way must be cleared in Michigan.

(e) Construction and maintenance of firebreaks.- In a number of States, almost all of which are in the Rocky Mountain Region, railroad companies are authorised or compelled by State laws to protect areas of forest from specified hazards by the construction and maintenance of approved firebreaks. In other States in the North East, a similar precaution is insisted on, while railroad companies are empowered to enter private lands for this purpose (under the supervision of State officials).

(f) Patrolling rights of way - Provision for such patrols, during or after traffic in dangerous seasons, is also made by a number of North Eastern, and other States. The effectiveness of these patrols is demonstrated by recent laws passed in the State of Washington (127) which relaxed provision for spark arresters etc. on railroad and logging locomotives, and substituted compulsory patrols behind trains along defined lengths of hazardous rights of way. In the States of Michigan and Wisconsin, train crews are required, under penalty of State Fire laws, to report all untended fires along rights of way in woodland areas to the nearest telegraph station or railroad section crew.

In Wisconsin and Minnesota, the State Forestry Administrations may order any Railroad company to institute moving patrols behind all trains even when State patrols are operating. If the Company fails to provide patrols when so ordered - the State will provide them at the expense of the Company.

(g) Control of logging operations. - In Northern Pacific States (e.g. Oregon and Washington) State forestry officials may close down all logging in times of serious danger - such as persistent relative humidities of less than 30 per cent. At other times logging companies are required to fireproof sites of logging engines or other serious risks, and to have man-power etc. available at any time for use on fire suppression. Similar legislation in the State of California prescribes clearing around (100 feet) all logging equipment, the fitting of special pumps and hose to all steam using equipment in forest areas, and the supply of fire fighting tools to all forest sites where engines of <u>any</u> type (petrol, steam, electric etc.) are in use.

(iv) Systems of fire control within States.

The varying powers possessed by different States, and the wide divergence in the actual organisations charged with law enforcement among various States, has already been mentioned. It is only possible to give here some examples of the variations existing between States.

In 1936 those State Forest Services which had direct control of all fire protection (and suppression) activities throughout their territory included the following:- Maine, Vermont, Massachusetts, Rhode Island, Connecticut, New Jersey, Pennsylvania, Delaware, Maryland (North Eastern Region); Michigan, Wisconsin and Minnesota (Lake States Region) and Washington, Oregon and California (Western Region).

In other States, local forestry organisations may not actually exist, but organised fire protection is directed by other State officials such as the State Board of Land Commissioners (Idaho and Colorado), or by the appointment of special State officers as Fire Wardens with power to take necessary action (North Dakota and Utah). In quite a number of other States a responsible officer of the State at least possesses adequate powers in respect of law enforcement, e.g. in Texas the State Forester - ".. shall enforce all laws pertaining to the protection of forest and woodlands, and prosecute any violation of such laws"..........

In the Western States particularly, there is a close liaison between State officials and U.S. Forest Service officers, and also with such volunteer or organised bodies as the Timber Protective Associations of the North West region. Forest Service officers and employees are enrolled as State Fire Wardens (ex-officio in the State of Montana) or are asked to assist in general law enforcement. The States protect areas not readily protected by the Forest Service, or assist Timber Protective Associations to do so. They also endeavour to bring their legislation into some degree of conformity with Federal Regulations so that offences occurring on any lands will be equally punishable.

In some Western States such as California, State powers in fire protection are delegated, where desirable, to Counties which possess adequate fire protection ordinances. This enables close supervision of local problems and spurs the interest of local officials and inhabitants in law enforcement and other phases of protection. County control is also exercised in such States as Alabama, Colorado, Delaware, North and South Carolina, Virginia etc. - the cost of such county or township control being borne either by the State or by the local bodies, or by a sharing of expenses.

In States where public forests are not greatly in evidence, such as Indiana, Utah, Ohio etc., the cost of fire control is met entirely from local funds, and until recent revisions due to the Clarke-McNary Act, was entirely without State supervision, although State laws were used in enforcement cases.

The majority of States possess powers to call on all persons when suppression forces are required, while many other States insist that landowners either contribute their share of protection costs or become responsible for "compulsory patrol" of their properties.

Able bodied adult persons who are called upon by responsible officials to assist in fire suppression, and who refuse to render such assistance, are guilty of punishable breaches in the State Fire Laws of California, Nevada, etc.

In some cases State laws prescribe that persons called to assist in fire suppression shall be paid a specified hourly rate for such services e.g. (Michigan, Minnesota) or shall be insured under Industrial Insurance Acts (Nevada).

In the State of Minnesota responsible State officers may also commandeer automobiles, tools, appliances etc., to assist in extinguishing fires, while in Ohio railroad employees (on permanent ways) are required to attend and extinguish all fires in the vicinity for which the railroad is responsible.

(v) Liability for fire damage and penalties for violating fire laws.

Apart from action taken by States against violators of State laws, County ordinances etc., persons guilty of these offences are, in most cases, liable to civil action from landowners, the State etc., for damage caused by them. In assessing damages, the cost of suppressing fires may or may not be included, with damages to standing timber, to the protective influence of forest etc., which are usually allowed under State common law. More recent legislation has aimed at the possibility of the States or individuals recovering from persons responsible for breaches of the law, both suppression costs and damage estimates. Persons responsible for damaging fire warning notices, fire tools or equipment have more recently become liable to conviction e.g., Michigan, Ohio, Wisconsin - in the latter State the penalties for such offence are fines from $25 to $100 and/or imprisonment for from 10 to 90 days. In the State of South Dakota anyone found guilty of breaking, removing or interfering with fire tools, equipment etc. owned by Forest Services is liable to a fine of from $100 to $500 and/or imprisonment for from 30 days to 6 months.

In some States (as in Washington) owners of land who neglect to provide adequate protection to their forest areas may be required to pay a certain sum (up to 5 cents per acre in Washington) to the State authorities, for providing necessary protection through public or co-operative organisations.

All offences against State laws are heard in State Courts - County Courts being used for the hearing of offences against County ordinances.

In more than half the total number of States, specially appointed officers, such as foresters, game or fire wardens, sheriffs or other judicial officers, are empowered to arrest any persons detected in any violation of State laws and to proceed against such persons before State magistrates etc. In the State of Wisconsin, any such law action is limited to those cases where damage resulted from the fire in question.

Persons assisting to secure convictions by giving information to law officers, may receive a moiety of the fines collected (50 per cent in the State of Alabama).

Fines collected from breaches of State Fire laws are usually paid into general State funds although laws in some States specify their use for school purposes (e.g. Colorado, Oklahoma).

To illustrate the scope of the Fire Legislation now in existence in the State of California a summary is given of the most important items included in such legislation by quoting various major offences against the State Laws, most of which offences are punishable by fines up to $500 and/or imprisonment up to six months:-

1. Backfires - Setting or causing backfires to be set except under supervision or permission of a State or Federal Officer unless it can be proved that such action was required to save life or valuable property.
2. Burning Materials - (a) Throwing or placing lighted cigarette, cigar, ashes, or other flaming or glowing substance or thing, which might cause fire, in any place where such substance may directly or indirectly start a fire.
   (b) Throwing any lighted tobacco, ashes, or any flaming substance which may cause a fire, from a moving vehicle.
3. Burning permits - Burning inflammable cover, blasting, setting off fireworks either on own land or on another's, between April 15 and December 1, without permit issued by the State Forester or his agent. Burning small piles on rocks, in yards, gardens etc., 100 feet from any timber, brush or inflammable cover not forbidden but at least one adult person must be in attendance at all times.
4. Camp Fire Permits - Maintaining or using camp fires on private land not his own, without permit from owner or from Forest Service (for adjacent area of National Forest) between May 1 and October 31 or April 15 - December 1 (depending on locality in Northern or Southern California respectively).
5. Camp Fires - Leaving a camp fire, started or attended by him, burning or unextinguished without some person in attendance, or allowing such fire to spread, unless the said campfire is confined in a stove, drum or other non-inflammable container so that it cannot escape. Fires in permanent and occupied dwellings are not affected.
6. Clearing around logging equipment - Using any wood, or coal, burning steam operated donkey or stationary engine between May 1 and October 31 in any forest or brush covered land without first clearing away all inflammable material, including snags, within a radius of 100 feet; unless fire prevention measures approved by the State Forester are adopted such as clearing 25 feet around loaders (with all rotten wood covered with dirt to 50 feet).
7. Escaping fires - Allowing fires to escape to lands of others without exercising due diligence to control them (does not apply within municipalities).
8. Firefighters - Refusal to obey summons by State Fire Warden, of all able bodied males, for assistance in fire suppression.
9. Fire tools, hose, pump etc. on Logging Equipment -
   (a) Between May 1 and October 31 all gasoline, steam or electrically driven donkeys or stationary engines operating in any woods operation, without a box of special fire tools available for a gang of 10 men, including at least 5 shovels and 2 axes. One box, for two such engines within 300 feet of each other, is satisfactory.

(b) Operating a steam driven donkey or stationary engine, locomotive, or loader, during the same period without an adequate force water pump (or water supply under a pressure equivalent to a pump) and not less than 200 feet of 1 inch (minimum) hose. (One installation will be ordinarily sufficient for two engines customarily working within 100 feet of each other).

10. Fire Trespass - Building fires on any land owned by another person where signs forbidding trespass are displayed at intervals of not over one-third of a mile apart on the exterior boundaries of such land, and at all trails or roads entering such property, without first obtaining the written permission of the owner, his agent or lawful possessor.
11. Fireworks - Setting off fireworks on his own or another person's land, in any inflammable cover, without a necessary permit, between April 15 and November 30. (Not applicable to municipalities).
12. Burning permits - Setting on fire, or causing to be set on fire, inflammable cover on lands not his own, containing inflammable vegetation, without permission of the owner, between April 15 and November 30, or May 1 and October 31, depending on locality. (Not applicable to municipalities).
13. Refusing aid - Refusing or failing to render assistance in fire suppression at the summons of the State Forester or his agent, unless prevented from doing so by sickness or other physical disability.
14. Setting fires to Structures and Materials - Wilfully or maliciously setting fire to bridges valued at more than $50 or to tents, fences, lumber etc. valued at more than $25.
15. Incendiarism - Setting or allowing, or causing, fires to be set on lands belonging to another person, or allowing fires to escape to the property of another person, wilfully or negligently is classes as a FELONY.
16. Shovel and Axe - Going or being on National Forest lands, designated as being hazardous, in automobiles or with pack stock, without a shovel (at least 36 inches long, blade 8 inches wide) and axe (at least 26 inches long with a 2 lb. head).
17. Smoking - On areas of National Forest, designated as being hazardous, during dangerous periods.
18. Spark Arresters - (a) Using any donkey engine, logging locomotive, or any other engine or boiler, in or near any forest, brush, grass, or stubble, unless proved affirmatively that such had adequate devices to prevent fires escaping from its smokestacks, ash pans, fire boxes, or other parts, or that every reasonable precaution had been taken to prevent fires therefrom.
(b) Operating a gasoline driven tractor or harvesting machine, oil burning engine, automobile tractor etc. in harvesting or moving grain or hay, or moving said machine in or near grain or grass lands, unless equipped with an effective spark-arresting device.

C. Law Enforcement.

In view of the large percentage of man-caused fires on all types of forest, and in all Regions, forest officers have general instructions that investigation into every man-caused fire will be carried out until it can be definitely decided whether or not a case exists against any person or persons.

All such investigations are in the hands of local officers, detailed instructions being issued to Forest Service officers and employees in the form of "Law Enforcement Handbooks" for each individual Region. Each of those handbooks gives detailed instructions in respect of investigation and prosecution procedure, as well as a summary of all Federal State or County fire legislation, together with its application at various specified times, or in certain areas within the Region.

Forest officers also make pre-season contacts with those Federal or State officials who are concerned with the prosecution or hearing of any charges which may be brought to the Courts. By means of these contacts, court officials are given an understanding of the seriousness of the fire problem, and the nature and extent of the efforts being made to reduce both careless and wilful use of fire. While these contacts are not intended to implant prejudice in the minds or judicial or other officers, it is at least represented to these officers that the interests of the State, or the nation, are seriously threatened by indiscriminate burning, and that progress is necessary in checking either deliberate or unintentional breaches of the law.

Prior to actual charges being heard in court, further contacts are made with prosecuting counsel, essential witnesses etc., to ensure that full co-operation and agreement exists on the forthcoming charges.

Pre-season contacts made by Forest Service officers with State or Co-operative Protection organisations also determine the respective territory in which each organisation will be responsible for law-enforcement.

(a) Investigational Work.

At times of serious hazard, even in the absence of any fire outbreaks, all officers and employees patrolling or stationed in or near forest areas maintain a close watch on the movements of all persons seen in the forest. If any suspicion attaches to such movements, notes are made of actual times and of the observations made. Local officers of the Forest Service often list possible incendiarists on special "suspect lists," and the movements of any such suspects are quietly observed and noted in writing. Following fire outbreaks, investigations proceed at the earliest possible moment consistent with progress in suppression, one observant employee or officer being often delegated to the task while suppression proceeds.

Officers are specially instructed regarding the necessity of approaching any inquiry with an open mind, and not making pre-determined conclusions on which any clues available are "hung". Clues such as tracks (of feet or tyres), camp fire or lunch remains, gun shells or other "personal" litter may prove valuable, if definitely associated with a particular person or with a time approximating that of the outbreak. As the onus of proving any charge rests definitely with forest officers, they are also instructed to treat each individual clue as only one link in a possible chain of evidence. For this reason every care has to be taken, to preserve tracks or other material clues from interference, in some cases possible fingerprints being watched for.

While hurried investigations are usually not thorough, the rapid following up of clues is often essential in such cases as horse tracks, possible association of a certain motorist with a neglected camp-fire etc. All persons whose statements may assist in building up a case are required by officers to furnish written statements, or conversations with them are recorded in the diaries of officers. Clues of a portable nature are carefully preserved, and are given private or hidden identification marks for possible reference in courts.

All officers are urged to use tact and diplomacy in law enforcement work of all kinds, particularly as many fires are started unintentionally, but courtesy does not allow officers to swerve from any course of duty demanded by breaches of the law. If offenders are not treated as criminals, but as "sinners", there is more chance of an ultimate improvement in their careless habits.

Where investigations reveal that a definite case exists for a breach of the law, prompt arrests or hearings of charges are usually most important if the action taken is to serve as an effective deterrent to the person responsible, or to others, in times of severe fire hazard.

(b) Powers of Arrest.

Although varying somewhat in different States, the various powers possessed by officers may be summarised as follows:-

1. Federal or State forest officers or any persons specially designated as National Forest or State Fire Wardens (in some cases also State Game Wardens) have power to arrest any person without warrant for a violation of Federal regulations, State fire laws, County ordinances etc., committed in their presence or under their observation.
2. Federal Regulations - Any Forest Service officer or designated employee may arrest, upon warrant, any person charged in a proper complaint with violating Federal laws or regulations concerning National Forests. Forest officers usually prefer these arrests to be made by properly constituted "Peace Officers" of the law, or U.S. Marshals, owing to the greater respect usually held locally for the powers of the latter officers. If necessary they either accompany such officer on his mission, or (in some cases) effect arrests themselves.
3. State fire laws - After being charged in a sworn complaint, any violator of State fire laws may be arrested, upon warrant, by State Foresters, Game and/or Fire Wardens, State Police etc., or by U.S. Forest Service officers and employees who have been appointed State Fire Wardens.

   In some States (e.g. South Dakota) such Forest Service staff are ex-officio State wardens. Recent legislation in a number of States (e.g. Ohio, Michigan) provides that any Forest officers and/or State Fire wardens may arrest violators of State Fire laws without warrant and take them before a magistrate for the purpose of laying a definite charge.
4. County fire ordinances etc. - Authority for arrest even with warrants, is usually confined to special appointees (County or State officials, or Forest Service officers specially designated for the purpose).

Arrest is not usually insisted on except in the case of flagrant and studied breaches of the law which are clearly proven, and which have caused either serious risk or severe actual damage. Arrest would also be necessary in the case of any sub-normal person acting in a crazy and hazardous fashion in the forest.

(c) Prosecutions in Courts.

It has already been mentioned that offences under Federal regulations are usually dealt with in Federal courts of law, but on occasions when prompt action is as important as the severity of penalties, Federal officers may use the State Courts for prosecuting violations under State laws. All forest officers are instructed not to proceed with prosecutions unless there is a reasonable chance of conviction, and unless senior forest officers decide that the investigation made has been sufficiently thorough. Doubtful cases are not abandoned before trial unless on the advice of State or Federal Attorneys.

Court actions are taken in two distinct ways:-

1. Criminal Action - in which the penalties of the law are invoked for any violations of either Federal, State or County fire legislation.
2. Civil Action - in which action is taken to recover, from persons responsible for fires, either costs of suppressing such fire, costs of removing designated hazards which are neglected by landowners, or an amount sufficient to cover direct and indirect damages to forest areas. In severe cases of fire, claims are made for both suppression costs and damage estimates.

In most cases of law violation, the causative agent is both criminally and civilly liable but prosecutions of both kinds are not proceeded with, unless neither action in itself will provide an adequate penalty for the offence committed. Criminal actions invariably proceed civil actions, mainly on the score of urgency where both are to be proceeded with. In cases of law violation, where negligence has caused small fires at limited cost and damage, criminal action is ordinarily sufficient.

In other instances, civil action may be taken in the absence of any criminal action as in the case of railroads causing fires when not criminally liable under State of Federal law, but where the origin of the fire can be proved and where heavy suppression cost and damage has resulted herefrom.

It is the usual proceedure of the U.S. Forest Service to settle civil actions out of court (by payment to the Service of suppression costs and/or damages), but to prosecute all criminal actions where law violations are considered proved, and the offence is considered serious.

1. Criminal actions - as previously stated these are usually heard in Federal courts for violations of Federal regulations, and in State or County courts when breaches of State or County legislation are involved. In the case of the Forest Service, flagrant breaches of Federal regulations are usually reserved for Federal courts owing to the more adequate penalties usually obtainable there. All prosecutions are listed at the earliest

possible date to demonstrate both guilt and penalty to others while the fire season still prevails.

The Federal regulations listed above which are used by the Forest Service for law enforcement on National Forests, have all the power of Federal laws in Court hearings. Action for similar offences in State Courts, and the penalties for such offences, depend on the provisions made in State legislation. In only a few States, such as California, do the provisions of State fire laws prescribe a variety of offences (and heavy penalties for same) comparable with those listed in the Forest Service Regulations.

In Federal courts, criminal actions brought by the Forest Service are usually conducted by a qualified Federal Attorney who receives support in Court from senior local forest officers who are experienced with court procedure. In State Courts it is not usually necessary to have so much assistance in prosecuting a case.

While Forest Service officers are not encouraged to prosecute doubtful cases, it is true that even unsuccessful cases may possess a tangible prevention value. Cases lost through some missing links in a chain of evidence, or through a legal technicality, may tacitly establish in the minds of public spirited sections of the community the guilt of the defendant, and may win public support for this and future instances of law enforcement.

2. <u>Civil actions</u> - These may take several forms depending on the particular breach of law, the severity of the violation, or the damage resulting therefrom etc. The main civil actions brought are:-

(i) Where Federal or State authorities (or Timber Protective Associations) take action against a landowner for not contributing "protection assessments" made on his lands, or, having themselves removed any serious hazards on any particular land, seek to recover the costs of such work from the landowner in question.
(ii) Where the Federal or State authorities (or Timber Protective Associations) seek to recover from any landowner the costs incurred by them in suppressing a fire on private lands.
(iii) Actionable cases against a landowner or other persons causing fires which have resulted in damage to forest areas owned or protected by Federal or State authorities etc.

In severe cases of this nature claims are made both for costs of suppression and for the damage caused to the timbered areas.

The U.S. Forest Service is usually concerned with actions included under (ii) and (iii) - any such actions being taken to Federal Courts, if necessary. As previously stated it is the policy of the Service to settle civil cases out of court when and where possible; the decision to settle such cases resting with various officers according to the total amount involved, and claimed, for suppression costs and/or property damage, as for example:-

Actions involving a total amount of not more than $300 might be settled by the Forest Supervisor

Actions involving a total amount of not more than $3000 might be settled by the Regional Forester
" involving a total amount of not more than $5000 might be settled by the Chief of the Forest Service
All claims for costs and damages for sums exceeding $5000 are referred to the Secretary of Agriculture for determination, settlement, or the institution of a suit to recover the amount involved.

Where Court action is decided on in any of the above cases, due to the circumstances surrounding the actual fire damage etc., all information bearing on the case is submitted to the Secretary of Agriculture, and thence to the U.S. Department of Justice to initiate action in Federal Courts.

It is the standard practice of the Forest Service to suppress all fires on private lands which may constitute a present or possible threat to National Forest. As soon as possible afterwards, claims are submitted to the landowner for reimbursement of such costs, even in cases where there is no definite breach of the law, or of written co-operative agreements, and where only a <u>moral</u> obligation thus exists on the part of the landowner to meet any suppression costs. Whether the obligation is a moral or legal one, officers do not present written claims to landowners when the sum involved does not exceed $10, but seek to recover this amount by telephonic conversation or by personal interview on a friendly basis.

The lengthy proceedure involved in assessing fire damages, details of suppression costs etc., for inclusion in claims made in major civil actions will be summarised, very briefly, hereunder:-

<u>Assessments of damages and suppression costs</u>:-

The principle behind all claims submitted by the Forest Service in Civil actions brought by them, is to place the U.S. Government in the same position, financially, after the fire as it was beforehand, but certain theoretical considerations of damage such as soil damage, loss of soil rent etc. are usually ignored for practical purposes of Court proceedure. For the same reason existing stumpages are used in claims instead of problematical future figures, while increased possibilities of insect and fungal attack to forests are also ignored. The main elements of damage which are assessed are (a) Loss of standing timber etc. (b) Possibility of securing natural reproduction in areas of Merchantable Timber or of Protection Forest, and (c) Other forms of damage.

1. <u>Merchantable timber</u>.

(i) <u>When the entire stand is killed and is unmerchantable.</u>
Damage is assessed at the full stumpages obtainable for all products obtainable on the area - the quantities of various products being estimated in accordance with usual proceedure prior to sales. If the stand is so inaccessible as to be unmarketable at the time of burning, the minimum stumpage rates for the forest will be used.

If the severity of the fire precludes the natural production of any commercial species, the cost of artificially establishing these species, based on costs of such operations elsewhere, must also be included in the claim.

(ii) Where the stand is killed, but where some salvage is possible within a certain period.

In such cases the timber is advertised for sale without naming a minimum price, and if sold, the damage is represented by the appraised value of the stand before the fire, less the value of salvage sales. If no sale is made the full appraised value is claimed, in accordance with minimum stumpages fixed for various timber types. For instance in the Central Rocky Mountain Region the following minimum stumpages (per 1000 super feet measurement) have been fixed (202) for various timber types:- Ponderosa Pine - $3·75, Lodge Pole, Limber, White Bark and Bristlecone Pine - $3·50; Engelmann and Blue Spruce or Douglas Fir - $3·50; Alpine Fir and White Fir - $1·50; Aspen - $1·00. While in this case it is usually not necessary to submit costs of artificial re-stocking, these should be included in the claim if natural regeneration is impossible.

(iii) Where part of the stand (single trees or groups) is not killed, and left undamaged.

In this case the damage is represented by subtracting the newly appraised sale value of undamaged merchantable timber from the appraised value of the entire stand before the fire. Increased logging costs of the undamaged trees, due to fire debris, are not taken into consideration except on extensive burns.

2. Unmerchantable timber.

(i) Naturally established stands - In the absence of tables showing the current value of young stands of various timber types such as those prepared (202) for the Central Rocky Mountain Region, the value of these stands is assessed by determining the annual per acre costs of protecting such stands, and compounding these costs at 3 per cent compound interest for a period represented by the age of the stand, plus a regeneration period (of 2-10 years). This latter method is based on the principle that the Government is at least entitled to the cost of protecting the stand until the age when it was destroyed, even though such costs had not been incurred for the full period. In cases where per acre charges of protecting similar stands have been determined for use in co-operative protection agreements, these are utilised to fix the protection costs, per acre, in the claim. Costs of artificial regeneration necessary to ensure future re-stocking, may also be included.

(ii) Artificially established stands - In these cases the actual establishment costs, plus a per acre charge for annual protection, are each compounded at 3% compound interest to determine the value of the destroyed stand.

3. Merchantable and unmerchantable timber on the same area.-

(i) Where the unmerchantable crop is a more or less even aged understory of the merchantable stand.

The value of each crop is assessed separately, as determined above for each type, and the total values are used in the claim where the unmerchantable crop would ordinarily have been used to restock the area. If the younger crop would have been of little use for restocking before the fire, it should be disregarded in the calculations. If natural reproduction is unobtainable after the fire, cost of (artificial) replacement is added to the claim.

(ii) Where unmerchantable and merchantable crops occur irregularly over the area, e.g. in selection forests.

The value of the merchantable timber is fixed as already outlined. The value of unmerchantable timber is then assessed either by ascertaining its average age and applying a protection value (compounded) for such age, or by dividing the young growth into various age classes and applying (compounded) protection values to each of these ages. Cost of replacing reproduction is also considered if necessary.

4. <u>Protection forests.</u>

Although the replacement costs of such a stand represent its present value for protection purposes it is usual to assess such values, for fire damage purposes, on the basis of the number of years necessary to protect the area until a new stand can afford the same degree of protection, including any extra time necessary to actually establish regeneration. A per acre charge for protection is then compounded at 3 per cent for the total period involved.

5. <u>Other forms of damage to forests.</u>

Chief of these is damage to forage, calculated on the present value of grazing rents on this or adjoining areas of similar carrying capacity, for the period necessary before forage will be restored to its condition before the fire. No claims are made for forage which was inaccessible or not in demand.

Loss of such improvements as cabins, barns, telephone lines etc. are also included in claims, based on their original or replacement costs, less depreciation charges.

<u>Costs of suppression.</u>

Complete tabulation of all costs incurred on a particular fire takes considerable time, so that several approximations are used, e.g. the cost of furnishing meals to fire-fighters. Instead of determining actual costs, a figure is used which is representative of similar district costs under similar conditions. The labour charges for C.C.C. employees are not included in full, owing to questionable efficiency - an average figure of $1·50 per day being used. In the case of other C.C.C. charges such as food supplies, payment of overhead salaries and expenses, actual costs are included in claims made.

Costs of tools damaged, lost, or burnt during fires is not claimed for owing to the uncertainty of proving the extent of losses actually due to fire. Supply of equipment to any fire is charged for, at least on a hire basis. Among charges which may be included in suppression cost claims are:-

(i) Wages - of temporary labour, fire fighters, foremen, guards, cooks, time-keepers, etc., as paid by Forest Service.

(ii) Meals - furnished to above staff by the Forest Service (at an average price for a certain number of meals).

(iii) Wages - of permanent foremen (Forest Service)

(iv) Salaries, lodgings, meals, subsistence expenses of Forest Service officers engaged at fire

(v) Labour costs for C.C.C. employees (at $1·50 per diem)

(vi) Meals - actual cost of meals supplied by C.C.C. staffs to their employees.

(vii) Salaries and expenses of C.C.C. "overhead", C.C.C. transport charges.

(viii) Transportation costs for fire fighters, Forest Service officers, equipment, food supplies etc.

(ix) Hire charges for use of cars, equipment, horses etc., freight charges etc.

PART III.

PREPAREDNESS ACTIVITY.

CHAPTER VIII.

DETECTION SYSTEMS.

A. Development of detection systems.

The necessity for all possible speed in attacking fires applies just as much to forests as it does to cities. Realising the fact that speedy attack could not be organised without adequate means of fire detection, foresters in U.S.A. have long concentrated on efforts to improve detection systems, and so obtain the most complete "coverage" possible over forest areas consistent with the cost of constructing and maintaining lookout systems or of employing patrols. As pointed out by Show and Kotok (168), early efforts to provide lookouts aimed at selecting a number of sites giving a wide range of vision, but having little reference to the location of fire hazards, frequency of fire occurrence, or to the protection of valuable cover types. The first permanent or "primary" lookouts were supplemented as thought necessary, or as finance permitted, in efforts to extend the total area of "coverage" on an area of forest, but little systematic extension resulted, mainly because of the errors made in selecting original lookouts. In many cases, both "Primary" and "Secondary" lookouts were supplemented by supplying telephones to approved volunteer detectors living in or near the forest, who reported such fires as came within their field of vision. The original selection of twenty high peaks as lookout stations on two National Forests in California meant that each of these stations had to "cover" an area of approximately 44,500 acres, or four times the area prescribed under modern detection planning. Studies made (168) of the effectiveness of these peaks for lookouts showed that on 65 per cent of the "seen area" there was only low risk of fire occurrence, while of the remaining area of high risk only half was visible.

In modern detection planning it is axiomatic that there should be direct visibility from lookouts to 65-70 per cent of those areas classed as "high risks" - which usually means that 80-90 per cent of normal fire occurrence is adequately "covered." Any increase in these percentages of seen area is impossible unless there is a tremendous increase in the number of lookouts. For instance, Hornby (88) estimated that 50 planned locations for "lookout firemen" would give effective "coverage" over 65-80 per cent of an area of one million acres of typical mountain forest, but some 500 of those stations would be required to provide anything like 100 per cent "coverage." It is generally agreed that once the "seen area" for all lookouts is approximately 80 per cent, most of the seen area from any new lookout, however well planned, is merely overlap of existing seen area.

The general advance in fire control planning has meant the laying of more emphasis than ever on:-

(a) Fuel types and their relation to burning conditions
(b) Frequency of fire occurrence, by defined zones
(c) The relative values at stake in various sections of the forest.

Not only are these factors important in themselves, but studied co-ordination of these and other major influences has enabled investigators, and practical administrators, to concentrate protective effort where it will yield the most effective results, within limits of economy, and at the same time give adequate protection under the most critical conditions.

As detection is basic to all suppression effort, it naturally follows that the location of lookout stations must be carefully planned. Modern fire control planning insists that areas of high risk must be reached by suppression forces within a prescribed period following the actual outbreak of fire. This period might be as short as 15 minutes, and is divided into certain limits of time for discovery of fires, "get-away" of fire fighters, and travel time to the fire. Such a system obviously demands that all areas of high risk be actually (not theoretically) visible from lookouts so that all outbreaks of fire thereon can be seen and reported within a space of a few minutes.

Different opinions still exist among experienced investigators as to the form that lookout systems should take, but there is certainly agreement on the need for planning the location of lookout stations. Hornby (88) in what is perhaps the most original and comprehensive approach to the planning of fire-control, has strongly favoured the use of a large number of "lookout-fireman", as compared with a few primary lookouts, for the Northern Rocky Mountain Region. On the other hand, Show and Kotok (168) were equally definite that the results obtainable from intensive patrols, even when materially assisted by volunteer detectors, fell far short of those to be expected from a carefully planned selection of primary lookout stations.

Throughout most of U.S.A. primary lookouts are predominant in detection systems. Even in Region No. I, where the value of lookout-firemen is so greatly stressed, some primary lookouts are still used as basic points for detection.

Supplementary detection efforts such as those by lookout-firemen, patrols, volunteers, are secondary both in the field of detection, and in their use by foresters. They are therefore generally referred as "Secondary Lookouts" to distinguish them from primary lookouts, the latter being on towers or on other structures, permanently manned by selected staffs, which maintain a continuous watch throughout all periods of fire risk. The high standard of efficiency in detection which is demanded by modern and planned fire control cannot be achieved solely by the correct location of a certain number of lookout stations. Other improvements in "spotting" fires have followed intensive studies made of factors affecting visibility, the most suitable types of permanent structure in which to house lookouts, and the most efficient equipment necessary to assist them in improving the speed and accuracy of detection. (The term "lookout" is used in present U.S. fire weather parlance to describe the employee engaged on detection, while "lookout station" or "tower" usually describes the structure in which he works, and lives).

B. Primary Lookouts.

This term describes the stationing of detectors in special types of lookout structure (cabins or towers of various types) throughout the fire season. Except where cabin space is limited owing to the extreme height necessary for effective vision, the lookouts are required to use their cabin for living as well as for observing, so that detection continues at least to some extent while they are awake, and they are available by telephone or radio at all hours of the day and night. Effective detection from lookout structures is possible only after their location has been determined by fire control planning - as already explained. Provided this planning has been well done, a system of lookouts is the best means of continually observing fire occurrence. Permanent lookouts have additional advantages over patrols etc. in that they are also available to report the behaviour of going fires, and the progress of suppression efforts, where the latter come within their field of vision. On areas where climatic conditions at the lookout site are typical of, or are comparable with, those prevailing in nearby forest types the recording of all meteorological figures, fuel moisture percentages etc. is another duty that can be easily performed by lookouts.

The great advantage claimed for primary lookouts over all other types of detection is that they offer permanent facilities for reporting, within a proscribed period of time, all fires which occur in areas definitely known and specially charted for observation.

Planning of lookout location also considers the effectiveness of primary detection units under varying conditions of visibility or burning conditions. If it is not possible to station additional primary lookouts during the "average worst" burning conditions, the permanent system of primary lookouts is reinforced by temporary detection stations in the form of either secondary lookouts or patrol-foremen, or of men acting in both capacities.

Research into conditions affecting visibility of lookouts has shown that original claims that detection of fires was certain over great distances have had to be modified. Provided that planned location of lookouts considers the varying visibility to be expected during various types of fire weather, the supplementing of primary lookouts will guarantee detection over all areas during any class of visibility, thus removing one of the main causes for criticising primary lookouts.

Show and Kotok (168) record the results possible with an adequately planned system of primary lookouts covering an area of 137,000 acres of high risk in California. The system was designed to cover 86 per cent of an area of 38,388 acres of "high risk", 73 per cent of 35,022 acres of "medium" risk and 53 per cent of 57,261 acres of "low risk" or an average cover of 68 per cent of all risk areas. Before the system was installed, the three areas of varying risk had only 13, 23, and 53 per cent of cover respectively. The discovery of fires during 1926-29 by the old system of lookouts was only 19·5 per cent of the total fire occurrence over the unit, but this discovery was improved during 1930 and 1931, under the newly planned system, to 56·3 per cent of all fires occurring. Show and Kotok stress the fact that a planned system of primary lookouts may at first seem expensive, but the cost is justified in cases such as this, where detection by selected lookout stations far exceeded that furnished by intensive patrols and also by the ready co-operation of volunteer observers.

In cases where primary lookouts are effectively "covering" a large area within a comparatively short radius, they have additional advantages in that they can observe the tendency of any "going" fire to "spot" smaller fires ahead of the burn, and can report such facts to either headquarters or field staffs supervising suppression efforts. After suppression has been completed, primary lookouts are also able to maintain a watch for some days to ensure that no fresh outbreaks of the same fire take place.

In some Western regions it is emphasised that lookouts are notably superior in detecting lightning fires, as they are in position, ready to note likely fire occurrence and meet the possibility of such fire occurrence much better than the more indefinite task of awaiting man-caused fires. In this connection it is admitted (168) that look-out firemen are of perhaps greater value in lightning risk areas at higher elevations, where efforts to extend the "coverage" of primary lookouts over areas of normally limited risk would be decidedly more expensive.

(i) Selection of sites.

A preliminary reconnaissance usually locates possible sites for primary lookouts which have either an effective "coverage" over local areas of severe risk, or an extensive coverage over large areas of variable risk. As previously noted, modern fire planning determines a maximum period (known as "Elapsed Time"), between outbreak of fires and arrival of suppression forces. All detection forces are located so as to furnish prompt reports on all outbreaks, and even in cases where primary lookouts, lookout firemen, patrols and co-operative observers are all used in the detection of fires, care is taken to ensure that primary lookouts serve as the basis of all detection plans. Once primary lookouts are covering areas of highest risk, secondary lookouts can be arranged for other areas invisible from primary lookouts (although within their range of vision), and for other forest areas of lower risk, so that all detection will conform to the standards laid down for "elapsed time". In Region No. VII of the Forest Service for instance, detection employees are required to furnish an accurate description of the location (within 20 chains) of any fire occurring on the "seen area", within ten miles of their lookout station, within two minutes of the time of discovery. The insistence placed on such a short period for reporting fires is necessary if the fixed period of 15 minutes of "elapsed time" is to be adhered to.

Permanent and primary lookouts are therefore only constructed where special maps showing the "seen area" from each prospective site, and the extent of such "seen area" for various types of fire risk, have demonstrated their exact location and the necessary height of the structure.

One illustration of the care taken in selecting sites for primary lookouts can be quoted here. The Black Hills National Forest in South Dakota comprises mainly a dry cover type of P. ponderosa, the forest area being under intensive timber management, and subject to periodical conditions of extremely high hazard. Following extensive reconnaissances, "seen area" was mapped from no less than ninety-two possible lookout sites before the existing ten lookout stations were finally selected as giving the maximum possible "coverage". The height of structures depends on the conformation of topography, presence of adjacent timber stands etc., as they affect the area to be seen from any particular point. Show and others (164) give a simple method for determining the necessary height of a tower in cases where a peak does not, in itself, give effective cover to many areas at lower elevations. High towers are avoided as much as possible, owing to the policy of housing lookouts in their cabins, and the greater difficulties (and costs) of building the standard type (14' x 14') of cabin on tall towers.

During the reconnaissance of possible sites, notes are made concerning such local factors as present or potential routes of access to the site, nearest water supplies, difficulties in anchoring or erecting a tower, cost of removing obvious obstacles to vision such as large rocks or trees.

The final determination of particular sites thus necessitates consideration of:-

1. The part that will be played by any particular site in either improving or maintaining standards of detection so as to conform with "elapsed time" standards.
2. The extent of "seen area" visible from a lookout structure of a certain (limited) height with particular reference to areas of highest risk and/or hazard.
3. Ease of construction, as determined by local factors.
4. Existing routes of access or the cost of necessary access, connection to communication systems etc.
5. Proximity to water supplies - important during emergency periods when transport of water is unreliable, but the lookout cannot be spared from the cabin for long periods.

The factors governing the number of primary lookouts to be erected on a particular area of forest include the following:-

1. Intensity of management and protection plans - which determines the percentage of various classes of risk which detection units will attempt to cover.
2. The extent of seen area possible from various sites suitable for primary lookouts. If such sites are not readily available, or if local conditions of topography necessitate the construction of a large number of primary lookouts, at a cost out of all proportion to the danger prevailing or values at stake, it may be necessary to abandon primary lookouts in favour of lookout-firemen, detection patrols etc.
3. The value of new or additional primary lookouts in improving detection to standards more in keeping with the fire plans laid down for a forest area, and ensuring the detection of all fires from a certain site within a prescribed period of time.
4. The range of effective visibility in any single sector of the forest, as affected by seasonal or daily variations, or by local complications such as the occurrence of defined smoke belts from industrial sources, or of persistent fog belts.
5. Practical or economic difficulties in the construction of a particular structure, owing to difficulties in access in tower erection, excessive height required etc.

(ii) Adequacy of lookout coverage.

Of the factors which govern the selection of original or additional lookout stations, consideration of the seen area visible from a station (of a certain height above ground level) is classed as the most important, once it has been decided to plan protection for any forest and to apply standards, such as "elapsed time", to such planned protection. Selected sites for lookout stations give the observer direct visibility over a maximum area of risk within a workable radius (less than 15 miles.) As previously noted, it is rarely possible for such direct visibility to exceed 70 per cent of the total area, theoretically within the range of observers, in mountainous topography. The methods used in California and elsewhere to determine the adequacy of lookout coverage are explained in full by Show and others (164), Shank (158) and Abell and Beeman (2) and will be only briefly summarised here:-

1. Fire Occurrence Maps:-

From records of past fires, the location of both man-caused and lightning fires is carefully plotted on special topographic or "drainage" maps, which also show the location of forest roads, boundaries. These past fires are charted until defined zones of occurrence for each type of fire origin can be traced in various parts of the forest, such as campers or smokers' fires along routes of travel, trends shown by lightning storm routes etc. The zones are charted on final maps to show definite areas in proportion to the intensity of actual fire occurrence - thus a zone where fires occurred repeatedly each year would occupy a larger area than one where only occasional outbreaks had been recorded. For each zone a figure is then obtained to show the number of fires occurring (during a 10 year period) per thousand acres, and zones are then listed according to whether they have had 0·8 to 1, 1·1 to 3, 3·1 to 5, 5·1 to 10, and more than 10 fires per 1,000 acres. Areas showing less than 0·8 per 1,000 acres are not included, as they are not truly representative of any risk trends.

2. Reconnaissance of the fire control unit is then made to locate probable sites for lookout stations, particularly those which overlook the most serious zones of occurrence. Assistance in locating possible sites is obtained from contour maps, or from information obtained from local rangers. As a rule, about five times the number of lookout stations ultimately required, is selected for review.

3. Seen-Area mapping - is possible by a variety of methods:-

(a) Profiling method - this can actually be done in the office without any reference to the field provided accurate contour maps (100 intervals) are available on 80 chain or 160 chain scales. Lines are drawn on the map radiating from the proposed lookout station, for the distances commonly used for detection (up to 15 miles in California).

On graph paper the contour points along each of these lines are plotted so that the topographical profile along the lines is revealed. Lines are then drawn, on the profile, from the proposed observation point to show what areas will be visible from such point, the extent of such areas being then shown, in colour, on the contour map. By repeating these profiles every 3-7 degrees around the proposed observation point, "seen area" can gradually be built up on the contour map for the whole theoretical range of vision.

A number of ingenious methods, such as "profiling boards", adapted slide rules etc. have been used to facilitate the actual method of profiling - the method described above being admittedly laborious.

(b) Photographic method -using a special photo transit camera, which produces a complete panorama, from any suggested lookout station after taking three 126° exposures (3° overlap on each side of each exposure). This camera is capable of exact levelling and orientation, and records photographically on each print the azimuth and vertical angle graduations in degrees, while index pointers establish a horizontal line across the prints.

While excellent "seen-area" maps can be developed from panoramas, it was found that the application of the method was rather limited in Californian topography.

(c) Relief Model method - requires accurate relief models of the entire area, preferably on an 80 chain scale. If such profiles are available, they can at least be used to save considerable time in weeding out possible lookout stations. Owing to the cost of preparing such models (60 square miles on 80 chain scale - $1500) their use is limited to those few instances when they are already available.

(d) Field sketching method - This is the standard method used in most Regions, its main advantages being accuracy and economy, and the opportunity it also offers for studying on the ground the necessary features which are being sought for various lookout points. Where heavy timber stands or topographical features (flat topped ridges) preclude sketching prior to any tower erection, profiling or other methods are necessary. Trained (and experienced) men are used, necessary instruments including alidade, Abney level, 50 feet tape, binoculars etc. The mapper selects a sector of 20-30 degrees mapping with the direction of the sun's rays (instead of into the sun) and working outward from the observation point, using prominent ridges or other features as the bases of his mapping. Accurate base maps for working are of course essential, experienced men can achieve good results from good topographical maps, but contour maps are usually necessary to give the best results.

4. Selection of sites.

The "seen-area" maps prepared by either of the above methods show by various colors the areas directly visible from each proposed site. These maps are transferred to transparent paper, and placed over the "fire occurrence" maps described above. The "visible fire-occurrence" areas (seen area from each site falling in each fire occurrence zone) are obtained by planimeter, and the various areas are weighted (by the average number of fires per 1000 acres) for each zone. Thus Class I - (0·8 to 1·0 fires per 1000 acres) might be weighted by 0·25, Class II (1·1 - 3·0 fires per 1000 acres) by 2; Class III (3·1 - 5·0 fires per 1000 acres) by 4; Class IV (5·1 - 10·0 fires) by 7; and Class V (more than 10 fires per 1000 acres) by 12.

The weighted acreage of each "visible fire-occurrence" area is then divided by 1000 to give a figure representing the relative value of lookout points. When No. 1 lookout station has been selected, the tracing showing its seen area is kept pinned down on the "fire occurrence" map so as to eliminate such seen area from consideration, while other stations are selected by repeating the method - (the areas seen from No. 1 station being given no weighting, when selecting No. 2 station). A point will be finally reached when additional lookout stations will contribute so little extra "coverage" of a forest that their construction is undesirable. In California, construction was not considered justified unless a site shows "coverage" of at least 25,000 acres of risk areas.

A final plan is ultimately prepared to show:-

(a) All observation points accepted as lookout stations)
(b) Areas blind to all such stations) (Shown by colors
(c) " visible from one, two, or more than two lookouts)

Fire control plans are then based on this and other information (such as routes of transportation, areas of hazard etc.) Such fire control planning may reveal that a particular zone of fire occurrence (such as a valley highway), or a limited area of valuable forest where severe hazards prevail, are not covered by any of the lookout stations selected. In such cases primary lookouts are supplemented by patrols or lookout-firemen which will specifically cover these limited areas at minimum cost.

In normal planning, primary lookouts will provide necessary cover of risk areas during normal fire weather, secondary lookouts not being used except in critical fire weather. During short periods of very high hazard, or low visibility, (or both) it may even be necessary to establish a third system of "emergency lookouts".

(iii) Factors influencing the efficiency of lookout stations.

Efforts made to determine the effective radius of lookout stations have been largely unsuccessful owing to the many factors which influence visibility. The human factor also contributes to the variation shown in performance of lookout stations, but efforts at training suitable employees, the supply of modern equipment, and careful checks made of the activity of lookouts, have largely eliminated the human factor. This factor cannot of course be entirely eliminated, even over-keenness and zeal on the part of a lookout under trying conditions may tire him and result in errors and/or ommissions on his part. Factors influencing visibility have occupied the attention of many investigators, and several trends have been revealed, as discussed hereunder. McArdle (119) found that the following factors were most important in the North Western Regions:-

1. Background - Dark backgrounds such as dense stands, or shaded slopes, offer much better visibility than such light coloured backgrounds as dry grass, dead timber, eroded cliffs etc.
2. Size of smoke columns - Small changes in the size of smoke columns do not greatly affect visibility, as even small "test smokes" could be seen for fourteen miles under average conditions. ("Test smokes" are usually provided by special smoke "candles" which provide smoke equal to that of average forest litter burning on an area twelve foot square).
3. Sunshine - On cloudy days, except when low driving clouds cause obscurities, contrasts between topography and general visibility are usually much better than when sunshine is experienced. The many minor effects of sunshine (shadows, glare etc.) are also eliminated on cloudy days.

Shadows cast by early or late sun cause complications when smoke is rising in these shadows. While visibility may not be greatly affected for smoke from shadows when the observer is looking away from the sun, it may be most difficult in the case of smoke rising in shadows between the observer and the sun.

It was found that smoke rising from unshaded areas could actually be seen better when facing a slanting sun than when looking away from the sun in that position. In practice however, this may not be borne out, owing to the distaste of lookouts for looking into the sun's glare, even when special glasses to eliminate glare are supplied. Solid objects such as trees, houses etc. cannot, however, be seen be seen better when facing the sun so that an observer may see smoke without being able to define its position except by azimuth reading.

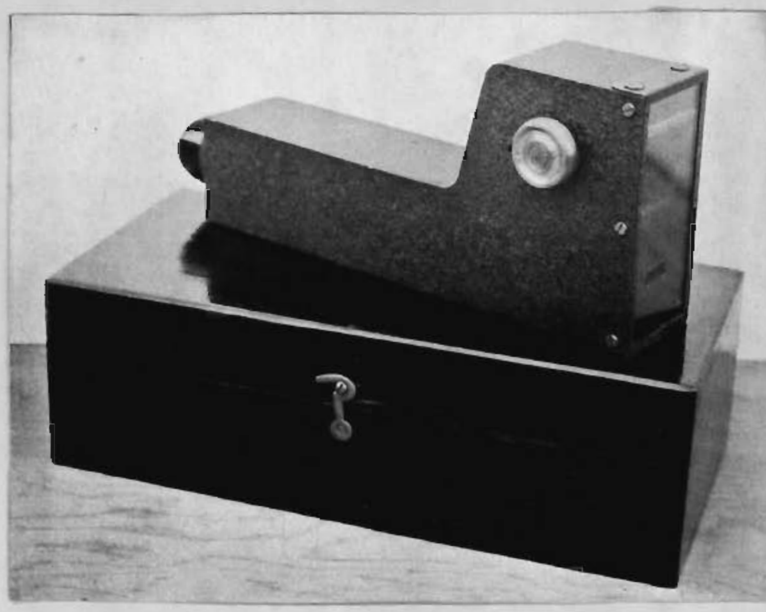
4. Atmospheric obscurity - Small increases in atmospheric obscurity due to haze, dust smoke etc. cause marked decreases in visibility. During continuous conditions of severe fire weather, this obscurity shows a great cumulative increase due to haze, smoke etc. Purely local factors such as the incidence of fog belts, or the drifting of industrial smoke, may also complicate vision, but these local factors are much less liable to variation than are daily or seasonal changes in obscurity, while it is usually possible to assess the effect of these local factors to a great extent.

The conclusions reached by McArdle have also been expressed by other investigators such as Show and Kotok (168) and Hornby (88). The latter points out that although visibility was better in Idaho when facing a low sun, the same was not the case once this low sun was hidden by cloud. In the latter case, the greatest vision towards the sun might be 10 miles, while a distance of 15 miles could be covered away from the sun. If atmospheric obscurity was marked, these distances might be reduced to 3·5 and 10 miles respectively. Hornby also points out that greatly reduced visibility caused by topographic shadows between the observer and sun in late afternoon was particularly serious, as 32 per cent of daily fires started in this period (3.30-7.30 p.m.) Additional factors found by Hornby to affect visibility included height and density of the canopy, air circulation, humidity, fuel type. Smoke was found to rise faster on the more open stands on Southern aspects as compared with the denser and taller stands on Northern aspects.

The limit of effective vision under fair to good conditions is generally accepted to be 15 miles, and primary lookouts should not be expected to give adequate detection beyond this distance. As explained by Hornby (88) this distance would be reduced to 8 miles under "average" burning conditions in Northern Idaho, or to six miles in the case of "maximum" burning conditions, necessitating reinforcement of primary lookouts by manning secondary or emergency stations. In summarising visibility factors, Hawley (76) states that 6-10 miles is the maximum distance for good cover under "average" conditions, although under most favourable conditions an extension up to 15 miles might be relied upon.

This is borne out by the experience of the various administrative Regions of the U.S. Forest Service, and some notes on the visibility relied upon in certain of these Regions will be of interest:-

(a) Southern Region - In this Region lookout stations may be manned throughout the year except during unsettled weather. On 50 per cent of the days when towers are manned, visibility up to 20 miles can be relied upon, but during severe



(Photo by U.S. Forest Service - Fire Equipment Handbook).

The Byram visibility meter.

(Photo by U.S. Forest Service.)

Lookout using Osborne Fire Finder - Lightning Peak Lookout Station - Idaho National Forest - Idaho.

fire weather this distance may be reduced to even one or two miles.

(b) South Western Region - In the clear dry air of Arizona and New Mexico visibility is usually so good that accurate detection of fires is not unusual for distances up to 20 miles. In the case of very broken topography there is of course great variation in the amount of "seen area" covered by any lookout despite this clear visibility.

(c) Central Rocky Mountain Region - Here the visibility is also extremely good, perhaps exceeding twenty miles, but this figure is reduced to fifteen miles when "seen area" is being mapped, in order to select the most suitable lookout sites.

(d) Inter-Mountain Region - Visibility of from fifteen to twenty miles can usually be relied upon - the only exceptions being on a limited number of days.

(e) Northern Rocky Mountain Region - In this Region "normal" visibility, on which Fire Control Planning is based, is eight miles. When this visibility drops to less than five miles, lookouts are taken off their towers and are used instead as moving patrols, except in cases where they can "cover" sufficient areas of high risk within this distance of five miles.

During recent years particular attention has been given to the possibility of improving visibility by equipping lookouts with such instruments as binoculars and "haze-meters". Reliable binoculars are now standard equipment for lookouts, and it is now intended to use "haze-meters" wherever they are required. The "haze-meter" is an ingenious and simple device invented by G.M. Byram, of the Appalachian Forest Experiment Station. As explained (25) by Byram, the spacing of lookout towers is based on average visibility, but day by day fluctuations in visibility at each lookout site are at least partly responsible for determining the number, kind and distribution of detectors. The most important factor affecting the visibility of "small smokes" is atmospheric haze. Byram maintains that the visual range of a small smoke is so closely related to haze, and to atmospheric transparency, that a measurement of haze can be directly translated into the distance which such small smoke can be detected by a lookout. While the effect of haze in decreasing air transparency is the same in flat or rolling country as it is in mountainous regions, it is much more easy to measure in mountain areas. In the latter regions, lookouts may use surrounding ridges as convenient targets for the estimation or measurement of visibility, but this is not possible in flat or undulating topography. Byram has contributed materially to the efficiency of detection systems by devising two types of haze meter - one being used in mountain areas, and the other in flat or rolling country. Both meters provide a scientific basis for the measurement of air transparency, and eliminate former guesses by lookouts as to the prevailing visibility range from their station.

In an interesting study of the fluctuations of visibility in Eastern U.S.A., Jemison (96) was of the opinion that while the effects of hour of day, season, or year on visibility could be definitely measured, the most important differences apparent were those between one forest and another in any forested territory in Eastern U.S.A.

For this reason it is difficult to adopt any average visibility distance in determining the location of lookouts on any single Eastern forest.

(Photo by U.S. Forest Service).
Standard 7' x 7' Lookout Cabin on new type of steel tower - Smith Creek Lookout Station - Idaho National Forest - Idaho.

(Photo by U.S. Forest Service).
Showing inside stairway on new type of steel tower (80 feet high) - Bishop Mountain - Targhee National Forest - Idaho.

Competent investigators agree that successful detection by any lookout depends mainly on:-

(a) Personal factors - such as the eyesight, experience or alertness of the employee acting as lookout.
(b) Physical factors - such as atmospheric haze, size of smoke, sunshine, backgrounds etc.

These investigators also agree that, without aid, the human eye (even in the case of the most expert lookout) cannot recognise those slight differences in atmospheric conditions which cause great changes in visibility distance.

The great importance of correctly measuring visibility distance is best illustrated as follows:-

(a) If visibility distance is 12 miles the lookout has theoretical vision over a circle having an area of 452 square miles.
(b) If this distance is reduced to 9 miles, the area of the circle is reduced to 255 square miles.
(c) If the distance is only 6 miles, the area of the circle is only 113 square miles.

If, for example, seven lookouts are sufficient for effective "cover" of a forest when visibility is twelve miles, it would be necessary to have twenty seven lookouts to afford similar "cover" to the area when visibility was reduced to six miles. It will be appreciated that accurate measurement of visibility by means of a "haze meter" will assist in eliminating errors in the staffing of lookout stations.

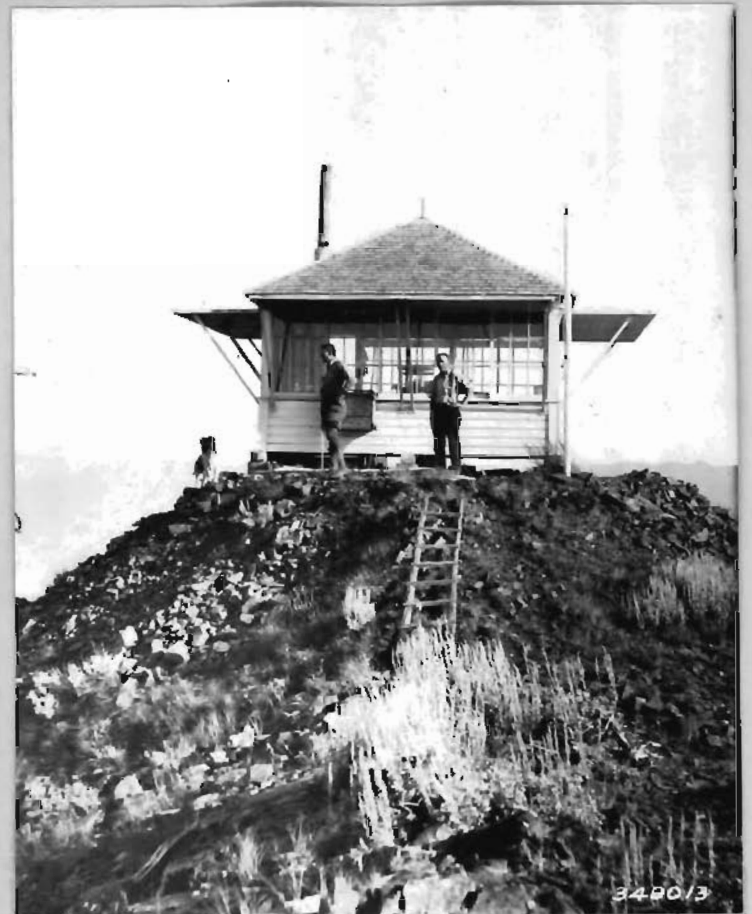
(iv) Standard types of lookout structure.

As previously mentioned, lookouts are housed "on the job", whenever possible, by fitting up their cabin as a combined living room and observation point. For dual purpose use of this nature a standard cabin measuring 14 feet square has been evolved for use on varying tower heights. Such heights are usually less than 50 feet, although designs are available for using these large cabins on towers up to 120 feet in height. Where the topographical features surrounding timber stand etc., require the use of towers more than 50 feet in height, a standard type of cabin, 7 feet square, is often used on a tower of the necessary height. In the latter case the lookout has separate living quarters erected as near as possible to the base of the tower; in the Southern Region he may also be allotted sufficient ground for cultivation purposes to assist in his subsistence.

The designs now available in the two cabin sizes represent the result of 20 years evolution by the Forest Service, the main requirements being, as stressed by Show and others (164):-

1. The maximum amount of unobstructed view from inside the cabin
2. The maximum possible use of combined living and working quarters to secure the most continuous and dependable detection service.
3. To provide comfort, convenience and protection for the observer.

The cabin, when erected, is usually aligned to the cardinal points of the compass. Plate glass is used in all doors and



(Photo by U.S. Forest Service).

Standard 14' x 14' Lookout Cabin with hinged shutters in open position - Acorn Butte - Idaho National Forest - Idaho.

(Photo by U.S. Forest Service).

Standard 14' x 14' Lookout Cabin with external shutters in open position, catwalk etc. (Number on roof is an indicato to commercial air-lines). Fly Creek Point - Challis National Forest - Idaho.

windows on all sides of the structure, wide panes of such glass, 47" high, commencing at a level of 28½ inches from the cabin floor, being specified. The obstructions offered to the view by corner posts, window frames etc. are restricted to a maximum of 8 inches. Lower edges of all panes of glass are set an inch "out of plumb" to avoid reflections. A "cat-walk" with hand rail is constructed outside the larger sized cabin for observation purposes. to permit frequent window washing, and to reduce the effect on the observer of close confinement inside the cabin.

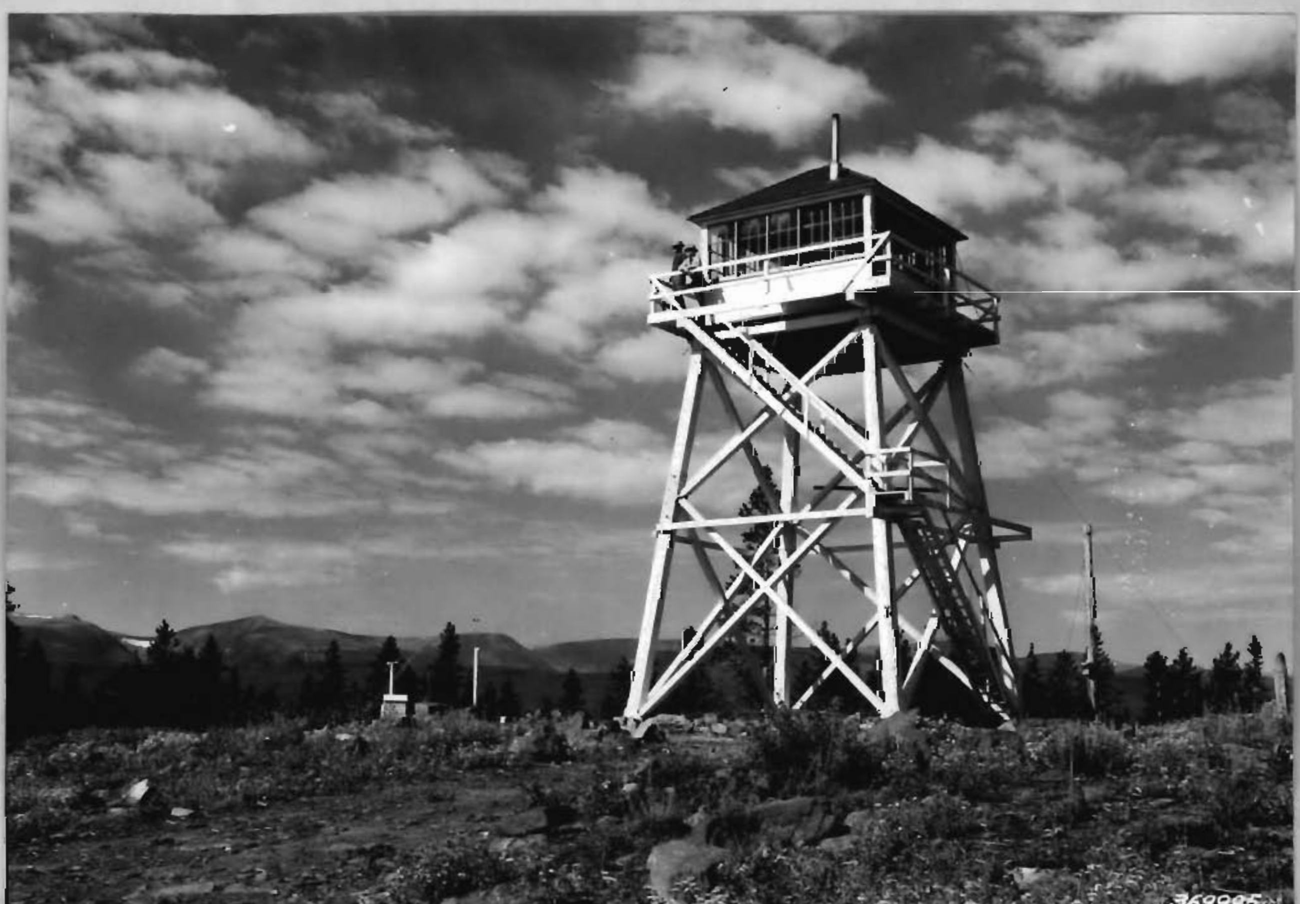
Tight metal covered hinged shutters, opening upwards and outwards, are used to provide complete protection to windows when the cabin is vacant. When these shutters are open, they function as awnings, being effectively supported either by wooden braces or by fastening them with large wing-nuts to extensions of the rafters. When so secured, the shutters are not affected by wind, and reduce the glare or heat of the sun inside the cabin.

The general design of the cabin, which is a four panel, hip roof (shingled) structure, is formulated in order to withstand unusual wind stresses, extremes of temperature etc. Following several fatalities in towers, rather elaborate protection against lightning is also designed, with special grounding of all metal furnishings, accessories etc., so that heavy voltages can be safely carried off. Details of lightning protection are given in a special publication (191) issued by the U.S. Forest Service. Interiors are painted in a special neutral or dull finish to reduce glare as much as possible.

Considerable thought has been given to the provision of built-in cabinets, careful arrangement of furnishings, working equipment, accessories etc., to provide the most efficient use of space consistent with neatness and convenience.

The cost of all materials for a 14 feet cabin is estimated by Show and others (164) at approximately $450. This would be increased to approximately $1670 when erected on low foundations after allowing costs of construction, transport of materials, provision of water supply etc. On a 30 feet tower the total cost of a complete structure would be approximately $2700. Materials for an 80 feet steel tower (inside stairway) are estimated to cost $1000, with an extra $2000 for construction costs.

As pointed out recently by Jones (100) the majority of towers erected prior to 1933, on the basis of plans and specifications, and tenders for construction, were of steel. The development of connectors for timber structures about the same date, did not at first assist the use of timber in tower construction, as pre-fabricated wood, cut to required tower sizes, could not be produced to offer a true standard of comparison with steel products. The experimental erection of several "timber-connector" towers was long delayed owing to defective pre-fabrication, and any tenders called for were still limited to the use of steel. The timber industry eventually improved its pre-fabrication during the large programme of tower construction (over 2000 towers) undertaken by the C.C.C. The preparation of suitable designs for timber towers was meanwhile entrusted to the North Pacific Region of the Forest Service, and after it was indicated that pre-fabricated timber could complete with steel as a material, at least on the Pacific Coast, 135 wooden towers were constructed. The heights of steel towers previously used in tendering, were altered to conform with those of timber designs for comparative purposes.



(Photo by U.S. Forest Service).

Standard 14' x 14' Lookout Cabin on Low Wooden Tower-Note Catwalk, Fire Weather Station.
Ute Lookout Tower - Ashley National Forest - Utah.

Designs now available for use by the Forest Service include the following heights (the height quoted being from the top of the tower "footing" to the level of the cabin floor):-

(a) 14 Feet Cabins -

(i) Steel - 30', 41'3", 54', 67', 83'1½", 100'4½", 120 feet
(ii) Wood - 30', 41', 54', 65', 83', 100, 117 feet.

(b) 7 Feet Cabins -

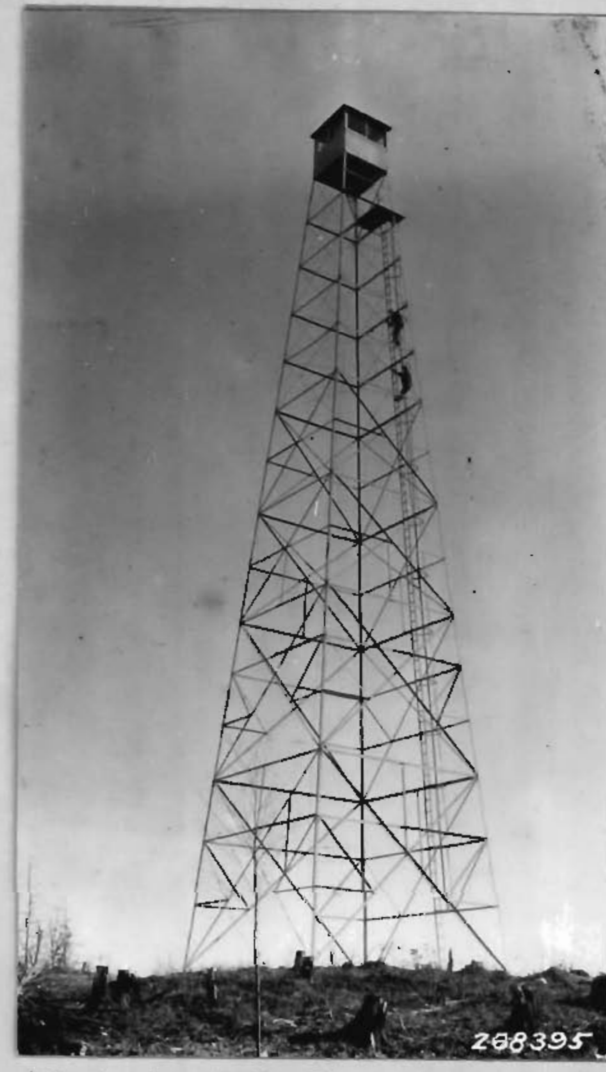
(i) Steel - 30', 41'3", 54', 67'6", 82'6", 99'6", 120 feet
(ii) Wood - 30', 40, 52' 66', 82', 99', 119 feet.

Standard cabins, of wood construction, are used irrespective of the material used in the tower. In cases where 7 feet cabins are to be used, the cost of same is usually included in tenders for tower construction, but 14 feet cabins are usually erected by Forest Service employees, or by separate tender, after towers have been constructed.

It is now the policy of the Forest Service to invite tenders for either wood or steel towers on a strictly competitive economic basis, and ignoring any advantages or disadvantages of the respective materials. If separate tenders are invited for purchase of materials, freight charges must be considered, after tenders have been based on F.O.B. costs at nearest railhead. Freight charges are appreciably greater in the case of timber (as discussed below).

If true comparisons between the respective materials are desired, it is considered by Jones (100) that the following factors must be considered:-

1. Fire hazard is a disadvantage of timber, although the use of fireproofing liquids on tower timbers, or the "fire-proofing" of the tower site should mitigate its effect.
2. Depreciation is not considered to differ greatly in respect of the two materials. Pending definite proof of any such differences, the same "life" has been adopted for each material for accounting purposes.
3. Comparative maintenance costs over definite periods are not yet available.
4. Comparative costs of erection are being kept - cost of wooden towers has been increased unduly in the past owing to faulty pre-fabrication, but improvements in this direction have lately been effected.
5. Cost of lightning protection is admittedly greater for a timber tower.
6. Transport costs of materials from nearest rail to tower site are much greater in the case of timber owing to its greater weight. This factor is increasingly important where sites are inaccessible, and "packing" of materials by horses etc. is necessary. In the case of steel and wooden towers for 7' cabins, 99'6" and 99' high respectively, the weight of steel tower materials is estimated at 18,200 pounds while wooden materials (Douglas Fir) would approximate 27,000 pounds in weight. If Southern Pine were used, the estimated weight of wooden material is 31,000 lbs. To these figures must be added the weight of cement, sand, gravel, water etc. to be transported for tower foundations. If road haulage is possible, differences in total transport costs can be arrived at by using "ton-mile" averages.



(Photo by U.S. Forest Service).

100 ft. Lookout Tower of old type with outside ladder.
Elk River Lookout Station -
Chequamegon National Forest -
Wisconsin.

(Photo by U.S. Forest Service).

Ornamental Lookout Tower erected at point of tourist interest - Manker Lookout Station - San Bernardino National Forest - California.

Despite the strong arguments for the use of wooden materials by any forestry administration, and notwithstanding the continual improvements both in pre-fabrication standards and in timber-connector design, very few fire control fire officers favour the use of wooden towers. As a result, tower construction in U.S.A. is almost wholly confined to the use of steel. Towers located at points of tourist interest, or situated on peaks or ridges subject to excessive wind velocity, may be of solid masonry construction, or of special and ornamental timber designs.

Surroundings of lookout stations.

Many of these stations occupy positions of great scenic attractiveness, while they are usually accessible by roads, or at least by trails. They are therefore a source of interest to many visitors, and the Forest Service encourage this interest in fire protection, provided that the attention of the lookout is not unduly distracted during periods of hazard. A visitors' register is available for signature by those persons visiting lookout towers.

Arrangements are made by special "Recreational Planners" to improve the immediate surroundings of lookout stations, and to carry out "landscaping" at least to conform with the general aesthetics of any particular site. Planting of shrubs, layout of paths, steps, parking spaces etc., and the general neatness and design of necessary buildings is executed to carefully prepared individual plans which aim at harmony with natural surroundings, and yet avoid all semblance of ostentation. Cabin interiors have to be kept in a thoroughly neat condition by the lookout, notwithstanding the fact that they are commonly used as living quarters by the individual concerned.

(v) Standard types of equipment for lookouts.

Although some minor variations are necessary under local conditions, the equipment in use on all lookout stations of modern type is practically uniform - including the following:-

1. "Fire finders" of the Osborne, Bosworth or Koch Type

These have been evolved in various Regions to overcome the obvious difficulty of using a fixed map in a cabin where it was sometimes necessary to sight "through" such building obstructions as window sashes, corner posts etc.. Firefinders of the type mentioned have the lookout map mounted on a circular metal disc, the rim of which is graduated to azimuth. The alidade is mounted to rotate around the rim of the disc - Between the sights is a graduated steel tape which provides readings of distance from the centre of the disc (the lookout site) to the fire outbreak. The entire mounting of the map disc and alidade can be moved (in two directions) to sight past any obstructions in the exterior of the cabin, and at the same time preserve an accurate orientation of the map.

(a) Osborne Fire finder - developed in the Pacific N.W. Region - This instrument provides for the exact levelling of the entire mounting, and provides vertical angle readings as well as those of azimuth. Vertical angle readings are useful in cases where definite landmarks or cross-bearings are lacking, and where there is a continuous timber canopy visible, as from a high lookout overlooking a flat terrain. The Osborne instrument is standard equipment for lookout stations in many Regions.

(Photo by U.S. Forest Service).

Wife of Lookout carrying on during temporary absence of her husband. Note interior of 14' x 14' Cabin, used also as living quarters, Bosworth Fire Finder - Hand Set Telephone on long cord etc. - Challis National Forest - Idaho.

(b) Bosworth fire finder - developed in the Northern Rocky Mountain region, is similar to the Osborne instrument in its use, but is of simpler construction. It has no provision for measuring vertical angles, but this can be provided for, if necessary, by using a simple type of pendulum vertical-angle reader. The Bosworth instrument has the advantage of a fixed base mounted on a specially designed metal stand, and this also reduces the cost of the instrument as compared with the Osborne type.

2. Lookout Map-

Maps on a scale of 160 chains are used except in the case of a restricted coverage, when an 80 chain scale may be substituted. The maps show either contours or topographical features, and are the most accurate available. Supplementary maps of surrounding forest areas, on a much larger scale, and containing more detailed information, are also available for reference. Those latter maps show azimuth circles for the various primary lookouts on the area. Each map used on a firefinder is mounted at forest headquarters to ensure accurate "centering" of the map, and to prevent any distortions on its surface. In such cases the back of the map is coated with shellac, which is allowed to "set" for a few seconds before placing the centre of map on the disc or board, and then allowing the map to settle in a level position by its own weight. Before the map is finally "set" in position by the drying shellac, the edges are temporarily lifted and the surface is smoothed down, beginning at the centre. After successful mounting, the map surface is given a coat of shellac, followed by a coat of either clear "Valspar") varnish, or a new type of "liquid cellophane".

3. Telephone - a desk (one-piece) telephone is necessary to enable the observer to make notes while using the instrument. An extra long cord is also a great advantage in allowing him to speak while looking through any of the windows.

Radio may be used in emergency or to supplement telephones - or to relay messages from fire suppression crews to headquarters via the lookout's telephone. Telephones are, however, standard equipment for practically all primary lookout stations throughout U.S.A. Elaborate lightning switches are provided for all telephones, in keeping with other efforts to reduce the risk from this source to observers or others in the cabin, while all observers have telephone repair equipment, in the use of which they are specially trained.

4. Binoculars - are now used almost universally, not to replace ocular observations, but to confirm the existence or location of any indistinct smokes seen with the naked eye. As noted by McArdle (119) small test smokes visible at 14 miles from the naked eye, should be seen at 21, 24 and 26 miles, with 4, 6, and 8 powered (magnified) binoculars respectively. Binoculars are also valuable in the close watching of risk zones where the lookout has direct vision within fairly close range of such zones (such as a road where smokers' fires may originate) Experience has shown that magnifications of 6 to 7 diameters are the most practical for use as lookout binoculars. Greater magnifications restrict the view, and give an unsteady image unless the observer rests his arm. Binoculars used have the objectives widely spaced, good definition over a wide field, with both interocular and individual eyepiece adjustments for focussing.

(Photo by U.S. Forest Service - Fire Equipment Handbook).

Specimen of panoramic photo (taken with photo-transit camera) - one of three photographs which give a complete panorama from a lookout station. Note horizontal and vertical graduations, level or zero vertical angle line.

5. <u>Sunglasses</u> - of properly constructed type with ground lenses in amber, green, or dark neutral colors are in general use. Exhaustive tests made in the Lake States Region have shown that the reduction in glare, and the prevention of eye strain and headaches on bright days by means of sun glasses, greatly increases the efficiency of lookouts. As the object in using such glasses is to avoid eye strain <u>cheap</u> glasses may not have the desired effect, although they achieve the required shielding of the eyes from strong ultra-violet light rays.

6. <u>Flashlights</u> - electric flashlights of a battery type are often provided for map reading when the observer is sighting night fires (with the cabin in darkness).

7. <u>Panoramic Photographs</u> - These are used in several Western Regions and have been found invaluable in providing a permanent and accurately orientated view from a lookout site. The pictures included in the panorama are taken by a special transit camera which has a levelling head, a full azimuth circle and vernier, an open sight alidade etc. It is also equipped with a solar attachment which enables the operator to obtain a true meridian and precise orientation from any "set up".

Negatives cover an arc of 126 degrees - three arcs being used to form a complete panorama using 3 degrees overlap on each side of the negatives. All negatives are precisely graduated in azimuth along their top margins, and their sides are accurately marked with a level line, with vertical angle readings, in degrees, above and below the level line. Once a lookout furnishes readings of azimuth and vertical angle for any fire outbreak - anyone equipped with a photographic panorama from the lookout site can determine in a few seconds the exact location of the fire, especially by applying a magnifying glass to the photograph. The use of panoramas greatly assists lookouts to become readily acquainted with their seen area, and is particularly useful (with vertical angle readings) in locating fires detected after dark by their glow.

8. <u>Miscellaneous equipment</u> -

The remaining equipment required by lookouts in the course of their duties includes stationery, pencils, rulers, meteorological equipment; all necessary forms for recording weather, fires, lightning storms etc.

Other equipment supplied is that required for living purposes, most important of which is some provision for water supply and/or storage. If springs are relied on, they are usually close to the station, so that the observer can obtain daily water supplies (3 gallons) in a round trip of less than one hour. In some cases delivery is made periodically, from trucks, to storages at the base of the structure, but this method is costly and most unreliable during severe conditions.

Recent provision has been made for the utilisation of rain water to provide a sufficient storage for the duration of the season - a 500 gallon tank being usually sufficient.

The remaining equipment is usually supplied from the following list:-

(a) Written instructions, fire control handbook, telephone directory etc.

(b) "One-man outfit" of suppression tools and equipment
(c) "Three day pack" of emergency rations
(d) Axe and shovel for general use
(e) Water bucket, brooms etc. for cleaning purposes
(f) Petrol burning lantern and spare mantles
(g) Telephone repair equipment including fuses, batteries, lightning arresters etc.
(h) Various hand tools
(j) A variety of kitchenware and a cooking stove
(k) Bed and bedding, alarm clock etc.

(vi) Lookout station personnel.

The care given to the selection of particularly suitable lookout sites, and to equipping lookout stations with modern apparatus, cannot achieve the best results unless lookouts are selected from the most competent and reliable men available, and unless these men are thoroughly trained in the duties expected of them. The main difficulty in obtaining men of suitable disposition and qualifications is that the employment offered to these men is purely seasonal, while the summer season is the most active in other phases of rural employment. It may thus be necessary to train new men as lookouts for each succeeding year, the general intelligence of the men available being often limited.

1. Qualifications sought in lookout men.

As defined by Show and others (164) those qualifications mostly demanded are:-

A. Inherent - Good Eyesight
Good health and ability to live at a high elevation without any discomfort.
Ability to live alone for long periods without evincing discontent, including cooking ability, general standard of cleanliness etc.
Capacity for continuous effort without undue stimulus or supervision.
Ability to describe in plain language those events occurring, even at times of mental excitement etc.

B. Acquired aptitude or knowledge such as ability to:-
Use all instruments supplied to the station.
Record notes, observations etc. on the forms supplied to him.
Correlate maps with visible topography and a knowledge of surrounding terrain etc. Recognise forest cover types, and virgin forests, cut-over areas, brush etc.
Distinguish reportable fires from dust clouds, eroded hillsides etc.
Judge the size of any fire, character of fuel (color and character of smoke), rate of spread (angle, volume and movement of smoke), nature of fire (crown, surface etc.), whether fire has ceased spreading etc.

2. Selection of suitable men -

This can usually be done by systematic elimination along the following lines:-

A. Eyesight tests and Physical Examination - Ordinary and special eye sight tests are applied to all candidates, weeding out those with poor vision when defects cannot be remedied by fitting glasses. When the health of any individuals is classed as doubtful, it is usually tested by medical inspection.

B. Examination of the history and previous occupations of applicants decides whether they are able to live and work alone without supervision, and without becoming discontented. Ability to cook, make notes, or oral descriptions, is usually ascertained from simple tests.

C. Individuals who survive tests as described are usually given rudimentary training as lookouts before being tested by examination to select the necessary number for employment, and for further intensive training in the duties demanded of them.

3. Duties of lookouts at "primary" stations.

Detection duties involve regular hours of duty during daylight hours, and special observations at night when so required (lightning storms or going fires). The observer must maintain constant observations so that any part of his field of vision will be seen at least once every 15 minutes, particular efforts being concentrated on zones of high risk. Detection requirements are:-

A. Reporting new fires - Prompt recognition of smoke, and a quick report to headquarters, giving azimuth readings, probable distance and location. As the smoke develops further reports are necessary concerning size of fire, rate of spread, fuels, slope, or other topographical description of the fire location, and of the direction it is taking. If anything bearing on the cause of fire is evident, it is also reported at once, together with advice as to whether the fire is located in a "seen" or blind area.

B. Reporting progress of fires - Continual reports are furnished on the development, direction, spread etc. of fire, any visible evidence of the arrival or effect of suppression crews, notes of any sections of fire under control, or those where the fire is still developing, or causing "spot" fires, changes in the direction of wind, or of that taken by the fire etc.

C. Intensive checking after lightning storms, after a fire has been "corralled" etc., to ensure that no outbreaks escape unnoticed in the localities concerned.

D. Meteorological measurements to be made each day in accordance with the equipment supplied, with special recordings of humidity, wind direction and velocity etc., while there are fires in the observer's territory. Visibility tests are made constantly each day.

E. Keeping a complete log of all daily duties, with actual occurrence of fires, lightning storms, false alarms etc.

F. Maintenance of all equipment in clean and working order, with necessary repairs at once to interrupted telephone services. All prescribed caution to be taken in the case of lightning storms.

G. Provisions and water supplies are carefully organised - daily water supplies are procured during "safe" conditions in the early morning e.g. Before 8 am.

H. All visitors to the station are welcomed and asked to sign the visitors' book, the observer's duties being explained and demonstrated, except when the lookout is constantly occupied during severe hazard conditions.

(Photo by U.S. Forest Service).

Temporary Alidade Location at Secondary Lookout Station -
Cache National Forest - Utah.

J. The lookout maintains the station and himself in a clean and orderly condition.

C. Secondary lookouts.

It has already been noted that primary lookouts are rarely planned to cover their entire field of vision, and that 30 to 40 per cent of such field must be covered by secondary lookouts during periods of severe risk, at least on those areas of greater value, or of higher risk. The various types of secondary lookouts used are as shown hereunder:-

(i) Detection by lookout-firemen.

In most forest regions in U.S.A. the use of lookout firemen is confined solely to supplementary efforts at assisting primary lookouts, as in areas of high risk or hazard not directly visible from one of a system of such lookout stations. In the Northern Rocky Mountain and North Pacific Regions, however, the greater part of detection effort is in the hands of lookout firemen, following the system prescribed by Hornby (88) in his exhaustive study of the fire situation in the forests of that Region. Hornby stressed the great value of lookout-firemen or "smokechasers" in rough topography, where they constituted a much less expensive and much more elastic system of detection. Their efforts could, for instance, be intensified under conditions of risk, or on hazard areas, approaching the maximum in severity, where every minute counts, and where 100 men are little more use than one man once immediate suppression is neglected. Hornby planned the location of his smoke-chasers so that several men from adjacent "spotting" stations would within a few minutes "jump" simultaneously on each fire that occurred, with reinforcements amounting to twenty men scheduled to arrive within 30 minutes. It was argued that this dual purpose staff enabled useful suppression forces to be kept away from high peaks or valley bottoms, as was the case with men engaged either on primary lookout duty or on valley patrols, and greatly facilitated the "routing" of a network of forest roads along mountain slopes at various levels. It was admitted by Hornby that much of the success claimed for his smokechasers was impossible of achievement without such network of forest roads. In Region No. I of the Forest Service (Northern Rocky Mountain) it is stated (200) that 60 per cent of all fires are handled by lookout-firemen, each of such fires being a potential disaster under the local conditions prevailing. The efficiency of the system was further demonstrated during the 1939 fire season in Region No. I. During the season some 2000 fires occurred in the Regional territory protected by the U.S. Forest Service, and over 97 per cent of these fires were controlled by one-man units, the size of each fire being usually less than ten acres.

In reviewing the possibilities of various types of detection in California Show and Kotok (168) admitted that lookout-firemen gave more detection for a given expenditure, and provided a means of accurately and quickly locating each fire. They considered however, that the time saved in detection was scarcely offset by the delay in getting adequate suppression forces to an outbreak. They also criticised a method which left possibilities of all detection points being rendered vacant within any sector of the forest, because of the outbreak of one or more fires.

The lookout-fireman method is agreed to be of particular value in "chasing" lightning storms in rough topography, especially

(Photo by U.S. Forest Service).
Lookout fireman en route to fire - Challis National Forest - Ida

(Photo by U.S.
Forest Service

Lookout-fireman
using radio en
route to fire -
Note pack of
tools.

in areas where the method is far cheaper than primary lookouts, owing to the limited risks obtaining there in the absence of storms.

The use of a smokechaser system, as pointed out by Folweiler and Brown (51) is based on the assumption that one man can take successful initial action against any fire which commences in his territory. Hornby estimated for instance, that only 60 smokechasers were required (with adequate roading) for a million acres of forest under maximum burning conditions.

(ii) Detection by patrols -

The use of patrols naturally varies tremendously with topographic conditions and with means of travel available to, or possible with, such patrols. It is agreed by most foresters that the use of patrols should be mainly confined to limited zones of concentrated fire risk which can be thus kept under continuous observation. In such cases patrols may be operating either in zones not visible from primary lookouts, or they may be concentrated on those sections of "seen area" where past and present indications point to an unduly high fire risk. They may also have considerable value in combining prevention, detection, and suppression duties along routes or in areas frequented by forest visitors. In the latter case the forest patrolman acts as both "policeman" and "fireman". Over a large area of forest it is agreed that an adequate system of patrols would be more costly, and probably less effective, than a co-ordinated system of primary and secondary lookouts. Patrols sometimes have a particular value in "blind" areas after lightning storms, where fires normally spread so slowly that moderate delays in detection may not be critical. The value of patrols becomes more enhanced as decreasing visibility lowers the effectiveness of primary lookouts. Under such circumstances intensified patrols may act as roving detection and suppression crews, reaching their highest efficiency when such patrols are motorised, and are equipped with two-way radio equipment.

(iii) Detection by outsiders -

The value of outsiders, or persons not employed by a forest service, in reporting fires, can be considerable during early efforts at forest protection. For instance, Show and Kotok (168) describe the results achieved by various forms of detection, for the National Forests of Northern California, from 1921 to 1930. Of 5994 man-caused fires during the period, 48 per cent were reported by outsiders, 36 per cent by lookouts, and 18 per cent by other forest employees. Lightning fires showed somewhat different trends, and of the 4623 fires reported from this cause, 28 per cent were detected by outsiders, 55 per cent by lookouts and 17 per cent by other officers. The preponderance of man-caused fires reported by outsiders, as against the smaller percentage of lightning fires, is understandable, as outsiders are often in the best position to report fires caused from lumbering operations, campers, smokers, railways etc. The main assistance rendered by outsiders, to the Forest Service, comes from:-

(a) National Forest Permittees - such as logging or grazing permittees, road or other construction camps, who are obliged to report and fight fires, and thus have an interest in their suppression.
(b) Ranches in or near National Forest boundaries - Service from this source is often unreliable, as owners and employees are usually busy during the summer months, and give only incidental attention to fire detection.
(c) Tradesmen - such as storekeepers, garagemen etc. are often

(Photo by U.S. Forest Service).

View of forest fire from aircraft scouting a large outbreak - Western U.S.A.

willing to assist, but are rarely in a position to give systematic attention to the job.

(d) Travelling public - may report a number of fires, but miss almost as many, especially when travelling fast along highways. It has been found that occasional, slower moving patrols along a certain length of road, actually detect more fires than do a large number of motorists.

(e) Business travellers - such as traffic patrols, mailmen, commercial travellers who are on familiar routes of travel, are much more efficient detectors than the general public. Their co-operation is usually sought, and suitable expressions of thanks made for any services rendered.

Despite the number of potential co-operators now travelling in or living near forests, a large number of fires can, and do, occur in the absence of detectors. Similarly, the provision of forest telephones to various centres of co-operation can scarcely be carried out on a sufficient scale. Volunteer detection can thus only become useful as an adjunct to regular methods by forest employees, except in occasional instances when a useful co-operator may be found to cover a small but valuable area shown as "blind" on the seen area maps of all existing lookout stations. It is suggested by Show and Kotok that in some instances volunteer efforts may act as a useful competitive spur to the vigilance of the regular lookout system.

(iv) Detection by aeroplanes.

Many claims have been made for the use of aeroplanes as a means of patrolling forests for detection purposes but experience with aircraft shows that their use is extremely limited. In some regions the assistance of commercial aircraft using defined routes over forest areas, and transmitting radio, was sought, but it was found that such aircraft could not give the definite information and intensive service hoped for. It has also been found that aircraft requisitioned in extreme urgency from the defence services were of little use owing to bad flying conditions, and because of the pilot's unfamiliarity with the terrain. It is admitted that aeroplanes can detect fires over a tremendous range of territory within a short period, but what is required in modern detection is accurate information concerning a restricted area.

The only use claimed for air patrols in modern detection is for special investigation of the results of lightning storms in areas remote from patrols or lookout services, or from usual means of communication. They may be also used, on occasion, when visibility is poor, and when lookout services cannot adequately "cover" the results of lightning storms.

The real use of aircraft in modern fire protection is in transportation rather than observation, as will be discussed later, but in the Californian and Northern Rocky Mountain Regions, the Forest Service personnel use contract aeroplanes, in emergency, for:-

1. Scouting specific areas of less than 200,000 acres following electrical storms, the area quoted being the maximum which aircraft can effectively cover in a single flight.
2. Preliminary examination of large fires to determine their location and suggested suppression measures, to locate the exact limits of a fire which has overcome suppression efforts, or to confirm otherwise inadequate reports of fire outbreak.

3. Patrol duty for detection during periods of low visibility and high risk.

It is stressed, however, that even the above use of aircraft for detection on defined areas is of limited use, and needs to be supplemented by ground patrols before the necessary details can be furnished. This is true even when observers in patrolling aircraft take photographs of any fires seen, and these photographs are developed in special "darkrooms" in the aeroplane while the machine is still scouting. In the latter case, two way radio conversation with local or Regional fire control personnel is used to transmit information conveyed by photographs following their development in the plane.

CHAPTER IX.

TRANSPORTATION SYSTEMS.

A. Roads.

(1) The importance of a planned road system.

In discussing the planning of detection systems it has been mentioned that all modern efforts at fire control planning aim to get at least a small suppression force to any outbreak of fire in the absolute minimum of time, a certain period known as "elapsed time" being fixed for each forest which denotes the time to be taken between the discovery of a fire and the arrival of the first suppression forces. As noted by Gisborne (60) and others, it is now standard practice in the U.S. Forest Service to correlate both the proposed routes and standards of forest roads, with the requirements of:-

1. Fire Control planning
2. Utilization and removal of products
3. Recreation needs
4. Administration
5. Assisting development of communities within or near forest boundaries.

Not only does fire control planning aim to get an initial suppression force to any part of the forest within a prescribed period, but modern objectives in fire suppression aim at complete control of any outbreak before 10 a.m. on the following day. The latter policy obviously demands the arrival of large suppression crews from outside the forest (towns etc.) within a minimum of time.

It thus follows that the road system of any forest under protection must be suitable for the fast transport of heavy vehicles, at least to various parts of the forest, with particular planning necessary for those areas of exceptionally high risk.

Initial suppression by lookout-firemen, or by small suppression crews held in readiness at key locations, demands a network of minor roads, none of which need be "trunk" roads, but these minor roads must be based on a system of "key" trunk roads before their construction is possible. As the main roads are required for the conveyance of large reinforcements from outside the forest, they must be designed to bring men from a certain town or locality to the worst areas of risk in the forest in the shortest possible space of time. Main roads must thus be of a sufficiently high standard to facilitate the fast movement of heavy vehicles, especially in those cases where it is necessary to overcome such handicaps as long distance from labour bases.

On the basis of these main roads, spur and link roads are then designed and constructed for the distribution of reinforcements to any part of the forest, and also to allow rapid movement throughout the forest by initial suppression forces stationed at secondary lookouts, or at other centres.

Planning of the whole or any part of the road system is done conjointly with the planning of detection. If adequate detection can be provided for any forest, at a low cost, so that all fires can be detected promptly, and thus suppressed by one or two men, an extensive system of main roads is obviously not necessary for fire control purposes. On the other hand, where topographical or other features prevent adequate detection "coverage" of any large percentage of a forest area at reasonable cost, it is usually necessary to develop an intensive system of major and minor roads, so as to ensure the speedy arrival of suppression forces at fires which cannot be detected promptly. General considerations of how to give the most effective protection by detection and transportation planning must of course consider other factors, such as fire occurrence in various zones, the behaviour of fires according to the rate of spread in various fuel and cover types, topography etc. The latter factors govern the actual time available for suppression action once a fire occurs, and consideration of such factors serves a useful purpose in relaxing or intensifying local plans for urgent detection and suppression measures. They do not however affect the general principle of co-ordinating detection and transportation measures in efforts to maintain or improve the period allotted to a particular forest as "elapsed time". Speed of initial attack depends essentially on a close integration of detection and transportation planning, whereas strength of ultimate attack is largely dependent on fire behaviour.

As stressed by Hornby (88), planned road systems are particularly important where a large amount of detection is handled by "lookout-firemen". Improved and planned road systems, as against haphazard road construction and trail travelling, enable a great reduction in the number of lookout-firemen required. For instance, Hornby estimated that to adequately "cover" a million acres of forest, where few or no roads existed, would require 145 smokechasers for average burning conditions, and more than 200 under maximum conditions of hazard. On similar areas of forest where highways and other speed roads formed the basis of a planned network of roads, the number of smokechasers necessary for the conditions described above would be only 30 and 60 respectively. The close co-ordination of detection and transportation needs is thus essential if initial attack on fires is to be developed in the most economical way, without any decrease in its speed and certainty.

Fire control planning goes further than a demand for, or a knowledge of, detailed road systems. It requires definite information concerning "travel time" along any particular route through the forest, based on the standard of various roads, varying gradients, curvature etc. The recording of these travel times over all roads in the forest postulates that roads must be maintained in good order so that these standard "travel times" may always be adhered to.

An adequate and planned road system also assists actual suppression work to a great extent by providing a network of ready-made and trafficable fire lines, and by assisting in the transport of still further reinforcements, food supplies, equipment etc., and may also greatly assist in the use of water on a particular fire. These latter considerations become increasingly important in the case of a fire on which it is necessary to have large numbers of men working and camping.

Efforts to extend road construction to conform with the avowed policy of improving all practical efforts at fire control planning have been greatly assisted by the activities of the C.C.C. During a period of slightly more than six years, ending 30/6/39, the C.C.C. had constructed for the U.S. Forest Service some 77,000 miles of highways and truck roads, some 7600 miles of foot trails, and some 6500 miles of animal trails. In addition, approximately 30,500 vehicular bridges and 6000 trail bridges were constructed during the same period. This large construction programme naturally aroused the fears and criticisms of conservation-minded persons, and of some foresters. Marshall (128) expressed the opinion that provision of truck trails had no great influence on the problem of getting men to fires during times of severe hazard, particularly when single-track types of trail were relied upon. He also asserted that the trails allowed a great increase in the number of careless visitors to the forest, and that risk conditions were accentuated owing to the drying out of fuels along the sides of trails. It is pointed out by Folweiler and Brown (51) that the provision of truck trails has increased the risk of fire occurrence in the North Western regions, owing to the number of persons who seek to enter forest areas at the height of summer to gather blueberries, or for other reasons. In answer to the above observations, other foresters point out that the forests are, and should be, available for use by the public at all ordinary times - the movements of visitors along trails, or anywhere in the forest, being easily controlled in times of severe fire hazard by applying the permit system of entry to forests, or even by total prohibition of entry. In an adequate defence of the policy of building truck and other trails in the Pacific North West Region, Buck (24) pointed out that the Forest Service had designed about 21,000 miles of truck roads for that Region (of which only 75 per cent had so far been completed.) He pointed out that many of these truck trails were the only means by which suppression forces could be taken to numerous lightning fires, and while hazards from human travel may have been increased, such hazards were concentrated along defined routes which could be adequately safeguarded. Meeting the argument that roads increased human travel and decreased the animal and game population, Buck pointed out that if roads and trails could preserve forests from large fires, game animals would thereby be preserved. He summarised the whole situation with the phrase - "Shall we have protected forests with roads, or unprotected forests without roads?"

(ii) Types of road in use.

Some National forests, and other forests of varying ownership, are fortunate in being served by either Federal or State highways, but the great bulk of roads constructed on forest areas are what is known as "Truck Trails", to avoid any confusion with public roads.

The U.S. Forest Service policy in respect of Forest Truck Trails is expressed (189) as follows:-

Transportation plans are designed to cover the needs of:-

(a) Fire Detection and Suppression, as determined by "elapsed time"
(b) Forest administration, development and utilisation in all phases
(c) Public use of the Forests, and for public travel within or across the Forests
(d) Development and utilisation of resources on which communities in or near the Forests depend.

Construction of roads aims at a standard that will ensure adequate service for future as well as present needs, with the object of eliminating heavy expenditure on "road improvement". It also aims at reducing construction difficulties, so that maintenance costs will be kept to a minimum. The main factors considered in designing routes and standards of truck-trails are their alignment, grade, width, surface, bridges etc. If fire protection is the paramount consideration, the location and standards adopted are based on a system which, for the least annual cost per unit of area, will allow all designated areas to be reached in a proscribed period.

Truck-trails are classified as follows:-

(a) Low Service - constructed to allow average road speeds of 15 M.P.H. or less.
(b) Medium " - " " allow average road speeds of 16-25 M.P.H.
(c) High " - " " allow average road speeds of more than 25 M.P.H.

(a) "Low Service" Truck Trails - are constructed primarily for protection purposes (e.g. to lookout stations) where public travel is negligible, and where slow speeds meet all needs. These trails often depart from standard road engineering practice in having many changes in grade (instead of a sustained grade), and having short lengths of maximum grades where same will avoid costly construction, and will not affect the prospective use of the road. Low Service Truck trails are single track in width (10-12 feet wide if unsurfaced, or 13 to 15 wide if surfaced, the width depending on the cross section of the road).

Good alignment of these routes is rarely attempted while excessive "cut and fill" is also avoided. Curves have a minimum radius of 40 feet, although 25 feet may be permitted on occasions where vehicles no larger than 30 cwt. trucks will be used.

Grades do not ordinarily exceed 15 per cent for elevations up to 3000 feet, 13 per cent from 3000-6000 feet, and 11 per cent beyond 6000 feet elevation. Variation with elevation is considered necessary, as motors are estimated to lose 3·5 per cent of their power for every 1000 feet rise in elevation. Where protection is the main purpose of low service routes - the grades quoted above may be increased by 5 per cent for distances not exceeding 500 feet, and the use of these "pitch grades" is separated by distances of at least 500 feet of ordinary maximum grades.

Maintenance of such routes is considered necessary only once a year (during the spring)

(b) "Medium Service" Truck Trails - for speed of from 16 to 25 miles per hour.

The main purposes of such construction are:-

1. Assisting fire protection where distance of travel, heavy loads, and high fire risk, require a moderately fast transportation of men and equipment.
2. Facilitating administration by connecting headquarters with ranger stations or other key locations, or providing links in the main transportation system of the forest
3. For hauling moderate quantities of timber or other

products, livestock etc.
4. To serve local community or industrial interests, recreation areas etc.

Medium Service routes are usually single track (10-12 or 13-15 feet wide) but may include lengths of double track (17 to 19 feet wide) - heavy side cutting and filling are avoided as much as possible, while alignment bears a strict relation to construction costs. Curves have a radius of not less than 50 feet. For protection purposes only, grades of medium service routes may be increased by 5 per cent, and for general public travel by 2 per cent, on the same conditions outlined above for low service routes (distances less than 500 feet etc.) The maximum grades to be used ordinarily are:- 11 per cent to 3000 ft. elevation, 10 per cent for 3000-6000 feet elevation, and 9 per cent above 6000 feet.

Maintenance of these routes is planned at least twice a year, in the spring to place the route in trafficable condition, and in the autumn to ensure that proper drainage is operating before winter precipitation commences.

(c) High Service Truck Trails - for speeds of more than 25 miles per hour.

These are designed for:-

1. Routes of the highest importance in the protection system, particularly from the viewpoint of speed of travel.
2. General tourist travel or traffic of other kinds through a forest area.
3. The backbone or main arteries of the entire road and trail system for the Forest.

This type of trail is largely (if not entirely) double track in width - 17 to 19 feet wide if unsurfaced, and 20 to 22 feet wide if surfaced (width depending on type of cross-section). They are usually constructed to give the best possible alignment, without incurring particularly heavy construction costs, so as to improve road speeds. Any necessary curves are "eased" as much as possible, in order that road speeds may be maintained, and the minimum curvature permitted on bends is a radius of 80 feet. Maximum grades permitted are 8 per cent up to 3000 feet elevation, 7 per cent from 3000 to 6000 feet, and 6 per cent above 6000 feet elevation. Where high service routes are used primarily for public travel, the above grades may be increased over a maximum distance of 500 feet, and at intervals of not less than 500 feet, by 2 per cent, provided no such increase is made on a curve of less than 100 feet radius.

Routes constructed to these specifications are intended to be constantly maintained in good condition.

B. Trails.

Despite the fact that many roads (Truck-trails) have been constructed in areas where foot or horse trails once provided the sole means of transport, trail construction is still highly important, particularly in mountain areas where road construction is difficult from the engineering and economic standpoint. As an example, Buck (24) points out that in the Pacific North-West

Region, transportation planning for the Region included the construction of only 20,825 miles of truck trails as against 35,284 miles of other trails. He points out also, that almost 85 per cent of those latter trails had been constructed leading up slopes from main valleys, or following strategic ridges, in rugged and mountainous areas.

Trails have their place in transportation planning, at least as a subsidiary to road systems. In extremely rough topography, or on areas where the fire hazard is rarely serious and values at stake not great, they may even constitute the main means of access. As explained in the U.S. Forest Service Trail Manual (188) trail grades are confined to 15 per cent or less, except for short distances. Trails to be used by pack-horses to any extent are less steep than foot trails, and solid "treads" up to 24 inches wide must also be provided. Various types of trail in use are:-

1. Way Trails - built primarily for foot travel, but can be negotiated if necessary by a loaded pack-animal.
2. Secondary Trails - built to a better standard than way trails, primarily for use by pack-animals and saddle horses.
3. Primary Trails - are frequently used by pack and saddle animals and may not necessarily be used solely for fire protection purposes.

Recreational use of forest areas has greatly increased the demand for, and use of, all types of trail. Many people prefer trail travel to touring on highways, at least for holiday or novelty purposes. It must be stressed, however, that the majority of trails on National Forest areas are constructed solely, or primarily, as a means of providing access for fire protection purposes to inaccessible areas. Both construction and maintenance of trails has been greatly improved in standards, and as regards costs, by the recent use of miniature "angle dozer" types of tractor. Such tractors are also useful along these trails during suppression action, especially if drawing a small two-wheeled trailer with rear castor wheel carrying supplies, tools, water etc.

On State and other public forests - the use of trails is largely coincident with recreation, particularly in the North Eastern Region where a high concentration of population demands the maximum in recreation from forest areas. The most famous of many trails in the North-Eastern region is the Appalachian Trail. As described by Avery (9A), the Appalachian Trail extends from Katahdin in Central Maine a distance of some 2050 miles Southwards through National and State Forests, State Parks, Private property etc., to Mt. Oglethorpe in Central Georgia, traversing fourteen States on route. Another famous trail (used mainly for recreation) is the "Pacific Crest Trail" in Western U.S.A. As mentioned by Foote (51A) this trail extends some 2300 miles from the Canadian to the Mexican borders along the crests of the Cascade, Sierra, Nevada and Desert Mountains. All except 175 miles of this distance is within the boundaries of twenty National Forests and five National Parks.

C. Railroads.

It can be generally stated that railroads are used for transportation mainly in the North Western Region, in areas inaccessible to other main routes of transportation, and where the size of the timber logged demands the heaviest means of transport.

Agreements between Federal and State Foresters and railroad companies provide for:-

(a) The use of detection patrols for following rail traffic during severe conditions.
(b) The use of "speeders" by forest officers investigating fires along railroads rights of way, or fires which are approaching such rights of way.
(c) Emergency transportation of suppression crews to any position along railroad tracks, including the provision of special tank cars of water, portable and other types of pumping equipment etc.

Similar provision is made, on a much more limited scale, for distribution of suppression crews along the routes taken by logging railroads in otherwise inaccessible areas in the North West. The compulsory and voluntary precautions taken by lumbermen in the operation of logging railroads, and "logging operations generally, have, however, greatly reduced the necessary for using this means of transport.

Railroads are freely used for the Regional distribution of large stocks of fire equipment kept at central warehouses for use, on any occasion, on any forest requiring same. The two main warehouses in Region No. I (Missouri and Spokane) for instance, carry complete stocks of equipment, tools, food and camping supplies etc. for 12000 men, in 25 man and 50 man units, ready for instant shipment. In addition, large stocks of one man and 15 man outfits, assembled plow and pump units, telephone and radio kits etc. are kept at these warehouses for immediate despatch by railroad (and by motor trucks and aircraft).

D. Firebreaks.

Firebreaks are not strictly a means of transportation, in that they are not constructed primarily to provide it, as is the case with roads or trails. Firebreaks are constructed primarily to impede the progress of fires in locations where natural barriers are not available for the purpose, and where access by roads or trails is insufficient for actual suppression of fires. Despite the large programme of road and trail construction being undertaken, the use of firebreaks is increasing greatly, particularly in the Southern, Lakes States and Californian regions.

As at 30/6/39 C.C.C. employees had constructed some 54,000 miles of firebreaks for the U.S. Forest Service as against 77,000 miles of roads and 14,000 miles of trails.

Excluding natural firebreaks such as extensive bodies of water, bare rocky ridges, strips of hardwood forest etc., and what can be described as secondary firebreaks (roads, trails, cleared strips along property boundaries or for power lines, telephones etc), firebreaks can be classified according to the construction and maintenance methods adopted. viz:-

1. Cultivated firebreaks - in which cleared strips are cleaned of vegetation mainly by annual or period ploughing. Old types of agricultural ploughs have been replaced in most instances by

heavy tractor-drawn disc types of special design, which plough strips 8 to 12 feet wide for an initial cost as low as $1·50 per mile, with maintenance costs from $0·75 per mile. These types of breaks are largely used in the Southern and Lake States for protecting units of variable size. Their use will probably be extended in these regions as equipment design for their economical maintenance (and construction) is further improved. In New England States, wide cultivated strips (to 50 feet in width) are used to some extent along railroad rights of way, with narrower strips cultivated along property boundaries, particularly where coniferous planting or regrowth is situated.

The use of graders for "scraping" of firebreaks in preference to maintenance by ploughing has not increased as much as would have been thought practicable.

2. Burned firebreaks - this system at first replaced the old method of protecting trees in the turpentining areas of the South, by means of which individual trees were raked around prior to light burning of the forest. Narrow strips were ploughed on each side of a break of variable width (3 to 100 feet) and the intervening space was burned, whenever possible, during "safe" conditions. Owing to difficulties experienced in obtaining sufficient suitable time for burning, and in the escape of fires from burning operations, this form of firebreak maintenance has been largely superseded in the South by increasing the width of ploughed strips (in some instances to the entire break width) despite the costs of such ploughing.

Elsewhere in U.S.A., burned breaks are used to a limited extent (e.g. State of New Jersey) for strips up to 100 feet wide along road edges, ownership boundaries etc., in forest areas. After brush is cut, trees are pruned etc. on the strips to be burned.

3. Shaded Firebreaks - The influence of dense forest canopy on the moisture content of ground and other fuels is well known, and fire fighters often find that suppression efforts are much simpler in dense stands where there is no accumulation of dry fuels. Most of the firebreaks under construction, or recently constructed in U.S.A., attempt to preserve as much living tree cover as possible, removing only dead trees or ground fuels, brush, undergrowth etc., and thinning out dense reproduction, without creating conditions for an increase in the growth of annuals etc. Shaded breaks along which hardwood species occur, either in pure or mixed stands, are the most successful, but their use is by no means confined to hardwoods. Strips up to 8 feet wide may be scraped to the mineral soil along shaded breaks, in order to improve either access or the effectiveness of the break.

Apart from their increased use on National Forests, breaks of this type have been successfully used along State Forest boundaries (e.g. Connecticut) or roadsides (New Jersey).

4. Grassed firebreaks - these are modifications of ploughed breaks, grasses of special types that remain green during the summer are sown on firebreaks, in order to reduce maintenance (ploughing) costs, or are encouraged to spread on breaks by the judicious clearing of tree cover. "Carpet grass" is used on

moistor sites (e.g. in Southern Statos) and "Contipede grass" under drior conditions. Tho success of grassed firebreaks is essontially dependent on the amount of grazing which can be maintainod along the broaks, so that the grass is always kept cropped. Although they have been exprimented with in South Eastern areas, they may not be successful thero owing to the number of fires occurring in February (and other winter months), when the grasses mentioned aro in a dry and inflammable state.

5. <u>Motorways</u> - this type of break, in which two ploughed, or graded, strips up to 8 feet wide are separated by a truck trail 12 feet in width, is used mainly in the Lake States region for protecting areas of valuable regrowth or of plantations. It serves the useful dual purpose of access and protection.

6. <u>Hand cleared breaks</u> - while most firebreaks are actually cleared, in the first instance, by hand, there are certain sections of breaks which must be maintained by hand owing to their being remote or inaccessible to mechanical maintenance. The maintenance work done by hand may even include baring a strip of mineral soil. This type of firebreak is avoided wherever possible, but is still to be found along ridges etc. in mountainous areas, notably along the steep and inaccessible ridges in the "Chaparral" covered mountains of Southern California. In the latter locality effective and economical maintenance of the breaks is a serious problem.

It is difficult to classify any appreciable length of firebreak under any one of the above headings, as it will be usually found that a single break combines two or more of the features mentioned. Breaks may be constructed either with or without overhead shading, and they may have a ploughed or cultivated strip, and also be burned at intervals. A certain break may also include a trafficable truck trail, at least for part of its length, and a foot trail along other sections.

Generally speaking, firebreaks are most effective when following contour lines, particularly so if such contour lines mark the division between cover (fuel) types, as in the case of grass or brush types on the lower slopes of mountains. Their actual location, however, includes consideration of such local factors as the amount of slope, exposure to wind, aspect, ground cover types, slash. Their planning follows that already mentioned for detection and road systems, viz. the best balance between risk, hazard, and economics. Construction is not now undertaken unless maintenance can also be handled in adequate fashion. The intensity of a firebreak system naturally depends to a large extent on risks and/or hazards prevailing. On plantation areas, or in turpentine regions in the South, a unit of 40 acres or less may be isolated by firebreaks, but the area of such protection units is usually much larger, and may be even more than 640 acres.

Recent efforts have been made to further reduce the cost of firebreak maintenance by spreading toxic chemicals along strips where deep rooted perennials and heavier growth have been removed in construction operations. Bruce (23) found that powered arsenic trioxide ($AS_2\ O_3$), spread at the rate of 16 lbs per acre of cleared strip, was effective for several years in preventing growth of herbaceous vegetation, especially on absorbent sandy soils. An equal application of sodium chlorate (in dry or dissolved form) was equally effective against deeper rooted perennials. The use of these chemicals would greatly reduce existing maintenance costs, especially those of hand maintenance, if their effectiveness could be extended up to 10 years, but this has yet to be proven. It

(Photo by K.D. Swan - Courtesy U.S. Forest Service).
Loading fire equipment (4500 lbs. load) in Ford Tri-motor Plane McCall - Idaho.

(Photo by U.S. Forest Service).
Pack train with load of fire equipment delivered by aircraft to Forest Aerodrome - Idaho National Forest - Idaho.

is further stated by Bruce that the white arsenic powder abovementioned has little, if any, taste or odor and is thus not fatal to stock, as is sodium arsenite. Crude petroleum oils of a low volatile nature have also been found efficient and inexpensive in preventing the development of herbaceous growth.

The Ponderosa Way -

No reference to firebreak construction in U.S.A. would be complete without mention of the Ponderosa Way - which extends a distance of some 650 miles along the Western slope of the Sierra Nevada Range in Western U.S.A. This break was constructed in an effort to control the spread of fires from the grass and chaparral types of the valleys and lower slopes into the Pinus ponderosa forests at higher elevations. The grass and chaparral areas are responsible for many "brushburning" and other fires, and such outbreaks were most dangerous in sweeping uphill at a fast rate of spread. By constructing this enormous firebreak, such fires could be stopped automatically or by back-firing, together with other action taken by suppression crews. As far as possible the break has been constructed under forest canopy as a "shaded break". Its width varies from 200 feet along contours to 150 feet on rounded ridges, and 50 feet on sharp ridges. Location of the break was designed to make fullest possible use of existing roads, or of other possible road or truck trail routes. As a result, approximately 25 per cent of the entire length is traversed by good roads, while truck trails follow the remaining distance except where they are deviated by impossible grades. The break is kept as close as possible to the lower edge of the forest type, and all ground fuels are removed from the above-mentioned widths, to give the greatest possible assistance to fire-fighters. As far as is possible with varying gradients, the roads and truck trails follow the centre of the cleared strip.

E. Air Services.

It is becoming increasingly evident that aeroplanes constitute a valuable means of transporting officers, men, and supplies to fires which occur in mountainous or inaccessible areas. In many cases the use of aircraft for such purposes is more efficient and economical than other means of transport. Considerable attention is therefore being given to the construction of regular and emergency landing grounds within National Forests. Some 70 landing fields are already available at the Supervisor's headquarters, or elsewhere, on the principal "fire forests" in Western Regions, while lookout stations and other aids to aerial navigation are being specially marked for the purpose. Supplies of magnesium flares, and special types of shields for reflecting such flares on to landing grounds, are even available for emergency night landings. The use of aircraft has been confined almost entirely to Western Regions, having been evolved there largely owing to difficulties in other forms of transport, but if aeroplanes can be used in the extremely difficult summer flying conditions of mountainous regions, they should eventually find a place in the rapid transport of men and equipment in the extensive forests of the South. The main uses to which aircraft transportation is now put are as follows:-

1. Transporting "overhead" staff from Regional headquarters,

(Photo by K.D. Swan - Courtesy U.S. Forest Service).

Supplies being dropped to fire camp by Navy type of parachute (load approximately 160 lbs.)

(Photo by K.D. Swan - Courtesy U.S. Forest Service.

Dropping supplies to a fire camp by means of Navy type parachutes - note grounded parachutes.

or from other areas of low fire hazard, to the outbreaks of large fires, in order to assist or relieve the local staff.

2. Transport of tools supplies, equipment and/or firefighters to inaccessible areas, having regular or emergency landing grounds, during severe fires.
3. Transport of tools, food supplies and equipment to the vicinity of large fires in inaccessible country for dropping by parachutes of various patterns.

In describing the results obtained on Idaho National Forest in using "loose packs" for dropping supplies of tools, equipment and rations, Shank (157) expressed the opinion that the method was not only feasible "under practically all conditions", but for at least 50 per cent of the forest was the cheapest means of transport. Wernstedt and Mays (219) have described the success achieved in dropping supplies from planes by using hessian parachutes, even such items as eggs, batteries, and complete radio sets being landed safely from heights up to 1000 feet. They also describe the transport of food and equipment to two actual fires in the Pacific North West region, when 1800 pounds of material was dropped at each fire instead of by tedious animal and "back" packs, that would require at least 10-12 hours in transit. The most notable use of aircraft mentioned was at the Summit fire on Wallowa National Forest in August, 1937, when no less than 120,000 lbs of supplies were taken to the 400 men and 50 pack horses used on the fire, in 141 flights made over an airline distance of 28 miles. Every conceivable type of equipment and food supplies was included in the "dropped" materials, including such items as eggs, fresh fruits, vegetables, telephones, headlights, petrol and kerosene lanterns, radios, knapsack pumps, first aid kits, 5 gallon cans of petrol, small stoves etc. Bales of hay were dropped in sacks without parachutes. Losses experienced amounted to only 6 per cent, which figure would probably have been exceeded if packing by animals, or on foot, had been resorted to. The weight of bundles dropped with each 7' x 7' parachute varied from 20 lbs. in the case of the most breakable articles (eggs, radios etc.) to 70 lbs. for dry foods, meat etc.

The use made of aeroplanes to date has not justified the general purchase of machines by the Forest Service, but arrangements are made for the contract hiring of suitable machines from private operators in "key" towns adjacent to forests. For example in Region I (Northern Rocky Mountains) arrangements are made to hire various types of aircraft, when considered necessary, from a number of operators at the following rates of hire:-

12 Passenger	or	4000 lbs of freight	- $80 per hour
10 "	"	3000 lbs of freight	- $50 " "
10 "	"	2000 lbs of freight	- $34·50 per hour or $0·55 per mile
6 "	"	1000 lbs of freight	- $25·00 to $32·80 per hour (type commonly used)
5 "	"	900 lbs of freight	- $20·00 per hour
2 "	"	500 lbs of freight	- $20·00 " "

During the 1938 fire season, it was estimated (78) that some 112 tons of supplies and equipment were dropped by parachute from planes hired by the Forest Service, apart from other supplies etc. delivered to landing fields.

(Photo by U.S. Forest Service - Fire Equipment Handbook.)
Portable power pumper, in special parachute pack, ready for aerial delivery.

(Photo by U.S. Forest Service).

Parachute parcel of equipment ready for dropping at forest fire camp - Idaho National Forest - Idaho.

The dropping of supplies by parachute is now far beyond the experimental stages, and is becoming standard practice in Western Regions. For instance, during the 1939 fire season, some 100 tons of supplies were dropped from contract planes in Region No. 5 (California), while some 125 tons were dropped in Region No. 1 Northern Rocky Mountains). Most of these supplies were dropped at "fire camps", but efforts are now being made to deliver water and equipment direct to men working on fires.

In a Californian review (205) of U.S. Forest Service practice in the aerial delivery of supplies, attention is drawn to the various methods of delivery used, such as the "Tight Pack" of the North Pacific Region. In California, a modification of the latter method is used, and close attention is being paid to increasing the efficiency of aerial deliveries. For instance, special packaging of most goods for dropping was discontinued, only special items requiring individual treatment and protection.

. The material used in parachutes in California is 10 or 12 ounce hessian (burlap) to which is attached at the corners (with a square knot and half hitch) a braided linen shroud line eleven feet long. The method of folding is important, not so much to ensure opening, but because there is a definite relationship between the method of folding a parachute and the speed with which it will open. For cargo dropping a quick opening is desired, so as to reduce the shock on the parachute and also on the lashing ropes of the load, and also to allow dropping at fairly low elevations without mishap. As the shock load developed when a parachute opens is approximately six times the weight of the load - a quick opening also helps to reduce the shock load.

After extensive tests of the size and grade of hessian sheets - 12 oz. material, 9 feet square, has been adopted as standard in California, this sheet being capable of lowering a load of 120 lbs. at a dropping rate of not more than 40 feet per second. In dropping supplies, aircraft fly at elevations of less than 1000 feet above ground to secure a reasonable degree of accuracy. Costs of dropping supplies, in California forests, from aircraft are estimated to be six cents per pound. This figure is twice that of pack delivery by horses, mules, or burros, combined with truck haulage, but no true comparison exists owing to the accelerated delivery of supplies by aircraft.

Older types of aircraft, which have low landing and stalling speeds, are greatly preferred, owing to the small size of landing fields in and around forest areas.

In Region Nos. 1 and 4 administrators favour the use of reject Army and Navy parachutes, constructed of best quality silk, for the dropping of supplies. They use the argument that the use of these parachutes cheapens delivery as loads of 180 lbs. can be dropped without difficulty and damage - thus reducing the cost of the total load dropped during a single flight.

Experimental effort is now directed towards the dropping of trained parachutists close to small fires in rough topography. As prescribed by U.S. Aviation Authorities for premeditated jumps, these men carry twin parachutes while their equipment also includes fire proof suits, fire fighting tools, three days' rations, ropes for use in case of tree-top landings etc. Now that the idea is passing quickly out of the experimental stage it opens up new possibilities for the early control of lightning or other fires which occur in extremely inaccessible country.

CHAPTER X.

C O M M U N I C A T I O N S.

The planning of systems of communication is just as important as those planned for detection and transportation, and has been attempted on much the same lines, viz., a study of areas served by existing and proposed communication systems. In some cases this planning has meant the reconstruction of entire telephonic systems within forests, in order that complete communication services would be provided without undue overloading of telephonic channels.

As all telegraph and telephone services in U.S.A. are controlled by private companies, the services operating in many areas of forest have remained undeveloped, except where the Federal or State Forest Services have either provided their own systems, or have extended the use of those available from outside centres. Because of their comparatively simple operation, and because of their proved service, telephone systems still remain the principal means of communication in forest areas, although the development of the more elastic and mobile radio equipment is becoming increasingly important and interesting to foresters.

For the present, radio is definitely acting as a supplementary service to telephones, but the use of both systems is being integrated, just as much as the whole system of communications is integrated into protection planning. Various details concerning each of them, must, however, be considered separately.

A. Telephone System.

Until comparatively recent times, almost the entire telephone system of the U.S. Forest Service comprised "grounded" lines (single circuit), extending over some thousands of miles. Planning of additional systems (which often meant the replanning of an entire forest system) and the construction on other forests of entirely new systems, has recently seen a great increase in the number of "metallic circuits" in use. The increase in the use of telephones can best be gauged when one considers that approximately 60,000 miles of telephone system were constructed on National Forests by C.C.C. enrollees between 1933 and 1939.

(1)Grounded lines. - the limitations of grounded lines are freely admitted in the U.S. Forest Service Telephone Handbook (196). On lines not exceeding 50 miles in length a total of 10 to 20 standard instruments, extension bells, repeating coils etc. is all that can be safely carried after allowing for the use of a few portable or temporary sets over the circuit during the fire season.

On lines exceeding 50 miles, from 8 to 12 instruments is the limit, depending on the extra length of line beyond 50 miles. A "grounded line" on poles might carry a few more instruments owing to reduced leakage. Temporary instruments not in service are temporarily disconnected to improve the remaining service. The length of serviceable grounded lines may extend from 40 to 50 miles in dense forests, or over high ridges, up to 75 miles in more open country of undulating character.

Except for greater interference from any other ground line, power, or telegraph lines etc., close to a grounded circuit, it should be possible to talk and ring as far on such circuit as on a metallic circuit. Three to four inch staples are most used for attaching lines to trees, hooks, pins, and wire rings being also used to some extent.

The "hangers" or wires by which the split reel insulators used are connected to the tree staples, vary in strength according to local conditions. They are made weaker where windfall is a serious trouble, and are strongest in locations where lines have to withstand strong winds or heavy snowfall. Even the strongest "hangers" are, however, designed to give way before the line could be broken. Construction and location of grounded lines includes the following considerations:-

(a) They must be protected, as far as possible, from high winds, falling timber, deep snow, land or snow slides, other ground lines, or electric power lines.
(b) They should be in plain view of minor roads and trails, unless very material savings can be effected in leaving curving roads to construct straight lengths of telephone line.
(c) Wire should be located so that it will not fall on to a road (exceptions are made in the case of foot trails)
(d) Lines should avoid crossing railways and main highways.
(e) The use of poles to be avoided where possible.

Spans used for ground lines on trees range from 135-150 feet in fairly open country, or 100-125 feet in timber, hangers being attached to insulators at heights of from 15 to 18 feet so that the average minimum clearance of the line will be 12 feet. It may be necessary to double the above heights above ground for telephone lines which traverse areas subject to very deep snow.

If portable telephones are used they are disconnected, as soon as possible after ringing off, owing to their "grounding" effect.

For use on fire protection, grounded lines have the advantage over metallic circuits in being cheaper to construct (almost no clearing or pole erection costs) and much more reliable (they can be knocked to the ground without serious injury and still give service).

(ii) Metallic circuits.

These circuits are being increasingly used on those parts of the U.S. Forest Service telephone system which carry the heaviest loads, in order that ground line networks need not be restricted. A full network of grounded lines has its limitations as described above, especially when more than 50 miles of such lines are in use on one circuit. The provision of additional primary lookouts has had the effect of overloading many grounded line circuits, as it is almost universal policy that primary lookouts be connected to forest headquarters by telephone. As a result, there has been increasing use of metallic circuits in the following forms, for at least a proportion of Forest Service networks:-

(a) Use of commercial Telephone Companies' poles.

(Photo by U.S. Forest Service).

Special lightweight aluminium portable telephone - weighs 4½ lbs. with batteries - Used by U.S. Forest Service.

(Photo by U.S. Forest Service).

Lightweight portable telephone weighs 19½ lbs. with case and batteries - used by U.S. Forest Service.

(b) Installation of double Metallic Circuits.
(c) " " triple " "
(d) " " "Phantom" circuits - e.g. Where two metallic circuits that are well balanced (each wire of same material, size and resistance etc.) are on the same poles, the use of two repeating coils allows provision of a third circuit without any additional wires being necessary.

As described by Brown and Funke (21), other improvements now being effected in Forest Service telephone systems include the following:-

1. Elimination of the static interference common to overcrowded grounded lines, or to lines being extended, by greater use of transposed metallic circuits or by the removal of grounded lines from sources of interference.
2. "Re-routing" of a certain percentage of grounded lines away from roads having high aesthetic values, or to reduce wire mileage appreciably. The original idea of having lines within view of roads or trails to facilitate their inspection and maintenance, no longer holds good in the cases of most forest roads.
3. Effecting good connections to co-operators, volunteer detectors etc., many of whom were in danger of being crowded off the circuits after years of service.
4. Better types of switchboard and general consolidation of office telephone systems at Forest headquarters, in order to reduce "loads".
5. Greater use of Commercial Companies' circuits, where linking with these circuits will reduce the length of Forest Service circuits and provide more efficient general working.
6. Adequate provision to be made for:-
   (a) Present and future requirements within any individual forest
   (b) Good service between adjoining forests, or between any single forest and circuits installed by State forestry organisations, co-operative agencies etc.

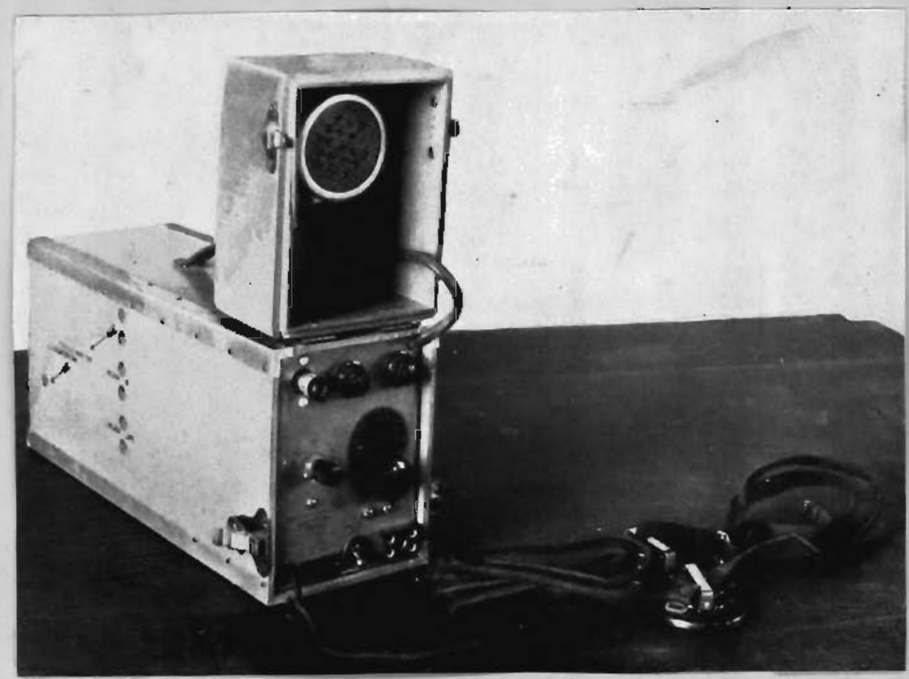
In the construction of both grounded and metallic lines, 12 gauge copper covered steel wire is now generally preferred to the 9 gauge galvanised iron wire formerly used exclusively. Although the breaking strain of both wires is approximately the same - the copper covered wire has a weight of only 96 lbs. per mile as against 314 lbs per mile for the galvansied wire.

For long spans etc., other gauges of copper covered steel wire are used as follows:-

(a) 10 gauge - for spans between 250 and 500 feet long
(b) 8 " - " " " 500 and 1000 " "
(c) 6 " - " " more than 1000 feet long, or for use on grounded lines of very heavy loading.

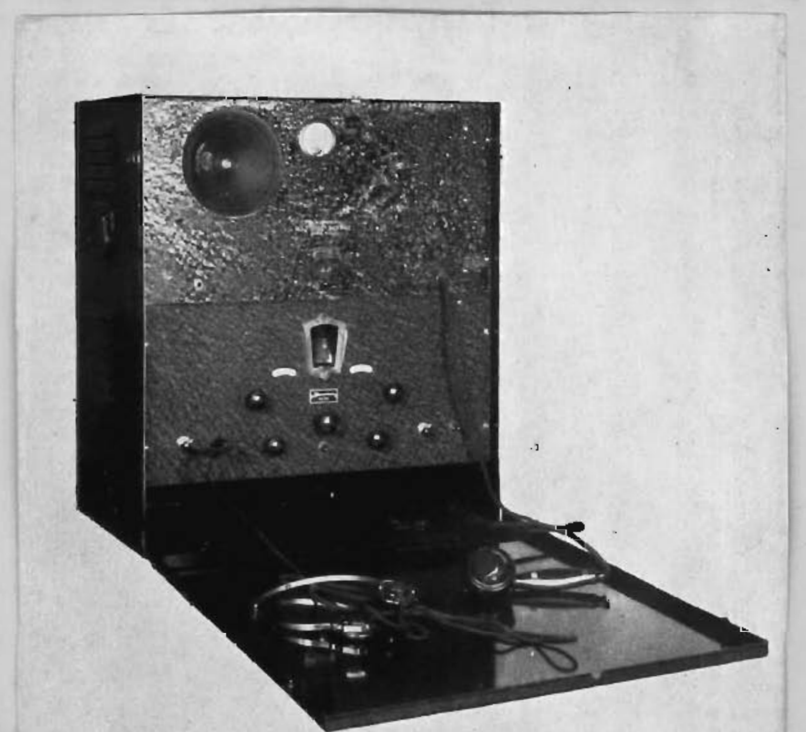
On heavy duty, or long metallic lines, or for contact with telephone company lines, 10 gauge solid copper wire is now being used exclusively.

While the U.S. Forest Service has been obliged, in many localities, to create its own telephone system for connection to commercial lines, no attempt is made to avoid the use of



Type P.F. Radiophone - U.S. Forest Service.

Type S.P.F. Radiophone - U.S. Forest Service.



Type M. - Radiophone - U.S. Forest Service
(All photos by U.S. Forest Service.

commercial lines. On the contrary, some forest officers would prefer to hand over to commercial companies at least part of their forest network in order to obtain a better service. In addition the cost of telephone calls through a commercial network is probably less than the maintenance of forest systems of telephone. Co-operation with commercial companies may in some cases reach the stage when all commercial lines are cleared for use by Forest Services during peak periods of emergency. For short distances of line carrying continually heavy traffic, the U.S. Forest Service arranges for the Commercial companies to provide automatic "teletype". Where the U.S. Forest Service telephone circuit is the only one available to local people, the latter are allowed connection to such circuit, provided that the Forest Service has prior use over all lines during the fire season. The Forest Service uses portable telephones in emergency, on both its own lines and those owned by commercial companies. In the latter case Companies grant permission only on general agreement that the use of portable phones will be confined to periods of emergency.

A recent development in the Intermountain Region of the U.S. Forest Service has been a "telephone amplifier" based on the use of a "vacuum valve". This ingenious device facilitates long distance conversation over heavily loaded or noisy landlines. At the present stage of development, two amplifiers are used at each "talking station", but it is hoped to so improve the instrument that it can be used satisfactorily at one end of the line only.

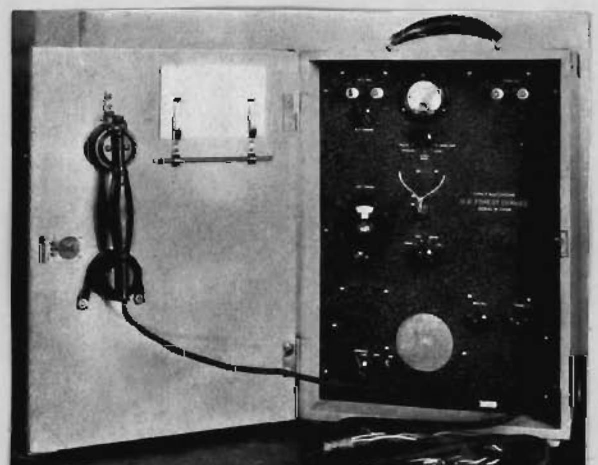
B. Radio equipment.

While radio communication may not supersede telephone systems, at least for some considerable period, it has become definitely established as a dependable means of communication for fire control purposes. even though still supplementary to telephone systems. Reliable telephonic communications already exist from most forest headquarters to Regional offices, or to headquarters on adjoining forests. Radio is usually most useful in improving communication within a single forest or ranger district, the better the telephone system within this area, the more efficient is the auxiliary service rendered by radio. As noted by Oettmeier (144) both one-way and two-way (duplex) communication, have a place in fire protection. One-way communication for small portable sets is perhaps the most efficient owing to the time saved in "setting-up" equipment, greater "portability" of kits etc. Two-way types of radio are of greatest use in rough and inaccessible areas, where considerable transmission of information takes place once a radio kit is "set-up". Two way types are definitely the most useful in sets designed mainly for mobile use in cars and trucks, aircraft etc., or for semi-portable types of radio.

The main uses of radio equipment, in present methods of fire control, are:-

1. Communication with forest headquarters from secondary lookouts, in isolated or inaccessible areas, not served by telephones.
2. For maintaining contact with crews held in readiness for suppression duty, but employed on other duties, pending emergency calls, out of reach of telephone facilities.
3. Communication between forest headquarters, and camps or working crews at "going" fires.

(Photo by U.S. Forest Service).
Type U (U.H.F.) Radiophone used
by U.S. Forest Service.



(Photo by U.S. Forest Service).
Type T (U.H.F.) Radiophone used
by U.S. Forest Service.

Where men are engaged on large or dangerous fires several miles from a telephone system, the use of radio is almost general in order to keep headquarters informed of the fire situation and to advise suppression crews of reinforcement action, forwarding of supplies, equipment etc. as requested by them.

4. Direct communication between aeroplanes scouting a particular fire, and suppression crews engaged on such fire, or proceeding towards it. Such communication has only recently been developed to give two-way conversation.
5. Two way communication between moving patrols in cars or trucks, and forest headquarters, in reporting the outbreak or progress of a fire. Similar communication is also available for use by mobile fire weather recording and forecasting stations mounted on special trucks, which proceed as close as possible to actual fires.
6. For communication between different crews working on a large fire.
7. To supplement or replace telephone systems when the latter are overloaded or interrupted during severe fire conditions, or are handicapped by slow exchange services, poor installation etc.
8. For connection between points where topographic barriers render telephone connection impracticable or too costly, or between points where the small amount of communication does not justify telephone line construction.

It is admitted by its most enthusiastic advocates that use of radio presents certain difficulties such as:-

(a) Requiring some proficiency or expert knowledge on the part of operators.
(b) Variable performance due to severe weather conditions in the summer, or to variations in topography or types of set in use.
(c) Limitation of use because of restrictions imposed on the use of radio - frequencies by authorities controlling same, or even total banning of radio when found to be eliminating telephone calls.

Larger types of set (or those with the greatest range) used by the U.S. Forest Service are known as high frequency kits (H.F.) and are capable of operation on radio-frequencies from 2000 to 20,000 Kilocycles, the Forest Service usually operating in the vicinity of 3000 K.C.

The more restricted types of set known as ultra-high frequency (U.H.F.) give their best performance only when communication stations have an uninterrupted and unscreened airline between them, and are operated on any frequency between 30,000 to 50,000 Kilocycles.

As described by the U.S. Forest Service (194) and elsewhere, the main types of radio kit now in their use may be summarised as shown in Table No. 40.

The most intensive use of radio by the U.S. Forest Service is in Region No. 1 (Northern Rocky Mountain Region) where a large central receiving and transmitting station at Missoula, Montana, operates a 24 hour service during the fire season with a range of 200 miles or more. This station is equipped with a "remote control" device which enables radio calls to be switched over to the telephone circuit which connects the Station to the Regional Office. Lookouts or other operators of radio, and

TABLE NO. 40.

Showing types of radio sets in use by U.S. Forest Service.

	TRANSMITS		RECEIVES		WEIGHT (IN POUNDS)	WORKING RANGE IN MILES	APPROX. COST	MAIN USES	REMARKS
	MORSE	SPEECH	MORSE	SPEECH					
H.F. TYPES.									
"P"	X	-	X	X	9	20	$50	Smokechasers' kit	Extremely portable but limited in range - uses dry cells.
P.F.	X	X	X	X	15	10 (SPEECH) 20 (MORSE)	$75	Smokechasers or stand-by suppression crews	Wider use than Type P. - often carried on motor-trucks - uses dry cells.
P.F. (kit-box)					35			Firemen	By using heavy batteries gives the P.F. much wider range
S.P.F.	X	X	X	X	58 (24lbs. with dry cells)	15 (SPEECH) 25 (CODE)	$150	Any field use where "portability" is not highly important	Preferable to P. & P.F. types except as regards "portability" and requires less operating skill - uses small dry cells or heavy batteries
I.	X	X	X	X	120	25 or more	$295	For mobile use in cars or trucks	Operates on 6 volt batteries or 110 volt A-C. current - gives good two way communication.
M.	X	X	X	X	125	50	$375	At headquarters	Uses A.C. current.
U.H.F. TYPES.									
T.	-	X	-	X	50-100	100 (visible)	$130	For "stand-by" use or between visible lookouts	Has two way operation - uses heavy type batteries
S.	-	X	-	X	8	50 (visible)	$50	Smoke-chasers, scouts, suppression crews	Very portable and easily set up. One way only - Uses dry cells
S.V.	-	X	-	X	18½	80 (visible)	$65	Scouts and suppression crews	Two way operation - uses medium or heavy batteries.
A.	-	X	-	X	40	---	-	Aircraft and cars (two-way use)	Uses either 6 volt or aircraft storage batteries.
U.	-	X	-	X	200	---	$400	Headquarters	Simple in operation - uses A.C. current - two way communication with T, S, S.V., and A kits of the U.H.F. pattern.

even officers using radio from moving cars and trucks, can thus carry on two way conversation with administrative officers at a Regional Office telephone. Several types of set are used in the field in Region No. 1 - the most favoured being the S.P.F. type, which has been used on a range up to 200 miles. In the Region, radio transmission seriously competes with telephones as a means of communication - for instance every forest in the Region collects and transmits to Missoula by radio, its daily recordings of fire weather observations etc.

In Region No. 5 (California) each forest subject to severe fire risk has its own radio station at forest headquarters, manned during each fire season by a competent (temporary) operator. In this Region the High Frequency S.P.F. sets are popular in rougher terrain, but the Ultra High Frequency types - S, T, and U are increasing in use, owing to their freedom from interference during thunderstorms, and because of less interference caused on wave lengths. It is of course necessary for these sets to be operating within visual range of each other, but difficulties involved in communicating between two such sets in rough topography are often overcome by relaying messages through a lookout station, on a peak or ridge within visual range. In Region No. 5, radio trucks are available at central locations for moving to fire outbreaks, where they maintain two way communication between fire headquarters and the nearest administrative office.

In Region No. 4 (Intermountain), radio communication is freely used - a twenty-four hour service being maintained at forest headquarters once fire danger becomes appreciable. Labour forces in the forest, available for suppression duty, are equipped with radio unless telephonic connection with existing circuits is much cheaper, emergency lookouts being equipped with radio under similar circumstances.

In Region No. 6 (Pacific North West) - the use of radio at lookout stations is practically confined to those secondary stations manned only during emergency conditions. Only two per cent of the lookout stations normally manned are equipped with radio. Communications is centred at a Central Station at Portland, Oregon, which is linked by automatic teletype transmission of messages to the Regional Forest Office in the same city. All radio development work for the U.S. Forest Service is also centred at the above radio station, - the various types of sets now in use by the Forest Service having been designed and tested at Portland. The manufacture of these sets for normal administrative requirements is, however, handled by private firms, subject to specifications prepared by the Radio Laboratory at Portland.

Fire control officers in the Region use medium high frequency sets in their cars, but are considering a change to ultra high frequency types of mobile set owing to the greater working range (up to 100 miles) of the latter.

In general use of radio within or between Regions, it is impossible to list call signs for all transmitting and receiving stations. It has been found more simple to number each type of set serially and use the serial number when calling another station, so that an example of a call would be - "SPF 139 calling M 39".

The SPF set is so suitable for general forestry use that its design has been made available to the British Columbia Forest Service - sets for use by the latter service being manufactured in Canada by the Canadian Marconi Co.

CHAPTER XI.

TOOLS, EQUIPMENT, AND SUPPLIES.

A. Tools.

The importance of the time element is still stressed in respect of tools, equipment and other supplies. Tools are of greatest assistance to suppression crews when they are:-

(a) Available for instant use.
(b) In sufficient number and of the right type for the conditions prevailing on a particular fire.
(c) In first class working condition.

Supplies of tools are organised in strict accordance with the above considerations, and particular care is taken that sufficient tools of the right type are so located as to meet any emergency. Their distribution is governed by source and "accessibility" of labour forces, by available means and routes of transportation, so that tools are always within reach of any labour force engaged. As is usual with any fire control planning, some reference to the fire history of the forest will indicate the major needs as regards number and types of tools required, and their most effective distribution. All Regions emphasise the need for having sufficient fire tools with all labour forces to be used on a fire, so that the tools go with the men, both in the case of forest labour, and also of emergency labour forces.

(i) Assembly and distribution of tools.

(a) Special tool outfits for fire use.
It is the policy in all U.S. Forest Service regions to segregate fire tools from those in use on other work. They are specially branded and marked, and are assembled in units of definite size for the use of 1, 5, 6, 10, 15, 25 and 50 men crews. They are "cached" on forest areas in specially designed waterproof tool boxes, which are marked to distinguish their use, and with their total weight shown. The metal parts of all fire tools are branded "F.S." and their handles are coated with red paint for a distance of six inches from the metal head, blade, etc. Other tools and equipment such as water bags, buckets, beds, tents, knapsacks etc. are marked with the Forest Service shield, or the letters U.S.F.S. are stencilled in letters at least one inch high. Tool boxes are designed to house tools free from any weather effects (such as rusting) in the most compact manner, and without any injury to the cutting edges of tools. Lists of all tools within any box are displayed on the underside of the lid, with special forms for entering any removal of tools from the box. All tools are kept in good working order by sharpening, greasing, testing handles for tightness, and prompt replacements are made before the fire season of any unsatisfactory tools. Rust development during storage is prevented by coating metal surfaces with liquid petroleum.

(b) Distribution of Tools.
As a general rule, the man power available, existing transportation facilities, and the relative fire hazard existing, govern the distribution of fire tool units of varying size. The early policy of "field caches" of tools at various locations throughout the forest, is not now greatly favoured owing

(Photo by U.S. Forest Service).

Assembly of 25 man kit of fire tools and fire camp gear - North Pacific Region.

to improved transportation facilities, and the close relation planned between such facilities and labour forces. The modern tendency is to have tool kits of various sizes assembled, mainly in special boxes and ready for immediate use, at places where labour forces are employed on other work, in camps, or in other locations, where the tools can be picked up at the same time as labour forces.

1. Forest officers' tool kit - It is mandatory for all officers travelling in forest areas to carry a suitable tool-kit comprising axe and shovel (or combination tool), water container (1 gallon), one day's rations, and (in some Regions) a portable telephone. Officers and employees using saddle horses are not required to carry tools, but if a pack horse is used an axe and shovel are usually obligatory.

2. Field caches of tools - as previously noted, these are now usually located in close association with labour forces, although the need for other caches ready for "pick-up" at strategic locations has not entirely disappeared. The size of tool kits (for 1, 3, 5, 6, 10, 15 or more men) and their make up, varies to some extent with local conditions of hazards. Fuel types and other influences, such as rocky terrain, cause variations in the proportion of cutting tools to digging tools, types of digging tools etc. Field caches of tools are, however, made up in various standard units of limited size, such as 5, 6, or 10 man outfits. In Region No. I, tool kits for small numbers of men (5, 10 and 15) are now being converted to "back packs" for conveyance in light weight packs. In the Southern Region heavier kits such as those for 12 man outfits are assembled in bundles, rather than boxes, for the sake of lightness.
3. Headquarters caches are maintained at the headquarters of Rangers or of the Supervisor on any individual forest, and include small outfits such as those mentioned for field caches, and larger outfits in 15, 25 (or more) man kits, for emergency use when reinforcements are called in, or to supplement the equipment of labour forces already sufficient to cope with an outbreak. Twenty-five man caches usually consist of tools for initial attack, supplementary tools and equipment for the same crew, and all camp equipment cooking gear etc. for their camp if staying overnight on the fire. Caches at headquarters are specially housed, if necessary in separate buildings, and their location plainly marked (and unlocked) so that no delays will occur when reserve supplies of tools are called for. On the Angeles National Forest in Southern California, subject to intensive protection because of watershed values, reserve equipment for 1500 men is available for emergency issue at the equipment depot for the forest.
4. Crew caches - are maintained at C.C.C. or other labour camps, where more than 20 men are employed, in the form of 20 man kits ready for immediate transport in tool boxes, crates etc. For smaller camps, 10 man kits are usually employed, except in the case of temporary camps of less than 10 men, where no arrangements are made for special kits if suitable tools for use in fire suppression are available at short call. Crew caches must be in position for loading and despatch within a period of two to three minutes.
5. Regional headquarters - As in the case of Western Regions, the Regional headquarters arrange for the storing in Service

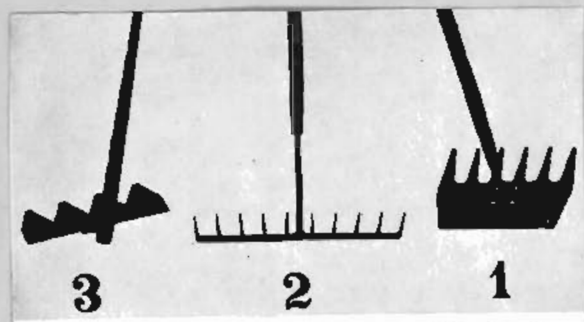
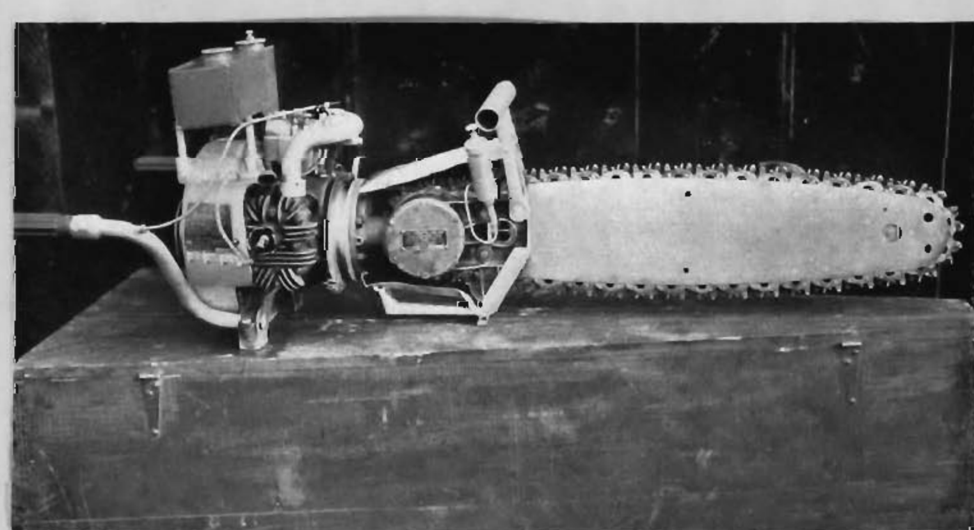


FIGURE 1-5.—Fire rakes: 1. McLeod tool, solid-head pattern; 2. asphalt-type fire rake; 3. combination rake and cutting tool.

(Photo by U.S. Forest Service).

Types of fire rake - 1. McLeod Tool solid head pattern - 2. Asphalt - type fire rake - 3. Combination rake and cutting tool.



(Photo by U.S. Forest Service).

Power driven chain saw for use in fire suppression. (Note specially shaped box for transport).

(Photo by U.S. Forest Service).

Contents of one day emergency ration for fire fighter - Northern Region U.S.A.

"warehouses" of extensive supplies of tools and all other equipment, mainly in large units such as 25 or 50 man outfits. As already noted, the two Regional warehouses in Region No. I carry stocks of reserve tools etc. sufficient for 12,000 men, and ready for any possible emergency. Similarly large stocks are held at centrally located warehouses in other Regions in Western U.S.A. such as the warehouse at Los Angeles for Southern California, which holds tools and equipment for some 3,000 fire fighters. In the Lake States Region, a centrally located warehouse at Duluth serves four national forests in the Region, and carries reserve stocks of equipment for 4000 fire fighters. Fire control officers point out that supplies from warehouses can be rushed by motor truck or by aeroplanes to any part of the territory they serve within a few hours - this period being much shorter than the time necessary to enrol strong forces of emergency labour, and to transport such labour to large fires.

(ii) Types of hand operated tools.

It is to be expected that variations between fuel conditions, topography, method of attack, means of access, presence of water supplies etc. between various forest regions in U.S.A. result in considerable variation in the types of fire-fighting tools in such regions. Within the administrative Regions of the U.S. Forest Service there is comparative uniformity respecting types of tools, but no great uniformity exists between such Regions. Each individual Region leans to a particular assembly of tools as can be seen in the 5 and 10 man outfits enumerated in Table No. 41. Most of the fire suppression in U.S.A. is still done with dirt, and there is little general use of water excepting for "mop-up" purposes. In the Southern States, with comparatively level topography, and light ground fuels, water can be easily transported in large quantities for use in direct attack on fires. In the Rocky Mountain Regions, difficulties of access and rough topography limit the use of water to portable types of pumps, and most reliance is placed on axes, shovels, saws, and several types of axe mattock, for clearing fire lines in the indirect attacks usually made on fires. In Eastern coniferous and mixed forests the use of rakes, with hand (knapsack) pumps, axes and shovels etc. is mainly relied upon. The most common types of hand tools used throughout U.S.A. are as follows, (all cutting tools being fitted with sheaths, for transport but not during winter storage):-

(a) Axes - $3\frac{1}{2}$ lbs. - double bitted - Western pattern.
(b) Shovels - Long handled (detachable handles for use in small packs) or D. handled.
(c) Axe-mattock - types of tool such as the Pulaski, or Kock.
(d) Saws-crosscut - $4\frac{1}{2}$ or $5\frac{1}{2}$ feet long (for felling snags) - Old fire hose used as sheath. Swedish bow saws are now coming into great favour for smaller sized material.
(e) Lamps - Electric Torches and/or Petrol (Coleman) or Kerosene lanterns, and spare batteries bulbs, mantles etc.
(f) Knapsack pumps with 5 gallon metal or canvas containers - for direct attack or "mopping up".
(g) Felling wedges - $1\frac{1}{2}$ or 4 lbs. each (5 to 10 lbs. each on the Pacific Coast).
(h) Felling hammer - steel - 4 lbs head.

(Photo by U.S. Forest Service).

Using knapsack spray pump on "mopping-up" - note specially curved and shaped type of knapsack container.

(i) Files - 8" - 10" or 12" for use with axes or saws.
(j) First aid kits - including dressings for burns, smoke injury to eyes, cuts etc.
(k) Rakes - using either replaceable V cutting blades from mowing machines (Rich Tool), or heavy tines (Council rakes), or a double edged flat blade.
(l) Mattocks - 3-4 lbs., for digging.
(m) Buckets - or canteens, holding 1 gallon or 6 quarts etc.
(n) Hand sharpening stones for axes etc.
(o) Water bags - 2 to 2½ gallon canvas type.
(p) Milk cans or 5 gallon "fish panniers" for carting drinking water.
(q) Brush hooks - short type of sickle blade.
(r) Hoes - D. type flat hoe.
(s) Peavy or Cant Hook.
(t) Telephone repair kits, including 2 portable field phones, 3 miles of spare wire etc. for connecting the fire camp to the nearest telephone circuit.

Notes on special types of hand tools and equipment.

(a) Axe Mattock types - The most important of these is the Pulaski Tool, a lightweight (3¾ lbs.) axe-mattock, well balanced to allow effective cutting with either blade.

(b) Rakes - A commonly used rake is the Asphalt type 16" long with 10 tines, the end of the rake being connected to the wooden handle by a square steel shank 10 inches long, and a steel ferrule and rivet. The McLeod tool is a combined rake and hoe for heavy duty work. It comprises a flat steel blade to which a steel ferrule is welded in the centre to take a four foot wooden handle. One edge of the blade is sharpened for cutting grass, roots etc. while the other edge is used to form six stout prongs. Both edges are approximately ten inches long. The Kortick Tool is practically the same as the McLeod, and has a demountable blade which is not generally favoured for rough usage. The Rich Tool consists of 4 V shaped mowing machine teeth riveted to a piece of one inch angle iron which in turn is welded to an "eye" suitable for an ordinary hoe handle. This tool has been found very suitable for chopping and raking in light brush, grass and duff. The cutting teeth are replaceable if broken or worn.

(c) Knapsack Pumps were first evolved in canvas material, which is still quite popular for ease in packing etc. but is gradually losing ground in favour of the more durable five gallon containers of metal construction.

(d) Lanterns, lamps etc. - Powerful electric torches, using dry cells, are used to a great extent, especially for small tool kits - spare batteries being wrapped individually to prevent leakage. Coleman type petrol lanterns give lights suitable for three to five men working together, while "forced draught" kerosene lanterns are also in use, but are not so highly thought of. For larger concentrations of men "Carbic Flare" lamps (Marshall-Wells Company, Spokane, Washington) are used. They are said to produce 8,000 candle power at a cost of 5 cents, per hour. A fully charged, "2 burner" light costs approx. $80, and burns for 12 hours without refilling, single "burner" lamps cost approx. $55 and burn for 6 hours. Refuelling is by "carbic cakes" weighing 2·5 lbs. each - a drum of 40 cakes (107lbs.) costing approximately $9.

Propane torch being used in hazard burning along railroad right of way - Olustee Section-Florida National Forest - Florida.

Showing rapid lighting achieved with Propane Torch - Olustee Section - Florida National Forest, Florida.

Owing to the amount of suppression work done at night repeated efforts have been made to evolve a better lighting system for fire fighters. One development reported (103) is the use of an old car headlight, and 6 volt - 25 watt globe, with a 6 volt 13 plate storage battery, the light being mounted on a metal (collapsible) tripod with 44 inch legs. The battery and its wooden case weigh 40 lbs., and the light and tripod an additional 9 pounds. A fully charged battery is said to provide a diffused beam of light, a distance of 300 feet, for a total period of 21 hours. For camp or other use, a string of 5 lamps can be used for a period of 9 hours on a charged battery, or a car or truck can be used, with engine running, to generate light indefinitely.

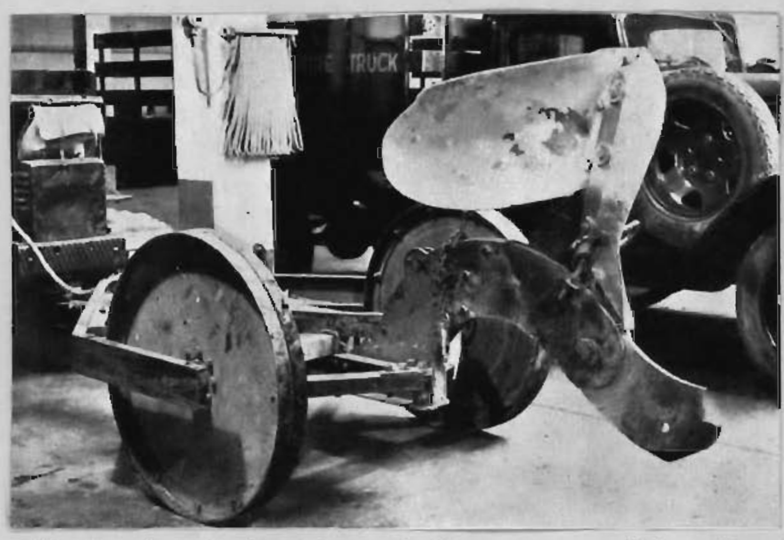
Such lights are useful on large fires and their use will probably be more generally developed. Not only can firefighters see where they are working (and walking), but wisps of smoke can be detected in smouldering ground fuels which would otherwise be indistinguishable.

Efforts to evolve a one-man electric lantern suitable for use by any employee while working have at least been partially solved with a new type of electric headlight. It comprises an elastic headband to which is fastened a light weight headlamp and bright reflector. This headlamp is connected to a brass battery case, which clips on to the employee's belt, and which holds two pairs of flashlight batteries and a spare light bulb. The top of the battery case is fitted with a "compound" switch which provides a circuit between either pair of batteries and the headlamp. By alternating the load on each pair of batteries, through the switch, the operator is provided with a three foot beam of light at a distance of five feet, for a continuous period up to seven hours. The weight of the entire unit is 13 ounces, and the batteries can be renewed at any time.

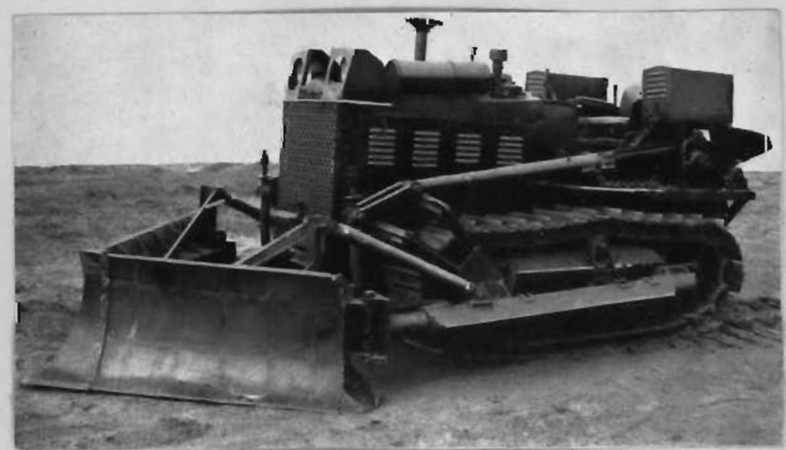
Other emergency lights used include the 75,000 to 80,000 candle power magnesium flares used (with special reflectors) for emergency night landings of aircraft engaged on scouting, transportation etc. at large fires. Two flares, which burn for several minutes, are used for each landing, and are stored at aerodromes ready for use.

(e) Backfiring equipment has been developed in various forms, but no completely satisfactory type of pressure torch has yet been evolved to enable the rapid firing of lengths of fire line established, or firebreaks, roads etc., used for fire suppression. Petrol or kerosene burning pressure torches (Hauck type) using a blow lamp type of burner, and hand pump, from a back pack of 1·5 to two gallons of fuel have not proved highly successful after extended trials, owing to frequent clogging of the "generator". A new type of flame thrower using knapsack pumps and tanks, and kerosene, diesel oil etc. as fuel, has been more successful, especially in damp conditions (53), but it is generally considered too dangerous to use owing to difficulty in preventing leakages of fuel. Small "fusees" or special compounds of inflammable materials, in a compact and and light form, and self igniting, provide a hot flame for approximately ten minutes and are used in many localities. Their great advantage is their very portable nature and efforts are now being made to have longer burning fusees made.

The most successful torch yet devised is the Propane or Butane Torch which is becoming popular in most Regions. The



(Photo by U.S. Forest Service - Fire Equipment Handbook.)
Fire Line Trencher used with tractor in fire suppression - Pacific North-West Region - U.S. Forest Service.



(Photo by U.S. Forest Service - Fire Equipment Handbook).
"Brush Buster" equipment fitted to medium sized tractor for use on fire line construction. - Pacific North West Region - U.S. Forest Service.

Propane or Butane used as fuel is in liquid (compressed) form, and is stored, under pressure in large cylinders of 45 or 90 pounds capacity. When released it is highly inflammable above a temperature of 40° Fahr. Care is necessary in handling the liquid during filling etc. of the torch owing to its blistering effect. One filling of a torch is usually sufficient for about four hours burning - a strong and hot flame being provided for that period. This torch is easily the most suitable type for backfiring under damp or cold conditions as at night. Owing to the inflammable nature of the fuel it was thought to be too dangerous for general use, but ordinary care is sufficient in handling both the tool and the small cylinder of gas (9½ lbs. weight) carried by the operator.

In some districts the old type of J shaped pipe kerosene "torch", with cotton wick, is still used under good burning conditions, but no replacements are made of this type.

For rapid backfiring on a large scale under unfavourable conditions the Californian Region is developing a portable power-driven flame thrower unit weighing approximately 70 lbs. and costing approximately $100. It can be carried along fire-lines and trails by two men, or can be loaded on a truck for roadside work. The unit is powered by a ¾ H.P. "Wisconsin". Air cooled engine and a small geared pump, and is operated by diesel fuel oil. In the same Region, a knapsack flame thrower operating under pressure from an interior cylinder pressure pump, and trigger release nozzle, is also being developed.

(iii) Types of power operated tools.

(a) Plough Units are important for fire suppression purposes in many forest areas. As trenching to mineral soil is the main activity in suppression work in U.S.A., ploughs that will assist in, or complete trenching operations, may do the work of up to 10 or 50 men respectively. In many Western forests several ploughs with suitable horses are always on hand to assist suppression crews, both horses and plough being transported as near as possible to any outbreak in special types of hired trucks or trailers. In some cases co-operating settlers arrange to provide horses at the fire line. The use of ploughs is advocated when more than 50 men are engaged on a fire in topography fuels etc. suitable for the working of ploughs. Especially popular are the lighter types of reversible hill-side plough such as the McCormick-Deering No. 209 or the Oliver No. 155, which weigh approximately 130 lbs. each, and assist fire line construction by breaking the sod. Each of these ploughs is readily collapsible for pack transport in inaccessible country.

For completing fire lines under more favourable working conditions, tractor drawn ploughs such as the Killifer No. 77 are often used, after both plough and tractor have reached the fire by motor truck. A special type of tractor-drawn plough developed in the Pacific North West Region (5) has a double mouldboard to turn the sods in alternate directions, so producing a "gutter" type of fireline. Much lighter than the Killifer type, this plough can be easily handled by a 35 H.P. tractor in difficult country. When not ploughing, the two mouldboards are raised clear of the ground, and the plough can then be drawn along on its two wheels. In Southern Forests, where heavy herbaceous ground cover is encountered during construction or maintenance,

(Photo by U.S. Forest Service).
Special two-disc fire line plough used on
Florida National Forest - Florida.

TABLE NO. 41.

Showing distribution of tools in assembled units for fire suppression in various Regions.

ITEM	5 MAN KIT			10 MAN KIT				25 MAN KITS		
	Region No.1 (For Back Packs)	Region No.2	Region No.4	Region No.1 (For Back Packs)	Region No.2	Region No.4	Suggested for General Use	Region No.1	Region No.4	Region No.6
Axes - double bitted - 3½ lbs (sheathed)	1	1	-	2	3	2	3	11	2	12
Bags - 2 gal (Water)	1	1	3	2	1	5	5	-	10	6
" - 5 " (Knapsack type)	1	-	-	2	1	1	1	4	2	6
Buckets - tin or canvas 6 quart	1	-	-	2	-	-	3	-	-	-
Canvas for packing	5 pcs.	-	-	10 pcs.	-	-	-	4 pcs	-	-
Compass - box pocket	1	-	-	1	-	-	-	-	-	-
Cups - tin - drinking	5	-	-	10	-	-	-	-	-	-
Canteen - 1 quart	1	2	-	2	3	-	-	4	-	-
1 gallon	-	2	-	-	2	-	-	-	-	2
Electric Torches	2	-	5	4	-	10	24	12	25	4
" spare batteries	12	-	10	24	-	20	48	-	50	-
" " bulbs	-	-	5	-	-	10	24	-	25	-
Files, 8", 10", or 12"	2	1	2	4	2	2	6	-	6	20
First Aid Kits	1	1	2	2	1	4	1	1	4	1
Fusees (for backfiring)	-	-	6	-	-	6	6	-	12	-
Kerosene lanterns	-	1	-	-	1	-	4	-	-	4
" supply - 1 gal.	-	1	-	-	1	-	4	-	-	4
Maps	1	-	-	2	-	-	-			
Mattocks - digging	-	1	-	-	2	-	-	-	-	-
Muslin -12' x 4' (markers for aeroplanes)	-	-	-	-	-	1	-	-	1	-
Pulaski Tools (sheathed)	3	-	3	6	1	5	7	16	12	-
Pumps for Knapsacks	1	-	-	2	-	-	1	4	1	2
Pack Frames	5	-	5	10	-	9	2	1	25	-
Rations - 1 Man day	7	-	5	14	-	10	20	-	25	-
Saws - 4½' long - Sheathed and handled.	1	-	-	2	-	-	-	-	-	-
Saws - 5½' long - Sheathed and handled.	-	1	-	-	1	1	1	4	1	3
Shovels	3	4	3	6	8	5	5	16	10	12
Saw - gauge and filing outfit								1	-	1
Spoons (dessert)	5	-	-	10	-	-	-	-	-	-
Stones - axe sharpening	1	-	1	2	-	1	1	-	2	8
Timebooks etc.	-	1	1	-	1	1	1	1	1	1
Towels and cakes of soap	-	-	5	-	-	10	-	-	25	-
Wedges - 2½lbs. felling	1	-	-	2	-	-	2	-	2	6
Radio or Portable Telephone								-	1	-
Grindstone								1	-	1
Pliers - pairs								1	-	-
Torch for backfiring								1	-	-
Wrench (adjustable)								1	-	1
Hammers - 2½ or 4 lb.	-	-	-	-	-	-	1			
" 4lb. or 8 lb.								4	-	3
Cant Hook								1	-	-
Padlock								-	-	1
Cobbler's Outfit								-	-	1
Hoes								-	-	12
Petrol Lanterns	-	-	-	-	-	-	2	-	-	1

(255)

(Photo by U.S. Forest Service).

Special "Brush Buster" Tractor for fire line construction mounted for transport on tipping-type semi-trailer truck - Pacific North West Region - U.S. Forest Service.

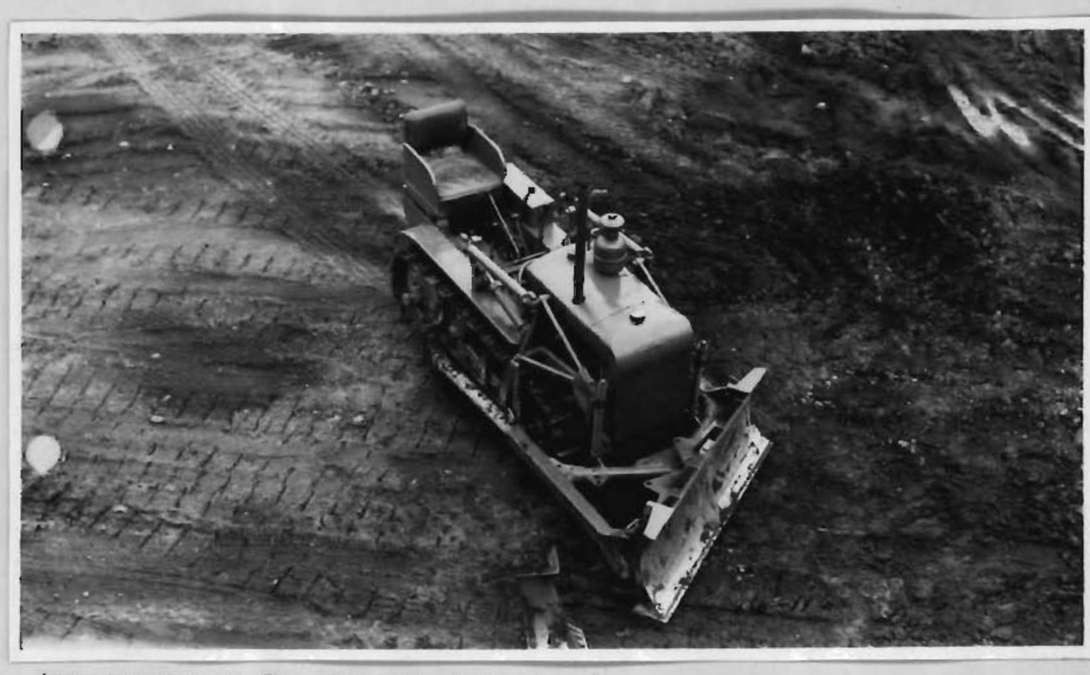
of firelines, a heavy "Hester" Plough using 3 or 5 large discs, makes an initial cut of 3 or 6 feet (according to the number of discs used), or an effective ploughed line of 5 or 10 feet. As the weight of this plough is stated (114) to be approximately 2500 lbs., it requires a powerful tractor for effective working. A smaller type of Hester plough, also used in Southern Regions, weighs only 1100 lbs. and is thus more adapted for general use. The Florida State Forestry Department has developed (186) an even more massive type of disc plough which weighs 3600 lbs and ploughs out a fireline 6 feet wide and 8 inches deep when drawn by a suitable (50 H.P.) tractor. A light type of 6 disc plough known as the "Athens", and drawn by two horses, is also used in light ground cover in the Southern Region. The Michigan State Forest Service has developed a strong type of mouldboard plough, weighing about 600 lbs., which cuts a fireline approximately 40 inches wide behind a 20-30 H.P. tractor. In the Lake States Region, a stump jump type of plough swivel-mounted in front of a heavy tractor, and known as the "Mesaba" plough, has proved very useful. In open grass types of the Central Rocky Mountain Region it has even been found possible to use a specially light man-drawn plough in gently undulating topography. From the above notes it will be seen that there is little effort at standardisation of ploughs - each Region endeavouring to evolve the lightest type of machine that will provide a satisfactory fire line in the ground cover peculiar to that Region.

(b) Trailbuilder Tractors - Tractors by themselves were first used in fire-line construction some 15 years ago when they hauled logs or crude scrapers along cleared strips to form rough lines in the mineral soil. As noted by Hanson (73), new types of powerful trailbuilders and bulldozen tractors will construct fire lines at a quarter of the cost of hand work, including costs of tractor hire etc., and the tractor firelines will be much more efficient in their construction. These machines are capable of working up and down slopes not exceeding 35 per cent and are extremely mobile, provided their transport to going fires can be arranged. They are now widely used in most Regions of U.S.A. and arrangements are made for their ready transport on large motor trucks of the semi-trailer type. In some cases, the trailer tilts on to the ground at one end so as to allow the tractor to climb on to the platform. They are all the more useful when equipped as "brush busters" - that is when the front blade is either fixed or adjusted into a V shape, so as to throw debris to each side of the constructed line. The heaviest types of caterpillar-tread tractor are usually favoured, and one has only to see one of these machines forming a line in heavy logging debris to realise their capabilities. In actual use, a heavy machine may be used to "bust" a line while another smaller bulldozer follows, in tandem, to scrape this line to mineral soil.

The increasing use of bulldozer tractors in fire line construction at outbreaks of fire can best be gauged from the experience of Region No. 5 (California) during the 1939 season. In that season, tractors of this type constructed some 200 miles of fireline, or 25 per cent of all fireline constructed at fires within the Region. During conditions of severe hazard, fire control officers know the location of all such machines working in and around their forest and are able to utilise the nearest machines at short notice, if necessary by means of prior agreement regarding hire etc.

(Photo by U.S. Forest Service).

"Bosworth Trencher" constructing fire line showing use by two men (one hauling) - Nicolet National Forest - Wisconsin.



(Photo by U.S. Forest Service).

Special miniature tractor constructed by U.S. Forest Service for trail construction and maintenance - convertible blade shown in angle-dozer position - Portland - Oregon.

(Photo by U.S. Forest Service).

Special miniature trail tractor with convertible blade in "brush-buster" position. Portland - Oregon.

(Photo by U.S. Forest Service).

Rear View of Miniature Trail Tractor - showing limited width of machine (36 inches) and special built-in water pump at rear - Portland - Oregon.

(Photo by U.S. Forest Service).

Showing Miniature Trail Tractor engaged in Trail Construction - Pacific North West Region - U.S. Forest Service.

The Pacific North West Region has developed in its own workshops a baby bulldozer suitable for the construction and maintenance of foot or animal trails, up to 42" wide, and which can be used for fire line construction or for hauling equipment, tools, supplies etc., along such trails in country otherwise inaccessible to mechanical units. It is also equipped with a power driven water pump for fire-fighting.

Apart from their assistance to suppression crews in the snigging of logs or heavy debris from firelines, pushing down sangs, stumps, and impeding trees, hauling water etc. in steep topography, opening trails for trucks etc., tractors are now becoming even more useful with the fitting to them, of large water tanks over their engines. Power pumps connected to such tanks enable tractors to make even direct attacks on fires.

(c) Bosworth Trencher - This is a "home-made" type of miniature rotary hoe constructed from miscellaneous parts to provide a machine weighing less than 100 lbs. which can be used to form a clean fire line. The framework of tubular steel, leaning on a single frontwheel, supports an air cooled 4 H.P. outboard motor which is used (with a strong "fan" belt drive) to drive a multi-tined rotating wheel. The tines rotate by centrifugal action and not by direct or rigid drive, this factor being most important as the tines are likely to strike stones etc. when baring a fireline to mineral soil. Such fireline must first be cleared and grubbed, after which the Bosworth Trencher is propelled along the line - one man pulling the machine with a rope while another supports it by two handles so that the rotating tines are kept in contact with the soil over uneven surfaces.

The main difficulty to date with this machine has been the use of a high speed lightweight motor for a fluctuating load - the engine being thus subject to racing, overheating etc. Efforts at improving the machine are mainly directed towards the use of a more suitable engine therein. Provided a line is suitably cleared, two men can clean a narrow fireline (to 12" wide) at normal walking speeds.

(d) Rowland Trencher - This is a new commercial product on the same principle as the Bosworth - supported by two wheels instead of by the single frontwheel of the Bosworth. It has yet to be extensively tried on line construction.

(e) Power Saws. Owing to the large number of burning or "snag" trees to be felled along or near firelines - fire control officers in Western Regions have been handicapped in their progress with hand tools. Power driven chain saws of a properly designed type, and weighing 85 lbs., have the great advantage of being readily portable and equally suitable for felling and cross-cutting.

Several working improvements such as narrower kerfs, better balanced engines, a "foolproof" oiling system for an engine working at all angles from the vertical, have been made to a proprietary design of Power Saw. The recent use of rakers on the cutting blade has effected even more improvement in its working.

(f) Power grinders - for grinding axes, mattocks, shovels, brush hooks, Pulaski and other tools, are used on large fires where more than 50 men are engaged with tools. They consist of three grinding wheels mounted on a suitable frame, driven by means of a V type link belt, and a 1 H.P. air cooled petrol engine. The total boxed weight of the unit is only 225 lbs.

(Photo by U.S. Forest Service).

Utility Truck and Trailer used for transport of Portable Pump (in box in truck) and 1500 ft. of hose (carried in trailer) - Sawtooth National Forest - Idaho.

(Photos by U.S. Forest Service).
Marsh Buggy - 4 wheel drive Marmon Harrington Ford developed for use as tank truck (Tank 425 gallons). Florida National Forest.

(Photo U.S. Forest Service).

Marmon Harrington 4 Wheel Drive on "Cab-over Engine" 2 ton Ford Chassis, - developed as Tank Truck of 425 gal. capacity - Florida National Forest.

B. Equipment.

(1) Motor Transport - Transport actively used on fire protection duty includes:-

(a) Government cars - These are used by U.S. Forest Service officers during the course of their administrative duties and are always kept in readiness for fire duty, assisting also in general transportation plans following fire outbreaks. Forest Service cars used by fire control officers are usually equipped with radio, and also with sirens for facilitating their rapid movement in traffic. If extra cars owned by the Administration are available, they are usually allotted to temporary "fireguards" who are mostly patrolling road routes, or to lookout-firemen likely to need cars to any great extent.

(b) Private cars - as owned by temporary employees such as fireguards, lookout-firemen etc. are used when necessary by these employees. Provided the vehicles are kept in a safe condition, in sound mechanical order, and are ready for any emergency, agreements are entered into with the employees for the use of their cars at locally fixed mileage rates. Similar arrangements for hire of cars etc. may be made with voluntary co-operators, fire wardens etc., who use their vehicles in suppressing fires, or in calling reinforcements etc.

(c) Rented or hired cars - where Government vehicles are not available, and temporary employees do not possess cars, any urgent requirement for a car is met by renting suitable types from used or hire car firms, or from private persons, subject to written terms and agreements respecting their use at certain hire rates.

(d) Other Government cars - not usually engaged on fire control, but on other work such as land acquisition, survey etc. for the Forest Service, are requisitioned, by previous agreement, in times of emergency such as severe outbreaks of fire.

(e) Forest Service Trucks - are usually of two types:-
1. Utility Trucks - or "Pick Ups" of 10 to 15 cwt. capacity, are used on most National Forests where a sufficient road system operates, for distribution of fire tools and equipment, telephone maintenance, or for any emergency fire duty. They may in some cases be fitted with small power pumps for using water on fires along or near roads.
2. Heavy Trucks - Efforts are made to equip all accessible Ranger districts on National Forests with at least one heavier type of truck, of 35 cwt. to 2 tons capacity. This vehicle is used as a general purpose truck, but its main use is in fire protection, and during fire weather all such vehicles are at defined stations fully serviced, and fully loaded. Fire equipment carried on these trucks usually includes prepared tool outfits for 10 to 25 men, power pumps and 2,000 feet of pump hose, tarpaulin, mess kits, one emergency meal ration, two portable telephones and emergency wire (or radio equipment or both). All the above items are specially packed for truck transport, while a "10 man" or larger crew is assigned for travel with the truck. In some cases special "fire-bodies" designed to house all necessary fire equipment are used to replace standard bodies during the fire season. A novel type of heavy truck is used in the Southern Region, a Ford Truck Chassis being fitted with oversize tyres and wheels and a special Four Wheel Drive. It can negotiate swampy and sandy country with ease and is therefore known as the "Marsh Buggy". A modified trailer type plough may be drawn by the "Buggy" to construct fire lines.

"Iron Horse" used to transport firefighters on mountain trails - U.S. Forest Service. Northern Rocky Mountain Region.

(Photo by Ruth Ambrose - Courtesy U.S. Forest Service).

Train of pack mules en route to large fire. Special U.S. Forest Service "float" of recent design in front of other vehicles - Northern Rocky Mountain Region.

(f) Trucks owned by other Government agencies which are located in or near forest areas during fire seasons, are usually available for immediate requisition, with or without men and equipment etc., depending on agreements previously reached, and subject to inter-departmental re-imbursements.

(g) C.C.C. camps etc. - The great majority of the large number of trucks operated by the Federal and State Forest Services are located at C.C.C. camps in and around forest areas. At each Camp there may be up to eight or nine Forest Service Trucks, and three or four Army trucks. As there may be up to three or four C.C.C. camps located on a single National Forest there is usually ample truck transport available on these areas. At the Camps, Army Trucks usually arrange for transport of food supplies, mess equipment etc., while trucks owned or hired by the Forest Services usually attend to the conveyance of men, tools and equipment. On trucks operated by C.C.C. trainees the speed governors usually fitted are rarely removed even during periods of severe hazard.

(h) Hired trucks - All forest officers are instructed to estimate their peak transport requirements for any fire season, and to enter into pre-season contracts for the hire of any vehicles necessary to complete transportation plans. A condition of all such agreements is that vehicles are to be ready for action within an absolute minimum (stated) period of time, and that operators of trucks "assume all ordinary risks."

(i) Tractors may be used and hired, with or without such equipment as ploughs, trail builder, "brush-buster" attachments, etc. where Government machines are not available and where the use of such machines offers an opportunity to speed or improve fire suppression effort (as already described).

(ii) Animal Transport.

Pre-season arrangements are made, in the more mountainous regions, for the contract hire of necessary saddle and pack-horses at such times as they may be required during the fire season. Special rates of hire are paid for any stock so used. Horses may also be furnished, to a limited extent, by co-operating settlers or ranchers as part of their voluntary agreements with Forest Services. Temporary employees on guard duty, who are paid for the regular use of their horses, are required to have these animals saddled, ready for instant use, when serious fire conditions force them to "stand-by" for instructions.

In Region No. I a special Remount Depot is located in a central position and is used to distribute both pack and saddle horses, to large outbreaks of fire, by means of railroads, Service owned or hired horse floats etc. Stock are only distributed to those Forests where suitable local arrangements cannot be made for use or hire of horses.

The stock maintained at the Remount Depot is used on other duties in forest areas outside the fire season, so that pack horses, especially, will not be intractable when required for emergency use at fires.

Mules are used to some extent to replace pack horses, particularly when the latter are not available on suitable terms. They are most sure footed on narrow trails, but are always liable to display their innate stubbornness.

(Photo - U.S. Forest Service).

Old type - Tank Truck developed in Southern Region equipped with 325 gal. tank, Hercules 6A Pump and power take-off. Note heavy front bumper bar and excessive "overhang" at rear. - Choctawatchee National Forest - Florida.

(Photo - U.S. Forest Service).

Close up of Choctawatchee National Forest Tank Truck showing outside tap for filling (canvas) knapsack sprays - barrel used to carry drinking water etc.

(Photo - U.S. Forest Service).

Rear view of Choctawatchee National Forest Tank Truck showing live reel, shut-off type of nozzle used on hose. - Florida.

(Photo U.S. Forest Service).

Choctawatchee National Forest Tank Truck at fire, using water on direct suppression - Florida.

(iii) Other means of transport.

This heading includes many different forms of transport, including the use of aircraft in all forms of transport (labour forces, tools, supplies etc.) the conveyance of heavy bull-dozers or other heavy tractors on tipping or rigid "semi-trailers", as already mentioned.

Free use is also made of trailers for the transport of one or two horses, such trailers being equipped with a single axle, balloon tyres, and specially designed bodies, which give the animals smooth riding and good protection from wind, dust, gravel, etc. In the Northern Rocky Mountain Region, specially constructed horse floats are used by the U.S. Forest Service for the rapid transport to fires of saddle and pack horses, mules etc. In the same Region a special type of power driven scooter known as the "Iron Horse" has been designed and constructed for the purpose of transporting a lookout fireman or other forest employee along narrow foot or animal trails in rough topography. The speed of the machine is limited to three or four miles per hour, but this speed is not greatly curtailed when carrying a fully equipped fire fighter along a trail having a gradient of up to 35 per cent. Use of the machine is thus much faster than ordinary walking up such gradients, while the rider retains his energy for suppression work. The "Iron Horse" weighs only 145 pounds, and costs approximately $170·00. Although it is an interesting and useful development for mountain trails, the machine has yet to be thoroughly tested by general use.

(iv) Water Using Equipment.

Despite constant efforts made to improve methods of fire suppression in U.S.A., the free use of water in fire fighting is by no means general. The bulk of the water delivered to fire-lines is used not in attacking fires, but in "mop-up" work. While the development of water using equipment has been quite recent, material progress has already been made. The rapidity of such progress almost prevents any adequate portrayal of the types of equipment developed, difficulty also being experienced because of the wide variation in equipment used in different Regions.

The principal types of water equipment to be briefly discussed hereunder are Tank Trucks of various capacity and design, Hose and other equipment, and Portable Pumpers.

(a) Tank Trucks.

Since the construction of roading systems in forest areas, the use of special trucks for the transport of water to fires, and for pumping water on to the outbreaks, has been rapidly developed. Such development has been most marked in the Californian Region, where high risks and extreme hazards make early control of fires imperative. The progress made in the Californian Region can best be gauged from the fact that during the 1939 fire season in that Region, "tankers" were used successfully on 25 per cent of all fire outbreaks within the Region. In meeting criticism that tank trucks are valueless for fires not accessible from roads, Californian foresters point out the experience of the Angeles National Forest during the same season, when 93 per cent of all outbreaks occurred within 300 feet of roads in the forest. In Southern California, in particular, the extreme need for safe-

(Photo by U.S. Forest Service).

Showing mounting of small water pump (for fan belt drive) on utility trucks using water for fire suppression. - Southern Region - U.S.A.

Utility truck used on fire suppression equipped with power take-off and Hercules type pump. Driver operating hose from his position in cab - Olustee Section - Florida National Forest - Florida.

guarding watersheds, and the value of forests for recreation purposes, has forced foresters to utilise modern tank trucks. The protection problem in parts of Southern California is rendered still more acute because of the infiltration of residential development to forest areas.

Any fire fighting organisation which has to rely on the use of tank trucks (instead of unrestricted access to water mains) for the suppression of structural or vegetation fires must necessarily be most efficient in the application of a restricted volume of water to a large fire. For this reason, the organisation perfected by the Los Angeles County Forester to protect an extremely hazardous type of brush forest, and also a good deal of valuable building development, is worthy of particular study. While much of the success of the Los Angeles County authorities is due to efficiency of organisation, the design of suitable equipment such as tank trucks is a material factor.

Utility Trucks ("Picks Ups") are scarcely suitable as "tanker" equipment although commonly used with pumps and small water tanks for speedy initial attack by patrols, smoke-chasers etc. Both 10 cwt. and 15 cwt. chassis are used, springs being usually strengthened to meet the increased weight of water, tools, etc. It is admitted by forest engineers, however, that the inertia effect of a water load in a moving vehicle is a severe strain on any lightweight chassis. Water tanks fitted to these trucks are either 60 or 80 gallons in size (occasionally up to 100 gallons), and are rectangular in shape, a good size for a 60 gallon tank being 58" long, 20" wide and 12" deep. The best location for such tanks is across the tray immediately behind the cab. Tanks are constructed of suitable (e.g. 14 gauge) galvanised iron or light sheet steel, and are adequately baffled against water surge. In many utility trucks small water pumps are bolted to the cylinder head of the engine, and are driven through an auxiliary pulley by a lengthened V type fan belt. The most suitable lightweight pumps for an assembly of this nature are the "Edwards" (Model 20) or the "Panama".

Despite the free use of this type of pump equipment, it is stated (186) that fan belt driven pumps give relatively poor performance for the following main reasons:-

1. Their capacity and pressure range requires several horse power of the engine load to yield maximum performance. While a pressure regulator is installed in the pumps to obviate their overloading, operators usually alter this adjustment to attempt greater performance, and thus wear out fan belts in very short time.
2. The fan and generator of any petrol engine are in themselves a load of several horse power, so that the extra load imposed by the pump is quite appreciable. Apart from additional strain on the engine, the load is really too much for any fan belt.
3. Changes in engine design and mountings which occur between various models of any single make of truck, make it difficult to standardise mounting of the pumps on cylinder heads.

It is generally considered that the Panama or Edwards Pumps would be much more efficient if mounted directly under the cab of a utility truck in which position they could be driven directly from a power take off, by means of a heavy V belt. This would enable the pumps to operate at low engine speeds, thus obviating the present necessity for speeding up a 40-80 H.P. engine to carry a pump load of from 5 to 10 horse power.

(Photo - courtesy Los Angeles County Forestry Department.

Utility Truck equipped with small water tank, power driven pump etc., used by patrols for initial fire suppression - Los Angeles County Forestry Department.

(Photo - courtesy Los Angeles County Forestry Department).

Utility Truck used for initial fire suppression by Los Angeles County Forestry Department. Rear view showing rectangular water tank (behind cab) - live hose reel, tools, tool box etc.

A fan belt drive Edwards Model 20 Pump mounted on a Fargo 14 cwt. Utility Truck for the use of the British Columbia Forest Service (Canada) pumps water from a 75 gallon tank, (or from a roadside stream), at a pressure up to 100 pounds per square inch. Once this pressure is exceeded (as in the case of kinked hose or shutting off the nozzle) a relief valve opens and returns water to the tank. The best results obtained from the outfit are with the use of 100 feet of $\frac{5}{8}$" rubber garden hose, on a "live" reel, at a working pressure of 70 lbs; the tank lasting 13 minutes under such conditions. Fairly good results are also obtained from the use of 500 feet of $1\frac{1}{2}$" linen hose with a nozzle less than $\frac{3}{8}$" in size.

When power take off pumps are used on utility trucks, one of the most popular pumps for the purpose is the Hercules 3A Roller Type. It is of course necessary for the truck to have a four forward speed transmission before a power take-off can be used on the gear box housing. The usual type of such take-off is the Spicer Standard (or Spicer Model 821 XX - Ratio 1·0 to 1·68), connected to pump (located either in front of or behind the cab), by a one inch diameter shaft and two Spicer universal joints. Utility trucks of this type operated by the Los Angeles County Forester carry tanks of from 75 to 100 gallons capacity, with rotary gear type pumps capable of delivering up to 30 gallons per minute through 200 feet of one inch diameter rubber hose mounted on a live reel. A heavier (Hercules 6A) type of pump operated with a 60 gallon tank on the Chippewa National Forest (Region No. 9) is stated (210) to develop up to 300 lbs. working pressure, and can operate at pump speeds up to 1200 R.P.M. Delivery can be made through 400 feet of $\frac{5}{8}$" rubber garden hose and/or 600 feet of $1\frac{1}{2}$" linen hose, using a standard screw type nozzle on the garden hose, or a $\frac{1}{4}$" tip nozzle on the linen hose. By using the garden hose at 25 lbs. working pressure the 60 gallon tank can be utilised for more than 15 minutes, this period being reduced to 10 minutes if the linen hose (and $\frac{1}{4}$" nozzle) is used at a working pressure of 50 lbs. per square inch.

Although classed as a 15 cwt. (International) Utility Truck - the Chippewa vehicle has the following weights:-

Weight of truck unladen	- 3760 lbs.
" " " plus all equipment	- 5549 "
" " " " " " and 4 men	- 6149 "
Maximum gross limit for chassis	- 6377 lbs.

Medium Sized Trucks.

Many types and models of such trucks have been evolved in various Regions to carry tanks of from 100 to 300 gallons capacity, and to use pumps of various types driven by power take-offs. During recent years most trucks of this nature have been designed to carry a water load of approximately 300 gallons, while the Hercules 6A Roller Type pump has been most generally used. Recent designs have also endeavoured to preserve a satisfactory power-weight ratio by limiting the "payload" of the vehicle to a figure well within the capacity of the chassis.

Experience in operating trucks on average forest roads has indicated the necessity for limiting the wheel base, and also the "overhang" at the rear of the vehicles. For the latter reasons, designers have welcomed the recent manufacture of "cab over engine" types of $1\frac{1}{2}$ to 2 Ton trucks in the low price field. Fitted with dual rear wheels, these chassis also have very little rear "overhang". A modern tank truck has recently been designed and constructed on this type of chassis by

(Photo by U.S. Forest Service).
1940 Model Tank Truck (290 gals. capacity) on 2 Ton "Cab-over Engine" type of chassis. Note well balanced load on 134" wheel base - flush panel bodywork - California Region - U.S. Forest Service.

engineers of the California Region, and will probably be placed in general use by the U.S. Forest Service. Particular attention has been given to the lowering of the centre of gravity in the superstructure, and this, combined with the short (134") wheelbase of the vehicle, should greatly improve the road-holding capacity of the trucks.

Some details of the construction of this truck will be summarised hereunder:-

Tank of 290 gallons capacity, having a flat rectangular shape 102" long, 44" wide and 15" deep, specially designed to fit close to the chassis in the centre of the vehicle. Construction is of 16 gauge galvanised "sheet metal", and the tank is mounted on a rigid 5 Ply base board one inch thick. By using a series of two-way baffles the tank is divided into twelve compartments, of equal size, to minimise surge.

Power take off of a heavy duty type is connected to the pump, through a needle point universal joint, by a special type of slip joint drive shaft. Standard types of power take off are designed mainly for the carrying of heavy loads at low speeds, but by using "filler blocks", direct transmission of power from the gear box has been "stepped up" to obviate speeding of the engine to obtain a satisfactory pump speed.

Pump - a Two stage Centrifugal Byron-Jackson pump having a greater capacity than the Hercules 6A Roller Type, and fitted for 1½" delivery pipes, is used. An electric primer, controlled by a dashboard pump, is fitted to the pump, together with a hand operated type of primer.

Hose - Both one inch diameter high pressure rubber hose (1500 feet), and standard 1½" diameter linen hose, are carried on the truck. The rubber hose is loosely coiled in a centre "hose basket" above the water tank while the linen hose is housed in two smaller "baskets" on each side of the tank. Pipe rollers are fitted around the tops of each basket to assist in the withdrawal of the hose.

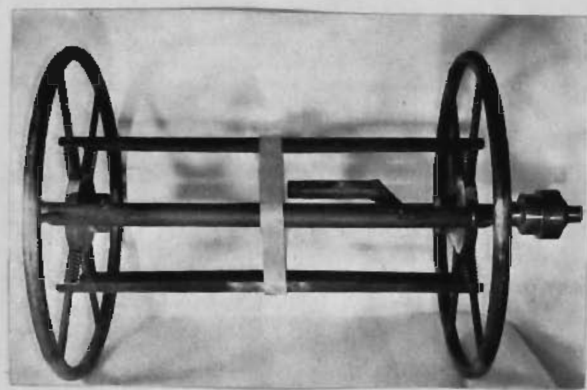
Crew-Two men are carried in the driving seat, with four more on a transverse seat immediately behind the cab. Apart from hose and pumping equipment, the truck carries a full kit of fire fighting tools for the six men concerned - also two knapsack sprays attached to the rear of the vehicle.

The gross (laden) weight of the truck is 11,000 lbs. which approaches the limit for a chassis of this capacity. While no performance data are available for the truck, its construction has embodied many improvements necessary to previous models, so that performance should be reliable.

Large Size Trucks.

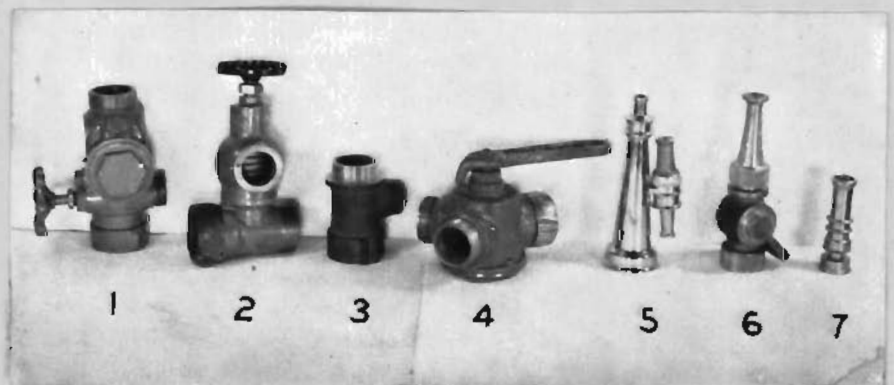
The use of tank trucks larger in capacity than 300 gallons is confined to State and County Forest Fire Departments - notably those in Western Regions. A brief summary will be given here of types of such trucks now placed in use by various Departments:-

Los Angeles County Forestry Department - This Department has pioneered the use of heavier types of tank truck equipment. As described by Davis (36), the latest types of such equipment are of 600 and 2500 gallons capacity. The former is built on a chassis of 180" wheel base with a V 12 cylinder, 185Brake Horse Power engine. The unladen weight of the truck is 13,700 lbs. and the weight when fully equipped is 20,685 lbs. With a full



(Photo by U.S. Forest Service).

Showing type of live hose reel used by U.S. Forest Service on fire trucks.



(Photo by U.S. Forest Service).

Showing nozzles, valves etc. used on hoses with portable pumpers, tank trucks etc., by U.S. Forest Service - (1) Swinging check and bleeder valve, (2) Pressure-relief check valve (3) 1½ "T coupling with 1" take-off (4) Siamese control valve (5) Screw tip nozzle with extra tip carriers (6) one inch shut-off nozzle with tip (7) garden-hose nozzle.

load, the truck can attain a speed of 50 to 60 miles per hour, or can negotiate a 30 per cent grade, with comparative ease. It is fitted with a two stage centrifugal pump-an auxiliary rotary gear type pump being also fitted to continue discharge of water when the truck is moving. Hose equipment includes two reels, each carrying 300 feet of one inch rubber lined linen hose, with a further 400 feet of this hose and 1000 feet of $1\frac{1}{2}$" hose of similar type. The 2500 gallon truck is built on a heavier chassis, with a 240 B.H.P. engine, 227 inch wheelbase, tandem rear wheels, air brakes etc. The vehicle has a weight of 28,000 lbs. unladen and 52,000 lbs. when laden and equipped. It carries a four stage centrifugal pump (with a maximum capacity of 900 gallons per minute), and 1000 feet of $2\frac{1}{2}$ inch, 1400 feet of $1\frac{1}{2}$ inch, and 200 feet of one inch fire hose, together with special "fog" nozzles for economy in water consumption.

Oregon State Department of Forestry - As described by Ferguson (46), the Oregon Truck is constructed on a 3 Ton G.M.C. Chassis of 160" wheelbase. The chassis is equipped with dual transmission (10 forward speeds and 2 in reverse), hydraulic booster brakes, and dual rear wheels. The body is built around a tank of 525 gallons capacity which is placed immediately behind the cab, and resting directly on the chassis, so as to lower the centre of gravity. An Edwards gear type pump (which can be used with saltwater) is driven by a power take off situated just behind and below the cab, and operated from a clutch control in the cab. The pump unit operates from a 2 inch intake, and supplies two $1\frac{1}{2}$ inch delivery outlets, one located at the pump and the other at the rear of the truck. The maximum capacity of the pump is 140 gallons per minute, delivered either from the tank or from a roadside water supply. The truck contains a number of lockers and boxes for housing fire tools and equipment, including 2500 feet of hose and two portable power pumping units (weighing 70 lbs. each). If necessary, these portable pumpers can be used to fill the tank truck from a water supply some distance from the roadside. It is stated that the truck carries hand tools, and other equipment, for the use of 50 fire-fighters.

Californian State Department of Forestry - This Department uses quite a variety of vehicles - the most modern and massive of which is a semi-trailer type of 2500 gallons capacity with very detailed equipment, including an electric generating plant to supply the truck, and to light powerful searchlight equipment.

Special Equipment for use on Tank Trucks.

Power Take Off.

As outlined by Funke (54), standard types of power take off on a truck transmission are not altogether suitable for use with water pumps. They are designed to take heavy loads at a low speed e.g. truck hoists. The use of low-powered water pumps with standard take-offs, meant that the engine had to turn at speeds $1\frac{1}{2}$ to 2 times as great, to give a satisfactory pump speed on a direct drive. In this way the truck engine would be developing 30 to 40 H.P. to actuate a pump with a load of not more than 5 H.P. - an unsatisfactory procedure from the viewpoint of economy and operation. By arrangement with pump manufacturers, standard take-offs have been fitted with suitable "pillow blocks" to provide approximately double the pump speed for a given transmission drive.

(Photo by U.S. Forest Service).

Showing tank truck being tested with both hoses - loose canvas hose at front of truck and rubber hose on live reel at rear - Wasatch National Forest - Utah.

This special take-off is a heavy duty type, with ball bearing mountings, connected by a standard drive shaft of the slip joint type, and by two oil tight universal joints, to the water pump. For standard makes of truck, the special type of take-off gave the following ratios:-

MAKE OF TRUCK	ENGINE SPEED	POWER TAKE-OFF SPEED
Ford	800 R.P.M.	1130 R.P.M.
	900 "	1275 "
	1000 "	1415 "
Chevrolet	800 "	945 "
	900 "	1050 "
	1000 "	1170 "

Auxiliary Cooling System.

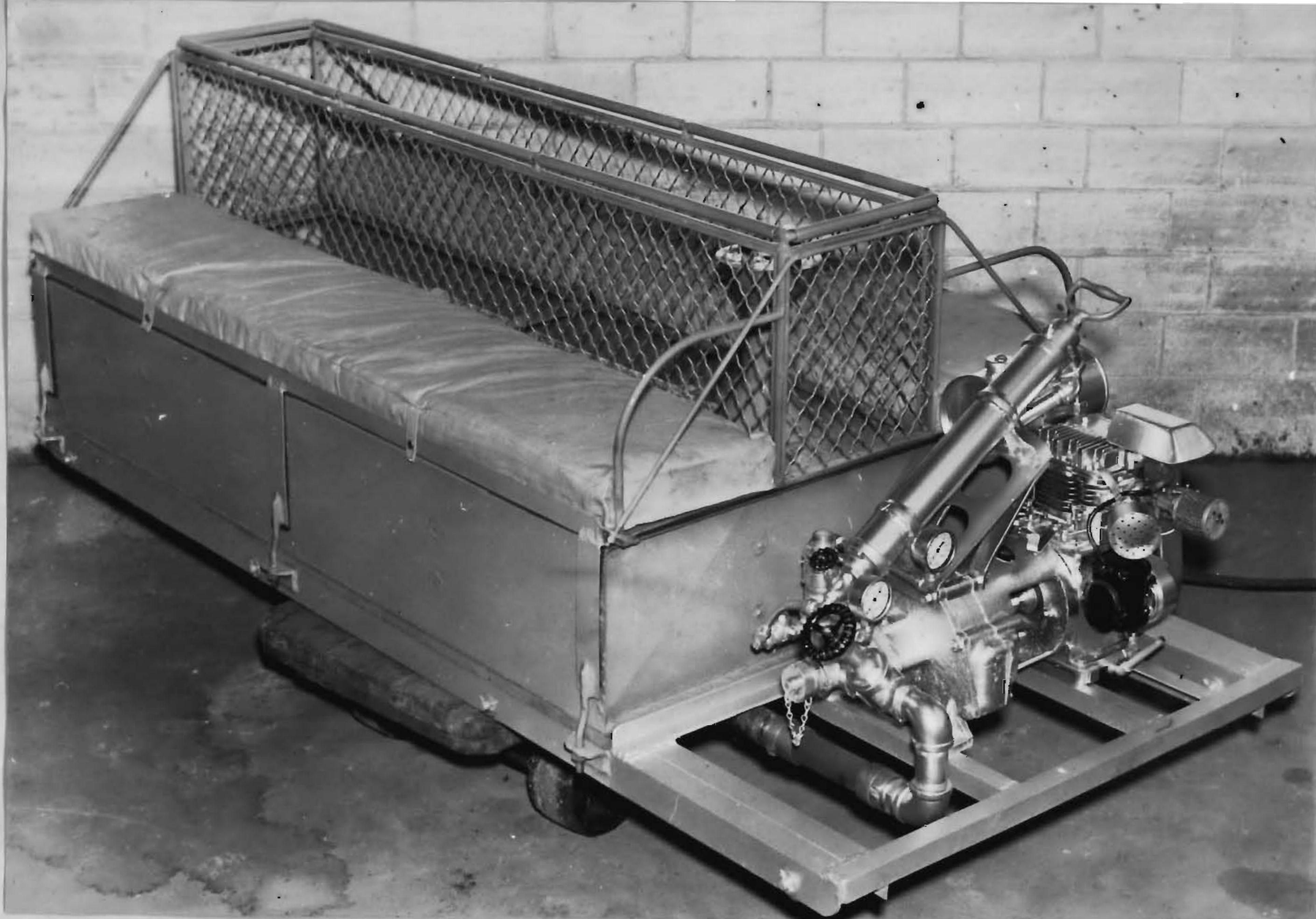
As explained by Oakes (143), an auxiliary cooling system is necessary to prevent overheating of tank truck engines when travelling to fires, or when pumping water on to an outbreak. The method described supplements the engine cooling system by the circulation of water from the truck storage tank, through the cylinder head and radiator of the engine, and the return of such water to the tank by means of a standard type of 6 Volt electric fuel pump. This pump is bolted to the dashboard inside the bonnet at a point low enough for water to reach it by gravitation from the storage tank, through $\frac{3}{8}$" copper tubing. The pump is controlled by a push button switch on the dashboard of the cab, connected to the ordinary wiring system of the engine. Flexible metal tubing connects the pump outlet to the drain plug of the radiator, with a ball bearing check valve between the end of the tubing and the drain cock, to prevent water draining from the radiator to an empty storage tank. Copper tubing ($\frac{3}{8}$") connects the radiator overflow to the storage tank. As standard types of fuel pump are not designed to pump water, the flat steel valve springs of the pumps must be replaced by coiled brass (or flat brass) valve springs. Costing only about $15 to instal, the pump is capable of delivering 15 gallons of water per hour to the radiator.

In the California Region, auxiliary radiator supplies are furnished to the latest types of tank truck by circulating water through a pump mounted in front of the engine, and driven by a crankshaft extension.

In other Regions various auxiliary cooling systems are used, including one method whereby the ordinary fuel pump of the engine is used to circulate water, while the petrol feed is maintained through a vacuum tank installation.

Hose.

Perhaps the most suitable hose for use on tank trucks is a single jacket cotton rubber-lined hose one inch in diameter. The great advantage of the rubber lining is the decrease in frictional resistance, but this type of hose is much heavier and has greater bulk than ordinary linen hose. After use it must be carefully dried before being stored in a cool, dry, and airy location. Linen hose, either single or double cotton jacket, and from $1\frac{1}{2}$ to $2\frac{1}{2}$ inches in diameter, is also



(Photo by U.S. Forest Service).
Special modern type of "Slip-on" Tanker Unit, mounted on angle iron frame, for use on ordinary trucks - California Region - U.S. Forest Service.

used freely. A mildew-proof or "Pactolized" type of linen hose is also used, but must be carefully dried and stored to obviate detioration.

On smaller tank trucks, a "Live Hose Reel" is of great value in allowing the use of pumped water without removing the hose from the reel. Such reels are specially constructed to operate at high pump pressures, and may carry from 100 to 500 feet of high pressure delivery hose. The reel is fitted with tight packing glands and spring cushioned cross bars on which the hose is rolled. This spring-cushioning allows for the hose expansion to be taken up by the cross bars as water passes through the reeled hose.

Nozzles.

Much research has been carried out in endeavours to evolve suitable nozzles suitable for the efficient but careful use of water. Perhaps the most advanced nozzle is the fog producing type, which is stated (36) to increase the efficiency of water twenty five times over. Shut off types of nozzle, used in conjunction with Siamese couplings and gate valves on the hose line, permit of great savings in water use, the hose line operator shutting off the water supply at the nozzle while water is returned to the storage tank. The diameter of nozzle tips varies considerably from $\frac{1}{8}$ to $\frac{1}{2}$ inch, but in most cases minimum sizes only are used on fire outbreaks.

(b) "Slip-on" Tank Equipment.

Such equipment includes a variety of tanks which are slipped on to trucks of ordinary body types. In some cases they are merely used as an auxiliary to tank truck supplies, or are operated in conjunction with a portable power pump, also on the truck, to assist in fire suppression. Owing to the high cost of tankers, engineers have attempted to design efficient "slip on" pumper units which could be easily moved on to any standard truck. Such a unit allows a truck to be used for general forest work throughout the year, and then adapted for suppression work during the fire season. The most modern unit of this nature has been recently evolved in the Californian Region by U.S. Forest Service engineers.

It comprises a flat rectangular type of tank 84" long, 46" wide and 12" deep of 195 gallons capacity, and constructed of 18 gauge galvanised "medium steel" with all joints riveted and soldered. Two way baffles divide the tank into twelve divisions of equal capacity, while it is mounted on a waterproofed plywood base board half an inch thick, and a reinforced $1\frac{1}{2}$ inch angle iron frame. The iron frame is carried on eight solid steel castors, four inches in diameter with plain pin bearings. Above the centre of the tank is a "hose basket", with wire mesh sides and an open top. The rods forming the top of the hose basket are covered with pipe rollers to facilitate the withdrawal of hose from the basket. The space on each side of the hose basket is used to form seats for fire fighters.

Another tank used, which does not provide this seat space, is of 238 gallons capacity, and measures 72" deep, 42" wide and 17" deep.

Securely fastened to the angle iron frame of the tank assembly is a neatly designed pump unit, including a two stage

(Photo by K.D. Swan - Courtesy U.S. Forest Service).

Power Pumper in use to pump water to fire outbreak from large stream - Northern Rocky Mountain Region.

(Photo by U.S. Forest Service).

Water from Power Pumper being used in "mopping-up" on large fire - Intermountain Region - U.S. Forest Service.

centrifugal pump - directly connected to a 4 H.P. Model A.K. "Wisconsin" single cylinder air cooled petrol engine. The pump is primed by a Bilge Type Hand Pump, while the engine is started with a rope starter.

(c) Power Pumpers.

These extremely compact lightweight units have been designed for the supply of large supplies of water to forest fires from streams, lakes etc. The aim throughout their design and construction has been to reduce weight as much as possible, so that the units can be transported by "back packing" or even by aircraft parachute. A variety of these pumpers is available for use by foresters, the most commonly used being the "Pacific Marine" Type "V", the "Edwards" Model 85, and the "Paramount Cub". The cost of these units approximates $400, and their average capabilities are from 35 gallons (or more) per minute at 200 lbs. pressure, to 65 gallons per minute at 100 lbs. pressure. In each case the engine is a high speed type with a maximum speed of 4000 R.P.M. or more. In British Columbia a modern type of small unit known as the Paramount Cub is made locally, and shows considerable promise. While power-pumpers usually approximate 70 lbs in weight, the total weight of each unit, equipped with hose, fuel tanks, and other fittings, ranges from 100 to 140 lbs. Up to 2000 feet of $1\frac{1}{2}$" linen hose is used with these pumping units, the nozzles for such hose being fitted with working tips from $\frac{3}{16}$" to $\frac{1}{2}$" in diameter. Without enumerating the various makes of pumper available, some discussion of the various types indicates the variety of pump designs incorporated therein:-

(a) Rotary Gear Type - delivers water at high pressure, against fairly high operating heads, with smooth efficiency. The main disadvantage is that any silt, sand or other sediment in the water used, soon grinds out the rotors of the pump and greatly reduces its efficiency. Its use is thus largely limited to clean water.

(b) Centrifugal Type - these high speed, high pressure pumps are comparable in efficiency to geared rotary types, and do not suffer any serious damage when water contains considerable sediment. The usual disadvatanges of centrifugal type pumps (difficult priming, greater bulk and weight) have recently been overcome in a Canadian built unit which incorporates self-priming, multi-stage type of centrifugal pump, and lightness in weight.

(c) Piston Type - These pumps are simple and dependable mechanically, and have large water capacities. Their main disadvantage is low pressure delivery and greater weight, thus restricting their use to roadsides etc.

The most common makes of pumper used by foresters require the services of an experienced operator, while the machines must be used in strict accordance with the manufacturers' working instructions. Special cards are used to enter up all details of the pump's working.

(v) The use of chemicals.

Many investigations have been made to determine whether chemicals could be used to replace water, or to improve its efficiency, in fire suppression. Chemicals may be theoretically applied to forest fires in a number of forms, such as:-

(a) Liquids - Single constituent liquids (such as undiluted Carbon tetrachloride) or the solution of various chemicals in water.
(b) Gases - such as Carbon dioxide, which are used in chemical extinguishers, and which prevent combustion by replacing the oxygen in the atmosphere with the gas used. On forest fires, or other fires burning in the open, conditions are not the same, as burning fuels can draw on abundant supplies of oxygen from the surrounding atmosphere by means of wind currents, or draughts, despite applications of "blanketing" types of gas.
(c) Solids - of certain kinds exert a smothering effect on fires by liberating gases which retard combustion, by excluding air from fuels in the case of various inert materials, or by effecting a decrease in temperature and/or an increase in humidity of the ground fuels. Typical examples are the bicarbonates (which release Carbon dioxide), and several heat-resistant compounds in dust form.
(d) Foams - owing to a large increase in volume over their original chemical solutions foams, offer theoretical advantages which have been exploited on oil fires, where they exert a blanketing action, and are more effective than water because of their great volume.

In theory, a chemical or a chemical solution is required that will lower the temperature of ground fuels and will prevent loss of moisture therefrom, that will isolate these fuels from oxygen, and will exert a toxic influence on the general growth of all light ground fuels.

The most successful results were first obtained with Calcium chloride in a 25 per cent solution with water, when applied either before, or during, an outbreak of fire. This solution exerted a definitely retarding effect, except when applied to the edge of a fire under conditions of high temperature and low humidity. If applied early in the fire season as a potential retardant; it was found that the advent of heavy rain might largely eliminate any permanent effects of the application. Slightly weaker solutions (20 per cent), of Ammonium sulphate gave slightly better results (221), but this substance costs approximately £40 per ton, as against £25 per ton for Calcium chloride. The application of either of these substances in powder form was of little value.

The U.S. Forests Products Laboratory (183) have made extensive tests on the retardant properties of various chemicals. Laboratory tests showed that Phosphoric Acid or its ammonium salts were twice as effective as pure water, for both extinction of flame and reduction of glow in wooden fuels. Extinction of flame was not important by itself in the still air of the laboratory, but rate of glow extinction was considered important, as, with any high wind velocities, glow is easily converted to flame. Potassium acetate, carbonate, and bicarbonate showed greatest ability to reduce flames, but monoammonium phosphate was superior in its reduction of glow in the wooden fuels used in the laboratory.

In field tests, made with the same chemicals, it was found that the "flame-reduction" types such as Potassium carbonate and bicarbonate were effective, to some extent, only on the lighter ground fuels such as dry grass, loose leaves etc. On the other hand the "glow-extinction" chemicals like Mono-ammonium phosphate were superior on glowing fuels such as twigs etc., and were markedly superior to water on all fuels except rotten wood. The tests made with mono-ammonium sulphate were in concentrations of 2·5 to 10 per cent with water.

Field tests to determine whether pre-application of these chemicals would retard a fire after application of water had evaporated, showed that Phosphoric acid and its ammonium salts were easily the most effective in this respect, and actually stopped small ground fires.

Fire foams were also made from mixing sodium bicarbonate, aluminium sulphate, and a stabiliser or "bubble former" such as extract of liquorice root - and bringing this mixture into contact with water. Such foams are greatly improved if the mixture is "loaded" with a fire retardant chemical like ammonium sulphate before contact with the water, in which case they are estimated to be eight times as effective as ordinary water in forest fire suppression. In the tests made, foams were found to be particularly effective on logs, branches, rotten wood etc., but only if a continuous layer of foam could be applied. Foams lose a great deal of their effectiveness if applied to ground fuels in green slash, bracken, etc., where the foam could not make real contact with inflammable materials.

For all the tests made, it was considered that mono-ammonium phosphate was easily the most practical and promising chemical for forest fire suppression, but the use of this or any other chemical was not considered worth while in cases where abundant water supplies were available. In cases where such water supplies were meagre or uncertain, as is often the case during prolonged conditions of severe hazard, it was thought that the use of the most suitable chemicals might make all the difference between success and failure of <u>initial</u> attack on fires.

In a summary (192) of extensive field tests made with mono-ammonium phosphate, it is pointed out that such tests are as yet inconclusive, but further experiments are warranted. An important objection to the use of this particular chemical was its corrosive effect on tanks, containers etc. For this reason it could not be used in a ready-mixed solution, and the period of four to five minutes required to mix a solution on arrival at a fire was thus a dangerous delay. In some cases sodium dichromate has been added to mixed solutions in order to minimise corrosion in containers.

Any determination of the most suitable type of chemical is not the whole story, as the superiority of any given chemical and/or its solution in water, is not a constant but varies with:-

(a) The rate of application, in relation to the size and severity of the fire.
(b) Prevailing wind velocity.
(c) The nature and arrangement of ground fuels.

Dependent on the conditions prevailing, the amount of chemical solution required may range from approximately the same amount of water, to only a small fraction of the amount of water required to extinguish a fire.

C. <u>Supplies</u>.

(i) <u>Food Supplies</u>.

The use of men on large scale fires demands that they be in the best physical condition, and forest officers usually undertake the feeding of all men employed on suppression duties. This is true of all fires handled by the U.S. Forest Service, food being supplied either as emergency rations or in cooked form wherever possible. In the case of C.C.C. enrollees, however, practically all commissariat arrangements at forest fires are in the hands of the Army authorities who control these camps.

Employees or officers of the Forest Service carry one day's emergency rations, in compact form, while travelling or patrolling on forest areas during times of hazard. As an example the one-man day ration used in the Pacific North West Region contains the following (tinned) goods:- 12 oz. Roast Beef, 2 oz. Coffee, 5½ oz. Corn Beef Hash, 8 oz. Grape Fruit, 3½ oz. Cheese, 1 lb. Brown bread (also tinned), 9 oz. Baked Beans, 8 Cubes Sugar plus a nail and piece of wire for improvising a coffee pot out of one of the tins. The arrangements made for the supply of rations to suppression crews vary between different administrative Regions, but in each case it is the responsibility of the local officer to make catering arrangements that will function in any emergency. Where suppression crews are called out urgently to fires, they are issued with standard prepared lunches, which are suitable for use at any time during a single season. They may be also (or alternatively) issued with similar foods prepared as rations for one or more days.

Subsequent arrangements vary to a great extent as regards the source of supplies for feeding established camps or working gangs of fire fighters. These supplies may be obtained, at the shortest possible notice, by lodging orders with local storekeepers for certain lists of goods for varying numbers of fire fighters. In such cases the storekeeper has been furnished with ration lists before the fire season commences, and undertakes to have all goods ready, so as to complete the list required within a space of minutes after receiving any order. Those storekeepers closest to forest areas who have the required stocks of necessary foods are selected when pre-season arrangements are made.

In other Regions a certain proportion of imperishable and/or packaged goods is kept available for instant use, and local arrangements made for the necessary supply of large orders in the event of major outbreaks occurring. In cases where local purchases are effected, none are actually made in those centres where any individual or group is suspected of incendiary action.

In cases where large suppression crews are proceeding to fires without any issue of prepared rations, telephonic arrangements are made for them to be suitably fed at any suitable refreshment room etc. which they may be passing en route to the fire, to save time at the fire when they actually arrive there.

In the case of large scale supplies, where cooks are appointed to provide an abundance of appetising food to fire fighters, fresh vegetables, fruit, meat, bread etc. are used as far as possible commensurate with transport facilities and the source of such supplies.

On the other hand, suppression crews being fed at fires in Rocky Mountain regions are usually supplied from carefully prepared lists and "packs" of food, designed to provide a "balanced ration" with an absolute minimum of weight. This course has been necessary owing to the large amount of transport by pack-animals, or by the men themselves, inseparable from fires in comparatively inaccessible areas. These ration lists of goods may even provide sufficient supplies to be back packed for distances up to, or exceeding, 5 miles, and sufficient to feed 25 men for as long as five days, (see Table No. 42). For initial supplies to firefighters, there are standard packs of rations for a number of days for gangs of, say ten men, (see Table No. 43). Supplies of these specially selected foods are more expensive owing to handling and packing costs, and special recipes are issued (199) and (201) in "Fire Camp or Lookout" Cook Books to utilise them to the best advantage. In Region No. I, special boxed lunches for 30 men are kept on hand for use at any time during the season, while other specially prepared packs include:-

(a) One man rations for 30, 45, 60, 75, 100 and 120 days (for use by one to three men on fires).
(b) One day rations in single units for each man (as quoted above).
(c) Air delivery units - 30 men's rations for one day, in four specially prepared packages.

Preparation of these special "packs" of food is done at the two warehouses in Region No. I, small units such as boxed one-man lunches, or supplies of one day rations, being distributed before the season commences, other "packs" being distributed by rail, truck or aircraft as required in emergency. Arrangements are also made to supply the adjoining Region No. IV with similar supplies.

Officers are instructed to use ordinary local supplies and sources of food as far as transport conditions will allow, owing to the greater cost of the prepared packs. In Region No. I, it is generally thought desirable to arrange for guards, and other employees engaged for the duration of the season, to be fed at ranger stations, or other centres, where their duties permit such a course of action. If stationed by themselves and away from their homes, it is also thought desirable for them to be supplied with the balanced rations, rather than provide their own food. A charge is of course made for all meals or rations supplied in this manner.

The making up of individual lunches is strongly advocated in the case of men going to, or working on, fires. In this way, men do not gather together in a single position at a fire, but eat their lunches without moving from their individual section of the fire line.

(ii) Camping Materials.

Cooking utensils, and all other items necessary for the maintenance of large numbers of men at fires, usually form an integral part of tool assemblies. In this way, the despatch of large gangs of men to any individual fire means that automatic provision is made for those men to remain at the fire for an indefinite period once tents, mattresses etc. are furnished from the nearest warehouse.

For instance, the Fire Camp Outfits used for a 25 Man Crew in the North West Regions comprise these four carefully packed packages:-

T A B L E N O. 42.

Fire Crew Ration Lists - used in the Intermountain Region (Region No. 4) - U. S. Forest Service.

ARTICLE	UNIT	FOR PACKING MORE THAN 5 MILES						ALONG ROADS, OR LESS THAN A 5 MILE PACK					
		THREE DAYS			FIVE DAYS			THREE DAYS			FIVE DAYS		
		5 MEN	10 MEN	25 MEN	5 MEN	10 MEN	25 MEN	5 MEN	10 MEN	25 MEN	5 MEN	10 MEN	25 MEN
Meat - Fresh	lbs.	-	-	-	-	-	-	-	60	150	50	100	250
Ham Cured	"	-	10	25	-	16	40	-	12	30	-	20	50
" Canned	"	12	12	25	20	20	40	16	16	30	24	24	50
Bacon	"	4	8	21	7	14	30	5	10	25	8	16	40
Eggs	Dozen	6	15	30	10	20	45	6	15	30	10	20	45
Bread	lbs.	12	24	60	20	40	100	14	27	45	24	48	120
Biscuits (Crackers)	"	8	16	40	13	25	65	8	16	40	13	25	65
Flour	"	12	24	60	20	40	98	12	24	60	20	40	98
Yeast with Flour	Yeast foam	1	1	2	1	2	3	1	1	2	1	2	3
Baking Powder	lbs.	½	1	1	½	½	2	½	1	1	½	1	2
Lard (used with bacon grease)	"	1	2	5	2	4	10	1	2	5	2	4	10
Sugar	"	6	12	30	10	20	50	6	12	30	10	20	50
Cane Syrup	Quart	1	2	3	1	3	5	1	2	3	2	4	10
Ground Coffee	lbs.	3	6	15	5	10	20	4	8	16	6	12	24
Tea	"	¼	¼	½	¼	½	1	¼	½	1	½	½	1
Cocoa	"	½	1	2	½	1	2	½	1	2½	½	1	2½
Milk	Cans	10	20	48	20	36	72	12	24	60	20	40	72
Butter	lbs.	2	4	10	3	6	15	3	6	15	5	10	25
Beans (dried)	"	3	6	15	5	10	25	3	6	15	5	10	25
Cheese (American)	"	2	4	10	4	8	20	2	4	10	4	8	20
Rice	"	-	3	6	3	6	12	-	3	6	-	6	12
Potatoes	"	8	15	37	12	25	62	15	30	75	25	50	100
Onions (dry)	"	1	2	5	2	4	10	2	3	8	2	5	12
Macaroni	"	-	2½	5	2½	5	10	-	2½	5	2½	5	10
Pancake Flour	"	5	10	-	10	10	-	5	10	-	5	10	-
Cereals, Oatmeal etc.	"	3	6	15	9	9	18	4	9	18	9	9	18
Jam	No.2 Tins	3	6	12	4	8	24	3	6	12	4	8	24
Vegetables canned (Corn, Peas, Carrots, Spinach etc.)	"	9	18	36	12	24	48	6	12	24	8	16	36
Fresh Vegetables	lbs.	-	-	-	3	5	12	3	6	12	5	10	25
Flour	"	-	9	18	-	18	27	-	9	18	-	18	27

Fresh or cured meat is used e.g. If 75 per cent of fresh meat shown is used, then 25 per cent of cured meat will be needed.

TABLE NO. 43.

10 Man Fire Crew Ration List used in Central Rocky Mountain Region, Region No. 2 - U.S. Forest Service.

ARTICLE	UNIT	DAYS 1	2	3	4	5
Fresh Meat (Instead of canned or cured meat)	lbs.	20	40	60	80	100
Canned or Cured meat (instead of fresh meat)	"	12	24	36	44	52
Fresh Meat (Used with canned and cured meat)	"	10	20	30	40	50
Canned or Cured meat (Used with fresh meat)	"	6	12	18	22	26
Eggs	dozen	2	4	6	8	10
Bread	lb. loaves	9	18	27	36	45
Crackers (Biscuits)	lbs.	6	12	18	24	30
Flour	"	8	16	24	32	40
Baking powder (if flour is used)	"	½	½	1	1	1
Lard	"	1	2	3	4	5
Sugar	"	4	8	12	16	20
Syrup	quarts	1	1	2	2	3
Coffee	lbs.	2	4	6	8	10
Tea	"	½	1	1	1½	1½
Tinned Milk	large tins	3	6	9	12	15
Butter	lbs.	1	2	3	4	5
Dried Fruits	"	2	2	3	3	3
Canned "	quarts	3	6	9	12	15
Rice	lbs.	2	4	6	8	10
Beans	"	3	6	9	12	15
Potatoes	"	10	20	30	40	50
Onions	"	1	2	3	4	5
Tomatoes, canned	large cans	3	6	9	12	15
Macaroni	lbs.	1	2	3	4	5
Cheese (American)	"	2	4	6	8	10
Erbwurst or Bologna	"	½	½	1	1	1¼
Pickles	Quarts	½	1	1	1½	1½
Salt	lbs.	1	1	1	2	2
Pepper	oz.	2	2	4	4	4
Cinnamon	"	2	2	2	2	2
Laundry Soap	Bars	1	2	3	4	4
Matches	Boxes	2	2	3	4	4
Paper Bags (for lunches)	Number	12	24	36	48	60

Mess Boiler (and cooking utensils)	-	weighing	116 lbs.
Mess Box (cooking and eating)	-	"	60 lbs.
Headlights and Miscellaneous Took Box	-	"	142 lbs.
Tool bundle (camp tools)	-	"	136 lbs.

All packages (and equipment therein) used for camp outfits are specially designed so that no useless or weighty materials or utensils are transported. Cooking utensils are designed to fit together, and to pack smaller items, for instance a large mess boiler of square shape carries quite a variety of equipment to a fire. Where special "packs" are prepared for air delivery, back-packing etc., such items as plates, cups, spoons etc. are of compisition paper, and these are discarded after being once used.

All metal utensils are carefully cleaned and stored during the winter period, the larger Regional warehouses having special facilities for washing in caustic soda. During storage, these metal utensils are coated with a colorless and tasteless mineral oil, which prevents rust development, and yet allows use of the utensil at a later date without washing.

Large fire camps are laid out according to prepared designs, with the dual object of preventing confusion and of providing the greatest possible comfort for employees. Such camps are under the special care of "Camp Bosses", who supervise cooking, supply and delivery of tools, supply and equipment, and sanitation etc.

Men suitable as camp cooks are employed on other protection duty, or are requisitioned locally as the occasion arises, in accordance with pre-season arrangements. Despite the fact that fire camps are located in forest areas, wood burning stoves for camp use are not popular, as they are heavy to transport and require the employment of valuable labour for wood-cutting. Special lightweight stoves burning either fuel oil, or natural (Petroleum) gas, are used instead.

The provision of camp lighting by means of flares, electric headlights (from storage batteries), petrol lanterns, is also provided for, as camp activity, including cooking, is usually continued throughout the night.

Tents are used only on large fires, or where climatic conditions at high elevation make them necessary. Special types of light kapok ground mattresses are freely used, these being carefully stored, with blankets etc., during winter months.

At larger fires in many Regions, a variety of goods required by firefighters is kept on hand and supplied to men at cost price, the value of such goods obtained by any employee being deducted from his pay. Among the items, stocked are tobacco, cigarettes, socks, gloves, laces, nails or soles for boots, shirts, trousers, etc.

CHAPTER XII.

P E R S O N N E L.

Careful organisation of Detection, Transportation, Communications, Supply of Tools and Equipment is so much wasted effort unless associated with considered plans for the selection and placing of adequate suppression forces, and for all necessary reinforcements of labour, under any conceivable conditions of fire hazard. It has already been explained that it would be quite impossible, from many standpoints, to maintain throughout the year, or even throughout the fire season, the large labour forces necessary at times of most serious emergency. With so much thought given to the need for a fast and efficient initial attack on all fires, and for intensive activity on fire prevention, it follows that considerable care is necessary in selecting those key members of the protection forces who are retained for the whole of each fire season. Unfortunately, it is rarely possible for forest officers to give these "key" men year long employment on the forest, while their services are usually sought early in the summer, when rural and agricultural activity is at its peak, and all reliable men in any country district are being sought for other occupations. The planning of adequate reinforcements is not so much a selection of suitable men, but is carefully planned staff work on the part of forest officers to make the best use of those available in the locality, or from the nearest available source of labour forces.

Added to the above considerations, is the need for making the greatest possible use of those labour forces employed by other agencies in or near forest areas, utilisation of volunteer or available assistance from landowners, or other co-operators, and of the man power employed by forest permittees, which is at the disposal of forest officers in an emergency.

A. Forest Officers - U.S. Forest Service.

(i) Supervisors - who are in charge of each National Forest. An extremely heavy responsibility rests on the shoulders of these men during times of severe hazard, and also at other periods during the year when they are making careful plans for any eventuality. During the greater part of the fire season they are required to be in the field, checking up on all details of preparedness, and on all plans made for emergencies, at the same time closely following the vagaries of weather and hazard conditions, so that no fire will catch their organisations unprepared. During severe conditions, such as prolonged periods of hazard, or extensive fire occurrence, they have the additional task of rallying their forces and of maintaining the morale of all their subordinates. On large fires, the Supervisor is perhaps the only person qualified to direct all action on the job, or to take charge of headquarters organisation as "dispatcher". When one considers that the average size of the unit under the care of a Supervisor is approximately a million acres, it will be understood that his task is no sinecure.

(ii) Assistant Supervisor - may act in such capacity only as a fire executive. He shares the duties, if not the responsibility, of his superior, and his main task is to relieve the latter by taking over office duty while the Supervisor is in the field, or vice versa. He must, above all, be thoroughly conversant with all details of fire control organisation and practice, and have the technical skill and experience to remedy any defect apparent in the organisation. He is actually a "Fire Assistant" to the Supervisor, and on most National Forests there is at least one Fire Control specialist on the staff available for such duty.

(iii) District Rangers - in charge of 200,000 to 300,000 acres of forest. The direct burden of all detailed fire control falls on these officers, owing to the intimate knowledge they are expected to have of their forest area, and of all necessary fire protection plans and action therein. In the event of large fires, the district ranger often takes charge as "fire boss" owing to his local knowledge and experience, unless relieved by a superior officer at times when additional and extensive administrative action is called for. All orders regarding men, supplies, equipment etc., for going fires are issued by him, or require his endorsement. All training of temporary employees, potential suppression crews etc. is his responsibility.

(iv) Acting Ranger - is selected from Forest foremen within a Ranger district, as the man most suitable to relieve, or assist, the Ranger during the fire season. During critical fire situations, the number of qualified and trained forest officers who are thoroughly competent fire executives, is all too few, and Acting Rangers are expected to overcome such deficiency by applying their extensive practical knowledge of the fire problem. They are particularly useful in Rocky Mountain areas, where the summer season is the only time available to District Rangers to carry out field work in connection with their ordinary administrative duties, and they cannot therefore be spared for suppression work.

B. Permanent employees - U.S. Forest Service.

It is not every National Forest that employs permanent employees as classified hereunder, but forest officers always hope for general forestry activity on their particular area to be speeded up, so that a selection of "key" employees can be given all-the-year employment. Only in this way can proved members of the temporary organisation be relied upon for duty each year. Special work is not created, however, to give full time employment to the most desirable men - such permanent work depending on the intensity of forest management, exploitation, planting, or stand improvement work being undertaken on a particular forest, and the degree to which C.C.C. labour is used on all forest work.

In selecting men for permanent employment on any forest, preference is invariably given to the most capable or indispensable members of the fire protection staff. Apart from their proven ability in a general or particular sense, those men having the tact and personality to contact members of the public, and who maintain a pride in their appearance, are given most consideration. They are paid from regular appropriations, as distinct from all emergency employees (paid from the "Fire Fund"), wear a forest officer's badge, and the standard uniform for guards, and are provided with car or animal transport, as their duties require same. The positions usually occupied by such employees are as follows:-

(i) Forest foremen - the most valuable of the proved local employees, who are paid salaries which vary in accordance with their all-round qualifications, and who are capable of assuming charge of any individual phase of prevention or suppression work.

(ii) Foremen - of lesser rank, and rated as Class 1, 2 or 3 foremen on general duties on which they are employed in the forest. They are capable of taking charge of any suppression crew or crews in emergency, with the object of getting the best results, both from the standpoint of achievement and of economics.

(iii) Headquarters Guard who is a qualified lookout-fireman, with special ability in handling administrative details, such as timekeeping, orders for supplies, fire and weather reports and records etc., who can carry on as Acting-Ranger when so required, but who is not usually required to supervise men engaged on protection or other forest work.

(iv) Lookout-firemen - who are most highly regarded in the Rocky Mountain Region, and in that locality have all the responsibility for vital initial attack on fires. They need not necessarily be men of extensive experience in forest work, being chosen for their physical condition and general alertness, capacity for the task allotted to them, and their prospects of achieving higher responsibilities. In some cases, wives of lookout firemen carry on detection work when their husbands are ordered to attend nearby fires. The free use of Lookout-firemen has now spread to many Western Regions, where hundreds of men are employed in this capacity at the height of any particular fire season. In the Pacific North West Region, Lookout-firemen are engaged by the month for the duration of the fire season, and are expected to be on duty continuously during such season. For this continuous work the men are allowed two and a half days leave for each month worked, leave of this nature being taken during any safe period of the season, or at the completion of the season's work.

(v) Labourers - Men are selected from temporary fire protection staffs who are capable of maintaining a good individual output of work, and who show distinct promise as potential foremen. Younger men are often selected, provided they conform to the general standard offering. These men may be required to stand by in camp, or at home, on Sundays or holidays without pay, but if employed on fire suppression on such days are paid for their work.

(vi) Per diem guards - as their name implies they are given employment in emergency, after being duly enrolled in this capacity prior to each fire season. Many of them are either forest permittees, or are employed by such permittees, and they have been proved to possess particular value on areas where conditions do not usually warrant a strong force of regular employees or emergency patrols. Following detailed instructions given them regarding the nature and sphere of their duties, they usually proceed to fires or commence duty either automatically, or following a definite call, when a fire occurs, or when certain hazard conditions exist. In the Inter-Mountain Region of Western U.S.A., serious conditions of hazard are not constant throughout each fire season, so that a large suppression force is not always available. To be prepared for any condition of emergency a strong "skeleton" staff is maintained, together with some 150 per diem guards, and a number of co-operators.

C. Temporary employees, U.S. Forest Service.

Owing to the seasonal nature of the employment offered, it is not easy to obtain suitable men who are willing to accept positions of responsibility for a short term, and who are capable of filling such positions. In some cases it is possible to obtain the services of the same men, of proved worth, for succeeding fire seasons, but provision has usually to be made, each season, for the selection of at least part of the temporary staff required. In the Californian Region, for instance, it is estimated that there is a 30 per cent "turnover" in temporary employees between any two fire seasons. Such selection demands a good deal of care and experience on the part of forest officers. It is possible in some districts to secure suitable seasonal employees from forestry students who have not obtained any regular employment after completing their courses. Even those students are subject to careful selection.

Temporary employees occupying "key" positions are paid from regular appropriations, made annually in accordance with fire plans, from Forest Service funds. When unduly severe conditions necessitate a reinforcement of these temporary employees - the additional men appointed, who can be classed as "Emergency employees" are paid from the "Fire Fund." Only in specially approved cases do temporary employees wear the official badge of the Forest Service, but they are usually provided with a card or letter of authority. As in the case of permanent employees, they are required to furnish themselves with the standard Forest Service Guard uniform. If food supplies are furnished by the Forest Service, the cost of same ($25 or more) is deducted each month from wages paid.

The usual employment of temporary men is as follows:-

(i) Guards or "Patrols" - who are paid according to a locally adopted grading and scale of wages, and are given a variety of duties in times of emergency, although usually concentrated on patrols when fires are absent from the area. They may provide their own horse or car equipment (on a mileage basis), or be supplied with same by the Forest Service.

(ii) Lookouts - are selected for their capacity to endure isolation, from men who are intelligent enough to use instruments, make recordings etc. Only men of good physical condition and tested eyesight are considered for selection, as already discussed in "Detection" plans.

(iii) Lookout firemen - Temporary appointments to these positions are made when the usual number of employees classified as lookout-firemen is not sufficient to cover all requirements during the fire season. The qualifications demanded of these men, are similar to those of regular employees.

D. Emergency employees.

(a) Co-operators - are selected from local settlers, or other residents, for the assistance they may furnish in voluntarily detecting fires, or in proceeding immediately to any fires seen by them. While their detection efforts are not paid for, it is usual to pay these men standard rates for fire-fighting, in accordance with the positions they fill on the latter work. They may be paid for time spent on "fire training" if such training is thought necessary, and if the co-operator is not in a financial position to devote his own time to the training period.

(b) Wardens - in some Regions there are local men living near forests who have outstanding qualities of integrity, leadership, interest and experience in fire protection etc., and who can be depended on to take efficient action in fire suppression in the absence of a forest officer. They are usually empowered to incur expenses on their own initiative for labour, transportation and supplies, and are often selected because of their ability to furnish or organise an effecient local suppression force. They are paid according to the number of hours worked, in accordance with the duties they perform, for example as crew-leaders etc, they are paid more than usual rate fixed for wardens. Like co-operators, they may also be paid for any training considered necessary on fire protection etc. (provided they stipulate payment for such period).

(c) Labour forces present on the forest - and employed either by the Forest Service, any branch of the Federal Government, contractors, or on any construction work for railroads, power lines etc. If these men are called on for service away from their usual occupations, they are paid at standard rates for fire fighting in accordance with pre-season arrangements made for obtaining their services in emergency. Forest Service employees on a monthly basis are not paid at any extra rates, irrespective of the time spent by them on suppression work.

(d) Reserve forces - called for suppression work from towns, industrial plants. Their actual hiring is done by a forest officer, or by an employment agency - men being required to sign contracts that they agree to work under specified conditions. Transportation is provided to and from the scene of the fire, except that men cannot be paid for more than eight hours of travelling time in any one day. Men furnished with transportation meals etc, and not reporting for work, are liable to prosecution for the costs of such transportation, and on charges of fraud. Men are only hired if in good physical condition, suitably dressed, and between the ages of 18 and 50 years. Those men who appear to be either troublemakers or intemperate, and who insist on carrying large bundles of personal belongings, etc., are not accepted. Any men classed as unsuitable, or unsatisfactory, or those quitting the job after their arrival at a fire, are paid off, and are not provided with return transportation to their homes etc., unless they have worked longer than 10-20 days. If they have left the fire, for similar reasons, after working 10 days or more they may be allowed payment for return travel time by ordinary means of travel, but not costs or means of transportation. No local labour is hired in any locality where fires are suspected to have incendiary origin.

(e) Rates of Pay to Suppression Forces.

Regular rates are fixed for each administrative Region (sometimes varying within such Region) prior to each fire season. The rates paid in several of these Regions are illustrated in Table No. 44. Although somewhat variable because of their application to a different fire season for each Region, these rates at least show the scale of remuneration applicable for various suppression duties. Among the various conditions laid down for payment of suppression crews in different Regions, the following may be mentioned:-

1. When subsistence is furnished by the Government - hourly rates of pay are reduced by five cents per hour (up to 12 hours), and daily rates by 50 cents per day.

2. Payment for men hired, on an hourly basis, is based on:-

   (a) Actual number of hours worked under the direction of a forest officer.
   (b) Walking time to and from work, as determined locally, e.g. In the Central Rocky Mountain Region - walking time is based on two miles an hour on roads or trails, and one mile per hour across country. If horses are used the speeds adopted are three, and one and a half miles per hour, respectively.
   (c) A reasonable (locally fixed) allowance to cover travel from point of hire to the fire and return - not more than eight hours per day of such travel being paid for.

3. Transport to and from fires to be furnished by the Forest Service whenever practicable.
4. Employees who are discharged or who leave the fire without approval, are not to receive return transportation if they have worked less than 10 to 20 days (according to Regions).
5. Only in extreme emergencies will crews be allowed to work more than 10 to 12 hours per day.
6. Employees engaged on a daily or monthly basis are not usually allowed overtime. In the Central Rocky Mountain Region, a period of less than eight hours for a daily employee is paid to the nearest quarter day. If daily employees in the same Region are worked for an unduly long daily period, an hourly rate equal to one tenth of their daily rate is used to calculate payment.
7. Employees must settle all disputes about time with the timekeeper or foreman before they accept their timeslip.

E. C.C.C. and other "relief" employees.

(a) C.C.C. enrollees - Although it is realised that C.C.C. forces are inefficient by comparison with other labour sources, the maximum use is made of C.C.C. men before outside labour is hired. Special arrangements are usually made for the selection and training, in each camp, of those C.C.C. enrollees most suitable for fire suppression duty. They are drafted into special units of from 15 to 50 men, and are trained in fire fighting by fire control training officers, and later by experienced officers connected with Camps. Realising that the best of C.C.C. labour is usually inferior in performance to that from other sources, forest officers usually call for additional men from the camps. They are rated in efficiency more or less equal with outside labour hired in emergencies, but only half as effective as the best local men available for regular fire duty. A great deal of C.C.C. efficiency depends on the training given by their Camp crew-leader, and also on the limitations placed on the number of hours enrollees are kept at suppression work without relief.

Selected men from C.C.C. camps may be given fire-season employment with the Forest Service as lookouts, smokechasers etc., when other suitable men are not available.

Special squads of 15 men are organised from smaller units of five men, each of which is capable of independent action. Larger squads, up to 50 men, are usually built up from the numbers of 5 and 15 men units selected and available for fire duty.

If it is thought necessary to organise the remaining members

T A B L E N O. 44.

Showing Rates of Pay to men employed in various capacities for fire suppression duty in various administrative Regions of the U.S. Forest Service.

CLASSIFICATION	NORTHERN ROCKY MOUNTAIN REGION SEASON 1938	CENTRAL ROCKY MOUNTAIN REGION SEASON 1939	LAKE STATES REGION SEASON 1939
Fire Fighters - hired reserve forces	$0·30 per hour	$0·25-$0·30 per hour	$0·20-$0·25 per hour
" " - from labour present on forest	$0·40 " "	" " " "	$0·25 "
" " - temporary "per diem" guards	$0·45 " "	--- -- - --	
Wardens or Co-operators in charge of 1-4 men	-- - --	$0·35-$0·40 per hour	
Temporary Foremen - Class 1.	$5·00 per day	" " " "	$4·16 per day
" " - " 2.	$5·50 " "	$0·40-$0·45 " "	$4·66 " "
" " - " 3.	$6·00 " "	$4·50-$5·00 " day	$5·16 " "
"Camp Boss" - under 50 men in Camp	$5·00 " "	$4·00-$4·50 " "	$4·66 " "
" " more than 50 " " "	$6·00 " "	$5·00-$5·50 " "	--- - -
Time Keeper	$3·00-$4·00 " "	$3·50-$4·00 " "	$4·00 per day
"Packers" - packing supplies for animal or foot transport	$5·00-$5·50 " "	$4·50 " "	$0·40 " hour
Radio Operators	$5·00 " "	$4·00-$4·50 " "	$5·00 " day
Pump " (portable pumpers)	$0·45 " hour	$0·40-$0·45 " hour	$0·40-$0·45 " hour
Ploughmen (or teamsters with plough horses)	" " "	" " " "	$0·35-$0·45 " "
Cooks - camps of less than 25 men	$5·50 " day	$4·00-$4·50 " day	$4·00 " day
" - " " more " 25 "	" " "	$4·50-$5·50 " "	$5·00 " "
Assistant Cooks	$4·50 " "	$3·50-$4·00 " "	$3·00-$3·50 " "
Flunkies (in cookhouse)	$3·00 " "	$3·00-$3·50 " "	$2·50-$3·00 " "
Sawyers (experienced men only)	$0·40 " hour	-- -- - -	$0·25-$0·40 " hour
Tractor Operator - Tractor 25-50 H.P.	S -- - -	-- -- - -	$0·50 " hour
" " - " 50-55 H.P.	-- - -	-- -- - -	$0·55 " "
" " - " + 55 H.P.	-- - -	-- -- - -	$0·60 " "

of any camp for fire duty, they are formed into units of 3, rather than the above units of 5 for men with better qualifications, the purpose of smaller units being to exercise greater supervision over their activities.

The men selected as smokechasers, special squads, reserve squads etc., may be called out for such fire duty at any hour of the day or night, in accordance with pre-season arrangements made with the Army authorities controlling each Camp.

As Camp authorities are still responsible for providing meals or temporary camps for C.C.C. men employed at fires, those men are kept together as far as practicable, and are not mixed more than necessary with other labour. They are not worked in shifts longer than eight hours, or for periods longer than five days, without relief, unless immediate relief is temporarily impossible. After any period of employment on fire suppression, all C.C.C. labour is required to rest for a "recuperation period" equivalent to that spent at the fire.

If C.C.C. employees are required to stand by for possible duty during severe conditions of hazard, opportunity is sometimes taken to spend such time in training the employees in elementary methods of suppression.

By arrangement with Camp authorities, all details concerning supply of rations, equipment, proper clothing etc. to suppression crews, are finalised so that no delays are caused when calls are made.

(b) Employees under E.R.A. (Emergency Relief Administration). These men are often available in or near forest areas, but are not always up to the physical standard required of fire-fighters. Theoretically their services can be arranged for, at any time, on fire suppression work. If used on this work, they are usually paid from Forest Service "Fire Funds" for time spent by them on such work in excess of the monthly allocation of time for which they are ordinarily required to work on their particular "jobs". If it is found that such payments for excess time lead to incendiary acts, their ordinary working time in the ensuing month is reduced by the amount of time spent on fire fighting.

When engaged for fires, they are usually put on the same conditions of work and payment as ordinary outside labour hired in emergencies.

Unlike C.C.C. employees, they can not be required to "stand-by" in camps after their regular hours or days of work, although volunteers may be accepted for such "stand-by" duty without payment except when called to fires.

It is difficult to obtain competent labour among this class of employee, and only those men who conform to general requirements of physique and ability are usually called out for suppression duty.

(c) Employees under W.P.A. (Works Progress Administration) who are employed either in camps, or from their homes, are paid entirely by the Forest Service for any periods spent on fire-fighting. If such periods do not exceed three days, the men return to W.P.A. projects without their rationed working periods being affected. For longer working periods on fires, their rationed periods of ordinary work are subject to reconsideration. Men are not usually called from W.P.A. projects, unless there is a marked shortage of more proficient labour.

(d) Youths under N.Y.A. (National Youth Administration) drafted for fire-fighting in accordance with arrangements made between forest officers and N.Y.A. administrators, are considered as temporary and emergency employees of the Forest Service for whatever period they are required by the Service. Responsibility for their pay, sustenance, compensations, etc., rests with the Forest Service during such period.

F. State Employees.

The duties and conditions of the many employees of State protective administrations, cannot be enumerated here, but an interesting summary can be given of the class of labour employed by a State (Louisiana) organisation:-

Louisiana employs over 400 fire wardens at a flat remuneration of $250 per annum, for which sum wardens are expected to attack any fire when so requested by a lookout, or to organise small suppression crews from their families and/or friends. Owing to almost chronic rural depression, the income mentioned is greatly prized by the wardens. All wardens are connected to a telephone, and must have someone available at all times to take a telephone call. Wardens are also required to work on holidays and during any season of the year.

By contrast - patrolmen employed by the Louisiana State Forester receive the sum of $50 per month, plus $15 per month for car and other expenses, while towermen are employed on a yearlong basis.

G. Training of personnel.

(a) Permanent employees - Although these men have been recruited for permanent employment because of their aptitude and experience in various phases of fire control, they are not allowed to rest on their laurels. It is freely admitted by most foresters that the general skill and efficiency of personnel engaged in fire protection lags some distance behind the advances made in the knowledge of fire behaviour, application of planned fire control etc. It is conceded that the key men in permanent positions are not always responsible for the deficiencies of casual labour forces, and that many permanent men may be faced with fires of far greater magnitude, than any previously experienced by them, but it is felt that the general results achieved in fire suppression still fall far short of perfection. The whole problem centres in the application of principles and methods which should be well known to all those men who are charged with directing labour forces in fire suppression work. Many of the shortcomings are traceable to lack of experience by all concerned in large scale fires, but it has been found that responsible and intelligent employees do not always grasp the significance of errors or achievements on large fires, even when they have actually had the requisite experience. The lessons learned during training over long periods are too often forgotten under the stress of severe fire fighting. While the training of temporary employees has been in practice for years, it is becoming more generally realised that men subjected to such training require more specific technical direction, rather than longer periods of desultory training, if their performance is to be improved. It is also generally conceded that higher officers of the fire control organisation require the most intensive and specific training. With the gradual building up of an adequate staff of fire control specialists among Regional forest officers, and the freeing of such men from administrative duties in other spheres, there should also be an eventual improvement in the standard of district officers, and of regular employees, within such districts. For the present, training may take the form of short but intensive group camps held during early spring, every few years, the issue of detailed instructions on every phase of the work to be performed by individuals. These efforts are followed by intensive "checking up" and inspection of all stages of preparedness, but the extent of necessary improvements in fire suppression technique cannot be adequately gauged until the whole organisation labours under severe strain. This generally means that assessments cannot be made regarding hoped for improvements until fires are under control, by which time the many variables such as weather conditions, fire behaviour, labour deficiencies etc. will have obscured the issue.

Intensification of the technical aspects of training, shortening the period between training camps, stressing leadership values, and concentration of effort on the younger members of the permanent staff, are the main endeavours being made towards most effective training of permanent employees. Opportunities for the individual training of an employee who shows the most response to general or group training, are not neglected whenever officers have the time available.

In Western Regions recent emphasis has been laid on the need for localising fire training of regular personnel. All such personnel on a particular forest undergo a pre-season period of training in a camp located each year in a different part of the forest. In this way the forest organisation becomes more closely knit, while employees acquire a useful knowledge of the adjoining territory not usually under their supervision.

(b) Temporary Employees.

Difficulties of training this class of employee are intensified owing to the large percentage of inexperienced men to be trained prior to each season, and, because of numbers, the necessity of effecting such training by means of large groups. It is true that the instruction necessary to these employees may not be as intensive, or scientific, as that attempted with permanent labour forces, except in the case of such individuals as lookouts, guards, co-operators etc., but it must be remembered that the majority of these men will have the duty of directing any emergency labour called in to large fires.

Wherever practicable, all temporary employees engaged for an individual fire season are given intensive group training on general lines, while as much individual training as possible is given to employees engaged on "specialist" duties, such as lookouts, lookout-firemen, guards etc. The same arrangements can be made for wardens or co-operators classed as emergency employees. Like temporary employees, the latter may be paid for any time spent in undergoing training.

Other emergency employees, such as labour crews in or near the forest, C.C.C. enrollees etc., are usually given rudimentary training by arrangement with those in charge of their activities, or by selecting "fire crews" for training (and future suppression duty) from the most suitable men available. As in the case of C.C.C. men, the appointment of camp personnel to positions in charge of "fire-crews" often allows an intensification of training.

The need for intensive training of temporary employees is particularly felt in Western Regions, owing to the great seasonal expansion usually necessary in the labour forces on National Forests during the severe conditions of summer hazard. In some Regions, as in the case of California, Fire Control Handbooks are issued to permanent and temporary staffs, which include detailed and specific instructions to temporary Guards on all phases of their duties.

In other Regions, as in the Pacific Northwest, a special Regional Manual (208) is issued for the training of temporary employees, and can be used either as a textbook for group or individual training, or as a reference manual for the use of these employees. Such manuals usually give explicit instructions regarding the undermentioned aspects of fire control:-

(a) Fire prevention - general aims and methods.
(b) Tools, Equipment and Quarters - their use, care and maintenance.
(c) Detection - the essentials demanded for successful performance of duty.
(d) Smoke-chasing - the essentials demanded for successful performance of duty.
(e) Small fire suppression - the importance of efficient "first attack".
(f) Reports - the use of standard forms etc. in submitting reports.
(g) Advanced training for responsible positions such as "Fire Boss", Pump operators etc.

CHAPTER X III.

THE ANNUAL FIRE CONTROL PLAN.

Each administrative division (Region) of the U.S. Forest Service prepares Regional Handbooks which serve as local text-books of reference in respect of Fire Control, either generally or for any particular phase of the protection efforts in the Region. Among such publications are the Regional Handbooks for Fire Control, and those for such detailed tasks as Law Enforcement, Guard Training etc. They conform to the standards evolved for the entire Service by senior administrative officers, fire and equipment specialists etc., but seek to broaden the application of country-wide standards according to local conditions or needs. They include detailed information of all kinds, and act as general guides to local administrative action.

In order to place local plans for Fire Control more clearly in focus, to provide bases for necessary action either before and during the fire season, or to furnish a yard stick by which the success of local planning can be measured, it is now standard practice for each administrative unit to prepare a pre-season Fire Control Plan. Such plans are prepared, early in each calendar year, either for a single National Forest, or for any smaller unit (such as a Ranger District) with such Forest.

Fire Control Plans are concise but forceful expositions of the objectives, actions and instructions which will be adhered to in a particular administrative unit during a single season. Their purpose is to ensure that any administrative or other action during such season, in respect of fire protection, will be the most desirable, and, at the same time, largely automatic, irrespective of any seasonal or hazard conditions which may eventuate.

It follows that such a plan calls for intensive local study, by the executive officer concerned, of the fire problem on his particular area, and of the most efficient, practical and economical means of accomplishing reasonably "fool-proof" protection of such area. In order to bear comparison with those for other administrative units, the local plan must conform to the general objectives laid down for Fire Control by the Region concerned. This conformity between plans also permits their general co-ordination in the event of any general danger which threatens any unit concerned. The production of a satisfactory and practical plan calls for experience and insight on the part of local officers, and seeks to eliminate the haphazard reasoning, characteristic of earlier plans for local action.

It must be conceded at the outset that no local officer possesses occult or other powers which enable him to predict the seasonal or other conditions of fire hazard which will prevail on his area during an approaching fire season. The purpose of Fire Control Plans is not to assess probabilities, but to provide for any conceivable eventualities. This can only be done by applying extensive local knowledge to carefully built up administrative records of fire history in that locality. Fire histories provide instances of the various trends, errors and occurrences to be guarded against in the future, and enable the officer reviewing same to concentrate future endeavour on any individual locality, or on any single agencies responsible for fire, while meeting any possible set of burning conditions with adequate forces and facilities.

A. The Fire Atlas.

This is the compendium from which all the significant and essential details of fire history can be extracted, in efforts to analyse the local situation which prevails, and to prepare plans for future action. The Atlas includes both special "Fire Maps", and statistical information compiled on special Forms, for the particular area of forest to be dealt with as a Protection Unit. The essentials of the Fire Atlas include all or most of the following:-

1. Maps -

(a) Fuel Type Maps - providing information concerning current hazards, by classifying the fuels on various parts of the area according to the varying "rate of spread", or resistance to control", of any fires which may occur in such fuels.

(b) Fire Occurrence Maps - which reveal the risks prevailing. They are prepared from 20 year records of lightning fires, and from ten year records of man-caused fires, or for any shorter periods in cases of less extensive records. These maps delineate "zones of fire occurrence" according to:-
   (1) Origin of fires
   (2) Season of burning
   (3) Frequency of fires
   (4) Size and severity of outbreaks.

(c) Seen-Area Maps - which indicate the scope and efficiency of detection plans. These maps show the location of lookout stations, volunteer detection units and the "seen area" from each of these points according to various Fuel Types. They also reveal the extent of unguarded areas having material values at stake, or occurring in any prominent zones of fire occurrence.

(d) Transportation Maps - which reveal the facilities available in the area for different routes of travel, together with definite information concerning "times of travel" along any particular route or between any two points.

(e) Communication Maps - which show the location of all telephone lines and instruments, existing or suitable sites for supplementary radio units etc.

(f) Man-power placement Maps - showing stations regularly occupied by smoke-chasers, permanent employees etc.

(g) Tractor Use Maps - showing zones on the forest where tractors and/or bulldozers can be readily and profitably used for fire line construction because of the nature of the topography, ground fuels etc., and the proximity of suitable machines.

(h) Aircraft Use Maps - showing zones where the dropping of tools, equipment and supplies to fire fighters from aircraft is the most feasible and most economical method of delivery.

(i) Tanker Use Maps - showing the areas easily served by tank trucks, the most suitable routes of travel for these trucks, locations of filling stations available for replenishing tank supplies etc. In some more inaccessible forests these maps indicate the areas which are readily served by portable pumpers rather than tank trucks.

2. Administrative Records.

These give exact and detailed information concerning past fires in regard to:-

(a) Costs of Prevention, Suppression etc.
(b) Causes - by seasons, or for shorter (e.g. ten-day) periods.
(c) Detection records - the number of outbreaks actually reported.
(d) "Elapsed time" standards, assessed in previous years.
(e) Any trends shown by man-caused fires, previous experience with law-enforcement.
(f) Records of previous damage - by area, or by financial estimates.
(g) Previous efforts at reducing hazards - success and cost of such efforts,

or any other cumulative fire data which are of assistance in analysing the situation, such as available local recordings of fire weather associated with previous seasons, or more particularly correlated with previous fires.

B. The Annual Fire Plan.

The scope of this Plan must obviously depend on the local importance of the "fire control job", but even in the case of normally "safe" areas, provision must be made, along broad lines, for any emergency. The units included within a single Plan may range in area from approximately 1000 to 300,000 acres (76). While development of fire plans has been most marked on National Forests, Fire Plans are also prepared for such other areas as those under the control of State or County Forestry Authorities, or covered by Landowners' Co-operative Associations etc. On the other hand, areas under State, County, or Private ownership may be included within Fire Plans for National Forest areas. Intensified plans are usually necessary on areas under logging activities, so that it is satisfactory to note that at least one group of lumbermen on the West Coast have carried fire protection far enough to evolve what is really a comprehensive Fire Plan (66).

An attempt is made hereunder to classify some of the main considerations given prominence in any major Fire Plan:-

1. Brief Statement of the Values at Stake - on the whole or any part of the area, from the viewpoint of Timber, Forage, Watershed, Recreation, Wildlife or other values.
2. Short Recapitulation of Fire History of the area - stressing the most obvious lessons or trends revealed by such History, such as causes of the outbreak and/or spread of any fires.
3. The Fire Control Objective for the unit - as expressed by "Permissible Area of Burn" for any single season. In cases this figure may be as low as 0·1 per cent (202).
4. Enumeration of comprehensive Prevention Activities to be undertaken -
   (a) Hazard reduction programme - on logging areas, private property etc.
   (b) Risk reduction programme - including particular attention to smokers, campers, visitors, industrial operations etc.
   (c) Educational programme - detailing arrangements for Exhibits; Lectures; Newspaper and Radio Publicity; Preparation and Distribution of Literature; Law enforcement arrangements; Contacts with citizens, officials etc.

5. Co-operative agreements drawn up, or in the course of completion, with adjacent Regions, National Forests, or Ranger Districts of the Forest Service; with all other Federal Government Agencies; State County or Private Agencies; Construction parties; Individual Co-operators etc. in respect of mutual assistance in preventing, detecting and suppressing fires, the most logical and efficient use of man-power equipment etc.
6. Detection responsibility to be defined, for specific areas, for the guidance of those participating e.g. Primary Lookouts, Lookout Firemen, Patrols, Individual Co-operators, Aircraft etc.
7. Accepted Time Standards for the unit - the actual period allowed for Discovery, Reporting, "Get-away", Travelling Time, in the event of any outbreak.
8. Location of all tools, supplies equipment - either in the field, or cached at District Supervisor's or Regional Headquarters, with full details regarding numbers available for immediate use in the field, and those in reserve.
9. Personnel -
   (a) Regional, Supervisor's or Ranger's staffs of Forest officers to be listed, with full details of emergency plans for communication by telephone etc.
   (b) Clear statement allocating among officers and permanent employees the responsibility for any action that may be necessary. Such responsibility embraces pre-season contacts, inspections and general efforts at "Preparedness" as well as emergency duties to be taken up concurrently with fire outbreak.
   (c) The number and suggested location of the various classes of temporary employee required to occupy definite positions during the fire season.
   (d) The nature and extent of the training to be given to selected temporary employees, such as outlines for collective or individual training for the various duties on which they will be employed.
   (e) Concise and explicit instructions formulated for issue to all permanent and temporary employees, individual co-operators, per diem guards etc., detailing the nature of their duties before, during, and after any outbreaks of fire.
   (f) Sources of all emergency labour are listed, together with labour agents or officers to be contacted when such labour is required.
10. Fire Danger Rating - The use of such ratings is set out, together with all administrative action linked to them. The responsibility for various individual action under certain conditions of fire danger rating is also set out, so that such action will automatically follow the fluctuations shown by ratings of danger.
11. Initial attack to be made on any outbreak of fire - allocating responsibility, time standards etc. to such attack, to avoid overlapping or confusion.
12. Emergency Plans for unduly severe conditions, including:-
   (a) Reinforcements required in Guard or other forces under certain conditions of fire danger rating, including the use of C.C.C. labour, relief available for key members of labour forces.
   (b) Restrictions necessary on the public, such as enforcement of campers or smokers' permits, closure of sections (or the whole) of the forest to visitors.

(c) Curtailment of any hazardous operations by sawmills, logging or construction crews.
(d) Additional means of communication to be provided.
(e) The sources of emergency labour to be checked to ensure such labour will be available.
(f) Issue of "Stand-By" instructions to all personnel, or to other sources of assistance such as C.C.C. or other labour forces.

13. <u>Contracts</u> entered into for aircraft, truck, or horse hire, at any time during the season, are briefly listed to indicate name of contractor, the nature of his contract, hire rates etc.

14. <u>"Regional Overload Plan"</u> - prepared for use in emergencies, which allows for Regional interchange or relief of "overhead" during prolonged conditions of hazard, or in the case of severe fires.

PART IV.

SUPPRESSION ACTIVITY.

CHAPTER XIV.

FIRE SUPPRESSION.

A. The Suppression Policy of the U.S. Forest Service.

The established policy of the U.S. Forest Service in respect of Fire Suppression, as determined by senior administrative officers in 1935, is stated as follows:-

"The approved protection policy on the National Forests calls for fast, energetic, and thorough suppression of all fires, in all locations, during possibly dangerous fire weather. When immediate control is not thus attained, the policy then calls for prompt calculating of the problems of the existing situation and probabilities of spread, and organizing to control every such fire within "the first work period". Failing in this effort, the attack on <u>each</u> succeeding day will be planned and executed with the aim, without reservation, of obtaining control before 10 o'clock on the next morning".

In transmitting this policy to the Forest Service, the Chief Forester further stated:-

"No fixed rule can be given to meet every situation, the spirit implied in the policy itself will determine the action to be taken in doubtful situations".

As "the first work period", means the period between discovery of a fire and 10 a.m. on the succeeding day, it will be noted that a speedy initial attack is specified, irrespective of any weather or other conditions prevailing at the time of, or following, the actual outbreak. It follows that a considerable degree of success can only be achieved with this policy if most fire suppression work is done during the night hours, when burning conditions are, in most cases, much less severe.

Many United States foresters agree that apart from mechanical advances in the provision of new equipment for suppression of fires, little progress has been made during the last twenty years in making the best possible use of man-power in fire-fighting.

In view of the heavy expenditures on actual suppression, it is felt that some progress in this direction is necessary, and the present objective of speedy initial attack on all fires is intended to reduce the number of large fires and the present heavy costs of their suppression. Once a fire is out of control, administrative officers are faced with the problem of getting adequate labour forces, supplies and equipment to the fire, making the best possible use of them while they are required, and at the same time trying to reduce costs to a minimum.

Criticism of suppression efforts is admittedly easy to those unacquainted with the extremely variable number of factors that must be contended with on any fire, while it can be truly said that no two fires of any magnitude show identical behaviour. The present practice of the U.S. Forest Service in subjecting all major outbreaks to review by independent specialists in Fire Control, does however, permit analyses of all action taken. Such analyses indicate whether any major errors of judgment were made in handling the fire, and should at least avoid the repetition of similar errors on other fires.

Some of the principlos now applied to fire suppression, as set out (202) in the "Suppression Code" for Region No. II of tho Forest Service, may be enumerated here to indicate the scope of the problem:-

1. Promptness in Discovery, Accuracy in Location, Speed and Accuracy in Reporting.
2. Exhausting every rosource to secure pertinent and corroborated reports on outbreaks of fire.
3. Dispatch of a qualified man or men, who can reach the fire first, and be fully informed and instructed.
4. Probabilities to be calculated, and placed on record, for every fire,prior to sending reinforcements. Such records to be subsequently checked for accuracy and completeness.
5. According to calculations made, follow up initial action with necessary assistance, and refill any key positions vacated.
6. Despatch of the best available "fire boss" to the fire, together with competent "overhead" as provided for in plans.
7. Prompt mustor and despatch of necessary suppression units, with adequate overhead, fully instructed, properly transported - not overlooking lunches or meals en route, supplies, regular and special equipment etc.
8. Communication by suppression units with Headquarters by telephoning en route to fire, and at first opportunity after arrival, are vitally important. Radio to be used where fires are three miles or more from telephones.
9. Continuous and speedy travel to fires, by day or night, is compulsory unless impracticable. If possible provide a horse for the "fire boss".
10. Thorough scouting of fires, if possible sketching same on maps, should proceed as early as possible.
11. Immediate and aggressive attacks required on all fires by day or night, unless topographical features, fatigue etc. make a night attack impracticable. Provision to be made for lights. Dawn attack to be compulsory.
12. <u>Tactics</u> - On the basis of scouting and other information, use the method which will effect control in shortest time, avoid all unnecessary work on fire. Make greatest possible use of special equipment (plows, pumps etc.) where practicable.
13. "Revamping" plan of attack - according to changes in weather, fuel types, topography etc., and provide for necessary reinforcements.
14. Camp locations to be as near as possible to the fire, with provision for water haulage, transport of supplies etc.
15. Remain fully informed,at alltimes,of conditions on all sectors, based on definite knowledge or information from lookouts, scouts etc. Use radio to assist in obtaining information and transmitting reports on fire to Headquarters.
16. Fire weather recordings or forecasts to be obtained from nearest available source to assist action at the fire.
17. Provision for relief of overhead and crew if the job is to exceed 18 hours of initial attack.
18. Written orders to be used in all cases, where possible, to avoid misunderstandings, and carbon copies retained.
19. Maintain daily log of arrival of man-power at fire, by various classes, by arrival and discharge of crews etc. Important events such as rate of spread, success or failure of control efforts, anticipated control etc. Records also to be kept of important orders concerning reinforcements, release of men etc., and these records to be preserved.

20. Care of all equipment, including its checking in and out of the fire camp. All equipment to be returned to camp, or properly accounted for, at the end of each shift.
21. The fire-boss to maintain a constant, steady, aggressive, assertive, cheerful, fair, alert and intelligent leadership, and to be always on the job with, or ahead, of his subordinates.
22. "Mopping up" to accompany or immediately follow completion of fire line, efforts to be concentrated on "corralling", leaving picked men to maintain fire lines until all forces are concentrated on "mopping up".
23. Release of men to be correlated with state of fire, weather data, and after consultation with the Forest officer in charge.
24. Abandonment of fire permitted only when "dead out", and when the withdrawal of all men has been approved by the District Ranger or Supervisor.

B. Methods of Attack.

(i) Types of Fire - As types of fire govern the action taken on their suppression, the usual classification adopted in U.S.A. will be explained here:-

(a) Surface fires - probably the most common of all fires in U.S.A. They burn on or near the ground in the forest litter, ground cover, brush, reproduction etc. Fires which burn only the surface layer of accumulated "duff" are also classed as surface fires. Damage from this type of fire is rarely sufficient to kill standing trees, but may lead to subsequent damage by insects or fungi to such trees. Regeneration, however, is usually damaged to a serious extent. Surface fires are noted for their extreme rate of spread, owing to the nature of the fuels usually consumed (e.g. Cheat grass in Western forests, or Wire grass on the Longleaf Pine ridges of Southern Forests), but they are usually the most easily controlled of all fires.

(b) Ground Fires - burn more slowly than surface fires, and are usually characteristic of those forests having accumulated layers of humus, peat or duff which have become so compacted that oxygen supplies required by fires cannot be readily obtained. They are not so common as surface fires because the fuels quoted above do not readily dry out so completely as to support combustion. Where ground fires do occur, they burn with intense heat and are destructive to most ground and tree vegetation. The damage mentioned is due to the penetration of fires to the upper layers of the mineral soil, in which vegetation roots are usually found. While they do not spread rapidly, ground fires are difficult to control, as the fire edge or constructed fireline must be thoroughly exposed to the mineral soil for a sufficient width to minimise the probable spread of fire through the lower layers of litter. Ground fires may be further subdivided into duff or peat fires, the latter being particularly noted for their ability to burn for extended periods, and to cause severe damage or death to any tree vegetation within the fire perimeter.

(c) Crown fires - which spread in the crowns of trees as well as on the forest floor. They are usually confined to coniferous types, where death of the entire stand often follows. As distinct from surface or ground fires, which may spread in any direction, crown fires usually follow the direction of prevailing winds. Exceptions occur in the case of fires which automatically "crown" when burning up steep slopes among heavy ground fuels in the absence of wind, but in such cases convectional currents have the same influence as wind has on level country.

In U.S.A. they are most common in the rough topography and coniferous forests of the North West, and in the dense Pine stands and inflammable ground fuels of the Lakes States and Central Atlantic Region (e.g. New Jersey).

Owing to the tremendous heat developed by crown fires, coupled with their rapid rate of spread among heavy types of ground fuels, they are noted for the difficulty experienced in their control.

(d) Spot Fires are due to the combined influence of prevailing winds and of convection currents produced by extensive crown fires. Small pieces of burning material are projected into the air by convection currents, and carried forward horizontally by winds to start fires in advance of the main fire, at distances depending on wind strength, fuels, topography, height of the stand which is burning etc. Spot fires make suppression work near the front (or "head") of a fire extremely hazardous or temporarily impossible, thus halting efforts at control. In other cases they require the detachment of part of the labour force for patrol, suppression of spot fires as they occur etc.

(e) Classification of fires by size - in U.S.A. fires are classified by the U.S. Forest Service according to the size they have temporarily or finally attained, being arbitrarily grouped as follows:-

Class A - 0·25 acres or less
" B - more than 0·25 acres, but less than 10 acres
" C - from 10 acres up to 99 acres.
" D - from 100 acres up to 299 acres.
" E - 300 acres or more.

(ii) Available means of controlling Fires - Forest fires differ materially from city or urban fires, in that reliance is not placed on the almost exclusive use of water, while little attempt is made in the forest to totally extinguish the outbreak. With the best means at their disposal, foresters usually have sufficient difficulty in contructing a fire line around a fire, and holding the outbreak within such fireline. This is known in U.S.A. as "corralling" a fire by means of "held line", and even around its perimeter the fire is controlled, rather than completely extinguished.

The principal means of controlling fires, which are readily available to foresters, are water and dirt. The use of chemicals, as already noted, offers some possibilities, but is still very much in the experimental stage.

(a) Water - is the most valuable means of extinguishing any type of forest fire, but is rarely available to the fire fighter in sufficient quantity for use in direct attack. Increasing transport facilities by means of road construction, coupled with improved types of equipment for transporting or using water, has greatly facilitated the extended use of water on forest fires during recent years. Even now, however, the use of water is largely confined to "mopping up" around the edges of fires, or for sparing applications at points where fires threaten to overcome efforts at suppression by other methods. It can be stated that equipment is made available, and is freely used, in cases where water can be located or readily transported. In Southern Forests, transport is comparatively easy, and water can be distributed in large quantities or even used by direct pumping or spraying from tank trucks. In the rough topography of most Western forests, water is available in sufficient quantity, but it is difficult to pump or transport adequate supplies of water in such topography. In the Pacific North West Region, Osborne (146) has stated that the maximum development of modern water-using equipment could not extend the use of water to more than 20 per cent of the fire perimeters in that Region.

On certain areas in Western Forests, the use of water can, however, be relied on, provided adequate supplies of portable pumpers are available, and that water can be located without delay. Efforts have even been made, as described by Crouch (34) to show on maps of a forest area, the zones in which water was available after setting up one or two, portable pumpers. Such information should undoubtedly assist officers directing suppression efforts to locate adequate supplies of water without delay.

In the Lakes States, the water table in forest areas is usually high, and adequate water supplies are obtainable at depths of from ten to forty feet. As a result, forest officers have developed methods for the sinking of "well points" by mechanical force, or by using hydraulic pressure, as described by Ashbaugh (8) and Stewart (175), to obtain water for adjacent or nearby forest fires within a space of minutes. Water is pumped from the "driven" wells by ordinary portable pumpers.

In isolated cases, water may be gravitated to fires, or pumped directly from streams, lakes etc. on to the flames.

(b) Dirt - is still used much more than water in controlling forest fires and may be the sole means available, where urgent initial attack does not rely on the use of water. Except in the case of slowly moving surface fires, which may be suppressed by throwing dirt on the edge of the flames or by direct "beating", dirt is used mainly as a barrier along the inner edge of constructed fire lines, or for smothering burning material such as roots, stumps etc. close to the outer edge. The shovel still remains the principal tool of fire fighters throughout the country.

(iii) Methods of controlling fires:-

On the majority of fires, control can only be effected by constructing a "fire-line" along the edge of the fire, or as near as possible to that edge. Fire line construction usually involves the clearing of ground fuels and also the "trenching" of the line down to mineral soil on a strip narrower than the fire line. For surface fires, where only light ground fuels are present, the fireline may be cleared to approximately four feet in width, with a trench eighteen inches wide on the outer edge of the fire line. The actual standard of the line construction necessarily varies with different fuel types, topography, rates of fire spread etc.

Among heavier fuels, where fierce surface fires show a tendency to "crown", clearing is much more important than trenching, and the width of the cleared fireline may extend to fifteen feet, with all vegetation removed therefrom. In such cases it is usually necessary to "burn out" the fire line, as it is constructed, to avoid the necessity for trenching.

In attacking a fire by means of fire line construction, full advantage is taken of any natural barriers such as clearings, burned areas, firebreaks, roads etc. in order to reduce the length of fireline necessary. Effort is concentrated on preventing fires from spreading to areas of high value, or into areas of more difficult fuel types, topography etc. On those sectors where a direct attack is possible on the actual fire edge, without risk of future "breakaway", line construction is avoided. Some areas of very low hazard may even be neglected altogether, while attack is concentrated on more important and more urgent sections of the fire perimeter. In determining the method of control, for any particular outbreak fire fighters usually consider one or more of of those listed below:-

1. <u>Direct Method</u> -
This involves a direct attack on the fire edge, with raking or scraping burning materials into the fire, cutting burning logs lying across the fire edge, throwing dirt on to burning stumps etc. Water may be used to secure direct control, as in Southern forests, or to cool the fire edge sufficiently to allow work to proceed. The main advantages of the method are that no risks are incurred through backfiring, and considerable progress can be made in "corralling". There is no delay in deciding which "snags" are dangerous, and felling gangs can thus commence work on these snags.

2. <u>Two-Foot Method</u> -
This is a modification of the direct method which is used when water supplies are scarce, and when fires are burning in deep litter. A trenched line is constructed down to mineral soil, within two or three feet of the fire edge, and the litter and soil excavated is thrown into the fire, which is permitted to burn out to the trench. The method is particularly useful in cases where a thick duff layer makes it difficult to determine whether the edge of a fire is actually out, or in cases where fire fighters are forced to work some little distance from the heat of the fire. It is a more costly method than the direct attack, but is much more reliable in many cases.

3. <u>Parallel Method</u>. -
This method involves the construction of a fire line at varying distance from the fire edge, but roughly parallel to such edge. It is used to avoid excessive heat or smoke, to shorten fire lines because of irregularities in the fire perimeter, or to include scattered "spot" fires within the fire line. The burning material between the fireline and the fire edge must be burned out, as the line is constructed, to secure the best results, and to have men concentrated near such

burning while they are constructing a fire line. The method is widely used, and is strongly advocated to avoid losses previously experienced through the "breakaway" of supposedly safe fire edges. It is the most expensive method of line construction, involving clearing of a new line, together with trenching in most cases, but by effective scouting the actual length of necessary fire line may be greatly reduced. On many large and fierce fires in Western Regions it is the only method of attack possible.

4. Indirect Method - (Backfiring) -
In this method firefighters drop back some considerable distance from the fire edge to use a recently or previously constructed fireline (or a firebreak, road or other barrier), from which to backfire. The success of the method depends greatly on the judgment of fire fighters in taking advantage of the draught of the main fire, slope variations, changes in wind direction etc. to send a small check fire back to meet a main outbreak. It differs from the parallel method in having a greater distance between fire and fireline, while it is also necessary to have a completed fireline before backfiring can be safely undertaken. Indirect methods are used in those cases where other methods fail or hold no promise of success - they are often used on the "head" of a main fire while other methods are being used elsewhere on the fire perimeter. The use of backfiring is usually associated with the most severe weather or fire conditions, and for this reason alone it can be classed as a very risky proceedure unless executed by experienced men. As stated by Folweiler and Brown (51), the indiscriminate use of backfiring by inexperienced persons is so dangerous that certain fire laws forbid its use except by fire wardens or by other authorised persons. The method is perhaps the only possible means of controlling fierce brush fires, and is widely used in California for fighting fires in Chaparral areas.

All the above methods involve intensive patrol of fire line (or edge) by reliable patrols, and also the felling of all dangerous "snags" within the burned area, anddetailed "mopping up" etc., after main suppression efforts are completed. One or more methods may be used on a single large fire, the actual selection of the method most suited to any particular sector being a major responsibility of the "Fire-boss", including as it does consideration of all local factors which influence the rate of fire spread and the success of suppression efforts.

(iv) Distribution of labour forces.

Careful location of fire lines, to secure the most economical control of a fire, cannot achieve the best results unless men are so distributed along these fire lines that the most effective use of man-power results. One of the cardinal principles adopted in suppression policy is that all possible efforts should be made to secure initial control of the most dangerous sectors of the fire. As such work is not only the most urgent, but also the most hazardous phase of suppression efforts, it follows that the most experienced men, under capable direction, should be concentrated on the worst sectors.

As regards the general rate of fireline construction, most foresters agree that it is far too low, even with the inexperienced labour commonly used, while it shows little tendency to improve. Efforts have therefore been made to plan the best possible location of men in suppression crews, so that line construction will proceed at a maximum rate of speed.

The evolution of these efforts is described hereunder:-

1. Squad Method - This can hardly be called a method in the true sense. Men arriving at a fire line carrying a particular tool commence working with same in company with other men using other tools. When a particular section of fire line is completed the squad move forward and commence another section. Men are often in each other's way, or are standing idle until a certain section of the fireline is completed. The only advantage apparent is a concentration of man power at a particular point if a fire threatened to cross the fire line there. Various efforts made to introduce some system into the "squad method have been unsuccessful.

2. Station Method - In this method men are allotted individual section of fire line, after the standards of construction have been demonstrated to them. The length of the section allotted to each man varies with the amount of construction involved. The method has the advantage of allotting responsibility, so that shirkers or inefficient workers can be culled out. After completing the allotted section each man moves forward to a new section, or remains to carry out patrol or mopping up on his original section. The main disadvantages of the method are the number of tools usually required by each man, and the possibility of a fire breaking through between widely spaced individuals. The method naturally involves considerable variation in the standard of constructed fire line.

The method may be modified by having a special "clearing crew" to remove all vegetation and heavy litter along the full length of the proposed fire line, leaving individuals to carry out trenching etc. of various sections as explained above.

3. Sector Method - In using this method, squads of men are broken up into small crews, each under a capable "crew boss", and each crew is allotted a sector for the completion of all fire line construction before moving on to the next sector. With efficient direction this method is much more successful than the two methods described above. It is particularly useful where various sectors of a fire are spreading much faster than others, enabling a concentration of effort on those most dangerous sectors.

4. The One-lick Method - As described by McReynolds (125), this method forms the entire suppression crew into a line, each man doing a certain task as the crew moves slowly forward. Each man has a tool for carrying out his particular part of line construction, with cutting tools at the head of the crew and shovels etc. at the rear. Provided the correct supply of tools is available, men may be detached at intervals from the rear of the crew for patrol or mopping up duty. As the men do not actually stop walking, fireline construction is undoubtedly speeded up by this method - in the case of lighter fuel types such construction may even proceed at a rate approaching normal walking speed. There is thus no waste time in "walking

men into the fire". Use of the method is admittedly harder on the men, but this can be relieved by halting the crew for brief rests at regular intervals. To secure best results, the method also involves some experience or preliminary training of all men engaged, as the line cannot be halted while an individual receives instruction or correction.

Water using equipment may be used at the head of the suppression crew if construction is proceeding close to the actual fire, or at the rear to assist in back-firing from the fireline. If difficulty is likely to be experienced in various sectors owing to different tools required etc., additional men can follow at the rear of the crew, carrying the necessary variety of tools, drinking water supplies etc. McReynolds mentions the efficient use of the method with a large crew of 192 men, all of which were quite inexperienced except for foremen.

It is generally agreed that concentration on this method, wherever practicable, will result in a great improvement in the rate of line construction. Campbell (27) quotes figures showing the production of "held-line" by this method, as compared with ordinary squad methods, in various fuel types on different National Forests within Region V:-

NATL. FOREST	FUEL TYPE and its classification re Hazard Prevailing.	(1) (chains	(2) per man hour)
Columbia	Douglas Fir, slash and reproduction - "Medium High"	0·59	0·13
Colville	Brush, grass, logs, etc. - "Medium Low"	2·00	0·50
Deschutes	Lodge Pole and Ponderosa Pine, brush, reproduction etc. - "Medium Low" -	0·80	0·50
Umpqua	Bug-killed Lodge Pole Pine, 50 cent dead and down - "Medium High" -	0·90	0·43
Rogue River	Dense Brush - "High Medium" -	1·00	0·35
Willamette	" " and Fir reproduction, some snags and logs - "Medium" -	0·48	0·26

(1) One Lick Method (2) Conventional Method

In a further review of the One Lick Method, it has been stated (192) that the method is far superior to any other employed in the South Western Region and all C.C.C. suppression crews have been trained in its use. The same review mentions even greater success in the Pacific North West Region, where the general use of the method during the 1939 season increased fire line construction rates by 40 per cent as compared with the previous three seasons. In the latter Region, the method was found very suitable for use by untrained fire fighters, but there was a tendency to construct more fire line than was really necessary at many outbreaks.

5. <u>Forty Man Crew</u> - Another method adopted in the search for less expensive fire construction is the development of the "Forty Man Crew". Members of this suppression crew are specially selected for their fire fighting experience, their physical fitness powers of endurance etc., and are required to stand by throughout the fire season at central points. They are not meant to replace small crews charged with initial detection and suppression measures but they are located at centres from which they can be rushed, at short notice, as first reinforcements. Members of the crew are equipped with a variety of special lightweight tools, and with rations for a period of three days, which can be "back-packed" for long distances from the nearest road.

The merits of the "Forty Man Crew" are summarized (192) as follows:-

1. The crew experiment has provided standards for the selection of fire fighters.
2. It has developed a self contained unit, requiring no supply of any sort for a period of 72 hours.
3. It has re-emphasised the benefits resulting from men being in good physical condition.
4. It has illustrated the importance of team work on large fires - as it produces a maximum output of fire line with a minimum of effort.
5. The crew has achieved almost impossible accomplishments on critical sectors (hot spots), where other crews would certainly fail.
6. Achievements of the crew under the most critical conditions have stimulated a competitive spirit among other suppression units.
7. Because of its reduced "travel time" to inaccessible fires - the crew effects better initial control.
8. Use of the crew reduces the need for "overhead" on fires and provides excellent training for future members of such "overhead".

It is pointed out that the output of the crew can be further increased if packs, supplies etc. were delivered by air. It is emphasised that there is no need to limit the crew to the exact number mentioned - on large fires especially, the crew could be readily expanded, as so many of its members are capable of serving as "overhead".

Intensive studies made (129A), by Matthews of the Pacific North West Experiment Station, of the effect of crew size on the output of constructed fireline, showed that such output decreases as crew size increases. This indicates an even greater need for the increased use of trained firefighting units, such as the "forty-man" crew.

C. Factors governing effective Fire Suppression.

(1) Adherence to "Elapsed Time" Standards.

As used in fire control by the U.S. Forest Service, "Elapsed Time" is the period fixed to cover the time between the commencement and completion of any particular phase of fire control. The fixing of such periods is an essential part of fire control planning, and enables the whole protection force to function on standards which are selected for the various values at stake, or for the various fuel hazards prevailing. While they serve an essential purpose in setting out definite objectives for certain activities, they also act as a spur to the personnel concerned, and as a measure of efficiency. The usual standards determined in the Fire Control Plan for each Forest, (or Protection Unit), are as follow:-

1. Discovery Time.

This refers to the period which is permitted to elapse between the inception of a fire (or the rise of a visible smoke column), and the time when it is discovered by a lookout. The limits of such period are usually fixed at 15 minutes, although an actual period may not be specified (as in California). The existence of large areas of high hazard within sight of lookouts may cause a reduction in the discovery period, owing to the need for urgent attack, but the prevailing fuel types in the "seen area" of any lookout usually influence the standards fixed for detection discovery.

2. Reporting Time.

This is the time which elapses between discovery by the lookout, and his report to the officer in charge of organising suppression action. In California, the shortest possible period is permitted for reporting fires - viz. two minutes for communication by Forest Service telephone lines, or five minutes when at least partial use has to be made of commercial lines.

In the Northern Rocky Mountain Region, the corresponding times fixed are five and fifteen minutes respectively, but in the majority of cases, Reporting Time is not permitted to exceed five Minutes, being reduced to three minutes in the Lake States Region.

3. Get-away Time.

This is the time which elapses between receipt of a fire report, and the actual departure of the initial suppression crew. In this case a short period is usually fixed for the urgent despatch of a "flying squad", with a longer period when a main suppression crew must also be sent. Get-away Periods fixed for the use of cars or for travel by foot are usually the same, but a longer period is allowed when a horse is used for travelling. In California, getaway on a saddle horse is timed at five minutes or ten minutes if a pack horse is also taken. In other Regions the period fixed for horse travel is usually longer, but rarely exceeds fifteen minutes - horses being kept tethered, if not saddled, at times of hazard.

For the use of cars, or for travel by foot, a maximum period of five minutes is usually fixed, but in California this period has been reduced to two minutes. When larger crews are sent by truck in response to the first report, the period fixed varies from 10 to 15 minutes only.

4. Travel Time.

This naturally varies considerably owing to varying topography, to differences in the number of existing roads, in the standards and surfaces of such roads, and to the means of transport available for use. Different periods are usually fixed for travel during either day or night.

To illustrate the range of specified speeds for travelling to fires, the standards laid down (206) in California will be quoted:-

On Foot		
Over good trails	3 M.P.H.	
Across country	2 M.P.H.	
On Horse		
Over good trails	3·5 - 4·0 M.P.H.	
Passenger cars or 10 cwt. trucks		Trucks of 30cwt. capacity
Paved Highways	- 45M.P.H.	- 35 M.P.H.
Dirt or gravel main roads	- 30 "	- 25 "
Single traffic dirt road-flat country	- 25M.P.H.	- 20 M.P.H.
" " " " -steep "	- 12 "	- 12 "

In other Regions, longer periods are usually permitted - Foot travel is specified at 2 M.P.H. on trails, and 1 or 1·5 M.P.H. across country - the corresponding figures laid down for horse travel being 3 M.P.H. and 1½ or 2 M.P.H. respectively.

For travel by car or truck in various Regions, travelling speeds are made as fast as possible consistent with safety. The speeds applicable to all forest roads are known, so that the time to be taken on any trip can be calculated within a few minutes. Although speeds are not always scheduled as fast as those laid down for California, (see above), they do not permit any loitering. The travel times scheduled hereunder for the Northern Rocky Mountain Region can be quoted as being more average than those adopted for California:-

Trucks of 20 cwt. or greater capacity	DAY TRAVEL	NIGHT TRAVEL
Paved Roads	20 M.P.H.	20 M.P.H.
Unpaved "	15 "	15 "
Cars or 10 cwt trucks		
Paved Roads	25 "	25 "
Unpaved "	20 "	20 "

As noted previously, it is specified that all travel to fire be continuous, unless hazardous or impossible during night hours, e.g. during fog or by horse or foot. In the latter case the journey must be resumed at dawn.

5. Control Time -

This is the period which elapses between the arrival of the first suppression unit and the time when the fire no longer extends its perimeter. This period is not identical with total time necessary for suppression, as a fire may be effectively "corralled" many hours before it is safe enough to withdraw suppression forces. In a surface fire there is usually a close correlation between control time and total suppression time, but this is rarely the case with large crown fires. At first sight it would seem quite impossible to estimate the time necessary to bring a going fire under control. On the other hand it must be remembered that the Forest Service policy calls for the corralling of all fires before 10 a.m. on the succeeding day, and to achieve this objective the local officer must have some means of calculating the number of men necessary to bring a fire under control within the period remaining before 10 a.m. next day.

In most cases the initial attack is made by a "flying squad" which can reach the fire fastest, irrespective of probable time necessary for control. If a general reference to the location of the fire, and the fire danger prevailing, indicates the need for a larger crew without further consideration, this crew is also despatched before the responsible officer completes a thorough "assessment of the probabilities".

The factors he must consider are as follows:-

1. Location of fire - in respect of fuel types, slope, general topography (angles of slope, exposure to winds), values at stake etc.
2. Weather conditions prevailing - including reference to readings of the local fire danger meter, time of day, season, wind direction and strength, general and local forecasts for the immediate future etc.

3. Rate of spread - as determined from tables prepared for the fuel type concerned, and for other fuel types immediately in the path of the fire.
4. Anticipated rate of fire-line construction, as determined from tables already prepared for various fuel types, or from local knowledge of the conditions, presence of natural barriers likely to be of assistance etc.
5. Reports available concerning the size of the fire, from which local tables will furnish details of its probable perimeter.
6. The number of men and tools available, their location, degree of crew fatigue on arrival at fire etc., including reference to available reinforcements of emergency labour.
7. Routes of travel, and average speeds, according to means of transport available.
8. Available overhead, officers, regular employees etc. to take charge of suppression action.

While all of the above factors must influence the actual number of men despatched, the actual number to be sent is based primarily on the following procedure:-

(a) Determine the fire danger rating (Extreme, High, Medium etc.) from the local Meter.
(b) For this rating, and for the fuel type in which the fire is burning, or to which it may extend, estimate the rate of spread for the fire, or make readings of same from local tables.
(c) With the above information in hand, estimate the length of the fire perimeter by the time an adequate force could reach it by a prescribed route of travel, including also the time which has elapsed since actual discovery.
(d) From local tables giving estimated rates of fire line construction per man hour in the fuel types concerned, or from local knowledge of such rates of construction, estimated the number of men required to be sent to the fire immediately.
(e) If this number is in excess of that already dispatched to the fire - send an adequate second force immediately. If sufficient men have already been sent, await advice from the fire, or from lookouts, which will give further definite information concerning rate of spread, difficulties or success in fire-line construction, local influences such as wind direction and intensity etc.
(f) Continue to send necessary reinforcements based on the method outlined above, according to definite reports received concerning fire perimeter, fire line construction versus rate of spread etc.; maintaining a close touch meanwhile with all available weather recordings, forecasts, trends etc.; and considering such factors as the approach of night or day, changes in burning conditions towards which the fire is spreading etc.
(g) Once a strong and sustained initial attack has failed, reconsider the number of men required on the fire, depending on the length of working shifts to be used by the initial crews, and by sufficient reinforcements for the introduction of shifts.

The "Fire Despatcher", who has charge of all administrative action concerning the forwarding of men, tools and equipment, maintains a full record, on special forms provided, of all calculations made by him of "probabilities". Such record includes the "corral time" calculated by him, according to reports made available by lookouts, or from the fire, and to the procedure adopted in estimating the hour at which such "corral" should be completed. When such estimates have to be revised, and additional forces despatched, a complete record of revised calculations must be made. Only in this way can the despatcher take action in a systematic way, or can a future assessment be made, from his records, of the correctness of such action. In some Regions, despatchers are assisted by specially prepared tables indicating, as a general guide, necessary action to be taken in sending suppression units to fires according to fire danger rating fuel types. The tables prepared for this purpose in the Intermountain and Central Rocky Mountain Regions are illustrated in Tables Nos 45 and 46 respectively.

6. "Mopping-Up" Time.

It is rarely possible to lay down standards for the time to be occupied in "Mopping-Up," a term applied to "securing" a fire once it has been completely "corralled". The shorter the period occupied by such work, the sooner will the heavy suppression costs of large fires be reduced by the withdrawal of men. For instance, during the severe fire season in the Pacific North West Region in 1939, as much as 80-90 per cent of the total suppression costs of approximately $1,000,000 expended by the Region were incurred on "mop-up". Lessons learned from past fires, at which careless mopping-up along well constructed fire lines only resulted in fresh outbreaks, have imbued foresters with the necessity for careful mopping-up. Present methods of executing the work aim at making the held fire-line safe indefinitely, irrespective of the severity of any weather conditions which might eventuate. The period is, of course, greatly reduced if adequate water supplies are available, together with necessary equipment, and the use of water on mopping-up is mandatory in most Regions. The period will, however, be greatly increased if a large number of snags are burning, or likely to burn, in close proximity to the fire line. The length of the period is also greatly affected by the suppression technique adopted - if an adequate number of men has been detailed to mop-up various sectors while fire line construction was proceeding, the final mopping up procedure is greatly simplified. Another factor to be considered is the natural tendency of all suppression units to relax, once fires are effectively "corralled", while it is also difficult to gauge the output of labour forces engaged on mopping-up, owing to the scattering of man-power on the variety of duties concerned therewith.

Local administrative officers and/or "fire despatchers" must have considerable local knowledge of the burned area, with which they can correlate information received from the fire front in determining what is a fair period to be spent on mopping-up. Determination of the period actually necessary for the work, is, however, more the responsibility of the "Fire-Boss", who is in the best position to judge whether undue risks are being taken in reducing the number of suppression crews too quickly. Once a fire is effectively corralled, intensive effort is mostly concentrated on careful mopping-up along its entire perimeter, with the dual objective of (a) consolidating under any weather conditions, successes gained in suppression efforts, and (b) reducing the number of men engaged at the fire as soon as possible.

TABLE NO. 45.

Showing Number of Men to be despatched to Fires in various Fuel Types, according to Fire Danger Conditions prevailing, Travel Times to fire etc., if the Control Time is to be limited to the "First Work Period". (before 10a.m. next day).
Intermountain Region - U.S. Forest Service.

Note - Humidity Periods adopted in the Region - e.g. Nos. 1,2,3,4, & 5, correspond to Fire Danger Ratings of Dormant, Low, Medium, High and Extreme, respectively.

TRAVEL TIME (HOURS)	NUMBER OF MEN FOR INITIAL ATTACK ON FIRES															
	BRUSH GRASS TYPES (HUMIDITY PERIOD)				DOUGLAS FIR TYPE (HUMIDITY PERIOD)				PONDEROSA PINE TYPE (HUMIDITY PERIOD)				LODGEPOLE AND OTHER TYPES (HUMIDITY PERIOD)			
	1	2	3	4 & 5	1	2	3	4 & 5	1	2	3	4 & 5	1	2	3	4 & 5
0 - 2	2	3	3	5	1	3	5	10	2	4	9	36	1	3	4	6
2 - 4	3	4	5	6	2	4	7	12	2	5	13	50	2	4	5	8
4 - 6	4	6	7	8	3	6	9	16	3	8	18	60	3	6	7	10
6 - 9	7	8	9	10	5	9	14	25	4	11	25	81	5	8	10	14
OVER 9	11	12	12	13	8	14	18	37	5	16	33	104	9	12	14	18

TABLE NO. 46.

Central Rocky Mountain Region - U.S. Forest Service - Table showing Number of men required for initial attack under peak (midday) conditions for different Fuel Types, and for average Burning Conditions, under various ratings of Fire Danger.

TRAVEL TIME	FUEL TYPE WITH HIGH RATE OF SPREAD			FUEL TYPE WITH MEDIUM RATE OF SPREAD			FUEL TYPE WITH LOW RATE OF SPREAD		
	FIRE DANGER RATING			FIRE DANGER RATING			FIRE DANGER RATING		
	HIGH	MEDIUM	LOW	HIGH	MEDIUM	LOW	HIGH	MEDIUM	LOW
HOURS - MINUTES									
0 - 15	2	1	1	2	1	1	1	1	1
0 - 30	3	2	1	2	1	1	1	1	1
0 - 45	5	2	2	3	1	1	1	1	1
1 - 00	6	3	2	3	2	1	1	1	1
1 - 15	9	4	3	4	2	1	1	1	1
1 - 30	14	5	3	5	2	2	2	1	1
1 - 45	35	7	5	6	3	2	2	1	1
2 - 00	50	10	6	8	3	2	3	1	1
2 - 15		20	9	10	4	3	3	1	1
2 - 30				15	5	4	4	2	1
2 - 45				33	7	5	4	2	1
3 - 00					11	7	5	3	2
3 - 15					25	10	5	3	2
3 - 30					40	20	7	3	2
3 - 45						38	11	4	3
4 - 00							25	6	4
4 - 15								12	7
4 - 30									
4 - 45									

Note - A "high" rate of spread for a fuel type is 12 chains per hour
A "Medium" " " " " " " " 8 " " "
A "Low" " " " " " " " " " 4 " " "

(Photo by U.S. Forest Service).

Fire Despatcher at work - Idaho City Ranger Station - Boise National Forest - Idaho. - Note telephones, radio, fire map etc.

(Photo by U.S. Forest Service).

Backfiring from firebreak in Chaparral Type using water from Tank Truck (hidden) - Temperature 112°. - Brown Mountain Fire - Angeles National Forest - California.

(ii) Effective use of man-power.

The securing of best results from a large and varied assortment of labour is attempted, in the Fire Plan for each Forest unit, by allocating sufficient officers, or permanent employees, to adequately supervise varying numbers of emergency employees. While initial suppression effort is almost entirely the responsibility of permanent employees, and is thus usually in safe hands, forest protection systems must be thoroughly organised to produce this much desired swift and certain initial attack. The qualifications and responsibilities of all protection employees and "overhead" have already been explained in discussing general personnel problems, as they affect suppression forces. It is the few large fires which cause most serious damage to forests, unless they can be met by a properly organised, and well directed, labour force. It is the duty of all administrative officers to plan their organisation, and so allocate responsibility, that the need for excessive emergency labour does not arise, or if this does happen that the most effective use is made of inexperienced man-power. This allocation of responsibility is discussed hereunder:-

(a) Responsibilities of "overhead" staff.

1. DESPATCHER.

In actual fire suppression tasks on large (or small) fires, the principal responsibility is that of the Fire Despatcher, some of his duties regarding the despatch of men having already been explained in preceding pages. The despatcher, or "dispatcher" as he is called in U.S.A., may not necessarily be a trained forester such as the District Ranger. In many cases, as in Eastern Regions, the Ranger hands over his despatching duties to a technically trained assistant, but in most of the Western Regions, all despatching is handled by temporary but experienced employees. Efforts are made to give these temporary employees as much work as possible, outside the fire season, on the maintenance of roads, trails, telephones etc. or as works foremen in C.C.C. camps. In the Southern Region, lookouts who are employed throughout most of the year, often combine detection duties with despatching. The use of temporary employees in such a responsible position is the clearest possible indication of the completeness of the District Ranger 's Fire Plan.

Apart from estimating "control time", and from despatching sufficient labour forces to complete corralling with such period, the despatcher has other major responsibilities as follows:-

(i) He receives and records reports from all fires, from lookouts etc., and is also in constant communication with Ranger or Supervisor headquarters concerning the spread of the fire, progress of suppression action etc.
(ii) He must be fully alive to the necessity for further reinforcements from the sources mentioned in the local Fire Plan, after making any necessary provisions for "Stand-By" of extra men to be required.

(iii) He fills gaps left in the detection or other phases of the protection organisation, due to the despatch of "key" men to take charge of suppression crews.
(iv) Having despatched adequate labour forces to the fire he must follow up such action, as soon as possible, by the despatch of adequate and necessary supplies of tools, equipment, food, water, camping materials, cooks etc.
(v) Wherever practicable he must arrange for the despatch and use of labour-saving machinery such as tractors, horses, ploughs etc., or for water required to assist fire-fighting etc.
(vi) Maintenance of up-to-date weather records from the best available source, and the correlation of weather trends with action taken, or required, on fires.
(vii) Maintenance of a map showing progress of fire, based on all reports received.
(viii) Maintain touch with neighbouring forests, or with other units or agencies co-operating in the supply of labour and equipment. If men have been called from these sources for initial attack, they must be returned as soon as reinforcements can take their place.
(ix) Assume complete charge of all action taken towards suppression, until such time as the "fire-boss" is able to establish communication from the fire or fire camp and can direct all necessary action from the scene of operations.
(x) Maintain a log of all action taken, messages received and despatched, including details of exact times of such action.
(xi) Prepare all necessary records of the fire, on the forms provided, including payments to fire fighters and others, total costs etc.
(xii) Prepare all necessary information for the press or for other mediums of publicity, and issue notices to administrative officers concerning restrictions necessary on the travel routes or on movements of the general public.
(xiii) Organise repairs to those communications which have failed, and direct the establishment of radio or telephonic communication to supplement that already existing, according to the size and location of the fire. This work involves the despatch of necessary radio or telephone materials, <u>with</u> competent operators and/or mechanics.
(xiv) Arrange for despatch of urgently required lighting equipment, where critical conditions probable on the succeeding day dictate maximum suppression effort at night.

2. <u>THE FIRE BOSS</u>. - usually the District Ranger is in actual charge of fire fighting, irrespective of whether the number engaged is less than twenty, or exceeds a thousand. Provision exists, however, for the Ranger to be deposed from the position if the Forest Supervisor is not satisfied with his handling of a particular fire. On larger fires he is allotted certain assistants, but he remains in central control of the situation. He attempts to obtain a thorough and constant personal knowledge of the behaviour of the fire, and of all action proceeding towards its suppression, but on large fires he must remain at a central camp, to which telephonic or radio communication has been effected, and rely on the reports of his assistants,

transmitted to him by special "scouts". On small fires, where less than 25 men are engaged, he may combine direction of fire-fighting with the duties of timekeeper, scout, and camp foreman, but for large outbreaks he requires assistants for such tasks.

In general, his duties and responsibilities may be summed up as follows:-

(i) Estimating the extent of the suppression task, and the most suitable methods of attack.
(ii) Maintaining constant touch with the progress of suppression efforts as compared with the rate of fire spread.
(iii) Making rapid decisions regarding the need for certain reinforcements within proscribed time limits, the uses of water-using or other labour saving equipment.
(iv) Maintaining adequate supplies of tools, equipment, food etc.
(v) Selecting the most central position for any necessary fire camp or camps, and directing the forwarding of all necessary camping equipment.
(vi) Directing the placement of suppression crews on the fire line, and arranging for the introduction of shift work if necessary.
(vii) Supervising arrival of men at the fire camp or fire, and their equipment with necessary tools, food supplies etc.
(viii) Directing the preparation of meals to coincide with the commencement or completion of shifts.
(xi) Directing the duties, responsibilities etc. of all subordinates.
(x) Maintaining constant communication with the dispatcher concerning progress of efforts at control, the need for further reinforcements, supplies etc.
(xi) Reducing the labour forces at the fire, as soon as weather conditions, or the completion of "mopping up", permit.
(xii) Keeping a comprehensive "log" of all suppression action taken, and of directions issued.

Depending on the extent of the fire, the "Fire-Boss" usually requires the undermentioned assistants, each of these having specified duties:-

(i) Fire Scout - The "Scout" on larger fires will either be an experienced forest officer or permanent local employee. His principal duties are to scout the fire perimeter, guide the movements or the necessary suppression action by labour forces, select possible camp sites, locate water supplies for camp or fire-fighting use, maintain a record of the progress of the fire (if possible by field sketching), keeping the Fire Boss constantly informed of such progress, making recommendations re control procedure, and acting as messenger between the "Fire-Boss" and the fire. When and where possible, the "Fire Scout" carries a portable radio set to maintain constant communication with the "Fire Boss"

(ii) Division Boss - This man is required on very large fires where separate suppression efforts are being conducted on various "Sectors", which may be manned from separate camps. A Division Boss may have charge of two or more sectors where distinct parts of a single fire require separate handling. He must maintain close touch with the Fire Boss by messenger, or by other means of communication, to report progress and to ensure that action being taken is in line with the general tactics adopted for the whole fire.

(iii) Sector Boss - This officer (usually a Forest Officer) works under the "Fire Boss" (or under one of the Division Bosses" on large fires) and usually has charge of two to four crews of 25 to 30 men each. He is charged with local planning of the efforts of his crews, over topographic sectors of one mile or more, to secure the best results at suppression from a particular output of man-power. He is responsible for the safety of the crews under his direction and is in a position to recommend changes in suppression strategy.

(iv) Crew Foreman or "Boss" - in charge of 25 to 30 men. This foreman is an experienced regular employee charged with leading his men in all necessary duties associated with fire line construction, or other suppression work. His main responsibility is to produce the maximum output of effective man-power from his crew by having them distributed effectively, suitably rested and fed, properly supplied with necessary tools, etc. It is the foreman's responsibility to discharge unsuitable men, check the movements of his crew (and their tools) in and out of the fire camp, care for injured employees etc. He maintains written records of time worked, fire line constructed, or other necessary data.

(v) "Straw-Boss" in charge of 8 to 10 men, has intensified control over largely inexperienced labour forces, and seeks to make the best use of these men on duties assigned to him by the Crew-Foreman. He closely supervises the work of his gang, makes best use of tool supplies, and ensures that the men engaged know how to use such tools. He is responsible for getting his men in and out of the Fire Camp, arranging for their meals, for the handing in or transfer of their tools etc. Separate "Straw-Bosses" are usually detailed for supervision of the clearing and other crews employed with Ploughing Units (horse or tractor drawn).

(vi) "Camp-Boss" in charge of specially established Fire Camps, is preferably a Forest Officer under the direction of the Fire Boss. In large camps he allocates the duties of Timekeeper to an assistant. He is responsible for the layout, discipline, sanitation etc. in the camp, supervises the cooking and serving of suitable meals or lunches at specified times, the checking in and out of all tools, equipment, food etc., the sharpening and repair of tools. Assistance is also given to the "Fireboss" in relaying, receiving or transmitting messages, maintaining telephonic or other communications, mechanical repairs to equipment etc.

In supervising time-keeping, he must maintain a close record of all men arriving or leaving the camp, the number of hours worked by each, travel time to which each is entitled, and also keep all necessary records of supplies, food, tools, equipment etc.

Other officials who may be used on large fires (e.g. California Region) are those specially in charge of such individual tasks as Communication, Transportation, Supply, Maintenance of Mechanical equipment etc.

(b) Some general factors to be considered.

In defining the responsibilities of those members of "overhead" concerned with fire suppression, most of the essential factors to be considered in organising man-power to the best advantage have already been mentioned. All Regions of the U.S. Forest Service, however, stress the importance of various other factors to which particular attention must always be given.

Some of these are listed hereunder, without any efforts at their elaboration:-

1. Necessity for adequate "overhead" - if necessary, relief or additional overhead to be sought from the Regional Office, and in some cases, flown to the fire.
2. First attack to be based on existing or "average bad" burning conditions, but with larger fires reinforcement action to proceed on the basis of "worst probable" conditions.
3. The maximum possible use of weather forecasts - if possible (as in Western Regions) by the use of mobile weather and forecasting units, taken as near as possible to the fire.
4. In determining strength of labour forces, due allowance to be made for the use of inexperienced labour (such as C.C.C. enrollees), or for fatigue of the initial crews.
5. On large fires, shifts should conform to local conditions, but should not exceed 10-12 hours (except for first attack), unless material gains will result. Undue fatigue is avoided.
6. If saddle stock is available for use by "overhead" etc., make the fullest possible use of same.
7. All possible use to be made of any machinery of mechanical equipment in the vicinity, or available at short notice, provided same can reach the fire in short time, and be profitable employed there.
8. Night work to be concentrated on at all times unless better results can be obtained by waiting until daylight. The "day crew" should be breakfasted and sent out to the fire line <u>ready to start work</u> at dawn.
9. The attack is to be sustained irrespective of conditions, as even the largest fires have an occasional lull which can be taken advantage of.
10. The morale of all men to be kept up, and the greatest care taken not to expose inexperienced men to conditions of serious danger. Food provided to the men should be adequate and appetising. All lunches to be packed individually to avoid "bunching" of men on the fire line.
11. All Fire-Camps to be kept in orderly condition, with no undue noise permitted when crews are resting.
12. Inefficient work not to be excused, and all waste in man-power, supplies, materials etc. to be avoided.
13. Reduction in suppression forces to be commenced once it is <u>definite</u> that "corralling" and "mop-up" have succeeded.

CHAPTER XV.

FIRE REPORTS.

The importance of fire history to fire control planning has already been emphasised, together with the need for accurate information so that the fire history can be built up. Modern policy in Fire Control calls for complete records of all kinds, with the object of building up permanent statistical records for future reference. These records, coupled with the various maps comprising the Fire Atlas, form the basis of all Fire Control Planning.

Various standard forms are used by the U.S. Forest Service for supplying information regarding all kinds of protection efforts and these are summarised hereunder:-

1. Individual Fire Reports - are furnished by District Rangers, within ten days of fire suppression, giving a mass of detailed information of all kinds for each reportable fire. Form 929 of the U.S. Forest Service which is used in reporting individual fires, is illustrated in Appendix No. "F" together with instructions for its use. It will be noted that the form is specially designed so that all data thereon can be converted to a standard code for statistical use. Form 929 is used to record only "statistical fires", or those which endanger National Forest land, and which are suppressed wholly or in part by Forest Service employees or co-operators, or those on which any suppression costs are incurred. The term "co-operators" in the above definition may include either individuals or organisations with whom co-operative protection is arranged. Examples of non-statistical fires, which are not reported on Form 929, are given in the printed instructions for use with the form.
2. Extra Period fire Reports - for fires which remain uncontrolled after the "First Work Period" has elapsed (e.g. after 10 a.m. on the day succeeding their discovery). These reports are furnished on mimeographed forms by the District Ranger.
3. Ten-Day Reports on Form 928, are furnished on prescribed dates e.g. the 10th, 20th, and last day of each month, by Rangers to Supervisors, and by Supervisors to the Regional Office. They list the occurrence of fires, general conditions of hazard etc. prevailing etc.
4. Annual Reports - of various kinds were formerly furnished on different forms but have now been eliminated because of the ease with which statistical data can be extracted from Form 929. Those data include a summary of fire damage appraisals.
5. Summary of action taken on State forests, private areas etc., under the control of State authorities. Submitted, on Forms 926 A & S, to State Foresters by Supervisors of the U.S. Forest Service - usually through the Regional Office.
6. Fireman's Report - on Form 592 or on local forms - describing action taken in initial attack re suppression, investigation of fire origin, rate of spread etc. Collected by Rangers and submitted to Supervisors, within ten days of fire suppression, to assist in the preparation of Form 929.

Numerous other reports, in accordance with standard practice, but on local forms, are used in various Regions. Among these reports are:-

(a) Telegraphic Reports - to Regional Offices, giving notice of the occurrence of all large fires, of fires costing more than £100, those of extra period occurrence, action taken etc., - forwarded on same date by night telegram.
(b) Preliminary Reports - by mail, within 24 hours of final suppression action, detailing the occurrence of fires or false alarms, suppression efforts, approximate cost etc.
(c) Lookout Reports - collected by District Rangers at suitably short intervals, and forwarded to Supervisors. Local Forms are used, on which the lookout provides all information regarding outbreaks etc., within a specified period.
(d) Lightning Strike Occurrence - giving full details of number of strikes, locality, time, duration of storm etc. - completed on special local Forms, and submitted in the same way as Lookout Reports (They may be completed by either Primary Lookouts or Lookout-Firemen).
(e) Special Reports on large fires such as "Held-Line Production" Report, Current Fire Record of Despatcher's Action etc., are submitted to Supervisors or Regional Foresters, for analysis and review, as soon as possible after completion of action on any fire.

These Special Reports may be submitted on a variety of local forms, as in the California Region, where the following forms are used:-

F.C.1. "Fire Organisation Form", details the organisation engaged on the fire and its major achievements.
" 2. "Cumulative Report" - Showing building up labour force on the fire.
" 3. "Man Power Record" - " man-power and overhead engaged, and for what periods.
" 4. "Transportation Sheet" - Showing details of all means of transport used.
" 5. "Crew Boss Time Report" - The crew employed by each Crew Foreman, and the shifts worked by them.
" 6. "Crew Boss Tool Record - Showing all tools received, returned, etc. by each crew.
" 7. "Temporary Fire Property Record" - Detailing all equipment transported to a fire in an individual truck or pack load, or transferred from one Fire Camp to another etc.

(f) Forms for Re-imbursement of C.C.C. authorities - detailing amounts due to the C.C.C. for meals supplied by their commissariat to Forest officers, employees etc. forwarded by C.C.C. Camp Commanders to Forest Supervisors.

PART V.

ECONOMICS.

169) 7012 (41·5
676
252
169
830

169) 7498 (44·4
676
738
676
620

169) 2389 (14·1
169
699
676
230

100·0

CHAPTER XVI.

ECONOMICS OF FIRE PROTECTION.

A. Some Economic Aspects of Fire Control Policy.

In previous pages an attempt has been made to show the influence of uncontrolled fires on forests and on their management. It has been indicated that some degree of fire protection is required if forests are to maintain or improve their productive capacity.

To a very large extent the forest lands of the United States have already been greatly depreciated in their productive capacity because of indiscriminate exploitation and uncontrolled burning. For this reason, effective methods of protecting such areas from fire are required. Partial protection will only perpetuate the existing stands of unmerchantable and partially stocked forest, while money invested in such partial protection can be written off as a loss. On the other hand, complete exclusion of fire from forests is practically impossible, however efficient the protective system involved. Experience in city and urban areas indicates that large property losses can, and do, persist despite scientific means of protecting such property and despite highly organised suppression methods. Even if total protection from fire were possible in forests, the cost of maintaining such protection would be inordinately high.

It must be admitted, at the outset, that fire protection expenditure on any forest area must bear some relation to the values at stake, and is thus directly correlated with the aims and intensity of forest management for that area. If timber production is the main object of management, a sufficient degree of protection must be afforded to protect the growing crop from damage or destruction. If watershed areas owe their principal effectiveness, as such, to a forest cover, the protection of such cover must be provided for indefinitely. The use of forests for recreational purposes has been discussed already, and the damaging effect of fire on scenic values needs no elaboration, so that areas used for recreation must be rigidly protected. It has even been shown that fire protection is a major factor in maintaining the proper balance of environmental conditions for wildlife in forest areas. As any individual forest may include most of the above considerations in its management aims, it follows that any evaluation of the values at stake is rather difficult to achieve.

Reference to the early pages of this report will indicate that the economic necessity for preventing and/or controlling forest fires is by no means generally admitted in U.S.A. On the contrary, certain regions like the South adhere to pioneering beliefs that burning actually benefits the forest, irrespective of the nature of such burning. While great progress has been made in a general movement to conserve National resources, the public still regard forests as inexhaustible in timber wealth irrespective of the amount of burning done in these forests. Some of the efforts necessary to overcome public disinterest in the protection problem, such as education, law enforcement, strengthening of State organisations controlling Forestry etc., have already been mentioned.

The greatest need of all is, however, the provision of assured and continuous financial support for a long-range scheme that would extend and improve the existing efforts at Fire Control. The value of a rapid and sure initial attack has been explained in previous pages, together with the need for heavy capital expenditure in providing the detection, transportation, equipment etc. necessary to furnish this initial attack. Because of their exposure to uncontrolled fires, many areas lack the existing values which warrant such expenditure, although their protection would prove profitable eventually.

The issues would be much plainer if all forest land was owned by Federal or State Governments, in which case fire protection could be handled as a national problem, and necessary improvements effected by direct budgetary appropriations. The whole position is, however, greatly complicated when one considers that some 70 per cent of the entire forest estate of the nation is held in private ownership by some four and a half million separate owners. Although much of this private forest land is hardly worth the costs of fire protection, it must be remembered that some 60 per cent of the old growth timber crop of the United States is in private lands. It is admitted by competent forest authorities that inequitable taxation of forest lands is a serious obstacle to the continued growing of timber crops on much forest land, so that private owners of forest land can hardly be expected to incur material expenditure on fire protection, more especially when one considers that these landowners are themselves responsible for loss than a quarter of the acreage burnt over each year on private lands. In addition, landowners should not be expected to contribute towards the cost of protecting their forest land from fire, because such land happens to be situated on watershed areas. The seriousness of the latter problem can best be emphasised by indicating the fact that some two-thirds of the forest area having a protective influence on watersheds is at present in private hands.

In short, fire protection as a national problem must remain a national responsibility. If the Federal Government assumes responsibility for enormous reclamation or other expenditures in flood control, erosion control etc., it should at least assume responsibility for national forest protection, if only to reduce the ultimate costs of reclamation. The State Governments should also assume a greater share of responsibility, inasmuch as any conservation of private timber resources builds up the resources of the State concerned, while States such as California, with extensive communities dependent on irrigation schemes, must have some real interest in preventing fire on watershed areas. As noted earlier in this report, the Chief Forester of the United States has suggested that current annual expenditures on the fire protection of State and Private Forest land be increased, from a total slightly exceeding Eight million dollars, to a total of Eighteen and a half million dollars, quite apart from C.C.C. expenditures, approximating 17 Million dollars per annum, on the fire protection of these lands. The Chief Forester agrees that the Federal Government should bear the greater part of such increased expenditure, by increasing its present annual contribution of approximately $1\frac{3}{4}$ million dollars to an annual total of 9 million dollars.

Increased appropriations for fire protection do not in themselves constitute a remedy for the economic losses associated with fires on private forest lands. The need for planning in fire protection, if maximum efficiency is to be associated with due economy, has already been emphasised in those pages, and any increased contributions by Governments should be expended in accordance with such planning. Private owners must conform to such planning and contribute towards its execution, at least to the best of their ability. Since the Federal Government first extended financial assistance to the States, and to private owners, for fire protection, the great majority of the States have improved their forest legislation and administrations. Machinery thus exists for a further extension of Fire Control, through the State authorities, to private lands requiring same. Sooner or later, Fire Control measures in rural communities must assume a form similar to the compulsory contribution imposed on all property owners for the suppression of fires in urban centres. With increased contributions from Governmental sources, those made by private owners may be reduced, but they will continue to vary according to the relative values of respective areas of private forest. With protection from fire ultimately improved on those lines, there would no longer be any serious obstacle to the development of forest fire insurance on a large scale, contributions by private owners being slightly increased in the form of insurance premiums. For the present, however, such schemes for large scale insurance have small promise of success.

It is perhaps significant to note, as mentioned in the 1938/39 Annual Report of the Chief of the U.S. Forest Service (195), that the present trend towards much desired improvement in the fire protection of Southern forests is the organisation of such protection on a County-wide basis, with all private owners contributing to same, according to compulsory assessments made of their forest values. Such extensions of the present system of co-operative protective organisations in rural centres would seem to offer the best means of generally improving forest fire protection on private lands, even though the present voluntary system of contributions was changed to compulsory payments of assessments made by Local Government authorities.

B. Fire Control Objectives.

The object of planned Fire Control is to secure adequate protection for any forest area, by means of expenditures having some close relationship to the values at stake, and the risks prevailing thereon. The term "Adequacy of Fire Protection" has been defined (190) by the Forest Service as "that which results in the minimum total of damage, i.e., cost of protection plus damage, with indirect losses, reductions in value to the public, as by the burning of watersheds, etc. included". In determining whether the protection offered to any area could be termed adequate, United States foresters have used two main standards of comparison based, respectively, on "The Least Cost Theory" and "Permissable area of burn".

(i) The Least Cost Theory - as explained by Flint (48) and others, this theory postulated that the amount to be spent on Fire Control on any individual forest area, plus estimated damage in spite of fire control, should equal the total of suppression costs and damage to the forest which resulted in the absence of any control measures. In actual practice, it was usually proved that where fire control was planned on this basis, the total costs involved were usually far less than those occurring prior to the introduction of control measures. Even if the total expenditure in each case were the same, that incurred on a planned basis would be largely spent on prevention and pre-suppression measures, so that the material losses experienced in the forest would be greatly reduced. In estimating damage to forest stands, it was of course necessary to prepare damage appraisals as already described in these pages, but in advocating the use of the theory, Flint considered only the material losses to the timber stand, and not the indirect losses sustained by the site, or to the regenerative capacity of the stand after death or severe damage. In applying this theory for the determination of relative values in various forest stands, Hornby (88) appraised damage at half the value of a mature stand, this figure to be used as an average throughout the Rotation. To this figure Hornby added varying amounts for recreation values, according to the extent such areas were used for the purpose. On remote and inaccessible forests, he used a minimum valuation of only one dollar per acre, one half of which was for recreation values.

Provided accurate appraisals of past damage are available in respect of material and indirect losses to the forest, the method of estimating prevention and pre-suppression expenditures provided for by the theory, is applicable to any administrative unit.

Such a method will demonstrate, in a practical way, whether restricted expenditures on the two items abovementioned are likely to result in heavy damage, or whether heavy expenditure on these items is not warranted because of the low values at stake. Application of the method necessarily implies that expenditures mentioned (pre-suppression, prevention etc.) will be the result of carefully formulated plans for Fire Control, in accordance with modern conceptions of such planning.

(ii) Permissable area of burn (or "Allowable Burn").

Owing to difficulties experienced in appraising the extent of fire damage to forest areas, many foresters adopted as their standard of adequate protection, the percentage which the area actually burned over annually formed of the total area under protection. Such percentage was then compared to an arbitrary percentage of "allowable burn" for the administrative unit concerned. This arbitrary figure was based on the amount of burning which any forest type could withstand, without seriously impairing forest values, according to the purposes of management. The ratio between the percentage burned over annually, and that prescribed by the "allowable burn", indicated whether protection could be classed as adequate or inadequate. Early efforts at arbitrarily fixing the "allowable" burn, usually aimed at selecting a figure which was less than existing percentages of burned area, in the hope of achieving some improvement in existing measures of fire control. In some cases this goal was achieved, and new and more exacting standards of allowable burn were fixed. These early efforts did not, however, allow comparison between various administrative units, as they did not allow for the wide variations existing in fuels, climate, risks etc., between various forest regions.

In order that the standards of efficiency reached in various regions might be better compared, the U.S. Forest Service prepared a list showing the percentages of "allowable burn" for each of the principal forest types in the country. As described by Kotok and others (215), this list was prepared after full consideration of the following major factors:-

(i) The damage which a given fire will cause to present and potential timber growth, and to other forest values.
(ii) The damage which a given fire will cause to the productivity of the site.
(iii) The difficulty experienced in restocking the area after burning.
(iv) The extent to which any fire will increase the difficulties, and the costs, of future fire protection.

The list prepared of the "allowable burn" for each forest type is illustrated in Table No. 47. It will be noted that the Spruce and White Pine types have the lowest rating, while the figure fixed for the Longleaf Pine Type is thirty times as high. In preparing the values shown in the list, the area covered by those fires used for silvicultural or protective purposes was not included.

From the list prepared for the various types, it is possible to prepare additional data showing broadly comparable percentages of allowable burn for any given Region, or smaller administrative unit. A distinction was made as regards ownership - the percentages adopted for different Regional and ownership classes being shown in Table No. 48, together with comparisons made, for such classes, between actual annual burns from 1926 to 1930 and fixed "allowable burn" percentages. From this latter Table it will be noted that, for the five year period indicated, the area of actual burn on State and Private lands was eleven times as great as the "allowable burn" for these areas, while the total area burnt on National Forests practically coincided with the percentage fixed as "allowable". As a comparison, it might be stated that figures derived from Table No. 3 which show the areas burnt for various classes of forest ownership during the period 1934-38, show that on National Forests, the percentage of actual annual burn during this period was only 43 per cent of the figure quoted as "allowable" for such Forests. Progress is also noticeable, during the latter period, on State and Private Forests, the percentage of actual annual burn being 7·97 times the "allowable" percentage for these Forests, as compared with eleven times the "allowable burn" during the period 1926-30.

The excessive figures of allowable burn still shown for State and Private lands are due to the tremendous acreage burnt annually on forest areas having virtually no fire protection (see Table No. 3).

Table No. 48 shows how the Southern Region constitutes the most serious problem, notwithstanding the fact that the "allowable burn" fixed for this Region was much higher than elsewhere.

TABLE NO. 47.

Showing Indices adopted for Effective Fire Control in Various Forest Types - (from a National Plan for American Forestry (215)- P.1399)

TYPE	ANNUAL ALLOWABLE BURN (per cent)
White Pine	0·10%
Spruce	0.10
Larch-Fir - White Pine	0·15
Northern Hardwood	0·20
Bottomland "	0·20
Larch-Fir	0·25
Douglas Fir	0·2 - 0·3
True Fir	0·2 - 0·3
Norway Pine	0·3
Ponderosa Pine	0·3
Mixed conifers (California)	0·3
Jack Pine	0·5
Appalachian Hardwood	0·5
Aspen	0·7
Slash Pine	0·7
Lodge Pole Pine	1·0
Shortleaf "	1·0
Loblolly "	1·0
Sand Pine	1·0
Oklahoma Hardwood	1·0
Longleaf Pine	3·0
Recreation Values	0 - 0·5
Watersheds	0·4 - 2·5
Brush and Non-Timbered	2·5
Non-Commercial Forests	2·0

T A B L E N O. 48.

Showing Objectives in Fire Control on National Forest and and on State and Private Forest land by various Regions.

(From - A National Plan for American Forestry (215 - P. 1399-1400).

REGION	ALLOWABLE BURN		RATIO OF ACTUAL ANNUAL BURN TO ALLOWABLE BURN - 1926-30	
	STATE AND PRIVATE FORESTS	NATIONAL FORESTS	STATE AND PRIVATE FORESTS	NATIONAL FORESTS
	per cent	per cent		
NEW ENGLAND	0·16	0·13	1·84	0·015
MIDDLE ATLANTIC	0·35	0·16	2·97	3·79
LAKES STATES	0·36	0·43	2·70	0·85
CENTRAL	0·59	0·50	5·36	1·03
SOUTHERN	1·34	0·90	14·19	1·02
PACIFIC COAST	0·49	0·27	4·96	2·78
NORTHERN ROCKY MTN.	1·05	0·56	0·99	0·87
SOUTHERN " "	0·41	0·49	0·56	0·70

C. Expenditures.

(1) Fire Control Costs and their trends.

The total costs incurred by the U.S. Forest Service, and by State and Private agencies, on Fire Protection have already been mentioned in discussing the general costs of Fire Protection, and the co-operative efforts made between Federal and State Governments. Reference to Table No. 7 will show that Fire Control costs on National Forests increased from 3·58 cents per acre, for the year ending 30/6/34, to 7·76 cents per acre during 1936/37.

This expenditure included Prevention, Pre-Suppression and Suppression Costs in the proportions shown hereunder:-

	Year Ending 30/6/34	Year Ending 30/6/37
Prevention Costs	17·9 per cent	13·2 per cent
Pre-Suppression Costs	70·9 " "	70·7 " "
Suppression Costs	11·2 " "	16·1 " "
TOTAL	100·0	100·0

It will be noted that by far the greatest proportion of expenditure has been for Pre-Suppression, and that the proportion shown by this cost has been stable, while prevention and Suppression Costs have changed irregularly.

The preponderance of Pre-Suppression expenditure is due largely to the activities of the C.C.C. in the construction of roads, trails firebreaks, lookout stations, telephone systems etc.

As shown in preceeding pages, the annual C.C.C. expenditure chargeable to State and Private Forests, in connection with Fire Control, has recently been more than twice the total of all other expenditure on such areas Opinions differ as to the effectiveness of much of the C.C.C. expenditure, and whether it is directly chargeable to the Forests concerned, more especially as the primary aim of C.C.C. camps was the rehabilitation of American youth, and not their use as employment agencies. As discussed later, the U.S. Forest Service have charged only a proportion of actual C.C.C. costs to Fire Control or other work on National Forest areas, the rate of $1·50 per diem being used to assess the value of C.C.C. labour. Without the assistance of the C.C.C, it is doubtful whether National Forests could have been given their present protection within a period of many years. It must be remembered that, prior to their dedication, and to the introduction of Fire Control measures, the majority of the National Forests could be classed as "wilderness areas", lacking almost all their present facilities of road travel, detection and telephonic services, residences, etc. The same was true, to a lesser extent, of the State and Private forest areas, where Fire Control improvements are largely due to C.C.C. activities.

With most forest areas in U.S.A. in rather a backward state as far as forest management is concerned, Fire Control costs, and particularly those necessary for "Pre-suppression", must remain at a high level for some time. The successful initial attack on which Fire Control depends, demands large expenditures on "Pre-suppression". The figure of 7·76 cents per acre, which represents the total costs of Fire Control on National Forests during the financial year 1936/37 is probably adequate - in fact it exceeds the estimate of 6·83 cents per acre per annum mentioned by competent authorities (215) as being necessary for the protection of National Forests. This figure includes, however, a considerable output of man-power by C.C.C. enrollees, and its maintenance is based on a continuance of support from the C.C.C. organisation. In the absence of such support, the U.S. Forest Service would be in a difficult position, as fire protection of its forest areas could hardly be developed from funds usually available for forestry purposes, nor would such funds allow the employment of necessary man-power during the summer seasons.

As National Forests (and other areas of forest) become more intensively managed, permanent and trained labour forces will be available for necessary employment on fire protection, while transportation systems and other improvements will be used for general management purposes, and will no longer be directly chargeable to Fire Control. In addition, the protection of forests over long periods will eliminate many existing areas of high hazards, such as those of poor stocking, or those carrying inflammable brush, snags etc. Judicious expenditures on fire prevention should also cause a gradual decline in the existing large percentage of man-caused fires.

The ultimate trend will thus be a material reduction in pre-suppression costs, with a possible slight increase in prevention costs, while suppression costs should show a decline with better trained labour forces, and with the extension of labour saving equipment. Even if a reduction in total costs of Fire Control on National Forests cannot be realised in the immediate future, it can at least be anticipated.

No such reduction in total costs can be anticipated for State and Private forests, in fact expenditures on these areas must continue to increase until protection is extended more generally, and until considerable improvements are made in the standard of fire control measures on such forests.

(ii) Allocation of Expenditures.

No definite data are available concerning the allocation of expenditures on State and Private forests for fire control measures. On the other hand figures usually quoted to show the comparative co-operative contributions of Federal, State, and Private agencies to such fire control are not truly indicative, as they largely ignore suppression costs. In addition, no attempt is made to allocate the heavy fire control expenditure by C.C.C. camps on forest lands owned by State and other agencies.

Discussion will therefore be confined to the practice in operation on National Forests, as determined by the U.S. Forest Service. The costs of Fire Control for the U.S. Forest Service, as described by Scott. (156) are sub-divided into the main headings discussed in these pages, viz - Prevention, Pre-Suppression and Suppression, which include the undermentioned items:-

(a) Prevention - All costs of educational efforts, admonitory action, law enforcement work, hazard reduction etc.
(b) Pre-Suppression - The costs of organising protection (together with all allied expenses), up to the point where the suppression of actual or reported fires commences.
(c) Suppression - includes the cost of suppression all fires, or in connection with false alarms. Costs of damage appraisal, where necessary in preparing fire reports, and of reconditioning fire tools and equipment after use in fire suppression, are also included.

Since 1934, all direct expenditures on the above items have been supplemented by "cost adjustments" made for indirect expenditures associated with Fire Control. These "cost adjustments" include the undermentioned items:-

(a) Maintenance (i) Of all fire control improvements e.g. Lookout stations, firebreaks etc. etc.
(ii) Fire control's share in the maintenance of general forest improvements, such as those made to Ranger Stations, roads, trails, telephone line etc. (distribution is made on the basis of annual labour costs in connection with the above improvements).
(b) Depreciation (i) On all fire control improvements.
(ii) " " equipment used to assist fire control, based on the use made of such equipment, at standard rates per hour or mile for motorised or other large equipment, and on the original cost of tools, smaller equipment, as allocated when these tools etc. are worn out, broken or lost.
(iii) Fire control's share of depreciation on general forest improvements, allocated in similar fashion to maintenance of such improvements (see (a) (ii) above).
(c) The value of C.C.C. or other "Relief" Labour, used on Fire Control work, where such payments are not made directly by the Forest Service, from allotments received by the Service for employing such labour on forest work. In computing the value of such labour, an "efficiency rating" of \$1·50, per effective man-day, is made.

The "cost adjustments" described above constitute almost two-thirds of the total expenditures on Fire Control, and they are allocated, with direct labour costs, into the separate headings of Prevention, Pre-Suppression, and Suppression, to give the per acre figures enumorated in Table No. 7.

CHAPTER XVII.

FOREST FIRE INSURANCE.

The significance of the proper management and protection of private forests in U.S.A. to the general improvement of forestry, and to the general public interest, has already been mentioned in these pages. The present difficulty is to reconcile the numerous problems associated with private timber-growing or, forest management, to the national needs. While the Federal and State authorities are co-operating, in many instances, to assist the development of private forestry, investors refuse to believe that there is a satisfactory ratio between risk and return in timber-growing on private lands. Until recently, the lumbering industry on private forest lands has been conducted on a liquidation policy, instead of being regarded as a long term investment. Apart from taxation troubles, this liquidation policy has largely been dictated by fear of losing timber assets through fire. This possibility of irreparable loss has rendered adequate financing of the timber industry almost impossible, and with a shortage of working capital, operators have been precluded from practising any form of continuous operation, much less any suggestion of sustained yield working. From the broad viewpoint of national economy, quite apart from the necessary maintenance of numerous forest values, the liquidation of private forest assets is to be deplored, and any possible remedial action encouraged.

Forest Fire insurance, which has proved such a signal success in Sweden, Finland, and Norway, has recently come under notice as a possible remedy to the situation, particularly since recent achievements in fire protection of forests in U.S.A. have demonstrated the long debated fact that fire damage to forests can be held to a "satisfactory maximum". Fire insurance of forests should not be regarded as a substitute for fire protection. On the contrary, the introduction of insurance to forest areas would call for even more systematic and efficient efforts at fire protection. As in the case of other private enterprises, insurance of private forest assets would not only increase their value as an investment, but would relieve owners of their present responsibility for effective protection of forests.

In their efforts to overcome the present speculative phase in the lumbering industry, certain more thoughtful operators have looked to insurance with some hope, but have found that the small amount of business being accepted by insurance companies was only effected through the payment of unduly high premiums. Admittedly, insurance companies cannot be expected to underwrite isolated "parcels" of forest fire insurance at low premiums.

Reduction of existing premiums can only be effected by a more general participation, by landowners, in any sound insurance schemes offering. Even then, rates must remain high until companies "feel their way" and build up adequate reserves of funds against the not-impossible conflagrations of unusual severity which can and do occur.

In addition, companies can hardly be expected to confine their risks to a restricted locality, when a single fire of unusual severity in that locality would result in a tremendous liability. For this reason, local and mutual insurance companies could never hope to succeed, unless blessed with extraordinary good fortune. Not only must any successful scheme of fire insurance become widely accepted before its premiums can be reduced to a minimum, but its sphere of operations must extend over various climatic (and forest) regions of the nation to avoid undue losses in a single season.

The difficulties associated with the correct appraisal of the fire risk, or of the standing crop, on any individual forest area have also been serious obstacles to the introduction of forest fire insurance, but these difficulties have largely been eliminated by practical efforts made, along those lines, by the U.S. Forest Service in fire control planning, timber, surveys etc. The Forest Service have gone a step further, as already described (see Page 205), in their methods of appraising damage to both merchantable and immature timber stands.

From the standpoint of forest fire protection, the introduction of comprehensive systems of forest fire insurance would be an undoubted stimulus. Owners of timberlands, once convinced of its practical possibilities, would undoubtedly fall into line from motives of self interest, while insurance companies would provide an impetus to all efforts at improving the theory and practice of fire control. From the national viewpoint, it would even seem desirable for the Federal and State Governments, to assist the establishment of all reputable efforts at forest fire insurance, by providing loans or backing to any operating Companies during an initial period.

In an admirable analysis and presentation of the possibilities of introducing Forest Fire Insurance to the Pacific Coast States, Shepard (159) has recently demonstrated, at least on paper, that such insurance is "feasible and profitable" at the comparatively low premium of 0·45 per cent, provided reasonable precautions are observed. This premium is based on adequate reserves for periodical severe losses, and also on assured annual premium incomes of $150,000. With higher incomes, the premium rate could be gradually reduced as reserves were built up, so that with an annual income of approximately one million dollars, premiums could be reduced to 0·30 per cent.

The deductions by Shepard assume all the more importance when one considers that approximately two-thirds of the entire merchantable timber crop of the United States is located within the Western States which the investigation embraced. In his final advocacy of insurance for forest areas in these States, Shepard stressed the fact that any company entering the field would require courage and determination, while forest owners would be required to lend both support and co-operation if both parties were to achieve necessary success in the undertaking.

RELATIVE HUMIDITY *If the relative humidity falls below 15% read the next danger class to the right. If this cannot be done because the fuel moisture is already under 5% then read the danger class for the next higher wind velocity.*

AVERAGE AFTERNOON WIND VELOCITY IN MILES PER HOUR	FUEL MOISTURE CONTENT IN PERCENT — As measured with duff hygrometers and/or ½" diameter wood cylinders.						
	25.5 or more	18.6 to 25.4	13.5 to 18.5	10.6 to 13.4	7.5 to 10.5	5.0 to 7.4	4.9 or less
0 to 3.4 Very Light	1.0	1.1	1.2	1.4	1.8	2.4	3.2
3.5 to 7.4 Light	1.0	1.1	1.3	1.6	2.0	2.6	3.4
7.5 to 12.5 Gentle	1.1	1.2	1.4	1.8	2.2	2.8	3.6
12.6 to 18.5 Moderate	1.2	1.3	1.6	2.0	2.4	3.0	3.8
18.6 to 24.5 Fresh	1.3	1.4	1.7	2.2	2.6	3.3	4.1
24.6 or more Strong to Gale	1.4	1.6	1.9	2.4	2.9	3.6	4.4

FIRE DANGER CLASS

The fire behavior usually associated with each class of fire danger is indicated on the inside of Slide B.

ACTION COMMENSURATE WITH FIRE DANGER CLASS

The Fire Control Plan for each Forest in Region One shows both number of men and specific positions to be manned according to measured class of danger existing. The plan for a particular Forest is based upon (1) occurrence rate, or number and distribution of fires, (2) fuel types, or rate of spread and resistance to control, and (3) potential damage. Table X of these plans lists the specific stations to be manned according to the danger class determined by this meter. Early and mid-season organization placement should consider recent danger and anticipate higher. Late season action should consider recent danger and anticipate lower classes.

A MODEL NO. 5 B

FOREST-FIRE DANGER METER

NORTHERN ROCKY MTN. REGION

SEASONAL FACTOR AND ACTIVITY OF LIGHTNING

July 11 to Sept. 10 with no lightning within past 48 hours.	July 11 to Sept. 10 with lightning within past 48 hours.
June 16 to July 10 with no lightning within past 48 hrs. Or Sept. 21 to 30.	June 16 to July 10 with lightning within past 48 hrs. Or Sept. 11 to 20 with or without lightning.
June 1 to 15 with lightning within past 48 hrs. Or Oct. 1 to 15.	Numerous land clearing fires in progress any time in May or October.
Before June 1 with no lightning within past 48 hrs. and with no land clearing fires threatening Or after Oct. 31.	Before June 1 with lightning storms within past 48 hrs. Or June 1 to 15 with no lightning. Or Oct. 16 to 31.

A

Lightning includes only those storms with one or more bolts reaching the ground.

FIRST — *Set index "B" below to indicate maximum visibility distance.*
SECOND — *Holding slides "A" and "B" tightly together set index "A" at proper date and activity of lightning.*
THIRD — *See other side of this meter.*

VISIBILITY DISTANCE

Central and Eastern Mont.	*Western Mont. and N. Idaho*
Small fires detectable up to:—	
MILES	
0.0 to 5.9	*0.0 to 3.9*
6.0 to 8.9	*4.0 to 5.9*
9.0 to 11.9	*6.0 to 7.9*
12.0 or more	*8.0 or more*

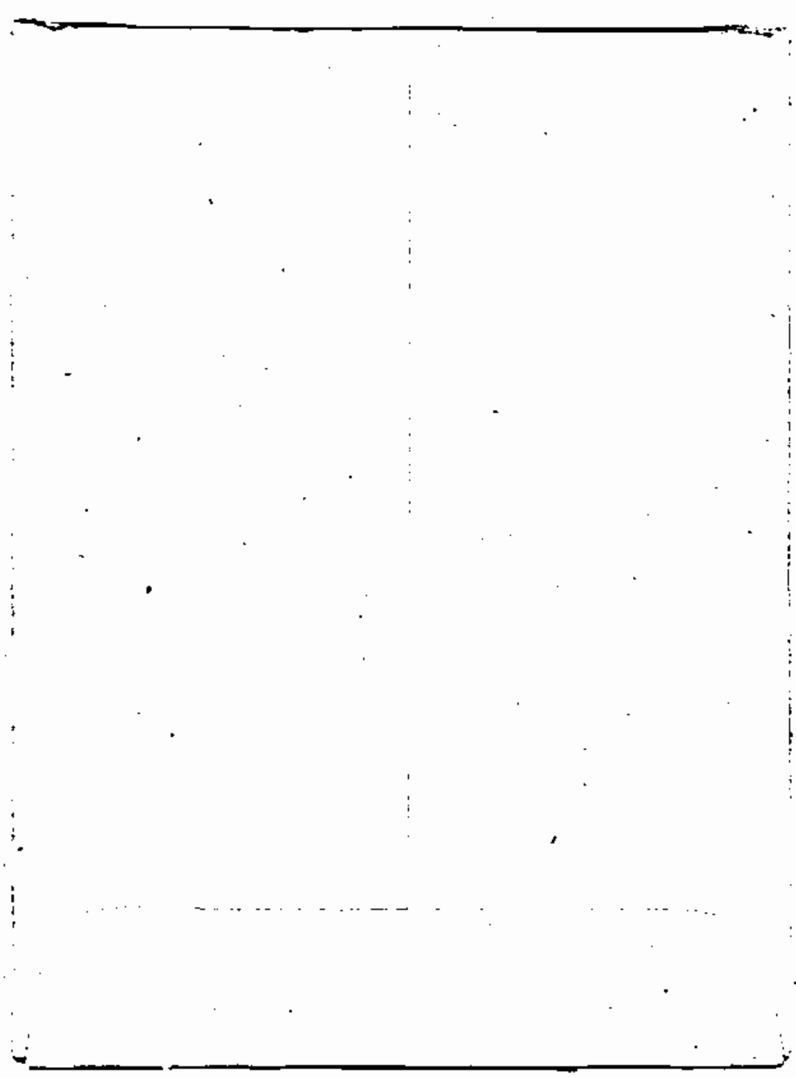
B

Visibility distance should be determined from measurements with visibility meters or from observations made by trained lookouts. See partial instructions on inside of slide A.

This Meter issued by The Northern Rocky Mtn. Forest and Range Experiment Station Missoula Montana

APPENDIX 'A'

Fire Danger Meter used in Region N°1. (Northern Rocky Mountain Region)



FOREST FIRE DANGER METER

For use in the coastal plain regions of the southeastern United States

IMPORTANT: Read instruction booklet before attempting to use this meter.

FIRE DANGER TODAY

AVERAGE WIND VELOCITY Miles per hour	CONDITION OF LESSER VEGETATION		
	Green	Transition	Cured
24.6 or more			
18.6 to 24.5			
12.6 to 18.5			
7.5 to 12.5			
3.5 to 7.4			
0 to 3.4	0 to 3		

NUMBER OF DAYS SINCE 0.50" OR MORE RAIN

FUEL MOISTURE CONTENT

IN PERCENT

As measured with wood sticks

25.1 or more	12.6 to 25.0	4.0 to 12.5	3.9 or less
1	1	1	2

CLASS OF FIRE DANGER FOR TODAY

Directions: (1) Set slide so that the present number of days since 0.50" or more rain appears in the upper window in the column indicating the existing condition of vegetation and in the row opposite measured wind velocity. (2) Read today's fire danger class in the lower window below measured fuel moisture.

Refer to presuppression plan for details of fire control organization required for each fire danger class.

FIRE DANGER TOMORROW

TOMORROW'S PREDICTED WIND VELOCITY	CONDITION OF LESSER VEGETATION		
	Green	Transition	Cured
Strong			
Fresh			
Moderate			
Gentle			
Light			
Very light	0 to 3		

NUMBER OF DAYS SINCE 0.50" OR MORE RAIN

PREDICTED STATE OF WEATHER FOR TOMORROW

Rain	Cloudy to unsettled	Fair to partly cloudy

CLASS OF FIRE DANGER FOR TOMORROW

Directions: (1) Set slide so that the present number of days since 0.50" or more rain appears in the upper window in the column indicating the existing condition of vegetation and in the row opposite wind class predicted for tomorrow. (2) Read tomorrow's class of fire danger in the lower window below the predicted state of weather for tomorrow.

Issued by

U.S. DEPT. OF AGRICULTURE FOREST SERVICE

Appalachian Forest Experiment Sta., Asheville, N.C.

Meter Type 7 October, 1939

Designed by George M. Jemison

APPENDIX "B"

Appalachian Fire Danger Meter - for use in the Coastal Plain Region of South-Eastern U.S.A.

APPENDIX "C".

Sample Invitation forwarded to landowners in the State of Montana, Region No. I of the Forest Service, when the areas owned by such owners require "listing" under protection agreements.

U.S. Department of Agriculture
Forest Service

.... , ... ,
(CITY) (STATE)

.... ,19..
(DATE)

Dear Mr..........

The..............National Forest is giving the owners of timbered and forest lands, lying in the vicinity of this Forest, an opportunity to protect the same from fire by paying in advance a small amount per acre, into a co-operative fund. The charge for this protection is.....cents per acre.

Contributions received will be used for fire patrol and suppression. The State Law recognises the U.S. Forest Service as a competent agency to protect privately owned lands from fire.

The records of this Forest indicate that you own timbered and forested lands totalling about........acres, described as follows...

If you desire to have these lands listed for protection, please forward your contribution for $.........., together with this letter, to the Regional Fiscal Agent, U.S. Forest Service, Missoula Montana, on or before.............,19... Your remittance should be made payable to the Regional Fiscal Agent, Forest Service. Please sign the Letter of Transmittal, printed below, on the blank line over the word "Co-operator".

If for any reason you do not wish to list for protection all the lands described above, please indicate to me before you send your contribution, the particular tracts you wish to have protected. I shall then send you a new form of letter, revised to correspond with your instructions.

Very sincerely yours,

....

Forest Supervisor.

A P P E N D I X "D".

SAMPLE FIRE AGREEMENT.

(Used with small owners of land in Region No. I, at flat rates covering both pre-suppression and suppression).

THIS AGREEMENT, Made this........day of.............19.., by and between..................of.............,hereinafter called the co-operator, and the Forest Supervisor of.......... National Forest, on behalf of the United States, for the protection from fire of timbered lands of the co-operator.

1. The Co-operator will, during the continuance of this Agreement, deposit annually with the Fiscal Agent, Forest Service Missoula, Montana, in accordance with the provisions of the Act of Congress of March 3, 1925 (43 Stat. 1132), $......per acre for the protection of the following described lands................. .... approximately ....acres, shown on the map hereto attached. This yearly deposit, amounting to $.......shall be made on or before May 1 of each year covered by this agreement.

2. The Forest Supervisor will provide fire control for the said lands, each year covered by this agreement, similar to that given by him to the lands of the United States within said National Forest, provided, that nothing in this agreement shall relieve the co-operator from responsibility for any fire which shall be the result of his negligent, wilful or unlawful acts, conduct, or operations, nor shall operate to prevent the United States from recovering the fire suppression expenses incurred for any such fire, as well as the amount of the damage done by any such fire, to the lands, timber or other property of the United States, and the co-operator shall reimburse the United States for the cost of suppression by the Forest Service of all fires caused by, or originating in connection with, the operations of the co-operator upon its said lands.

3. This agreement shall be in force from the date of execution hereof to April 30, 19..., both dates inclusive, provided Congress shall make the necessary appropriations for each year until the said date. Should Congress fail to make such appropriations at any time during the continuance of this agreement, then the obligation of the United States to furnish protection to the said lands of the co-operator shall cease at the expiration of the period for which appropriations are available, and the Forest Supervisor shall so notify the co-operator.

4. Either party to this agreement may terminate the same, by written notice to the other party, between December 1 of any year covered by this agreement and March 1 of the year immediately following.

5. No member of, or delegate to Congress, or Resident Commissioner, shall be admitted to any share part of this agreement, or to any benefit to arise therefrom. Nothing, however, herein contained shall be construed to extend to any incorporated company, if the agreement be for the general benefit of such corporation or company.

........................Co-operator.

................Forest Supervisor.

APPENDIX "E".

SAMPLE CO-OPERATIVE AGREEMENT.

(To be used in Region No. I with large owners, at flat rates for pre-suppression, and pro-rata actual costs for suppression).

THIS AGREEMENT, Made this..............day of..............19..,
between the United States of America by the Regional Forester, Northern Region, Forest Service, Department of Agriculture, hereinafter called the Regional Forester, and the.................. Company, hereinafter called the Company.

WITNESSETH: Whereas the Company owns or controls certain tracts of forest lands intermingled with or adjacent to forest lands of the United States and forest lands protected by the United States within or adjacent to..................National Forest, and -

WHEREAS: The existence of forest fires on any of the aforesaid lands jeopardises the forest and timber on the lands of both the parties hereto, and it is to the mutual advantage of the United States and the Company to co-operate in preventing, controlling and speedily extinguishing all forest fires occurring on any of the aforesaid lands. NOW, THEREFORE, in consideration of any of the premises and of the mutual promises hereinafter set forth, it is hereby agreed as follows:-

As used in this agreement, fire prevention and presuppression costs shall include the costs of construction and maintenance of necessary fire improvements, and all expenses necessary and incidental to the control of fires, except expenses for their suppression as hereinafter defined.

Fire suppression costs shall include all expenses of and incidental to the actual suppression or extinguishment of fires.

1. The Company shall, prior to May 1 of each year, describe in writing and file with the Supervisor of the.................. National Forest, a list of the lands which under the terms of this agreement will be subject to fire control under direction of the Regional Forester for the ensuing fire season.

2. On or before April 1 of each year, the rate for fire prevention and pre-suppression for the ensuing fire season shall be determined by the Regional Forester or his representative, and the duly authorised representative of the Company, on the basis of actual average costs. The Company will make payment for fire prevention and pre-suppression costs on or before May 1 of each year, in accordance with the instructions in a letter of transmittal to be furnished to the Company by the Regional Forester.

3. The amount which shall be paid by the Company to the United States for suppressing each fire, shall be determined by the percentage ratio which the area burned upon the lands listed by the Company under this agreement, bears to the total area burnt on National Forest lands, plus all areas burned on lands which have been listed with the United States Forest Service for fire suppression thereon.

4. Expenditures for fire suppression will be pro-rated and paid currently as far as practicable, and, as soon as possible after the close of each fire season, the accounts will be adjusted and final settlement made. Any amounts due to the United States shall be paid in accordance with the instructions in the letter of transmittal to be furnished the Company by the Regional Forester.

5. The Regional Forester agrees to provide the same degree of fire control on the lands of the Company which are covered by this agreement, as is given the intermingled or adjacent National Forest lands.

6. Nothing in this agreement shall relieve the Company from responsibility for any fire which shall be the result of its negligent, wilful or unlawful acts, conduct or operations, nor shall operate to prevent the United States from recovering the fire-suppression expense incurred for any such fire, as well as the amount of the damage done by any such fire to the lands, timber or other property of the United States.

7. This agreement shall be in force and effect upon execution by both the Company and the Regional Forester and until it shall be revoked or terminated in the manner provided for by paragraph eight hereof.

PROVIDED that should Congress fail to make an appropriation for fire control at any time during the continuance of this agreement, then the obligation of the United States to prevent and suppress fires on the lands listed by the Company shall cease at the expiration of the period for which appropriations are available, and the Regional Forester shall so notify the Company.

8. Either the Company or the Regional Forester may, by written notice to the other submitted not less than 30 days in advance, terminate this agreement at any time between December 1 of any year and May 1 of the next succeeding year.

9. No member of, or delegate to Congress, or Resident Commissioner, shall be admitted to any share or part of this agreement or to any benefit to arise therefrom. Nothing, however, herein contained shall be construed to extend to any incorporated company, if the agreement be for the general benefit of such corporation or company.

IN WITNESS WHEREOF, the Company by its................, and the United States by its Regional Forester, have executed this agreement on the day and date first above written.

UNITED STATES OF AMERICA	...................COMPANY
By.....................	By............President
Regional Forester.	

MEMORANDUM OF AGREEMENT.

Between the UNITED STATES and the................Lumber Company
....................19..

Under the terms of that certain agreement dated..........19.. made and entered into by and between the............Company and the United States of America, it is hereby agreed by and between the............of the Company, and the Regional Forester, that the prevention and pre-suppression costs for the season of 19..., shall be ¢....pre acre for lands listed under this agreement for protection.

....................Company
By................
(TITLE)
By..................Regional Forester

(333[A])

APPENDIX "F"

Fire Report Form N° 929 (with directions for use) - used by U.S. Forest Service

Form 929
Revised
October, 1939

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE

INDIVIDUAL FIRE REPORT

ALL CLASSES OF FIRES

Ranger District________

Regional Fire Number________

1 IDENTIFICATION	Code Nos.	Col. Nos.
a. Name of fire:________		
b. Ranger's fire number:________		
c. Twp.:____ R.____ S.____ Mer.____		
d. Region:________		1
e. Forest:________		2-3
f. Supervisor's fire number:________		4-7
g. Year discovered:________		8
h. Month discovered:________		9
i. Day discovered:________		10-11
j. State:________		12
k. County:________		13
l. Ranger district:________		14

2 CLASS OF FIRE	Code Nos.	Col. Nos.
		15

3 CAUSE OF FIRE	Code Nos.	Col. Nos.
a. General:________		16
b. Specific:________		17-18
c. Class of people:________		19
d. Reason:________		

4 FIRE STARTED ON	Code Nos.	Col. Nos.
		20

5 TIME	Date	Hour	A.M. P.M.	ELAPSED TIME Hour	ELAPSED TIME Min.	Code Nos.	Col. Nos.
a. Origin: guess: (____) known: (____)							21
b. Discovered:________				(b-a)			22-23
c. Reported:________				(c-b)			24
d. First attack:________				(d-c)			25-26
e. 1st. reinforcements:________				(e-d)			27-28
f. 2nd. reinforcements:________				(f-e)			
g. Max. no. line workers:________				(g-c)			
h. Max. no. men mobilized:________				(h-c)			
i. Fire controlled:________				(i-d)			29-31
j. Fire mopped up:________				(j-i)			32-34
k. Fire out:________							

6 PHYSICAL CONDITIONS	Code Nos.	Col. Nos.
a. Pt. of origin in seen area from 0-1-2-3 L.O. Sta. (____ (occupied)) (____ (not occupied))		35
b. Visibility rating:________ (miles)		36
c. Discovery distance:________ (miles)		37
d. Danger rating class:________ (regional symbol)		38-39
e. Wind velocity at time of first attack:________ (miles)		40-41
f. Wind velocity at time of greatest run:________ (miles)		42-43
g. Timber type at point of origin:________ (regional symbol)		44-45
h. Fuel type at point of origin:________ (regional symbol)		46-47
i. Worst fuel type on area:________ (regional symbol)		48-49
j. Exposure:________		50
k. Elevation above sea-level:________ (feet)		51
l. Slope:________ (percent)		52

7 BEHAVIOR OF FIRE	Code Nos.	Col. Nos.
a. Character of fire on arrival:________		53
b. Area when discovered:________		54-55
c. Area on arrival:________		56-57
d. Area when controlled: (____ (N.F. and other inside)) (____ (outside))		58-62
e. Perimeter in chains at first attack:________		63-64
f. Perimeter in chains when controlled:________		65-67
g. Av. chains perimeter increase per hour origin to attack:________		68

8 ACCESSIBILITY AND MAN POWER	Code Nos.	Col. Nos.
a. Regular action: (____), Independent action: (____)		69
b. Disc. by:____ (class of discoverer) ____ (location)		70
c. Rprtd. to: ____ (name) ____ (location)		
d. No. men in 1st. attack: (____), Boss:____ (name)		71-72
e. No. men in 1st. reinforcements:________		73-74
f. No. men in 2nd. reinforcements:________		
g. Max. no. of line workers:________		
h. Max. no. of men mobilized:________		
i. Miles traveled by road by initial attack force:________		75-76
j. Miles traveled by trail by initial attack force:________		77-78
k. Miles traveled cross country by initial attack force:________		79

REMARKS:________

9 CROSS REFERENCE (Class B and larger fires only)	Code Nos.	Col. Nos.
a. Region:		1
b. Forest:		2-3
c. Supervisor's fire number:		4-7
d. Year discovered:		8
e. State:		9
f. Class of fire:		10
g. Cause of fire (general cause):		11

11 AREA BURNED BY TIMBER TYPES			
Type	Acres	Code Nos.	Col. Nos.
TOTAL ACRES			

(Complete above table only if requested by R.F.) (not a part of regular report)

12 MAP RECORD

Scale______ Inches = 1 mile

10 ACCOMPLISHMENTS (Class B and larger fires only)	Code Nos.	Col. Nos.
a. Total chains of held line:		12-15
b. Total chains of lost line:		
c. Total man hours on line:		16-19
d. Av. chains of held line per man hour of labor:		

13

a. Is this fire being reported to the State by another agency? yes (______) no (______)

b. If answer to the above question is (yes), give the name of the agency________

14 SUMMARY OF FIRE DAMAGE

(Items A and B for Class B and larger fires only. Items C, D, and E for Class C and larger fires only)

Objects of Damage	N.F. Lands (1)	Code Nos.	Col. Nos.	Other inside N.F. (2)	Code Nos.	Col. Nos.	Outside N.F. Prot. by F.S. (3)	Code Nos.	Col. Nos.	Outside N.F. Not Prot. by F.S. (4)	Code Nos.	Col. Nos.
A. Acres forest land burned:			20-22			38-40			56-58			74-
B. Acres non-forest land burned:			23-25			41-43			59-61			77-
C. Timber resources destroyed:												
a. M.B.M. (volume) (convert cords into M.B.M.)			26-28			44-46			62-64			
b. Young growth (acres)			29-31			47-49			65-67			
c. Other values (dollars)												
d. TOTAL VALUES (dollars)			32-34			50-52			68-70			
D. Non-timber resources damaged:												
a. Watershed (dollars)												
b. Recreation (dollars)												
c. Wild life (dollars)												
d. Improvements (dollars)												
e. Forage (dollars)												
f. Other values (dollars)												
g. TOTAL VALUES (dollars)			35-37			53-55			71-73			
E. GRAND TOTAL DAMAGE (dollars)												

REMARKS:

a. Examined and approved______ (day) (month) (year)

b. Approving officer______ (name) (title)

c. Date report written______ (day) (month) (year)

d. By______ (name) (title)

INSTRUCTIONS FOR PREPARATION OF FORM 929

(Revised October, 1939 — Effective January 1, 1940)

The following instructions and interpretations apply to individual items or captions within designated blocks. They apply to the Administrative entries only. Coding instructions will be issued by each Regional Forester.

GENERAL

929 reports must be prepared for each statistical fire. (929 reports for non-statistical fires are optional with a Region or a Forest but shall not be assigned a Ranger's or Supervisor's number and should be otherwise be plainly marked as non-statistical.)

A statistical fire, in National Forest practice, is a fire which is suppressed wholly or in part by Forest Service employees or cooperators and on which action is taken either to prevent the fire from spreading to or burning over National Forest or other lands for which the Forest Service assumes protection responsibility. Suppression action must be actual work on the fire itself and fully defensible in respect to the threat of spreading to National Forest lands or Forest Service protected lands. When National Forest land is protected by some other agency, a fire should be reported and given a regular serial number, even if no Forest Service employee participated in its suppression. When the required data cannot be obtained on such fires for items in blocks 5, 6, 7, 8, and 10, enter "unknown."

Representative examples of *non-statistical* fires are as follows:

(a) Fires that have gone out naturally when reached.

(b) Railroad fires confined to the right-of-way which do not endanger Forest Service protected land and are suppressed by railroad employees with or without Forest Service help.

(c) Small fires resulting from legitimate slash or debris burning operations when extinguished by the causative agency.

(d) Abandoned campfires which because of the condition of forest fuels or weather conditions cannot spread, or are confined to improved fireplaces or stoves.

(e) Individual incendiary sets when all sets burn together and are suppressed as one fire. In this event all sets will be reported as one fire.

(f) Individual incendiary sets which are suppressed separately, where less than 1/4 mile intervenes between any two adjacent sets. Only one fire will be reported for any such sets.

(g) Burning buildings, automotive equipment, haystacks, sawdust piles, etc., which under the prevailing conditions are not a menace to Forest Service protected lands.

(h) Fires from any cause, confined to private lands, which do not endanger Forest Service protected lands and are suppressed by landowners or others responsible for their suppression with or without Forest Service aid.

The Regional Fire Number will not be assigned by the reporter. Such numbers will be entered in one unbroken series in the Regional office as reports are checked and mailed to Washington.

For Class "C" and larger fires, every item not blocked out on the form must be filled in. Enter "O" or "none" or "unknown" if no other entry is applicable. The only exceptions are as follows:

Item "d, Reason," Block 3: Follow Regional instructions.

Blocks 11 and 12: Follow Regional instructions.

Block 14: Fill in only those spaces where there is burned acreage or damage to record.

For Class "B" fires, fill out all spaces as for "C" fires with the following exception:

Block 14: Make one entry only. That one will be the acreage burned and will go in the proper space in either item A or B. See instructions for Block 14.

For Class "A" fires, do not fill in any blocks on the back of the form except Blocks 11, 12 (follow Regional instructions for these), and Block 13. Every item on front of form must be filled in as for "C" fires.

1 IDENTIFICATION BLOCK

(a) *Name of fire:* Enter name which received greatest use during period of action. Name should usually associate fire with nearest prominent geographic or cultural feature.

(b) *Ranger's fire number:* Number fires consecutively in the order in which they are reported on 929 by District Ranger. Numbering will begin with first 929 report of each calendar year.

(c) *Township—Range, Section, Meridian:* In country having a rectangular survey, enter legal description of point of origin. If there is no rectangular survey, follow Regional instructions.

(d) *Region:* Enter number of Region responsible for action. Example—Region 1, Region 2, etc. For inter-Regional fires, enter in parenthesis the number of the second Region.

(e) *Forest:* Enter name of Forest responsible for action. For inter-Forest fires enter second Forest in parenthesis.

(f) *Supervisor's fire number:* Number fires consecutively as 929's are received by Supervisor's office. Numbering will begin with the first 929 report of each calendar year.

(g) *Year discovered:* Enter year of discovery.

(h) *Month discovered:* Enter month of discovery.

(i) *Day discovered:* Enter day of discovery.

(j) *State:* Enter name of State in which fire originated. Enter "Canada" or "Mexico" when fires originate in those countries. For inter-State fires, enter name of second State in parenthesis.

(k) *County:* Enter name of County in which fire originated.

(l) *Ranger District:* Enter name of Ranger District responsible for action. For inter-District fires, indicate other District in parenthesis.

2 CLASS OF FIRE BLOCK

For Class of Fire, enter the letter symbol descriptive of the Class:

A=¼ acres or less.
B=More than ¼ acre but less than 10 acres.
C=10 acres or more but less than 100 acres.
D=100 acres or more, but less than 300 acres.
E=300 acres or more.

3 CAUSE OF FIRE BLOCK

(a) *General cause:* Select from the *General cause* list provided herein, the most appropriate cause and enter opposite the word "General" in this block. For incendiary fires enter the number of sets in parenthesis after the word "incendiary."

(b) *Specific cause:* Select from the *Specific cause* list provided herein, the most appropriate cause and enter opposite the word "Specific" in this block. Be careful not to use "other" when the proper specific cause is included in the list. When "other" is used, write in the appropriate specific cause in parenthesis immediately following. For example, "Other (Signal fire)."

(c) *Class of people:* Select from the *Class of people* list provided herein, the most appropriate classification and enter opposite words "Class of people" in this block.

Be careful not to use "other" when the proper specific class is included in the list. When "other" is used, write in the appropriate specific class in parenthesis immediately following. For example, "Other (Children)."

(d) *Reason:* To be used in conformity with Regional instructions.

LIST FOR "CAUSE OF FIRE" BLOCK

GENERAL[1]	SPECIFIC		CLASS OF PEOPLE
Lightning	Lightning	Moonshine[10]	Camper
Railroad	Berry land-burning	Oil or gas well[11]	Fisherman
Lumbering	Blasting	Playing with matches	Hunter
Campfire	Brakeshoe	Power line[12]	Picnicker
Smoker	Branding	Pyromania	Traveler
Debris-burning	Burning building	Range burning	Construction-worker
Incendiary	Burning vehicle	Refuse burning[13]	Miner
Miscellaneous	Cooking fire	Repelling predatory animals	Timberman
	Exhaust[2]	Right-of-way clearing	Rancher-farmer
	Fireworks	Rubbish disposal[14]	Stockman
	Fuel sparks[3]	Safety-strip burning	Other
	Fusee	Slash disposal	(If caused by lightning classify as "Other")
	Glass[4]	Smoking[15]	
	Grudge fire	Smoking bees or game	
	Hot ashes	Spontaneous combustion	
	House or stove flue sparks[5]	Tie disposal	
	Insect and snake control[6]	Warming fire	
	Job fire	Other	
	Land clearing[7]		
	Logging line[8]		
	Meadow burning[9]		

[1] For definitions see 1939 Glossary of Terms Used in Forest Fire Control.
[2] Such as fires from exhaust pipes of automobiles, trucks, and tractors.
[3] Such as fires from locomotives and smokestacks of sawmills and donkey engines. Do not use this specific cause for fires from sparks from open fires for cooking or warming, house flues, or flues of stoves used in houses, tents, or out of doors.
[4] Do not include fires from glass placed by incendiaries.
[5] For fires from all chimneys or stove pipes projecting from dwellings or tents or from pipes of stoves set up in the open.
[6] Include fires set for control of ticks, red bugs, boll weevils, etc. Do not use this specific cause for fires started in smoking bees.
[7] Do not use for fires caused by burning of stubble or grass from fields.
[8] Including fires from blocks or sheaves.
[9] Including fires from burning of stubble or grass from fields before plowing.
[10] Include fires from stills; their destruction by law officers; also fires set for chance to sell liquor to fire fighters.
[11] Use for fires from operation or burning of such wells.
[12] Include only fires caused by electrical current from transmission lines.
[13] Such as fires from sawmill refuse burners and from burning of dead animals.
[14] Such as fires from burning of village dumps or rubbish from around homes.
[15] Use this for all fires attributed to "smoker" in the general cause list.

4 FIRE STARTED ON BLOCK

Enter the point of origin of fire strictly in accordance with the following scheme. (In Regions 7, 8, and 9, for "National Forest Boundaries," read "Protection Boundaries" when protection boundaries are drawn inside legal boundaries of National Forests or Purchase areas.)

(a) *National Forest land.*

(b) *Other inside:* Refers to non-National Forest lands inside the National Forest boundaries.

(c) *Outside prot. by F. S.:* Refers to lands outside National Forest boundaries on which the Forest Service has assumed protection responsibility.

(d) *Other outside not prot. by F. S.:* Refers to lands not protected by the Forest Service but on which action is taken to prevent fires from spreading to lands under the protection of the Forest Service.

5 TIME BLOCK

General: Follow the action of the man doing the first effective work on the fire line in recording specific and elapsed-time records. The time of the first discovery which results in first effective work on the line is to be recorded in every case. Where no elapsed time occurs, enter "O." In A.M. and P.M. column use "A" for A.M.; "P" for P.M.

(a) *Time of origin:* Enter known or best guess of the date, hour, and minute the fire started. Indicate whether "known" or "guess" by check mark.

(b) *Discovered:* Enter date, hour, and minute when discoverer of fire becomes certain that object seen is a fire or when he makes a report on which action is taken.

To figure elapsed "discovery" time subtract (a) from (b).

(c) *Reported:* Enter date, hour, and minute instructions concerning fire are received by man who goes to fire.

To figure elapsed "report" time subtract (b) from (c).

(d) *First attack:* Enter date, hour, and minute first actual suppression work on the fire is started.

To figure elapsed "first attack" time subtract (c) from (d).

(e) *First reinforcements:* Enter date, hour, and minute first reinforcements to the initial attacking force arrive on fire.

To figure elapsed "first reinforcements" time subtract (d) from (e). If none arrived, enter "none."

(f) *Second reinforcements:* Enter date, hour, and minute second reinforcements arrive on fire.

To figure elapsed "2nd reinforcements" time subtract (e) from (f). If none arrived, enter "none."

(g) *Max. no. line workers:* Enter the date, hour, and minute when number of control line workers, including those off shift, and control line overhead, reaches the maximum. For this and the following item (h) only, make no particular effort to record minutes accurately on fire fighting jobs lasting 24 hours or more.

To figure "max. no. line workers" time subtract (c) from (g).

(h) *Max. no. men mobilized:* Enter the date, hour, and minute when total manpower (including service of supply) mobilized for the fire, reaches the maximum.

To figure "max. no. men mobilized" time subtract (c) from (h).

(i) *Fire controlled:* Enter date, hour, and minute when the *control line* was completed.

To figure elapsed "fire controlled" time subtract (d) from (i).

For definitions of "control line" and "control a fire," see 1939 Glossary of Terms.

(j) *Fire mopped up:* Enter date, hour, and minute when organized mop-up work was completed.

To figure elapsed "fire mopped up" time subtract (i) from (j).

For definition of "mopping up" see 1939 Glossary of Terms.

(k) *Fire out:* Enter date, hour, and minute when patrol was discontinued and fire abandoned.

6 PHYSICAL CONDITIONS BLOCK

(a) *Point of origin in seen area from 0-1-2-3 L. O. Sta.:* Enter actual number of planned *occupied* lookout stations from 0 to 3 that can *see* point of *origin* of fire. Enter actual number of planned lookout stations from 0 to 3 that are *not occupied* but which if they were, would *see* point of *origin* of fire. Count emergency stations and unconstructed stations if they are in the planned system. Do not include cooperator detectors.

(b) *Visibility rating:* Enter visibility rating in miles at time of discovery. Obtain rating from nearest visibility rating station.

(c) *Discovery distance:* Enter to nearest mile the horizontal distance between point of origin and point from which fire was discovered.

(d) *Danger rating class:* Enter Regional symbol for Danger Class existing on day of discovery for the area in which fire started.

(e) *Wind velocity at time of first attack:* Enter estimated wind velocity at fire in miles per hour on arrival of first attacking force.

(f) *Wind velocity at time of greatest run:* Enter estimated wind velocity at fire in miles per hour during greatest run.

(g) *Timber type at point of origin:* Enter Regional symbol describing timber type observed at point of origin.

(h) *Fuel type at point of origin:* Enter Regional symbol for the fuel type observed at point of origin.

(i) *Worst fuel type on area:* Enter Regional symbol for the fuel type which contributed most to difficulty of control.

(j) *Exposure:* Enter the predominating exposure at point of origin of the fire. Use one of the following symbols which is most descriptive of the exposure: N, S, E, W, NE, NW, SE, SW, flat, creek bottom, mixed, ridgetop.

(k) *Elevation above sea level:* Enter elevation in feet above sea level at point of origin.

(l) *Slope:* Enter average slope in per cent at head of fire on arrival of first attacking force.

7 BEHAVIOR OF FIRE BLOCK

(a) *Character of fire on arrival:* Indicate the behavior of the fire at its most active point by *one* of the following terms, each of which is defined in parenthesis:

Smoldering—(Include fires that are smoldering or flaming but making a linear spread of 2 feet or less per hour.)

Creeping—(Linear spread of over 2 feet but less than 10 chains per hour, and without spotting or crowning.)

Running—(Linear spread of 10 chains or over per hour, but without spotting or crowning.)

Spotting—(Use this for a fire throwing wind-borne, fire-starting sparks or embers ahead, regardless of rate of spread.)

Crowning—(Use this for any fire advancing primarily from crown to crown in brush or tree growth, regardless of the rate of spread.)

(b) *Area when discovered:* Enter estimated area of the fire in acres and tenths when first seen. If less than one-tenth acre in size, record in hundredths of an acre. If less than one-hundredth of an acre, record as a "spot." If more than 10 acres in size, enter to the nearest acre.

(c) *Area on arrival:* Enter the area on arrival of first attacking force in acres and tenths. If area is less than one-tenth acre, record in hundredths of an acre. If less than one-hundredth of an acre, record as a "spot." If area is greater than 10 acres, enter to the nearest acre.

(d) *Area when controlled:* When final area lies on both sides of a National Forest boundary, it will be entered in two separate figures, the total of which will not be entered, but which will equal the total acreage of fire. In the first parenthesis, enter the total of the area burned on both NF land and other land inside the National Forest boundary. (Inside protection boundary in Regions 7, 8, and 9, when the protection boundary is drawn inside the legal boundary.) In the second parenthesis, enter the total of the area burned outside the NF boundary (or protection boundary when it is inside the legal boundary) whether such lands are protected by Forest Service or not. In either or both of these parentheses enter final area in acres and tenths. Where area is less than one-tenth acre, record area in hundredths of an acre. If less than one-hundredth of an acre, record as a "spot." Where area is more than 10 acres, enter to the nearest acre. When there is no area to report in one of the parentheses, enter "O."

(e) *Perimeter in chains at first attack:* Enter the perimeter of the fire in chains at the time of first attack.

(f) *Perimeter in chains when controlled:* Enter final perimeter of fire in chains.

(g) *Average chains of perimeter increase per hour from origin to attack:* Divide the perimeter in chains at the time of first attack (item e) by the elapsed time in hours and tenths of hours from origin to attack (d-a in the time block). Enter the result here in chains and tenths. Round off decimal fractions to nearest tenth of a chain. Example: If the perimeter is 25 chains and elapsed time is one hour and 40 minutes:

$$\frac{25 \text{ ch.}}{1.7 \text{ hrs.}} = 14.7 \text{ chains increase per hour.}$$

8 ACCESSIBILITY AND MANPOWER BLOCK

(a) *Regular action:* Enter check mark after words "regular action" if first action on the fire line was taken by Forest Service employees or Forest Service cooperators.

Independent action: Enter check mark after words "independent action" if first action on the first line was not taken by Forest Service employees or Forest Service cooperators.

(b) *Discovered by:* This refers to the first discovery which resulted in initiation of control action. Record in this space one of the following classes of discoverer:

Lookout—Established lookout stations of Forest Service and other organized protective agencies.

Patrolmen—Moving *detection* personnel.

Other F. S. Employees—Includes Forest officers, crewmen, project men, packers, truck drivers, etc.

Planned Cooperators—Those with whom fire control contract or cooperative arrangement exists.

F. S. Permittees—Includes all persons holding special-use or free-use permits or grazing, timber-sale, and similar contracts. Includes agents and employees of such permittees.

Airplane Observers—Includes any person discovering a fire from aircraft.

Others—Any discoverer not included in above classes.

Location—Refers to location of observer at time discovery was made.

(c) *Reported to:* Enter name of first man to go to fire.

Location: Refers to location of the same man at the time he receives instructions or information causing him to go to the fire.

(d) *No. men in first attack: Boss:* Enter number of men in initial attack, including the boss. Enter name of the boss in charge of the initial attacking crew.

(e) *No. men in first reinforcements:* Enter number of men, including the boss, reaching fire as first reinforcements to initial attacking force. If none arrived, enter "none."

(f) *No. men in second reinforcements:* Enter number of men, including the boss, reaching fire as second reinforcements to initial attack force. This is the third contingent of manpower to reach fire. If none arrived, enter "none."

(g) *Maximum number of line workers:* Enter greatest number of actual control line workers. Include overhead. Include men off shift who are strictly control line workers.

(h) *Maximum number of men mobilized:* Enter greatest number of men associated with the suppression of this fire at any one time. Include line, service of supply and camp forces, Forest officers, etc. In other words, the total manpower mobilized for active participation in the control of the fire.

(i) *Miles traveled by road by initial attack force:* Enter in miles and tenths the distance the initial attacking force traveled to reach fire by a road usable by auto or truck. Do this even if the road was traveled on foot or by horse. Enter "O" if a road was not used. Do not include boat, railroad speeder, or airplane travel.

(j) *Miles traveled by trail by initial attack force:* Enter in miles and tenths the distance the initial attacking force traveled by trail to reach fire. Enter "O" if a trail was not used. Do not include boat, speeder, or airplane travel.

(k) *Miles traveled cross country by initial attack force:* Enter in miles and tenths the distance initial attacking force traveled cross country to reach the fire. Enter "O" for no cross country travel. Do not include boat, speeder, or airplane travel.

9 CROSS REFERENCE BLOCK

(To be filled in for Class "B" and larger fires only.)

Enter information identical with that shown in Identification Block items (d), (e), (f), (g) and (j); Class of Fire Block; and in Cause of Fire Block, item (a) or *General.* The only exception is where the fire burns in two or more States or Forests. See "Master and Supplemental Reports" under Summary of Fire Damage Block, No. 14.

10 ACCOMPLISHMENTS BLOCK

(To be filled in for Class "B" and larger fires only.)

(a) *Total chains of held line:* Enter to the nearest chain the total number of chains of held line actually worked, including barriers backfired. Omit barriers not backfired.

(b) *Total chains of lost line:* Enter to the nearest chain the number of chains of worked line lost. The total length of line worked is the sum of items (a) and (b).

(c) *Total man hours on line:* Enter the total number of man hours put in on mop-up and line work up to the time fire is *controlled* regardless of whether or not the line was held or lost. Include line construction men, line overhead, water boys, scouts, lunch carriers, etc. Exclude camp men, service of supply, transportation and all other men having similar duties.

(d) *Av. chains of held line per man hour of labor:* Divide item (a) by item (c). Enter the result here in chains and hundredths.

11 AREA BURNED BY TIMBER TYPES BLOCK

This block is provided on the fire report for those Regions desiring this information. It is not to be filled out unless the Regional Forester requests this to be done.

In any event, these items are not to be coded. Code columns have been provided for convenience should a study of this information be required at some future date.

12 MAP RECORD BLOCK

Follow Regional instructions.

13 FIRE BEING REPORTED TO THE STATE BY ANOTHER AGENCY

(a) Check in appropriate place the answer to the question.

(b) If answer to (a) is *yes* enter the name of the agency.

14 SUMMARY OF FIRE DAMAGE BLOCK

(Items A and B will be filled in for Class "B" and larger fires only. Do not divide the acreage of "B" fires among the eight spaces on lines A and B. Put the entire acreage of a "B" fire in the space where the largest portion belongs. Items C, D, and E will be filled in for Class "C" and larger fires only. When there is no acreage or damage to record in a space, leave it blank. This applies to "B" as well as larger fires. Include in Column 1 all acreage and damage on NF lands, even if such lands are protected by some other agency.)

A. Acres Forest Land Burned:

Enter to nearest acre by land location in Columns 1, 2, 3, and 4, the acreage of forest lands burned. Examples of forest land are: Reproducing brush fields, commercial timberlands, young growth stands, brush fields with scattered reproduction, alpine timberlands, etc.

B. Acres Non-Forest Land Burned:

Enter to nearest acre by land location in Columns 1, 2, 3, and 4, the acreage of non-forest lands burned. Examples of non-forest lands are: Non-reproducing brush fields, sagebrush areas, grass lands, etc.

The summation of Columns 1, 2, 3, and 4, items A and B, must equal the nearest whole number of acres in the total of the entries in item (d), area when controlled, in Behavior of Fire Block, No. 7.

C. Timber Resources Destroyed:

(a) *M.B.M. (volume):* Enter by land location in Columns 1, 2, 3, and 4 the volume of merchantable timber products destroyed, expressed in the nearest whole number of thousands of board feet. Convert cords into board feet.

(b) *Young growth (acres):* Enter by land location in Columns 1, 2, 3, and 4 the nearest whole number of acres of young growth destroyed. This figure is contained in the "acres of forest land burned" given in item A.

(c) *Other values (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the value of other timber resources destroyed.

(d) *Total values (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the total value of "timber resources destroyed." This figure will be the calculated value of (a) plus the calculated value of (b) plus the money figure in (c).

D. Non-Timber Resources Damaged:

(a) *Watershed (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the appraised value of the damage to watersheds.

(b) *Recreation (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the appraised value of the damage to recreation resources.

(c) *Wildlife (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the appraised value of the damage to wildlife resources.

(d) *Improvements (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the appraised damage to improvements. Do not include the value of improvements unless destroyed as a result of a forest fire. For example: If a hotel were destroyed by a fire caused by a spark from a fireplace, its value would not be included here. However, if it were destroyed as a result of a spark from a forest fire, its value would be shown.

(e) *Forage (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the appraised damage to grazing.

(f) *Other values (dollars):* Enter to nearest dollar in Columns 1, 2, 3, and 4 the appraised value of all other damage to non-timber resources.

(g) *Total values (dollars):* Enter to nearest dollar the total recorded damage to non-timber resources.

E. Grand Total Damage (Dollars):

Enter to nearest dollar in Columns 1, 2, 3, and 4 the grand total damage caused by the fire. This figure is a summation of items C, d and D, g.

Damage on outside lands not protected by Forest Service: In filling out Column 4, follow any special instructions from Regional Forester. In the absence of such instructions, apply the following rules: Omit acreage and damage from statistical fires in areas protected by other organized protective agencies; but include acreage and damage from statistical fires in areas not protected by other organized agencies.

Master and Supplemental Reports: An occasional fire will cause burned area and damage in (1) one Forest but in two States, (2) two Forests in one State and in either one or two Regions, and (3) two Forests each lying in a different State with the two Forests included in either one or two Regions. In addition, fires may sweep in or threaten to sweep in from Canada or Mexico.

In such instances it is necessary to keep clear records of area burned and damage done by Forests, States, and Countries. This will be accomplished by making master and supplemental reports for each such fire.

The Master Report will have the words "Master Report" entered just above the Identification Block, No. 1 on page 1 of the form. All blocks will be filled out in the usual manner except Summary of Fire Damage Block, No. 14. The name or number of any other Region, Forest, State or Country to which the fire swept should then be added *in parenthesis* on the appropriate line or lines in the Cross Reference Block, No. 9. The Summary of Fire Damage Block, No. 14, will show only the acreage burned and damage done in the Forest, State, or Country in which the fire originated.

The Supplemental Report will have the words "Supplemental Report" entered just above the Identification Block, No. 1. No other numbered blocks should be filled in except Cross Reference, No. 9; Summary of Fire Damage, No. 14; and, if so instructed by the Regional Forester, the Report to the State Block, No. 13.

In the Cross Reference Block in this supplemental report, fill in item (c), Supervisor's fire number; item (d), year; item (f), class of fire; and item (g), cause of fire (General cause) with exactly the same entries as in the Master Report.

Fill in the remaining items in the Cross Reference Block as follows:

a. Region: Same number as on Master Report if only one Region is involved. If two Regions are involved, enter first, the number of Region to which fire swept, followed, *in parenthesis,* by number of Region in which fire originated.

b. Forest: Same name as on Master Report if only one Forest is involved. If two Forests are involved, enter first the name of the Forest to which fire swept, followed, *in parenthesis,* by name of Forest in which fire originated.

c. State: Same name as on Master Report if State or Country to which fire swept is the same as the State or Country in which fire originated. If not, enter first the name of the State to which fire swept, followed, *in parenthesis,* by name of State or Country in which fire originated.

Fill in the Summary of Fire Damage Block to show only the acreage burned and damage done in the Region and/or Forest and/or State to which the fire swept.

(OAKLAND 11-21-49-2 500)

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Note - Abbreviations Used in quoting Literature Cited:-

Journ. of For. - Journal of Forestry (U.S.A.)
Can. For. Chron. - Canadian Forestry Chronicle
For. Expt. Station - Forest Experiment Station
Dept. of Agric. - Department of Agriculture
Amer. Forests -"American Forests"
Tech. Note - Technical Note
" Bull - " Bulletin
Circ. - Circular
Misc. Publn. - Miscellaneous Publication.
U.S. For. Service - U.S. Forest Service.
For. Research Note - Forest Research Note.
Bull. Amer. Meteorological Society - Bulletin - American Meteorological Society.
Journ. of Agric. Research - Journal of Agricultural Research (U.S.A.)
Agric. Expt. Station - Agricultural Experiment Station.

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