Forest Fire Control Equipment

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INTRODUCTION

This paper is prepared for the purpose of presenting in logical order each kind of equipment most applicable to the activities of forest fire control in the United States in accordance with the present high standards of execution. Special effort was made to include the latest developments in all cases, because of the rapid progress being made in remodeling old equipment and in designing new devices which in many cases will revolutionize the existing method of forest fire control.

To those trained in the practice of forestry, the need of adequate fire control is very evident and is ably expressed by our late Chief Forester in the following words: "The beginning of forestry is fire control, and until fire is systematically kept out of the woods all attempts at permanent use of the land for timber growing must be abortive" (25).

By an anology of fire control with war a clearer scientific approach may be made to the basic principles upon which all fire equipment must be developed, and to show the need for better devices as well as a more unified effort in its development by all agencies concerned.

The tactics and maneuvers in fighting forest fires are not unlike those of an army in battle (1). The success of an army is largely dependent upon the kind and supply of equipment, and to a very great extent the same is true with a fire crew. The more adaptable and efficient the equipment the greater the chance of quickly suppressing the enemy. Of the many desirable features of

equipment as practicability, dependability, and durability, and that combination which affords the fighter the greatest speed in attack, and suppression is the most important. Speed is essential, as that able military strategist, Napoleon, once stated "time is everything in war," and so it is today in fire suppression work. The development of scientific warfare has greatly speeded up the development of fire control devices in ideas as well as equipment directly converted to use in forest fire fighting, such as the caterpillar tractor, airplane, and the use of chemicals as administered from the air.

From use of fire control equipment of three different forest regions of the west the author has repeatedly observed the wide diversity in design, and construction and use of the same kind of equipment used in fire control work. Further study discloses even a wider divergence and less appreciation of what has been done by the other agencies even though all are striving to the limit of facilities at hand to improve such equipment.

The fact is acknowledged that a crew equipped with back-pack outfits containing hand tools would be quite out of place in the easily accessible sections of forests in California, Arkansas, New York, and others, and vice versus for an elaborate fire truck on the National Forests in the Rocky Mountains which has but a few miles of road.

There are many examples to sustain the fact that one or more agencies are spending funds for research on a piece of equipment that has already been perfected by others unknown to themselves. A prominant example is the container required to supplement the hand water pump. Directly after the pumps were adopted as standard equipment by

the United States Forest Service, two northern regions immediately transformed their five-gallon man-pack canvas water bags for use with this pump, while for over four years other regions and agencies experimented with various containers to replace the cumbersome back-pack metal cans which had been recommended by the manufactures of the pumps. The canvas container has proven its superiority and is now being adopted by all regions. The need for faster development of better equipment is too urgent to permit time and funds to be spent in duplication of effort.

Complete nation wide studies on the subject are now available. A catalog of the fire control equipment used by the United States Forservice (26), which was compiled from recommendations of the Spokane Fire Equipment Conference held last season has been prepared, but has not been released at the present writing. Many works are available for each region, state, county, and fire associations dealing with single items or a number of items and are the principal source of information for the material contained in the following pages.

The subject naturally divides into five major divisions of prevention, detection, communication, transportation, and suppression, and has been treated in this order with each division as a separate section with prevention as Section I and so on. All equipment pertinent to each part is delt with in that connection. This method necessitates some duplication in presenting the same item, but due to the manner in which each item is treated, this is not an inhibiting factor as it is believed to be more essential that a presentation of the merits and qualifications of each item is more desirable than specific

details of design and construction.

Where a number of devices have been developed for the same purpose one has been selected on the basis of material presented in tests and general acceptance as a whole. Wherever possible reference to specific makes or the manufacture's names have been avoided.

Library research yielded the largest per cent of material especially the Journal of Forestry issues, and Fire Control Notes. Correspondence with various agencies was not fruitful of usable data as results of tests of new devices not yet printed are in the formative stage and are not to be recommended.

All sources of data are acknowledged in the bibliography.

SECTION I

PREVENTION

The United States Forest Service considers fire prevention as a field open to much improvement and satisfactory equipment in a wide diversity of types is greatly needed. Under this general head the equipment is best divided under each of the major causes of fire to which devices may be applied. Principally among these are railroads, lightning, lumbering, campfires, smokers, and miscellaneous. Also instrumental equipment for measuring fire weather is included in this division. Devices for the reduction of causes of fires are treated in the following paragraphs.

RAILROADS

Spark-arresters of all kinds and types have been developed and used with varying results. A large portion of locomotive fires can now be eliminated by a newly developed Cyclone Spark Arrester as proven by intensive tests. When properly installed, the manufacturers state they are prepared to guarantee that the locomotive will be sparkless with any kind of fuel, and at the same time produce steam just as freely (40).

Outside exhaust on oil or gas burning engines have proven of great benefit.

Rail sprinklers to avoid brake-shoe fires prevent nearly 100 per cent of such fires on extended tests. The cost is negligible and need be used only in stopping and on down grades. Automatic control of the sprinklers greatly facilitate their use (40).

Ash trays placed in all types of passenger carrying conveyances, as provided by law, have reduced smokers fires from trains as well as from other conveyances.

LUMBERING

Automatic sprinklers around donkey settings have greatly relieved the logging operator's worries in regard to such fires as well as the forest owners (40).

CAMPERS

These are a major cause of forest fires and one which is increasing year by year with the increasing numbers of visitors to the forest, despite the advance warning given and the follow up of strict law enforcement. Properly prepared camp sites with camp stoves, ovens, or fireplaces seems to be the answer to this problem. Refuse burners constructed of heavy wire or similar material situated in convenient safe places in camp grounds or other locations frequented by campers are highly desirable (40).

Hydrants with fire hose and with proper assortment of nozzles supplemented by fire lines have proven their worth in connection with major camp grounds in a psychological way as well as in suppressing fires around such areas.

INSTRUMENTAL EQUIPMENT

The accurate determination of weather conditions and their influence on forest fuels in addition to better fire weather forecasts has long been an imperative need. Through the use of instruments, for ascertaining and interpreting weather conditions by measuring the weather elements - temperature, wind, precipitation, relative humidity forest administrators now are able to predict fire weather

and be prepared for any emergency. All instruments used in the above connection are more or less standardized and most of them may be observed at any Forest Service Headquarters or Weather Bureau Station throughout forested areas.

RAIN GAUGE

This gauge is commonly a metal container used in conjunction with a specially designed rule for measuring the amount of precipitation in any form. The catchment container consists of two copper or galvanized metal cans, one 6 inches in diameter and from 1 to 2 feet in height and the other 2 inches in diameter and of corresponding height to the larger into which it is placed and an inverted cap covers the larger with a drainage hole into the smaller container. The wooden rule is designed so as to give a direct reading in inches, tenths, or hundredths of inches.

WIND GAUGE OR ANEMOMETER

Various designs of this instrument have been developed, but the one most used is the type which registers the 24 hour movement of the wind in miles and the wind velocity at any one time in miles per hour. This instrument consists of a vertical axis connected at its upper end to horizontally mounted cups which catch the air movements and revolve the axis to produce the movements of the dial which is geared to the lower part of the axis. A supplemental device of importance is a buzzer wired to the dial and charged with an electric current produced by a dry cell battery.

The Beaufort Scale of windforce, based upon observations of the effect of air movement on land objects as measured by the anemometer,

is easily understood and memorized, and is very useful for forest officers in the field where it would be impracticable to carry an anemometer.

RELATIVE HUMIDITY

Two standard instruments are used to measure this element. The Sling Psychrometer is a simple and portable instrument consisting of two standard thermometers, the bulb of one being kept moist and the other dry. Available charts interpret the readings secured as the proper per cent of moisture in the atmosphere. This instrument should be included as part of the necessary equipment for every fire suppression crew as well as the ranger and guard stations.

The Hygrograph is a delicate instrument designed to give a continuous relative humidity record over any period of time desired. Specially prepared forms are mounted on a cylinder revolved by the mechanism of an eight day clock under the recording pen which is controlled by the contraction or expansion of blond human hairs as influenced by a moist or dry atmosphere (40). This instrument is in common use at headquarter stations where permanent records are desired.

TEMPERATURE

Instruments for recording this element are well known and in common use. Specially constructed tubes allow for maximum and minimum readings to be secured for any station at which they are placed. The chief purpose of such readings is to determine the mean temperature for that location. The Thermograph is similarly constructed and gives continuous readings of temperature as the Hygrograph does of relative humidity. The chief difference is that the recording pen

is controlled by a flexible bulb filled with mercury.

DUFF HYGROMETER

M. E. Dunlap of the Forest Products Laboratory invented this instrument for the purpose of determing the moisture content of the forest duff (21). Data recorded has not produced a workable correlation with other fire factors and is therefor being largely replaced by the newly developed wood cylinders for determing the moisture content of forest fuels (22).

WOOD CYLINDERS OR HAZARD STICKS

Wood cylinder moisture records are intended to be an index of all the factors heretofore enumerated and as records over a longer period are obtained they are becoming more intensively applied (23).

There are many modifications of this device, but the one being generally accepted and the most accurate consists of two cylinders of Ponderosa pine wood one $\frac{1}{2}$ inch in diameter and the other 2 inches. These are placed on wire racks in a wire enclosure situated on a representative site, and are carefully weighed to the nearest 1/10 of a gram on spring balance scales. This weight when referred to calibrated charts produces a cross reading of moisture content in per cent.

EVAPORIMETER

C. G. Bates of the Rocky Mountain Forest Experiment Station invented this instrument primarily to help study the transpiration of forest plants, but the records have been found valuable for determining the rate of evaporation of forest fuels, and is becoming popular in use with Wood Cylinder records (12).

FIRE-DANGER METER

This device was developed in the Northern Rocky Mountain Experiment Station. It gives an integrated rating of the combined effect of fuel inflammability, air humidity, wind velocity, visibility, season of the year and other factors involved in the determination of fire danger at any time or place (48). This device depends upon the above mentioned instruments for its basic data. It is in whole a means of interpreting the records derived from all those instruments, and it bids fair to become the largest single factor in successful fire control.

INSTRUMENT SHELTER

Wooden shelters with locks are necessary where fragile instruments are exposed. These are designed to provide a maximum of air circulation and protection from rain.

MOBILE UNITS

Important progress has been made in applying fire weather recordings to the job by equipping a light automobile with all the necessary instruments for ascertaining and interpreting weather conditions in particular localities. Management principles applied to fire control have a great need for forecasts as supplied by these units in order to handle intelligently the day to day intensity of preparedness (27).

SECTION II

DETECTION

Engineering developments and accumulated experience have done much to lower the excessive discovery time of forest fires and to more accurately check upon the qualifications of the personnel. The equipment necessary for the best performance of lookout men must first place the man in the most advantageous position, which is accomplished either by airplane or elevated observation stations. Once in position a function of equipment is to improve ones power of vision and to help determine the need for more or fewer observers to secure the required coverage of all the area. Probably the most important function of detection equipment is that of determining the exact location of fires discovered as this is a vital point in fire dispatching and suppression work.

Equipment developed for detection uses are given in the following paragraphs.

LIVING QUARTERS AND TOWERS

The adoption of the standard 14 x 14 foot lookout house was a boon to the piece of mind of the lookout man and thus allowed him greater concentration upon his duties. As direct visibility of all forest areas to be protected is the ultimate and necessary goal of detection planning, the placing of standard houses on steel or wooden towers varying in height from 12 to 100 feet has done much to bring about the partial realization of that goal (27).

BINOCULARS

That type used by the United States Navy was found to be the

best for the type of work to be performed (48). They should be used only after locating a smoke or likely fire and then only to determine such details as the standard reports demand.

These binoculars are equipped with a mil scale which allows the computation of the exact size of a fire of known distance from the observer. A specially prepared alinement chart aids in the calculation (9).

PERISCOPE

The navy periscope as applied to detection has proven successful to the extent of tests thus far completed. Their major advantage is in increasing the range of vision. Many fires have been discovered while still small up to a distance of 40 miles (50).

AIRPLANE

The use of airplanes equipped with short wave radio has become standard practice with the Forest Service during and after electrical storms. When a smoke is found, the observer plots its location as accurately as possible on his map. At all times he keeps a log of the flight, using time as a basis. This log is usually written in triplicate, by the carbon process, in a convenient special notebook (17).

If the radio fails or contact cannot be established with the ground force the map and a copy of the log are dropped at the proper station if landing facilities are not available (17).

The type of airplane for this work should have slow cruising speed when throttled down and low landing speed. The cruising range should be at least 6 hours. Maneuverability and staunchness are

essential. The airplane should have a short take-off and rapid climb to facilitate the use of small mountain meadows at high altitudes for emergency landing fields. Maximum visibility is greatly desired especially beneath the plane. The primary essential is a dependable engine, because of the scarcity of landing fields and the rough topography over which low flying is necessary to obtain the objective (17).

GOGGLES

Goggles are an invaluable aid to lookout men during the sunlight hours of the day. The specifications for standard goggles as determined by the branch of forest research are given in the following sections (34).

Color - smoked glass is the best color and has a slight tendency to absorb haze. Amber and reddish colored goggles are to be avoided as they tend to make blue smoke invisible.

Density - that density which transmits 15 to 20 per cent of the radiation in the open is best while in houses 26 per cent should be transmitted.

Shape of the lens - pear-shaped lens are best by test.

Optical quality of lens - should be absolutely optically correct.

Additional data brought to light through the above research, further shows the need for this equipment, is that 55 per cent of 12,000 fires start between the hours of noon and 6 p.m., and 2/3 of the fires are discovered while looking toward the sun.

VISIBILITY METER

The Byram Haze Meter designed to determine visibility conditions in terms of visibility distance or the maximum distance in miles at

which a standard size smoke column could be distinguished in the direction specified under the existing conditions when the measurement is made. The measurements are quite accurate in distance of 10 to 16 miles, but under 10 miles the error becomes increasingly greater (35).

There has long been a need for instrumental methods of measuring visibility conditions in the vicinity of lookout stations in order that forest administrators might know when the number of lookouts on duty should be increased and when this detection force might safely be reduced. The Byram Meter is fundamentally correct, and without a doubt is the answer to the need for such an instrument.

FIRE FINDER

The Osborne Fire Finder of 1916 is still standard equipment for this use although the original instrument has many modifications at present. It is so designed as to give both horizontal and vertical readings in degrees from the station to the fire (16). It is typically an all metal instrument with revolving line of sight upon a graduated base with an index on the sighting bar to give the azimuth reading to the fire. The center of the instrument is made large enough to permit the mounting of a $\frac{1}{2}$ inch scale map of the area adjacent to the station at which the instrument is situated. Various types of bases are used to elevate the instrument, all of which are satisfactory as long as they meet the requirement of rigidity. The vertical reading is most valuable when used in conjunction with a contour map or one with numerous elevation stations. Small levels are supplied with each finder to facilitate leveling it (3).

An attractive feature of this instrument is the leveling screws, which rest upon a sliding base, allowing the instrument to be shifted in order to clear the line of sight of building corners or other obstacles in the desired line of vision.

COMPASS

The compass is becoming more and more important in locating fires and going to them after discovery. As better maps and trails and section line markers are being used in directing men to fires. The new floating disk compass has eliminated the chief difficulty that guards have had in using compasses in the past, by forgetting which end of the needle to read and which is the east and west markings. The new compass replaces the needle with a graduated aluminum disk with magnetized bar underneath. The outstanding advantage of the disk is that the correct reading is at the line of sight directly in front of the operator, no matter in what direction he is going, and the reading is not likely to be taken at any other point. The azimuth on the disk is graduated clock-wise and the east and west markings are not reversed (52)

PLOTTING EQUIPMENT

The fire dispatcher and other members of a fire control organization are dependent upon reliable methods of plotting in order to most efficiently and accurately locate fires, from the data given by the reporter. The standard map board with each lookout station located within an azimuth circle and equipped with individual pull strings has proven basic for this work. Receding string reel with glass topped push pins attached to the end of the strings is a convenient item in

connection with dispatcher maps (2). Protracters of practical size and reliable make are important supplements of this map in recording bearings from or for compasses for points without azimuth graduations.

PANORAMIC PHOTOGRAPHS

Panoramic photographs of each lookout with graduated scale mounted upon them serve to give the dispatcher the identical view as that of the lookout reporting the fire. These photographs mounted in atlas form on a vertical axis near the dispatcher's desk have been a major step in aids to the dispatcher (40).

The transit camera for taking panoramic photographs from fire lookout stations, which was devised by W. B. Osborne, has been invaluable, not only in the preparation of photographs for the use of the dispatcher and members of the fire suppression organization, but also in connection with visibility studies for determining the location of lookout stations and in preparing lookout visibility maps (6).

SECTION III

COMMUNICATION

Communication is a vital part of fire control. Its need is felt in every activity, and where accidents or fires occur it may become the primary limiting factor. Each forest unit in organization, business, topography, history, geography, local inhabitants, climate, and forest cover are reflected in some way in that forest unit's communication system.

Two major types of communication devices are used in fire control work at this time. These are telephone and short wave radio. Short wave radio, though not a substitute for telephone, is used to supplement the telephone system in districts remote from established communication or when telephone communication is out of order. It is also good practice to substitute the radio to avoid heavy telephone investments for short seasonal use and for intercommunications between administrative units.

The two types of administrative organization, centralized and decentralized, influence to a large extent the kind of communication used (4). For centralized units long distance conversation is necessary which demands metallic circuit lines and low frequency radio instruments and decentralized may utilize grounded circuit lines and ultra-high frequency radios.

TELEPHONE COMMUNICATION

The grounded and metallic circuit lines have interchangeable instruments and are, therefore, considered together in the following sections dealing with instruments.

Metallic lines are replacing grounded lines in all cases where such action is advisable, although much more expensive, there is no limit to distance to which they will carry signals. Whereas, the maximum workable range of grounded lines is less than 75 miles with a maximum load of 31 decibles. Metallic lines require pole construction with solid tie insulators which necessitate a wide right-of-way clearance of trees susceptible to windfall.

The grounded system is the less expensive and constitutes the major mileage of Forest Service lines. It is principally a tree line utilizing No. 12 steel-cored copper wire with porcelain split tree insulators. In areas subject to heavy lightning storms it is good practice to provide partial ground rods on tie trees at regular intervals.

The following table should in all cases be consulted in formulating plans for new units in order to avoid overload troubles which are common to most of the existing lines (4).

Table 1

Decible Ratings Assigned to Telephone Lines

Unit	Decible rating or load-weighing factor	
1 mile grounded line	0.20	lb. loss
1 mile metallic line	0.0417	" "
Each ringer	1.00	" "
Each tap or leg	1.00	" "
Each repeating coil	0.50	" "
Each switch	0.50	" "
Receiver off hook	3.00	" "
Transmitter in use	2.00	lb. gain
Through exchange (power)	5.00	" "

TELEPHONE INSTRUMENTS

The standard instrument for lookout stations is any of the standard makes of wall phones equipped with an extension cord for the chest horn transmitter and head phone receiver. This arrangement allows for freedom of movement of the person while taking and reporting fires. It may be used at dispatcher headquarters also. Standard lightning insulating equipment is necessary in all cases for the safety of the operator as well as for the permanence of the equipment.

For office and Ranger headquarters the new craddle type high powered instrument, which utilizes two standard dry cell batteries is becoming increasingly popular for use in place of Wonderphones with boosters and other expensive devices used to overcome excessive overload on grounded lines.

Dispatcher and Forest headquarter stations, where a large number of lines converge, have new and complicated call and ringer systems which are necessary for the smooth functioning of the communication system.

The Adam's portable phone, measuring $9\frac{1}{2}$ x $3\frac{1}{2}$ x $2\frac{3}{4}$ inches and weighing $2\frac{1}{2}$ pounds complete with batteries, is invaluable for fire control work as well as for administrative purposes (21).

RADIO

Short wave types of radio are now standard fire control tools (27). Types have been developed for every need, from airplane instruments to long distance inter-forest sets. The development is so rapid that detailed descriptions are out of place here. The general trend is to produce types transmitting and receiving voice signals only,

as very few of the Forest Service personnel are familiar with code signals. The "Duplex" types are now being adopted which allow exchange of messages without switching from transmit to receive. These types are specially suited to conditions where experienced operators are not available. The disadvantage of voice transmitting sets is the large amount of power required and the reduction in range from that of code system which is nearly twice that of voice systems (44).

Two systems of radio communication are in use in different sections of the United States. The two-way system, though more cumbersome and bulky than the one-way system, can be of more value in inaccessible regions or where return messages are essential. Regions where truck or auto patrol and suppression units are used in all parts the one-way or police system has proven highly satisfactory. Some authorities state that where the one-way system can be used at all it is more efficient than the two-way system. The chief advantage of the one-way system is that it can be used very satisfactorily while in a mobile position (33).

The most important factors guaranteeing the successful operation of radio are good antenna and ground for all operating stations. Poor installation of these items may reduce the capacity of the transmitter by 1/5, and reduce otherwise satisfactory service to no service at all (44).

At present the disadvantages of radio in satisfactory service are static, interference and the lack of ringing or calling facilities (43).

The following types of radio equipment are being used for different purposes throughout fire control regions.

Type P Radio Unit

Transmits code (e - w) only, but receives both voice and code. Its rated working range is 20 miles, and is designed primarily for smokechasers. It weighs, complete, 9 pounds. Its use is limited because it does not transmit voice.

Type PF Radiophone

This set transmits and receives both voice and code, weighs 15 pounds complete, has a working range of 10 miles by voice and 20 miles by code (39).

Type SPF Radiophone

Transmits and receives both voice and signal, is simple to operate and especially good for standby as it has a built-in loud speaker. The portable set-up weighs 20 pounds with a greater communication range than the PF. The kitbox complete with radio weighs 58 pounds.

Type M Radiophone

This high powered set, utilizing 110-volt alternating current, was designed especially for communication with the field from Supervisor's headquarters and central equipment depot, and for use as a central communication station on large project fires.

Type T Radiophone

This ultra-high frequency "Duplex" transmit and receive radio has a range of about 100 miles over optical paths. It is designed for standby operation with a built in loudspeaker. The weight complete is 50 pounds portable and 100 pounds total (45).

Type I Radiophone

This set is a complete transmitter-receiver intermediate in power between the SPF and M radiophone. It can be operated only from 6-volt storage batteries or 110-volt alternating current. It is primarily a modified M set for storage battery operation in remote places or from trucks and other large vehicles (45).

Type A Radiophone (U.H.F.)

Designed to meet the Forest Service requirements in airplane use. Its desirable features are that it can be installed in any type of airplane, easily and cheaply, and is free of static interference common to other models of airplane radio. This set supplies communication from the plane to ground for short distances.

Type FXB Transmitter

This transmitter is a Collins type used at the central station for one-way communication with mobile units or others who are equipped with receivers of Philco types 810 PV and 811 PV (Police variable). These receivers have a tuning dial instead of a fixed frequency which makes them more valuable because it can receive messages broadcast from stations having different frequencies than that assigned to the central station (33).

Type SV Radiophone

This radiophone is the newest design in the ultra-high frequency field. It weighs about 16 pounds, complete, and has a power output of about one watt. The unit has an improved stability of transmitter frequency and the receiver performance is

better than older models. It may be used for lookouts, portable, and mobile communication (45).

The "grounded" antenna for ultra-high frequency installations on lookouts, and the fact that these frequencies have no fading and static, makes it possible to communicate during thunderstorms and at other periods when heavy static might paralyze low frequency radio communication as well as telephone communication over grounded lines (45).

Experience has demonstrated that it does not pay to set up a communication system for handling regular administration traffic on radio channels also to handle fire traffic, as a large fire will so overload the channel that a breakdown in the administration communication system results.

SECTION IV

TRANSPORTATION EQUIPMENT

The primary means of transporting men and supplies to fires is by automotive equipment, and will probably continue to be where roads and motorways are available. Where transportation to inaccessible areas is necessary and roads are not available the horse and mule pack train is the primary means by ground except where topography allows the construction of tractor trails which may be traversed by light tractors drawing a special type of trailer of one or two ton capacity. The use of airplanes for transporting men and supplies to fires in remote regions has become standard practice with the Forest Servie. The use of back packs by men for short distances is a last resort where the topography prevents the utilization of any of the above means. The streams and waterways of many forest areas allow the use of boats to great advantage. These methods of transportation are treated in the following paragraphs.

TRUCK AND OTHER AUTOMOTIVE EQUIPMENT

Where this type of equipment is used, the load capacity and speed of transit are the two major factors. The Forest Service standard heavy duty truck is a six-cylinder, two ton truck not to exceed 170-inch wheel base, with single tread over-sized tires, same front and rear. Larger trucks are permissible where road conditions allow economy and speed of operation. Duel wheels may be used on any size truck where practical. Heavy trucks are essential when it becomes necessary to transport tractors and other heavy equipment to fires (42).

A light duty truck of $\frac{3}{4}$-ton capacity or less is a real need on Ranger districts on fire forests where there is sufficient mileage of roads and motorways. Suitable interchangeable racks or bodies for trucks are necessary where pack stock or plow horses are to be transported.

Special trailers for light truck or cars are important items for Ranger district administration or fire control (5).

TRACTORS AND TRAILERS

Light tractors equipped with bull-dozer and drawing a trailer of one or two ton capacity may eventually replace the pack train in many areas. Tractor trails need not be as wide as truck roads and would be required only in a few places in an area of moderate topography. An interesting factor is that the tractor after drawing a loaded trailer to the fire, could be used to construct a machine made fire line, other things permitting (27).

PACK EQUIPMENT

Decker saddles are recognized as standard pack equipment by all regions where established horse or mule pack trains are maintained. These saddles are to be used with one wool blanket and one hair pad for protection to the animal's back. Rope haulters of army style have been found the most economical of all types used. Other equipment as leather hobbles and Swiss bells are necessary.

The Nelson "Indian pack board" is standard for smokechasers and other firemen when heavy loads are to be back packed. Canvas knapsacks are most economical for back pack fire crews of 5 to 50 man units.

TRAIL GRADER

For the construction of fire control trails and ways, D. L. Beatty of the Missoula office in Region 1 has created a workable unit. The blade has detatchable points to fit various types of soil and vegetative growths. It is horse drawn and builds from twice to four times as much trail as can be done with hand labor (21).

AIRPLANES

Where ground transportation is poorly developed or where a material saving in time can be made, the use of airplanes is recommended. In any fire problem where speed is essential they are without an equal and since methods of dropping supplies and equipment from airplanes to fire camps or ground crews has been developed, their use has become invaluable. An important field in the use of airplanes on fire is that of treating small fires from the air. Results to date have not proven satisfactory, but the field has not been exhausted (27).

The type of airplane for general use in transporting men and supplies to fires should be a high wing cabin monoplane with door and chairs removable (43). The same principles apply for planes in this use as those listed for planes used for detection purposes.

Airplanes used for transporting large numbers of men and supplies long distances should be larger than those used in scouting fires or dropping supplies and equipment to the fire as maneuverability and slow cruising speed are important factors in the latter case (17).

Two satisfactory methods have been developed for dropping material from airplanes; these are the loose package method and the retarder method which utilizes homemade parachutes.

The loose package method was developed in Region 4 of the Forest Service and has proven very satisfactory for all materials which will resist a moderate shock. The items to be dropped are placed within a sack of canvas or burlap which is tied at the top. The larger the sack the less danger of damaging the articles within.

Table II gives a summary of the results of the 14 tests carried out by the officials of the Idaho National Forest (43).

Table II

Test	Class of Supplies	Drop (ft.)	Wt.	Per cent of Load Lost	Container	How Prepared
1	Food supplies	375	57	4.2	Sack, mail	Tied loosely
2	Emergency rations	275	53	2.0	Sack, mail	Tied loosely
3	Emergency rations	300	84	5.4	Sack, mail	Tied loosely
4	20-man mess outfit	300	40	None	Sack, mail	With 11 lbs. excelsior
5	1-man S.C. outfit	375	35	*	Pack cover	Tied tightly
6	Fire tools	300	21	None	Pack cover	Tied tightly
7	Baby shovels	200		None	None	No wrapping
8	Pulaskies	200		None	None	No wrapping
9	Fire tools	200	198	None	Mail bag	Tight-Parachuted
10	Food supplies	300	28	None	Mail bag	Tied loosely
11	Food supplies	300	33	1.5	Mail bag	Tied loosely
12	Emergency rations	300	5	None	Sack	No preparation
13	Emergency rations	300	5	None	Sack	No preparation
14	Emergency rations	300	5	None	Sack	No preparation

* This test might be considered 100 per cent failure, as fire tools were broken.

The authors of the tests in table II state that they are entirely convinced that getting supplies to men by airplane is feasible under practically all conditions (43).

The retarder method should be used for all articles which test prove will be damaged when dropped by other means (20). The chute used in

this method may be made by ripping open a burlap wool sack and tying shrouds 17 feet long of clothes-line or sash cord to the four corners. A chute thus constructed will safely lower 100 pounds. This parachute can be made in 5 minutes at a cost of 40 cents and can be used repeatedly.

The articles to be dropped are sacked or wrapped and tied to the shrouds of the chute. A chrome yellow stringer is tied to the center of the chute for the purpose of making the load easier for the ground force to locate.

The procedure in dropping supplies is to first drop a pilot load for a guide and then spot and map all loads dropped. This map and other information is dropped to the ground crew before leaving (51).

The use of airplanes to the fullest extent in fire control work necessitates the use of emergency landing fields and often during darkness when the use of lights or flares is highly desirable. Research in this field has developed a satisfactory light in the magnesium candle flare which has a rated candle power of 80,000 and burns for a period of 3 minutes. It radiates a beam for 1 mile and in all directions. As a further aid, large reflectors, mounted on tripods and placed at the ends of the field, focus the light on the field and curtain the glare of the flare from the eyes of the incoming pilots (8).

The improvement of existing landing fields and the selection and development of additional fields is urgently needed. The Department of Commerce standard marking rules and regulations should be used in establishing landmarks for air travel such as numbering

lookout houses or otherwise marking them (43).

BOATS

In regions where water transportation is feasible, the use of boats for transporting men, supplies, and equipment has proved to be economical, but lacks the important factor of speed. In general their use is more adaptable to fire patrol and administration work than for fire suppression duty.

The size, motor, and construction requirements vary with the conditions of the water upon which the boat is to be used. Those used in ocean waters should in general have twice the length, strength of construction and cruising range than that of boats used in inland waterways. The propelling power should be the maximum consistent with the size and use of the boat. Diesel motors are especially adapted to large boats used for transporting heavy loads while gasoline engines are the best power for patrol or light boats where a quick get-away and speed are essential (5).

Protective organizations in Alaska and in sections of the Lake States are at the present time utilizing water transportation to the fullest extent in fire control work as well as in administrative work.

SECTION V

SUPPRESSION EQUIPMENT

Fire suppression is the major field of the forest protection problem. Development has been most rapid in the mechanization of fire suppression equipment and has to a large degree revolutionized fire line construction. The adaptation of power driven equipment and chemistry to this work is going on at an accelerated rate, and especially so since scientific men have been employed to help in this work.

There is a wide variation in the kinds and types of equipment used in suppression work. The major divisions are chemical, motorized, power, hand, and miscellaneous. Each of these divisions may be further divided according to the kinds within that group.

Chemistry is a means rather than a device, but is treated as equipment in this paper because of its close relationship with tools for fire suppression. Research in the field of chemistry for the purpose of finding an effective fire extinguishing combination is carried on by the Forest Service under the direction of the Forest Products Laboratory. This research has already demonstrated the potentialities of chemicals to fire.

Motorized equipment has made the largest advance in application to fire suppression. The use of tank, truck, tractors, and mobile pump units to suppress fires bids fair to replace hand labor in line construction.

Hand power equipment of many types has been adapted to fire

control work, and as they become perfected the possibilities for more efficient use by all protective agencies becomes assured. The portable power unit, portable power saw, pumps, and others are the principal units under development at the present time.

The use of hand equipment is rapidly being replaced by the power units except in the remote inaccessible areas for which practical power units have not been perfected.

Miscellaneous tools and equipment consists of fire camp equipment, horse drawn tools, and various kits and outfits.

Chemistry in Fire Suppression

CHEMICALS

The results already obtained from research in applying chemistry to fire suppression indicates that the value of chemical compounds in fire extinguishing, fire retarding, and fire proofing, is so great that this use can be developed to the point where the rate of efficiency will eliminate the possibility of any large fires.

Experiments by the Forest Products Laboratory have resulted in the segregation of a number of chemical agents which are suitable for cellulose fire control. The agents were selected on the basis of the following influencing or limiting factors in the order of importance.

1. Adaptability as efficient agents.
2. Costs and commercial availability.
3. Animal life hazard.
4. Metallurgical activity.

Important properties of chemicals to be considered are that the efficiency of spread of a solution is closely related to its surface tension properties. The alkaline or basic liquid solutions and dry mixes were more efficient as regards spreading properties than those of an acid nature.

Hydroscopic action is no indication of a beneficial fireproofing property, furthermore, they have the decided disadvantage of quickly clogging the equipment used for discharging. Dusts of several mixtures of dry material can be satisfactorily applied. The high metallurgical activity of several of the most efficient agents means that resistant metal containers must be used.

Some of the more important agents as determined by experiments are.

1. Ammonium arsenite (compound with arsenite radical).
2. Antimony (ranks very high) has high atomic weight, and can be finely powdered and is principally a fire extinguisher agent.
3. Arsenic - ranks higher than antimony, but its highly hydroscopic nature makes it difficult to use.
4. Boron - is the old reliable fire proofing chemical as made from zinc chloride and borax. Ammonical solution of copper borate penetrate deeply and when dry the wood will be highly resistent to fire. Its use is in fire proofing.
5. Copper - the efficient salts are relatively low priced, but not as efficient as other agents.

6. Fluorine - one salt, magnesium fluo-silicate, shows considerable promise.
7. Iron - ferric chloride is a low cost, efficient fire extinguishing agent, but is highly active from a metallurgical standpoint.
8. Magnesium - one salt, the chloride, shows promise when finely divided.
9. Phosphorus - especially phosphorus oxychloride is the most efficient oxygen inhibiting agent that was worked with, but is highly active metallurgically.
10. Potash - potassium carbonate shows promise as a fire retardent.
11. Zinc - zinc chloride has an established background as a fire proofing agent.

Certain combinations of dry materials when added to water increases their fire extinguishing properties in the ratio of 25 to 1. Efficient dusts and solutions can be produced in commercial quantities at a reasonable price and can be stored both in a dry form and in concentrated solutions in readiness for any fire emergency. Dust mixtures can be applied practically from an airplane (10).

Calcium chloride, because of its high deliquescent nature, has a limited use in forest fire control. Its principal use is as a fire retardent, for when applied dry to combustible materials, the chemical by increasing the moisture content, decreases inflammability. It is, as most other agents, extremely soluable, and does not endure stormy periods (47).

Calcium chloride as used to retard fires in ground litter in pine forests gave satisfactory results when permitted to remain overnight on the test plots on experiments in Region 5.

The weather of the morning the test plots were fired was, temperature 79 degrees F., relative humidity 43 per cent, with practically no breeze. Table III is a summary of the overnight application tests (24).

Table III

Quantity CaCl Applied		Fire Reduced to (Speed)	
Total Pounds	Pounds Per Sq. Ft.	Per cent	Remarks
¼	0.016	100 (no effect)	
½	.032	100	
1	.063	100	
2	.125	100	
4	.250	40	Center not burned
6	.375	30	Center not burned
8	.500	0 (Stopped fire)	Burned outer edge
10	.625	0 (Stopped fire)	Burned outer edge

The practicability of such applications have not been determined to date, but they show promise of the use of chemicals in fire control (24).

The foam producing chemicals have long been used in fire control work. Fire foams are created by the mixture of two chemicals (Sodium bicarbonate and aluminum sulphate) plus a stabilizer (such as extract of licorice root) brought into contact with water. The volume of foam produced is about eight times the volume of water used.

Three methods of mixing are used in present practice depending upon the kind of application desired, whether from tank truck pumps, back-pack rig, or from aerial bombs. The methods are,

1. One powder method - all dry chemicals are mixed together in advance and fed into one hopper above the generator, through which a single stream of water is passing. With pumper and hose lines, and with tank trucks this method is the simplest and the best suited.
2. Two powder method - compound A and compound B are fed into separate hoppers and meet as two solutions.
3. Two solution method - compound A and B are separately mixed with water and held in solution in storage until mixed, as with hand extinguishers. This method is adapted to back-pack rigs and aerial bombs as the dry powder cannot be mixed quickly enough with water.

In experiments, with foam as a fire control agent, carried out in Pennsylvania the foam compounds were fortified or "loaded" with the flame-retardent chemical, ammonium sulphate. Other chemical agents have not been tried as yet.

The results of the above tests show promise in this field of fire research, and a few facts definitely established are listed.

1. A gallon of water mixed with a pound of foam compound is more fire suppressive than a gallon of water.
2. With back-pack rig the tests showed a ratio of 8 to 1 in effective footage of line, as between foam and water treatment.

3. Reignition after application is much slower when foam is used than when water is used.
4. Foam is effective either as a knock-down or mop-up substance and is much more effective in either case than an equal volume of water.
5. Packing the heavy chemicals to the fire line in rough country is a disadvantage to be considered (24).

Airplanes are used in Russia to spread caustic soda before the steppe fires of that country. This method of fighting these dangerous grass fires has proven very successful. A ton of caustic soda is enough to form a protective belt for five kilometers. (Taken from Fire Control Notes, August, 1937 as quoted from Moscow News, Moscow, Russia).

Motorized Equipment

The suppression of forest fires is beginning to reflect the increasing use of the gasoline and Diesel motor in all parts of the United States. Those areas having relatively smooth topography and a large mileage of roads, and numerous lakes and streams favor the use of such motor driven equipment as trucks, tractors, and pumps (28).

TRUCKS

Large and small trucks designed for water transportation and use of water or foam on fires have a definite place in fire protection (27). Other trucks of heavy construction with 4-wheel drive and especially equipped with disk, harrow, or plow tools

have proven the most economical means of maintaining fire breaks in the Lake States (37).

There are many types and designs of tank trucks in operation over the United States all of which have many good features. They are similar in basic requirements of size and construction and in the special power take-off from the transmission for the purpose of driving built-in power pumps for refilling the tank as well as pumping water to the fire line (11).

The Oregon State Forestry Department has recently developed the most up-to-date tank truck yet constructed (15). This truck was designed with the idea of carrying into the forests the advantages of city fire-fighting methods. It is constructed on a three-ton chasis with 160 inch wheelbase, dual transmission, giving ten speeds ahead and two reverse. It is covered over all with a metal panel with tools and equipment fully enclosed in compartments specially constructed for each kind of equipment carried.

The tank is 525 gallon capacity, with the power take-off pump located at the rear of the cab. A special clutch operated from the cab is provided for engaging the power take-off. A system of valves makes it possible to pump either directly from a stream or from the tank. The capacity of the pump is 140 gallons per minute.

The truck will carry 8 men in addition to the regular equipment for 50 men consisting of two power pumps with 1,600 feet of $1\frac{1}{2}$ inch rubber-linned cotton hose (15).

The smaller units are constructed on a ton-and-a-half chasis and carry smaller equipment throughout (15). A unit recently

developed for use of private agencies and others in fire protection is the "pick-up" chasis with a 50 gallon tank. A small pump driven by a power take-off from the truck engine pumps water from and into the tank. The live reel, which holds 200 feet of hose, and hand equipment for 10 men are additional items which make this a very complete initial attack unit (38).

A late invention of great possibilities for efficient fire control is the dry ice unit. The commercial dry ice (CO_2) is used as a source of power for water pressure in connection with tank truck. The unit as built consists of two 25 pound capacity converters, a pressure gauge, a live hose reel and hose, and a 50-gallon high pressure boiler-plate water tank with a safety pressure release valve. The dry ice is placed in the converter, and when a temperature of 77 degrees F. is reached it produced a pressure of 933 pounds per square inch and will maintain this pressure until the last drop of liquid is used from the tank. The total weight of the unit loaded is 1,183 pounds for the light truck or pick-up model.

The advantages of this unit over the regular tank are (14).

1. Its low cost.
2. Portability - the unit may be placed on any kind of mobile unit.
3. Pressure is independent of the motor and may be operated at all times.

The Washington State Division of Forestry has constructed a dual purpose truck capable of 50 miles per hour on roads or rail-

way. It is equipped with exchangeable rims which can be exchanged in 20 minutes (31).

This truck carried the conventional equipment and in addition had a wench and cable for helping the truck from difficult places and for clearing the road. It also carries 4 other smaller pump units used to relay water to the main truck tank or to the fire directly (31).

The latest model of tank truck has been designed for the use of foam as well as water and the probabilities are that this type will replace the others as new trucks are built (27).

The primary idea behind the development of tank trucks is speed. As more intensive fire control planning is developed the necessity for keeping fires small becomes greater and in order to keep them small, they must be reached before gaining a foot hold. It is a problem where seconds in reaching the fire may save the day (46).

The essential features of a fire truck are dependability, simplicity, safety, reasonable cost, ample clearance, low center of gravity, limited weight, ample power and traction, controls and equipment conveniently arranged, and essential hand equipment.

The truck engine should be capable of producing 1 horse power to each 158 pounds of load and there should be two transmissions with one for the highway at a high rate of speed and the other for steep slopes (38).

Another unit which is appropriate here is the railroad tank cars. Large tank cars equipped with both steam and gasoline engines are now common equipment in most logging camps in the Pacific Northwest.

The gasoline engine pump, mentioned above, as additional equipment for tank trucks has a large variety of uses in fire control. The standard model has a 5 horse power air cooled engine which drives the pump with direct connection.

The smaller units have a two-cycle air cooled engine and rotary pump which are built as one unit. They are primarily a portable unit with horses or back-pack. Linen hose for these units is standard with the Federal Forest Service (5).

Two 5 gallon fuel containers are a special feature of these portable fire pumps. They are constructed in such a manner that the handles, filling hole and spout are protected, and the cans are made flat to facilitate packing and transporting (32).

Power pumps vary in capacity and size. The portable units may be carried by from 2 to 4 men. The rotary pumps deliver from 35 to 40 gallon per minute at 35 pounds pressure through a 3/16 inch nozzle opening at distances of 1500 feet with rises in elevation up to 500 feet (30).

Portable pumps have been used in relays on forest fires to carry water up to distances of 1 mile with a rise in elevation of over 2000 feet (49).

Their principal use is in knocking down fire to permit crews to work more closely to hot spots and in mop-up work where they have proven themselves to be especially effective when in the hands of skillful and efficient men.

TRACTOR AND TRACTOR EQUIPMENT

The greatest field of power in mechanized equipment lies with the caterpillar tractor and associated tools. The realization of this potential power has led many designers to overstep the limits of practicability and develop units which sacrifice speed for power and, therefore, have only a limited use in the most accessible areas.

The 2 ton brush cutting attachment for big tractors is an example of this overstepping. Besides being slow this unit represents an initial investment equal to that of 3 or 4 lighter and more portable tractor units (40).

The tractor that has the widest adaptation to fire line construction is the gasoline powered 30 or the Diesel powered 35 with a various assortment of attachments including bull-dozers, rippers, scrapers, drags, plows, and ditchers.

The number 15 "Killifer" ditcher for a 2-ton tractor has given excellent results. Its weight is 850 pounds, and is mounted on two wheels. This unit operates equally successfully in many forest types and will build an excellent fire line from 50 to 60 inches wide, at the rate of 1.5 to 2.5 miles per hour. The tractor breaks down reproduction 15 to 20 feet high and the plow digs it out and throws it aside. When tripped it can be pulled over large logs, and will operate on side slopes of from 40 to 45 per cent and on head slopes up to 75 per cent (40).

The front end bull-dozer has been most adaptable to the widest range of conditions encountered in fire line construction. It can

be used in clearing, trenching, or building a way for itself through otherwise impassible spots.

The bull-dozer attachment can be used to the maximum when supplemented with a ripper. The style recommended for general forest-cover conditions is a three toothed, two wheeled unit of about 1500 pounds weight. This combination is superior for use in the lodgepole pine type where bear grass constitutes the primary vegetation. In actual tests on going fires the two-ton tractor using the bull-dozer and ripper attachments have constructed a 6 foot trench at the rate of from $\frac{3}{4}$ to $1\frac{1}{4}$ miles per 8 hours (40).

Region 6 has attached the "Killifer" plow directly to the tractor and eliminated the wheel carrier. They have also developed this plow of the wheeled type (5).

The "Vaughan" tractor and plow unit is finding increasing favor in locations where it can be operated. This tractor is provided with an 8 H. P. engine and has a total weight of 920 pounds. It has a caterpillar track, and is operated from the ground. The special plow attachment is built in at the rear center and has a rounded blade point on the share which prevents the plow from catching under roots or stones. A double moldboard throws dirt to each side making a wide trench and eliminating much of the follow-up work with hand tools. On tests it made from 1 to 1.75 miles of line per hour in the open Yellow pine type. It climbed 47 per cent slopes and plowed around a 45 per cent slope. The width of the trail is from 35 to 40 inches in light sod types (40).

The results obtained with this "Baby" unit compares favorably

with the larger caterpillars in fire line work and will have a great deal to do in leading the way for the development of smaller tractor units.

The portability and small initial cost of small tractor units are important factors in favoring their use over the larger outfits, although, the larger units are indispensable for use in fire line construction (29).

The disk plow attachment for tractor is essentially valuable in fire break construction and maintenance. It is also practical for line construction on going fires in grass types. The double disk plow has been developed for suppression work and the heavier models weighing 400 pounds are becoming increasingly popular throughout the southeastern United States in the Southern pine type. They have also been used to a limited extent on the Pacific Coast in fire line construction (5).

Power Equipment

POWER PLANT

A portable gas-electric power plant equipped with drill machines has greatly advanced the feasibility of falling snags and in clearing right-of-ways for fire lines.

The plant weighs 118 pounds, and can be divided into two units for back-packing. It has a 4 cycle air-cooled engine and a one kilowatt D. C. generator and is very compact. It gives ample power for operating two $\frac{1}{2}$ inch drills, which together will bore 1 1/8 inch holes in round snags at a speed of from 40 to 50 inches per minute.

Trees up to 30 inches in diameter can be bored for loading with explosives in less than one minute and 40 inch snags in 2 minutes (40).

This power unit can be used with other attachments.

WOLF SAW

Rapid progress has been made in the development of this power driven portable saw for adaptation to fire line construction. It weighs 85 pounds and has a 3 foot chain saw. In tests this unit doubled the speed of a fire crew. It cuts timber up to 70 inches in diameter in one hour, and makes 11 cuts per hour in 26 inch timber. The chain saw needs filing only once in 3 days (13).

BOSWORTH TRENCHERS

The Bosworth trencher is a new invention having great possibilities. There are a few weaknesses in the present models when applied to all types of ground cover, but these can be overcome when more data from experiments show just what is needed. This machine has a light 2 cycle air-cooled motor which drives a brush constructed of spring steel cushioned in crepe rubber. The working model, completely equipped and fueled, weighs 60 pounds. When reduced of fuel and handles for back-pack transportation it weighs 50 pounds. The frame is constructed of bicycle frame tubing with a metal shield over the brush to protect the operators (7).

A brush trencher of the wheelbarrow type is being designed and can be operated by one man. It will have several advantages compared with the Bosworth type, chiefly, in that it may be operated by one man and can be more rigidly constructed.

That these units are practical was proven by tests in which two men with one machine constructed 15 chains of high quality trench per man hour, in Yellow pine, lodgepole, and grass types.

The brush scatters light fuel over a distance of 4 to 12 feet inside. In not too rocky soil a layer of dirt can be spread over or concentrated on an area within this distance (7).

GRINDERS, PORTABLE POWER

Portable power grinders have a definite place on any fire where 50 or more cutting tools may be used. These units consist of an ordinary hand grinder remodeled with a built-in small air-cooled gasoline engine. They are light weight very portable by back-pack or any other means of transportation (43).

Hand Equipment

Up to the present time hand tools for use in fire suppression have had the greatest application, largely, because nearly all of such work has been accomplished with them. Regardless of developments they shall always be a necessary part of any assortment of good fire equipment in most of the forest areas of the United States.

The principal requirements of hand tools are lightness in weight, compactness and durability. For any region the tool designed for the cover type predominating in that region should be used.

Hand tools are classed as those used by individuals on fire line construction, and mop-up work. The major kinds are treated in the following paragraphs.

SHOVELS

Both the long handled and short handled or "Baby" shovel are imperative tools to the equipment of any fire crew. They are the chief tools with which dirt may be handled in quenching fire in burning materials. The "Baby" shovel was designed to replace the Koch tool in smokechaser and back-pack outfits.

PULASKI TOOL

This tool was invented by E. C. Pulaski of the Coeur d'Alene National Forest in Region 1 and is designed to give the fire fighter two tools with the weight of one. It is used in conjunction with the "Baby" shovel in all back-pack fire outfits and has been adopted as standard equipment by the Rocky Mountain Regions. The tool combines the ax and hoe in one, and is about 5 pounds in weight (40).

MCLEOD TOOL

Where the duff is of a type which can be removed by a shallow digging tool, this one has met with much favor, especially in the hardwood forest regions. It uses either a rake or wide hoe blade on a single handle and is used mainly as a scraping tool (40).

KOCH TOOL

A combination tool of old design, consisting of a detachable shovel and hazel hoe with a reversible handle. Its weight was the factor which lost it favor in regard to more newly developed tools.

HAZEL HOE

This wide bladed long handled hoe is a favorite with old fire fighters where hand constructed trench is necessary in sod or

small vegetative growth (41).

KORTICK TOOL

A tool very similar to the McCloud tool in design, but of heavier construction in the metal parts. It has the rake and hoe blade (40).

AX

The double bitted ax is an indispensable tool in any wood work, and is not likely to be replaced by any other tool as long as hand tools are used in fire control work. The size and weight of the ax varies with regions and the size of the material in which it is to be used (41).

CROSSCUT SAW

Falling and bucking crosscut saws are used in fire control work, with a 5½ foot felling saws being most extensively used. Longer felling saws and more bucking saws are necessary for crews working in large timber. Each fire outfit should have a hammer of at least 2 pounds, 2 falling wedges, two saw handles and kerosene as sufficient saw equipment.

Break-down felling saws have a limited use except in back-pack outfits where the cumbersome full length cross cut saws are both dangerous and tiresome to carry. By the application of the principal used in the inserted tooth circular saws to the cross cut saws a full length break-down cross cut saw has been developed which is both compact and dependable in use (40). Particular care must be taken in transporting and handling these saws to prevent damage to the connecting ends of the two halves.

WATER CARRYING EQUIPMENT

Canteens, and water bags (hand and back-pack) are very essential items in any fire suppression work. The two-quart and four-quart sizes of canteens are now standard (43). Two-gallon hand sacks and five-gallon back-pack bags or cans are the most used in large crews.

The hand force pump and back-pack water bag of five-gallon capacity with various sizes and types of nozzles are becoming increasingly important in use in suppressing grass fires and in general mop-up work on all forest fires (49).

Special back-pack tanks with a three pound compact rotary pump unit has been designed for use with fire foams, chemical solutions, and water (49).

A high pressure hand spray pump, designed to operate with small quantities of water, has been developed in Region 6 for use on grass fires (5).

BACKFIRING EQUIPMENT

There are two separate needs for backfiring equipment based on the two types of backfiring practiced. For the purpose of burning out unburned patches inside for short distances along the line and for use on small fires where large equipment is not practical. The railroad fuses are the most used (36). They are light in weight and require no auxiliary equipment in order to operate.

The long burning, hot flame, special backfiring equipment is adaptable to the indirect method of attack on forest fires. Mechanical backfire equipment is generally divided into three classes according to the method of feed. These classes are the gravity

feed, the blast type pressure torches, and the flame throwers. The flame thrower has proven most efficient, and is being adopted by the Forest Service as standard equipment. This torch consists of a tube having a $\frac{1}{4}$ inch iron pipe thread on one end which will fit the "Indian" and Forester type pump furnished with standard back-pack outfits. The fuel used is kerosene, saw oil, Diesel oil, and fuel of similar grade.

The fuel is passed through a check valve on the pressure stroke of the pump which causes a turbulence in the oil. A specially designed chamber in the nozzle collects the fuel so that the fuel leaving the opening consists of a solid stream surrounded by a fine film of vapor. A wick tube is attached to the end of the pump so as to suspend the wick $1\frac{1}{2}$ inches beyond the nozzle. This wick is saturated with oil and ignited. The pump is operated in the usual manner in backfiring with this device. The blast of heat from this pump is intense, thus making it especially valuable for backfiring at night or in fuels not readily ignited. It also can be used to cover the damp fuels with oil and then ignite them (19).

Miscellaneous Equipment

LIGHTS

Lights for night work are essential equipment in modern practices of fire suppression. The need for satisfactory lights for night work on the fire line has long been felt by all administrators of forest lands, and the lack of them has been the inhibiting factor in the development of fire control technique.

The electric headlight or flashlight has met this need so fully that it has been adopted as standard by all fire control agencies (42).

BEDS

The Kopok sleeping bag has solved the problem of having suitable bedding for fire fighters. These beds are compact, light in weight (10 pounds) and bulky enough to provide sufficient warmth. They are better adapted to dropping from planes than rolls of blankets.

PLOW UNITS

Horse drawn plows are adaptable to many forest activities, but none as important as fire line construction. Plow units, though largely being replaced by mechanized equipment, will for sometime be a necessary part of fire equipment in regions having a topography too rough and inaccessible for motorized equipment.

The plow for this unit should be a reversible side hill plow of about 130 pounds.

The horse for this unit should be well broke, sure-footed, gentle, steady, and dependable. The best weight is from 1400 to 1800 pounds.

A table of the standard requirements for plow units is given in the appendix (42).

CAMP EQUIPMENT

In general camp equipment is standardized in nearly all regions. The mess kitchen outfits are packed in metal containers. The largest unit is the 25 man outfit which contains 462 pieces and is packed in double boilers (18).

The 2-section Kimmel stove weighing 65 pounds is standard with the Forest Service.

Miscellaneous items necessary in fire suppression work are medicine kits or chest, timekeeper's kit, cobbler's outfit, saw-filing outfit, and commissary; containing articles of clothing and tobacco.

Where nationwide standards have been adopted for any of the above mentioned outfits a table of contents is listed in the appendix.

SUMMARY

A notable fact of this study which is important in summing up is the rapid progress that has been made in developing fire control equipment during the last two decades.

This progress is still going on at an accelerated rate, especially so in mechanized equipment and in fire suppression devices.

The development of hand tools has reached a somewhat static position. Further improvement will depend largely upon the results of present research in the field of new schemes for stopping fire.

New devices have been improved to the point that they are not only practicable, but are being adopted as standard equipment by the majority of agencies engaged in fire control. The most important of these are the radio, airplane, tractor, power equiment, and devices for fire weather forecasting.

Through the leadership of the Forest Service there is more unity between fire control agencies at present in developing fire equipment. This unity lacks organization which if secured will do much in advancing the cause, both in time and funds saved.

The field of prevention is young and better equipment can do much to reduce the number of fires. This field broadens out to the extent that it is out of the jurisdiction of fire control agencies. The cooperation of manufactures of passenger vehicles and other items responsible directly or indirectly for starting fires is greatly needed.

Detection equipment has nearly reached its limit in perfection. Improvement lies in developing new ideas and in perfecting the use of those already developed. There is no record of experiments with army observation methods in connection with the detection of forest fires. The idea that army blimp or small balloons might be adaptable to forest fire observation has possibilities.

Communication devices have advanced to a satisfactory position in fire control. The telephone system is still standard in all cases with radio being supplemental. In no case should any administration of fire control organization depend entirely upon a radio system. Radio regulatory restrictions should be amended so as to permit state and private forest protection agencies greater freedom of use with this vital means of communication. At present the federal agencies are free to use radio with a minimum of regulation, while state and private agencies are barred from using radio except under the regulations of the Federal Communication Commission, which are too restricting to leave radio a practical instrument for these agencies.

Both the one-way and two-way radio methods of communication are satisfactory where applicable.

Chemicals offer great possibilities in retarding or extinguishing forest fires, but no combination has been found to date which is practical. Present experiments with chemicals are in line with water in an attempt to find something that will make water more effective as a fire control agent.

There is much to be done in developing mechanized equipment which can be depended upon to replace hand labor on fire lines. It is a matter of experimentation in the field to determine what the happy medium is for each kind of equipment for each set of field conditions.

It may be stated that fire control equipment has been developed to such an efficient stage that most of the forest fires occurring may be satisfactorily controlled, but the big job is to stop those few fires that "blow-up" from inception and defy all efforts of control crews during the first run. The airplane and chemicals or some similar substance, which can be used from the air, seems to be the most likely solution to this very important problem.

Table IV

Standard Requirements for Fire Pump Units

1	Pump, Edwards or Pacific, or equal. Reconditioned each season if used.
1	Hose, suction, with 6" strainer, gauze covered, 1½ inch, wire ribbed, fitted with male and female expansion ring couplings: 10-12' for 4 cycle units.
1	5 gal. gas tank. Back pack type (Indian or equal) with 5 ft. gas line.
1	Check valve, 125 lb., 1½" swing check.
1	Funnel w/strainer.
2	Nozzles 5/16" dia. opening.
1	Nozzle, 3/16" dia. opening. Or two adjustable nozzles.
3	Spanner wrenches, small with loop handle.
1	Pair pliers, 6-8" combination.
1	Screwdriver, 4 to 6 inch blade.
1	Wrench, 6" Crescent.
1	Gun, grease, Zerk.
1	Can grease, 1 lb.
2	Gallon good grade of medium-bodied paraffine base oil. Use one pint oil per gallon of gasoline for lubrication. White rags or waste.
1	Siamese valve.
24	Gaskets, rubber coupling, 1½".
1	Flashlight or Stonebridge lantern.
1	Knapsack with heavy canvas inner-lined bag.
2	Starting ropes.
1	Small ball pein hammer.
1	4" cold chisel.
1	Spark plug wrench.
2	Extra spark plugs.
1	Pack frame.
10	Gallon gasoline.
1	Pound waterproof grease.
1	Pack cover.
1	Instruction card for 4 cycle outfits.
1200'	1½" hose.

For 2 cycle units - the grease gun can be ommitted; but 1 gland and 1 double end 5/16 x 3/8 wrench, 1 quart measure with trip spout, and 1 instruction card should be furnished and:

¾	inch instead of 5/16 inch nozzle.
1	Duplex auto pail or equivalent.
1	4' back-pack-can hose.

Table V

Standard Requirements for Plow Units

Take for initial Attack	Standard	
1	1	Plow, about 130 pounds. Reversible McCormick-Deering No. 209 or Oliver No. 155.
1	1	Singletree, heavy, full length strap type, approx. 3 inches by 28 inches.
1	1	Harness, single set, heavy work type, with butt chains.
1	1	Collar.
1	1	Packsaddle, Decker, for large horse. With pads, blankets, cargo and sling ropes.
	1	Extra plow share.
	1	Set plow bolts, extra.
1	1	10 inch wrench, Crescent.
1	1	Pair pliers.
	1	Chain, log, 5/6 x 12 feet with hooks.
1		Clevis, half twist, plow.
	1	Nosebag.
	1	Brush and curry comb.
	1	5 Gallon water bag.
1	1	Halter.
	1	Set hobbles.
	25	Feet No. 9 or 12 wire.
	1	Lantern, gas, extra generator, 12 mantles, 1 gallon gasoline boxed.
	1	Container, canvas, for small tools.
	1	Axe, with sheath.
	3	Beds, Kapok, back pack.
	1	Bale of hay.
10	50	Pounds of oats.
	3	Emergency rations.
2	2	1-man smokechaser's outfit (man back pack).

Table VI

Standard Requirements for
Twenty-Five-Man Mess Outfit

1	Container, 25-man galvanized.
1	Cover, for 25-man container.
2	Pans, half oval.
2	Pails, half oval and covers.
1	Box, knife and fork, tin.
1	Pail, tin 6-quart 8" diameter, 10" deep, with cover.
1	Pail, tin 9-quart 8½" diameter, 12" deep with cover.
1	Pail, tin 13 quart 9" diameter, 12" deep, with cover.
1	Pail, tin 16 quart 9½" diameter, 12" deep, with cover.
2	Pans, fry 12".
30	Pans, tin, 1 quart.
12	Pans, tin, 3 quart.
4	Pans, enamel, 3 quart.
30	Plates, tin.
30	Cups, tin.
30	Knives, table.
30	Forks, table.
30	Spoons, dessert.
12	Spoons, table.
2	Spoons, basting, 14".
1	Fork, meat.
1	Knife, butcher, 7".
2	Knives, paring.
2	Lifters, pot.
1	Masher, potato.
3	Openers, can.
1	Turner, cake.
1	Whip, egg.
6	Kettle chains.
1	Alarm clock.
2	Files, 8" flat mill bastard.
50	Bags, paper.
30	Sacks, lunch (cloth).
4	Buckets, canvas water.
1	Stone, scythe.
10	Towels, dish.
150	Towels, paper.
4	Knapsacks, white, No. 10 duck.
2	Pounds nails 20d.
2	Pounds nails 40d.

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