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FIRE CONTROL NOTES

A PERIODICAL DEVOTED TO THE TECHNIQUE OF FOREST FIRE CONTROL

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GEORGE K. SCHAEFFER

FOREST SERVICE • U. S. DEPARTMENT OF AGRICULTURE

FORESTRY cannot restore the American heritage of natural resources if the appalling wastage by fire continues. This publication will serve as a channel through which creative developments in management and techniques may be communicated to and from every worker in the field of forest fire control.

Volume 9 Number 1

FIRE CONTROL NOTES

A Quarterly Periodical Devoted to the

TECHNIQUE OF FOREST FIRE CONTROL

The value of this publication will be determined by what Federal, State, and other public agencies, and private companies and individuals contribute out of their experience and research. The types of articles and notes that will be published will deal with fire research or fire control management: Theory, relationships, prevention, equipment, detection, communication, transportation, cooperation, planning, organization, training, fire-fighting, methods of reporting, and statistical systems. Space limitations require that articles be kept as brief as the nature of the subject matter will permit.

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THE HELICOPTER—A NEW FACTOR IN FIRE CONTROL

FRANK J. JEFFERSON

Assistant Regional Forester, Region 5, U. S. Forest Service

Foresters, in their effort to manage wild land more efficiently, have been continually envious of and wishful for the ability of the bird: to travel swiftly; to see rough terrain at close range, but in perspective; to hover and to alight in small spaces. Who wouldn't want to make more useful use of time, avoid leg weariness, and bypass the discomfort of an ill-fitting saddle and a bum horse? In none of the activities of a forester does this need assume greater significance than in the field of fire control. Small wonder then that some, and especially those charged with fire control work, have followed with avid interest the development of rotary-winged aircraft during the past half generation. Here is what they watched:

Developmental History

1922—United States Army makes its first helicopter take-off and landing.

1929—Autogiro Co. of America formed, produced a rotary-winged machine—used largely in the advertising field.

1931—Helicopter reaches height of 500 feet—horizontal speed of 50 miles per hour. (A prospect.)

1931—S. A. Nash-Boulden, supervisor of Los Padres National Forest, made partial flight over his forest in autogiro, believed to be first flight by forest officer in rotary-winged craft. Prophesied success.

1935—Army Air Corps purchased two autogiros for purpose of laboratory and flight testing. Proved successful for artillery fire direction operations. (Encouragement.)

1937—German helicopter reaches elevation of 11,700 feet, speed of 68 miles per hour. (More encouragement.)

1938—Army Air Corps starts school for autogiro pilots.

1939—Sikorsky develops successful helicopter.

1939—Army Air Force switches to helicopter. It is of interest to know that Dave Godwin was Forest Service member of the committee that made this decision.

1942—Sikorsky demonstrates helicopter, proves it to be a feasible machine; 5,000-foot elevation, 78 miles per hour. Made 761 mile cross-country trip. Its potential value in fire detection and suppression recognized by staunch advocators.

1943—Helicopter used by Army to transport wounded from jungles of Burma to base hospital. (A lift to proponents.)

1944—Sikorsky Aircraft now operating helicopter production line.

1944—Lacking facts as to mountainous services, western regions prepare transportation plan based on predicted helicopter transportation probabilities.

1945—Forest Service and Army Air Force in collaboration test use of helicopter in mountainous areas. (Has possibilities with skillful pilots.)

1946—Helicopter used in a limited way, but successfully, on Castaic fire, Angeles Forest. (Punches pulled due to theoretical limitations.)

1947—Helicopter used as key working tool on five major fires in California national forests. (Pilots went "all out" to give service.)

This chronology might lead to conclusion that the course of rotary-winged aircraft development and adaptation to the problems of transportation and supply service in mountainous areas was one of smooth sailing. Such was not the case. Many discouragements confronted the inventors and proponents of the machine, as test model after test model disclosed flaws of mechanical design, displayed impractical ideas as to load and elevation limitations, and a myriad of similar disappointments. The handful of foresters who, over the long years of its developmental infancy, daringly visioned and voiced their belief in the successful adaptation of the helicopter to forest fire control steadfastly faced skepticism of their co-workers.

Three people (Pat Thompson, Dave Godwin, and Ted Norcross) got their dander up. Action started. In 1944 an analytical study was undertaken of the feasibility and cost of helicopter transportation as compared to costly roads in fire control work on certain selected forests (Circular E–2963). The study, while based on theoretical operation costs and performance hoped for but not yet attained, served two purposes: (1) It indicated that helicopter transportation, if it met expectations, would result in better fire control at lower cost, and (2) it stimulated interest in the study of the new type of aircraft.

At that time there was little factual information as to the performance of these machines under the conditions of wind, topography, and elevations common to the forested land of the West. As a matter of cold fact, all conceptions as to mountain performance were speculative. There had been no tests.

Testing for Mountainous Forest Fire Control

Gen. H. H. Arnold, Chief of the Army Air Force, had, from almost the beginning of his career, been deeply interested in the aerial phases of forest fire control. He served as one of the earliest of fire-reconnaissance pilots. This interest in 1945 lead to the Army Air Force and the Forest Service joining in a series of helicopter tests under western forest conditions, using Air Force "Sikorsky" machines and skilled Air Force pilots. The Angeles and San Bernardino Forests were selected as proving grounds for these tests. March Field, internationally known and "Hap" Arnold's old command, was the operating base. The tests included, among other things, determination of the allowable pay loads which with machines of the type tested (Sikorsky R–5) would permit safe landing and take-off under varying conditions of flight distance, altitude, temperature, wind velocity, and weight dis-

tribution. The findings of these tests are reported in the January 1947 issue of FIRE CONTROL NOTES. Significantly, the machines were demonstrated to be (within their limits) feasible working tools for reconnaissance, supply and personnel transport under mountain conditions.

In 1947 two privately owned Bell model 47–B helicopters moved into southern California. Immediately arrangements were made by contract to run these through the same tests as given the Sikorsky machines. Results were satisfactory. A full report of these tests will appear in FIRE CONTROL NOTES.

The Pay-Off

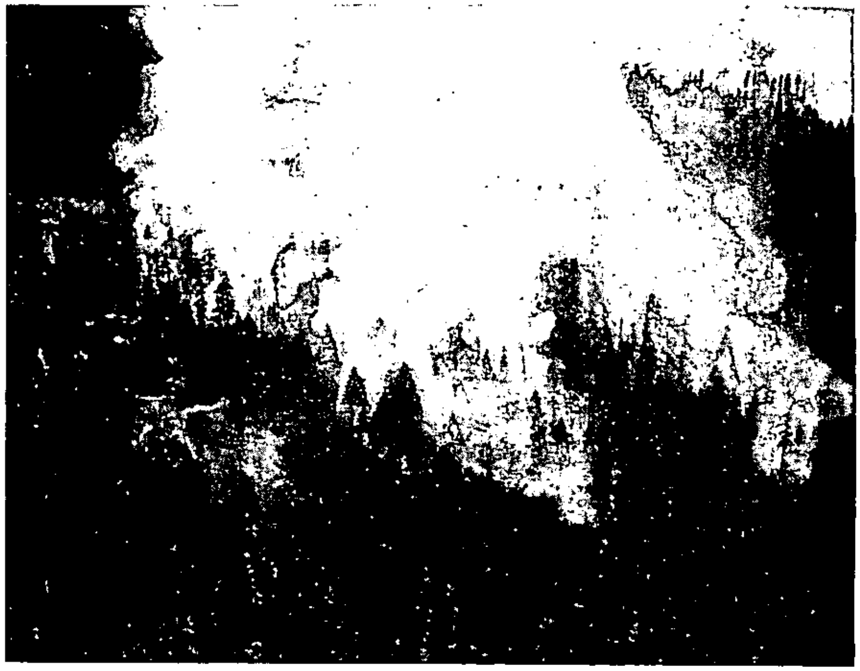
An Army Force Sikorsky model R–5 was used for reconnaissance and a small amount of supply dropping on the Castaic fire in 1946. It did all that it was asked to do, but it worked under the "tight wraps" of the test conclusions. Nobody stepped out into the field of "what can the damned thing do?"

The golden opportunity for a test of positive performance under trying field conditions came with the Bryant fire on August 5, 1947. This fire started in Big Tujunga Canyon of the Angeles Forest, which is an area characterized by very high watershed values, considerable home investments, rapid rate of fire spread, and steep, inaccessible country. Further, the fire was a direct threat to all of the suburban development on the north side of Los Angeles. The Forest Service was not disposed to leave any possible resource unused. There were available the two Bell helicopters owned by the man who had participated in the earlier tests of the Bell and who was very much interested in proving the worth of the helicopter. These were pressed into service.

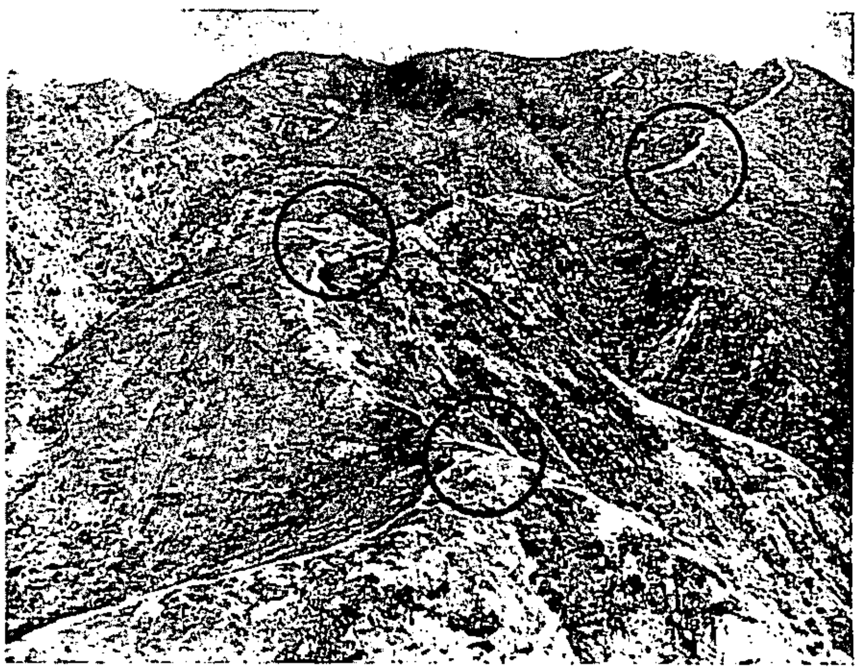
Two of the primary physical factors affecting the performance of helicopters which were encountered exceeded substantially the conditions of the earlier test operations. Temperatures were up to 107 degrees as compared to the 100-degree temperatures under which the tests were conducted, and elevations were operated successfully up to 5,400 feet as compared to the 3,500-foot elevation which was felt to be about the upper limit under the test conditions. Wind, a third important factor affecting the performance of the machine, was, of course, variable but generally exceeded the 0 to 5 miles employed under test conditions. With this set of conditions, and with two helicopters, two willing, skilled, and courageous pilots, and an experimentally minded fire manager, a fresh chapter in fire suppression history was written.

Successful undertakings on the Bryant fire, which were later duplicated on the Cleveland, Eldorado, Mendocino, and Tahoe Forests, establish the place of the helicopter in fire suppression.

1. The fire boss and his two zone bosses by helicopter personally investigated ground conditions, action strength, and fire behavior requiring major decision in strategy and tactics and without delay and with complete mutual understanding converted strategy to action. It is certain that without this coordinated and on-the-line size-up of the situation the usual lags in action and debating of decisions incident to a large fire would have occurred. This complete coordination could



Fire scouted by helicopter. Note ease with which manpower and tool requirements can be determined.



Typical section of line showing ease of transporting key overhead to critical portions of line.

not have been attained through use of legs, horses, or cars. The lines were too long and country too rough to accomplish a complete size-up quickly by orthodox methods.

2. The line boss, responsible for execution of control action in an area which could be covered once by conventional method in not less than 12 to 14 hours, was able to give on-the-ground (this literally) supervision to division bosses several times during the shift.

3. The Scouting and Plans organization with two flights per day obtained more timely information on which to base fire behavior estimates and control force requirements than would have been possible with three to five ground scouts working from daylight to dark.

Note detail with which ground cover can be observed from helicopter for Scouting and Plans organization.

4. The service and supply chief was able to visit secondary bases of operation once each shift and provide the constructive advice so often lacking to this group in the fire organization. As a result of such visits, overstocking of supplies was avoided and distribution of scarce strategic items on the basis of actual need was assured.

The value of the helicopter in the field of service and supply is further indicated by these typical incidents:

(*a*) Eighty fresh personnel were placed on one division by helicopter in 3½ minutes per man as against 3½ hours by ground travel. Half of the crew were active on the job in 1¾ hours, compared to the whole worn-out crew in 3½ hours. Absence of fatigue and resultant high morale paid off in the form of at least a doubled rate of line con-

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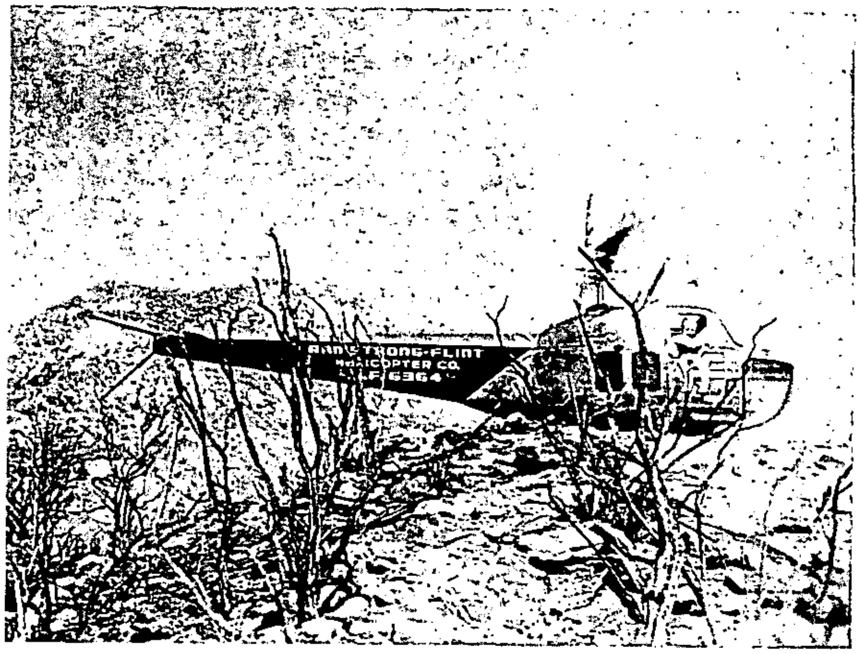


Six skilled fire fighters landed here and were able to hold fire on this ridge. Landing spot 8 by 8 feet, elevation 3,600 feet.

struction. Active action on the line started within 4 minutes after the first man (the division boss) took off and stepped up progressively from then on. Also, the helicopter and its first passenger beat the proverbial "cock's crow" signal of dawn by a few minutes. This may or may not have been risky, but the old red rooster drooped his tail feathers the rest of the day. This crew was based on the line (actually) for 1½ days and subsisted with hot meals, lunches, and water from the base camp by helicopter. They finished their assignment in a happy mood.

(*b*) Men were needed, urgently, on a strategic hot spot in a remote and almost inaccessible situation. The first man was on the line 15 minutes after the need was discovered; 1 hour later the sixth man arrived. The helicopter had found a usable 2 by 4 landing spot. By conventional methods these men would have arrived not less than 6 hours after the need was known, worn-out by hiking, and probably too late to have been effective.

(*c*) A need developed for additional leaders to direct a snag felling operation. Plenty of workers, but green hands, were on the line. The extra leaders required were on the job, by helicopter, within 10 minutes.

(*d*) Extra saws and felling tools were needed for this job: another 7-minute mission for the bellhop of the skies.

(*e*) A truck tipped over, 25 men were injured, 3 seriously; 2 hours by road to the nearest doctor or hospital, 4 hours round trip. The helicopter had the last of these 3 seriously injured men in the hands of a doctor 45 minutes after the accident was reported. Landing spot was on an "out curve" on a 9-foot truck trail.

(*f*) Back-pack pumps and water were urgently needed—2 hours walking time from the nearest road. The first of these was delivered within less than 10 minutes after the order was placed.

(*g*) A critical situation requiring extra men, tools, and water developed on a sector. Pilot Knute Flint was asked to reconnoiter and report the nearest available landing spot. Within 5 minutes he was back. His need was a competent smoke chaser, an ax, and a pair of pruning shears. His plan: to hover low over the selected spot; throw out the tools; the man climb out, let himself down 5 feet, and clear brush clumps off a knoll top. During the clearing interval, 15 minutes, Flint would return for the needed supplies and start delivery. Mission was accomplished per schedule, and the sector held. The landing spot was within 3 minutes of the job to be done.

So much for the Bryant fire. When the results of this operation were summarized, it was found that the grit and skillful service with which field conditions were met were much more favorable to operation of the helicopter than was anticipated during the testing operations. Landings with full load were being made at 5,400 feet. Maybe this was on the dare-devil side, but it worked. Successful fire control has frequently had its genesis in dare-devil try.

In the language of the Angeles personnel, the helicopter had "shed its diapers" and had grown up to a full-fledged and effective worker. Following this performance the helicopter was used on the Cleveland, Eldorado, Mendocino, and Tahoe Forests on similar missions. In every instance the findings on the Bryant Canyon fire were substantiated, and in some cases exceeded. Tom Bigelow of the Klamath Forest, a veteran of 25 years of fire service, says: "After 25 years I have seen what I have dreamed of—a service that gets me and what I need there right now."

On the Allen Ranch fire (Eldorado Forest) the initial landing was made on the top of a lumber pile. On the Bloody Run fire (Tahoe Forest) landing was on a tiny sand bar in a difficult canyon, but a crew was supplied from this base for 2 days. These are accomplishments on going fires.

For the future, we believe that if the Forest Service does not embed itself in a shell of orthodoxy, including conventional plane service, the need for a large overhead organization on major fires, with many men serving Supply, Plans, and Line, should be a thing of the past. The justification for these have been the span of control limitations occasioned by the travel time between given jobs in the total operation. Planning control of the fire, for example, consists of gathering accurate and timely information on which behavior and control force requirements can be based. With one man covering in intimate perspective 10 to 40 miles of perimeter an hour, there is little need for time-consuming ground scouting as we have practiced it. In sharp contrast to the limitations of a plane, a helicopter can work with safety just a few feet above the ground cover and follow closely the profile of a fire's perimeter. Its action is precisely that of a vehicle following the ups and downs of a cross-country road in hilly country. Likewise, due to its ability to work "just above the tree tops," splendid, closely detailed observation results are had under smoke conditions that make plane observations or "across the gulch" ground observations wholly useless. It's also "aces" for spot-fire scrutinies. A close down hover or a couple of tight circles at a bad spot gives the answer.

In servicing fire fighters, elaborate secondary camps with the usual primitive and labor-consuming equipment and the temptation to camp at the water hole will go out of the picture. All the services such as cooking and tool reconditioning can be performed at a central point where the best of facilities are available and still accomplish the same end product—well-fed and well-rested men camped on the line.

Line supervision of control work has to date been territorally assigned on the basis of walking or saddle-horse time to attain the required frequency of supervision. The helicopter can provide this frequency in one-twentieth of the time. This would indicate that when we know how to use the machine one man can adequately supervise the top line work on any fire situation which we have experienced in recent years. His big need will be a stenographer, a radio, and a loudspeaker.

The need for division boss caliber supervision is due to the inevitable occurrence of localized critical situations at numerous points along the fire perimeter. With a continuously current observation coupled with a means for depositing this caliber of man where needed and when needed, the half-mile "division" that has been necessary in some of our more rugged terrain will go out of the picture. Just what this will add up to in terms of skilled personnel necessary for a specific operation is yet to be determined, but it is a certainty that if Les Covill, Tom Bigelow, Hi Lyman, Glenn Thompson, and their successors, don't have to use their legs to move their eyes and brains around they're going to be the boss men on a lot longer fire lines.

Interestingly, well over 200 men were transported by helicopter this season with but one objector. To the rest it was as welcome as a taxicab on a rainy day; in fact, several tried to develop hitch-hikes from line camp to home base. It's a mighty easy way of getting from hither to yon without getting leg weary.

The Future of Rotary-Wing Aircraft

Today we have the Bell Model 47–B which is a proven working tool when combined with sufficient pilot skill. A Sikorsky S–51 is capable of performing our job, but its production is so limited that its availability for suppression work is doubtful. What then can we reasonably expect in the near future? The surprising thing is how much can be accomplished with small capacity machines. We have thought in terms of four- and five-place ships. The little fellows have shown themselves to be producers. We can't afford to bypass them. The fact that development work is proceeding so rapidly is one reason that the present models are not being produced in greater numbers. Let's develop with the commercial development, but keep even or a pace ahead of it. Obsolescence is a real factor when dealing with a $20,000 to $70,000 piece of equipment. In the hopper at the moment are several different dual rotor craft that, if they meet claims, will provide an operating ceiling of 13,000 feet with pay loads up to 1,500 pounds. It is quite possible that the smaller type helicopter, which due to size alone is a more versatile machine, will be redesigned to permit spot landings and take-off at greatly increased ceilings.

Experts in the field of helicopter design believe the 25- to 30- passenger machines are well within the realm of possibility, but they are

going to lack the flexibility of the little fellows that can land on a dime. I'd count the big fellows out—they will require too much in the way of prepared landing spots.

The variety of uses to which the helicopter can be put is far from completely known. For example, more positive water bombing of free burning fires is a reality. Also, the whipping up of backfires by a rotor-inspired breeze, which was done on the Cleveland, and the retarding of a free-burning brush fire by kicking an adverse wind in its face, likewise an accomplished fact, open up a lot of speculative possibilities.

Let's give this machine the respect that is due, use it, and save a lot of our successors unresolved questions, achy joints, and sleepless nights.

Conclusion

Foresters cannot afford to overlook the helicopter in any plans for forest management involving reconnaissance, transportation of personnel, equipment or supply, or special project service, whether they be concerned with fire suppression, timber survey, snow surveys, range reseeding, tussock moth control, or road and trail studies. The helicopter, in good condition and with skillful pilots, while not a panacea for all our transportation and service problems, is a proven implement available for its proper place in the field of wild land management. Let's give it its place in our plans.

Dispatching Aids.—A method for recording data on going fires which should prove of assistance to dispatchers when lightning storms are in progress is suggested. A brief discussion of the proposal follows:

1. Cover the regular forest map of the area being affected by the electrical storm with plexiglass sheet and secure it to map with scotch tape.

2. Indicate on plexiglass by previously determined symbols—

(*a*) Location of each lightning strike likely to result in a fire.

(*b*) Time of discovery for each fire as reported by the lookout or lookouts.

(*c*) Rainfall showing whether light, moderate, or heavy.

(*d*) Number of men sent to the fire as they are dispatched, and time of departure.

(*e*) Whether there are sufficient men to handle the fire, whether more men are needed, etc., as determined from reports of initial attack men.

(*f*) Time and number of reinforcements dispatched.

(*g*) Report of control of a particular fire.

3. This graphic method will—

(*a*) Provide information on the path of the storm.

(*b*) Indicate the extent of precipitation, which will help the dispatcher to determine where his danger areas are.

(*c*) Help the dispatcher mobilize forces at desired locations and in numbers required to handle the situation.

(*d*) Provide the dispatcher with a picture of the location of each fire and the number of fires involved.

(*e*) Show the fires to which forces have been dispatched and the number of men involved, as well as follow-up forces required, when fires are controlled, those still giving trouble, etc.

(*f*) Prove of assistance in the development of a plan for follow-up detection, either aerial or lookout or both, after the storm.—H. S. PALMER, *Timber Management Assistant, Sitgreaves National Forest.*

ROVING FIRE POSTERS

ALAN A. McCREADY

Staff Assistant, Harney National Forest, U. S. Forest Service

In the Black Hills area commercial trailers are often used for advertising, the trucker furnishing the space and the advertiser the materials and artistic skill. Many of these trucks cover a wide range of territory and are seen by a great many people. This seemed an effective way of putting over a fire-prevention message.

The Buckingham Transportation Co., who also have national forest timber contracts in South Dakota and Colorado, were first approached with this idea. They offered the use of a brand new 40-foot trailer. Its maiden run was to be to Minneapolis, after a trial appearance in the "Days of '76" parade in Deadwood; and runs to Denver and Ogden followed.

Harney fire prevention sign on the Buckingham trailer.

Several of the Harney people collaborated on the idea for the layout, and Forest Service painter Carl Wiehe, who has a flair for panoramic paintings, carried it out. About 10 different colors and shades of synthetic enamel, adapted for outdoor weathering, were used. The punch line was painted in bright red.

A second trailer, operated by Roy Bristol between Custer, S. Dak., and Denver, is now carrying a similar fire message, though with a different public appeal approach.

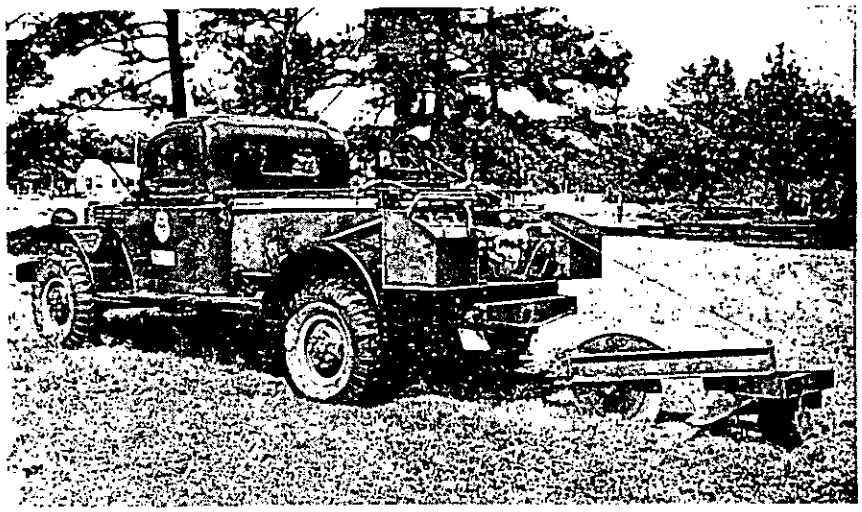
These large trailers are well suited to this type of advertising. The surface is expansive and usually unbroken, and the base paint is necessarily high-quality weather-resistant enamel. We know this way of plugging forest fire prevention gets across to the public by the number of favorable comments we have heard about it.

FLORIDA'S MOST MODERN FIRE TRUCK

Owen R. Douglass

Fire Control Chief, Florida Forest Service

To combat woods fires under the special conditions offered by Florida terrain, the Florida Forest Service has developed what we consider one of the best all around combinations, an all-purpose fire-line plow and fire-fighting vehicle.



Truck with middlebuster plow lowered by the hand-operated winch nearly to working position.

This is the 1-ton Dodge power wagon equipped with 9.00x16 mud and snow tires, and a front-mounted winch. It is the standard commercially manufactured truck to which has been added certain special equipment by the Florida Forest Service. Although rated at only 1-ton capacity, the truck has been loaded considerably beyond the 1-ton limit through the use of helper springs.

Limited experience in operating these trucks with heavy loads has not indicated that any particular trouble will develop. The trucks are purchased with cab and chassis only, then a 275-gallon specially constructed tank is mounted on the chassis. The tank weighs 800 pounds empty and 3,000 pounds filled. A compartment is constructed into the tank at the rear for mounting any auxiliary pump. The weight of the auxiliary pump and engine is about 200 pounds.

The plow, illustrated in the photograph, was designed and developed by the Florida Forest Service at Lake City during the summer months of 1947. It is a middlebuster plow capable of making a fire line approximately 4 feet wide under almost any Florida conditions.

It is a simply constructed plow, using the rolling coulter and middlebuster principle for operating. The plow is attached to the truck by a specially constructed draw bar mounted between, and fastened to, the rear of the frame. It is easily detachable. It is hinged both vertically and horizontally in order to allow it to be raised and in order to allow it horizontal leeway for tracking behind the truck when in the ground. A simple hand-operated cable winch is used for raising and lowering the plow. The weight of the plow is approximately 600 pounds. It is manufactured in Lake City and distributed from Jacksonville.

By using the low-range transfer case and four-wheel drive of the Dodge there is more than ample power for pulling the plow without overloading the engine.

Use of the plow during the actual suppression work saves much time in mopping up fires, and with the present scarcity and high cost of labor it is believed that the plow will more than pay for itself in one season.

This unit is located in St. Johns County, Fla., and indications are that the operation will be most successful.

A Simple Binocular Holder.—Many ingenious towermen with time on their hands think up a lot of good ideas but say nothing about it. On a trip through New Hampshire with Bill Branch of the Chief's office, we visited a tower which had a binocular mounted on the rear sight of the Osborne fire finder. Bill Emerson, lookout watchman at the Warner Hill Tower (near East Derry, N. H., for many years operated by the New Hampshire State Forest and Recreation Commission), gave birth to the idea which may be of use to others. Emerson made the device for his personal convenience, but it also appeared to be particularly useful in making a systematic search of the terrain.

The device is simple and cost of material should not exceed 50 cents. A light metal window sash pulley was cut off midway and attached to a ¾-inch wooden block about 4 by 5 inches in size. A light metal spring clip for holding the binocular in place was fastened on top of the woolen block. The open portion of the sash pulley fits over the rear sight of the alidade. The binocular support is adjustable which facilitates a systematic search of terrain between tower and horizon.—EDWARD RITTER, *Region 7, U. S. Forest Service.*

Dawn Patrol.—As one means of meeting the hunter fire problem, the Stanislaus National Forest in Region 5 has been using what is known locally as the "Dawn Patrol." One such patrol, actually an evening patrol, is made the afternoon and evening prior to the opening of the deer season. The rest are made on week ends and especially Monday mornings at dawn.

This prevention approach is simply a plan-wise method of assuring personal contact of every hunter camp to check the proper care of campfires, issue smoking warnings, and detect and extinguish unattended campfires.

The forest is blocked out into small natural units and every able-bodied man in the organization is assigned a unit. The units are balanced in size depending upon concentration of hunters and distance to cover. It usually requires from 2 to 4 hours to cover a unit.

On one Monday morning dawn patrol, eight unextinguished campfires were located and put out. In 1946 with 20,000 hunters, two fires were caused by unextinguished campfires. In 1947 one fire was caused by a campfire. In all three cases, the responsible parties had not been contacted by the patrol.—NEAL M. RAHM, *Assistant Forest Supervisor, Stanislaus National Forest.*

FUNDAMENTALS OF FIRE BEHAVIOR

H. T. Gisborne

In Charge, Division of Forest Protection, Northern Rocky Mountain Forest and Range Experiment Station

[Used May 5, 1947, at 40-man Fire Boss School.]

Our job of fire control can be done, in fact has been done, in several ways: By brute strength and little attention to the conditions we are attempting to control; by observation of what is happening but with little or no understanding of why the fire is behaving as it does; or by practical application of knowledge of the basic laws of chemistry and physics that are actually determining the rate at which a fire is spreading. Let us look into the most significant factors that affect fire behavior.

FIRE IS A CHEMICAL PROCESS

Combustion is a chemical process. It is classified that way because combustion, with or without flame, is a molecular reaction in which molecules of oxygen in the air combine with molecules of cellulose and lignin (which make wood) and thereby change most of the solid into gases. These gases are molecules of different substances. They are no longer cellulose and lignin. Such changes of substance are chemical not physical processes. When these changes occur at such a rapid rate that heat and flame are produced the process is called combustion or fire.

When you look into the fundamentals of combustion and find that there are only three basic factors or three essentials to this chemical process it is obvious that we are overlooking a bet if we fail to consider each of these three things in our calculating.

Three Essentials of Combustion

Completely controlling the chemical reaction called fire are only three essentials. They are: (1) Fuel or something that will combine with oxygen rapidly enough to generate heat; (2) heat enough to raise that fuel to the ignition point; and (3) plenty of oxygen in contact with the fuel or with the gases evolved from the wood. Remove the fuel as we do when we dig a fire trench, keep it from being heated to the ignition point, as we do when we widen the trench or when we use water, or shut off the supply of oxygen as we do when we throw dirt, use water, or bury a burning log, and you can stop the spread of any fire. *Every one of our methods of fighting fire is based on one or more of those three simple essentials.* THERE ARE NO OTHER WAYS.

1. Fuel.—Chemically all of the fuels that carry our fires are practically alike. From grass and brush to tree needles, tree trunks, and rotton wood on the ground they are all of the type that the chemist designates as $(C_6H_{10}O_5)_y$. This means that there are 6 atoms of carbon, 10 atoms of hydrogen, and 5 of oxygen in each molecule of cellulose. Starch, which is found in the roots, seeds, and leaves of all plants is very similar, differing only in the subscript. The chemists designate the various starches as $(C_6H_{10}O_5)_x$.

This point is important to remember because it helps to reduce some errors of judgment based on the belief that the chemical nature of our fuels differs very materially. When $C_6H_{10}O_5$ burns every molecule of that substance combines with six molecules of oxygen. The resultant products are gases, 6 molecules of carbon dioxide, and 5 molecules of water vapor. Fire makes water out of the hydrogen and oxygen atoms that are in every molecule of wood. The chemist writes it this way: $C_6H_{10}O_5+6O_2 \rightarrow 6CO_2+5H_2O$. Unfortunately that water is not of any help to us because it exists as a gas, a superheated gas, which rises straight up and away from our fuels. The water that really counts is the moisture content of the grass, trees, or brush before they burn.

Because of this similarity of chemical composition of our fuels it is obvious that we should not calculate probabilities on the belief that different kinds of wood or brush or grass burn differently. The leaves of grass, trees, and brush, and the bark and wood of trees are all largely cellulose. The big variable which produces really significant differences in fire behavior is not the chemicals, it is the moisture content.

There are, however, two other ingredients in wood in addition to cellulose that are of some, perhaps academic, significance. One of these is lignin, a substance for which the chemists do not know the formula. The significance of lignin lies in the fact that it has a slightly higher heat content than cellulose and that it leaches and decays more slowly. Hence old wood is likely to have lost more cellulose than lignin and therefore will have a slightly higher heat content per pound of material remaining than fresh cut or freshly killed wood. Differences in the pitch content are also known to affect the heat of a fire.

There are also some other minor differences in the chemical nature of plant and tree leaves but a series of tests of the fat and oil content of the leaves of six different genera of weeds and brush which were made for three consecutive summers failed to reveal anything significant. Instead this chemical study made at our Priest River laboratory confirmed the finding that moisture content is THE big variable.

2. Ignition.—When there is plenty of fuel, the next essential of combustion is that it must be heated to the ignition point. For dry cellulose a temperature of only 400° to 600° F. is required. The average usually used is 540° F. The point that is of practical importance is that if your fuels are even moderately dry they do not have to be heated very hot to reach this ignition temperature. In other words the kindling temperature of grass, wood, cotton batten, or cellulose in any natural form is easily produced. It is not an abnormally high temperature. You will build more held line and have to charge up less line lost if you remember that simple fact and then do something about it.

The key to ignition is the ease with which a fuel can be heated to 540° F. That ease naturally depends upon one obvious difference in fuels, i. e., their size. The fine fuel naturally heats clear through and reaches 540° far quicker than a heavy fuel like a log. Size of fuel is therefore the significant feature to watch, other things such as moisture content being equal. Actually, size and moisture content influence the process of combustion in much the same way. Make a stick wetter and you reduce its ease of ignition. Similarly, the bigger the stick the harder it is to ignite it. The wet stick and the big stick both require more time or more heat to raise their surface temperature to the ignition point. And that is another good basic fact to keep in mind both in sizing up probable fire behavior and in deciding on tactics to use along the line. Let your fire burn through the heavier fuels where it will burn more slowly. Fight it at those places where it would go into finer fuels and spread faster. Also, fire line construction is easier in the fine fuels. You gain in two ways by using this basic knowledge.

Size of fuel is also worth noting from another angle. Take 10 pounds of dry grass or dead pine needles, 10 pounds of dry branchwood, and 10 pounds of log in one chunk and ignite each of them. What happens? The needles will liberate their B. t. u.'s (British thermal units) in a few seconds, the branches will release theirs in a few minutes, while the 10-pound log may take half an hour to release its heat. Ease of ignition is, therefore, not the only difference in fire behavior to expect in accordance with different sizes of fuel. The rate of release of the energy is also tremendously different.

This feature, combustion rate, is what a football player would call the triple threat of fire. And this rate of release of energy is the one feature we fail most often to recognize. The three threats involved are: (1) The more sudden the release of all this heat the farther it will radiate a temperature of more than 540°. And that means something to your tactics. It means that if the fuels are even moderately dry, a wider fire line is needed wherever you find an appreciable volume of fine fuels. This applies to both stopping a fire and in backfiring. (2) The faster the release of those B. t. u.'s the greater the volume of gas suddenly created, hence the faster it will rise overhead. That also means something to tactics employed, because the swifter the rise of hot air the greater the chance of sucking up blazing embers and carrying them up and over the line, if the smoke is leaning across the line. That means spot fires. (3) The faster this release of energy and the faster the uprush created by it the greater the local wind velocity created by the fire. Moderate to large areas of fuel releasing their energy suddenly are creating conditions that breed not only higher wind velocities but twisters or even big whirlwinds. I once saw one of the really big ones whirl like a tremendous barrel and move across 2 square miles while I was running 200 yards along the top of Desert Mountain, on the Flathead Forest.

3. Oxygen.—This last essential of combustion is one that we can't do very much about. Combustion engineers who design and operate boilers do a lot by controlling this one of the three essentials. But under our conditions there is almost always plenty of oxygen to facilitate combustion of our fuels. Under free burning conditions such as occur on a forest fire about 10 pounds or 133 cubic feet of air is needed for the complete combustion of only 1 pound of dry fuel.

The one time when we do something to reduce the oxygen supply is in throwing dirt. While that dirt does lower the temperature of the fuel it lands on, the principal function of dirt is to shut off or at least reduce the supply of oxygen. Moist dirt is superior to dry dirt primarily because it lowers the temperature more. But when either moist or dry soil covers the surface of the fuel the major benefit is by cutting down the oxygen supply. Water also does the same thing if enough is applied to form a film over the surface of the fuel. But here too the major benefit is in lowering the fuel temperature below the ignition point.

Combustion a Molecular Chain Reaction

The public has heard and read a lot recently about atomic fission, so controlled that it becomes a chain reaction and thereby makes possible atomic bombs. More understanding of the fire job and better financial support by the public may follow when we show that the job of fire control is definitely one of stopping a chain reaction which differs from the bombs primarily in that ours is a molecular instead of an atomic chain reaction.

A chain reaction may be compared to a chain letter; you receive one but you send out two or maybe three or four. Each of the recipients of one of these letters similarly sends out two or three or four. The thing spreads like wildfire. The first problem in producing an atomic bomb was along this line. That problem was to obtain certain chemicals which when assembled in a sufficient quantity and arrangement, known as the "critical mass," would perpetuate the process of splitting atoms of uranium into atoms of two other elements, barium and krypton. It was known as far back as 1939 that in this splitting tremendous energy was released and that the process then split other uranium atoms which in turn released more energy and split more atoms, the process continuing and accelerating as long as there was a supply of a suitable fuel in a proper arrangement and condition. The job of the atomic physicists was, therefore, to produce this chain reaction yet control it. Our job is simplier. It is merely to control the molecular chain reaction that is fire.

As you can see, fire is a similar process in that if you heat one molecule of a fuel to the ignition point its process of changing from $C_6H_{10}O_5$ into CO_2 and H_2O may release enough energy to ignite several other adjacent molecules of $C_6H_{10}O_5$. If the fuel is in a critical condition (dry enough), as compared to a critical mass (large enough), that process then becomes a chain reaction and not only spreads like wildfire but it really is wildfire in our case. Whereas the nuclear physicists have to make their fuels, and arrange them carefully in an atomic pile, our fuels are arranged for us and then, periodically, are put into proper condition (dryness) such that the chain reaction starts whenever and wherever the spark is applied.

If this sounds farfetched or academic let me call your attention to one more fact, which I know you will not dispute. It is this: That when our fuels are in their most critical condition, i. e., their driest, we have some molecular chain reactions which are so violent that we *cannot* stop them, just as there is no stopping an atomic bomb once its chain reaction is started. Furthermore, we have occasions when combustion in the form of a forest fire approaches a rate and even a

magnitude rivaling an atomic bomb. Those of you who were on any of our big fires in 1929, 1931, and 1934 probably saw some of these explosions. Many of them covered several square miles in only a minute or two.

If you will keep this chain reaction idea in mind, and if you will size up your fire, either as a whole or on your sector, in the light of the three basic essentials of combustion you may be able to calculate the probability of one of these explosions. If you can do that you may be able to save your own life and the lives of your men, as well as improve your fire control tactics.

There is one basic criterion to watch, however, in trying to anticipate a molecular chain reaction at an explosive rate. This is moisture content of the fuel, for it is moisture content not mass, nor volume, nor size, nor arrangement of fuel which *first* determines whether or not a forest fire can truly explode. And you should remember that this moisture content not only can be but is being measured. You can get these measurements every day if you want them.

MOISTURE CONTENT THE CRITICAL VARIABLE

We have not had any true forest fire explosions in Region 1 since 1936. I believe there were a couple of minor ones that year on the Little Rockies Fire on the Lewis and Clark Forest. But we had several really big ones in 1934, 1931, 1929, one or two in 1926. You have all read about those in 1919 and 1910. The main reason why we have not had any explosions in recent years is this matter of moisture content. Our fuels simply have not dried out to the critical condition that developed in those earlier critical years. Hence, it is evident that the critical variable in fire behavior is moisture content of the fuels. Consequently I want to call your attention to some of the possibilities available to you for improving your calculation of probabilities by watching fuel moisture above all other elements.

Basis of Fuel Moisture Measurements

You all know about the fuel moisture indicator sticks used at some 175 fire danger stations in Region 1. There are some things those sticks will tell you far better, far more accurately than you can estimate. To make best use of those stick measurements you need to know: Why we use half-inch sticks, how they are made, and how accurate they are.

For four consecutive summers, 1922, 1923, 1924, and 1925, I collected at periodic intervals samples of the the five major dead fuels that burn in a forest fire. I took these samples to the laboratory and determined their moisture contents. I found out which fluctuated the most, and which the least. On this basis I selected the top layer of duff, half-inch sticks, and 2-inch-diameter branchwood as the best representations. We therefore used duff hygrometers, half-inch sticks, and 2-inch sticks at several fire danger stations for the next 5 years to measure fuel moisture. Then at the suggestion of the rangers in a regional meeting and despite my protest, we discontinued used of the 2-inch ones. Finally in 1942, with the Model 6 Danger Meter, we dropped duff moisture and began to rely solely on the half-inch sticks.

From a technical viewpoint these half-inch sticks alone fail to represent our fuels in two ways: (1) They do not show the true benefits of light rains as well as duff moisture measurements did; (2) after heavy rains they dry out faster than either duff or 2-inch-diameter sticks. The error is therefore always toward showing more danger than would be revealed if all of the significant *forest* fuels were measured. The half-inch sticks are not too fast, of course, for cheatgrass, but this fuel type does not cover a large percentage of our area. Furthermore, after it has cured, cheatgrass responds so closely to changes of relative humidity that humidity measurements can very well be used as an index of moisture content of that one fuel type. Finally, cheatgrass changes moisture and flammability so rapidly that you might as well always be ready for the worst.

The half-inch sticks which we now use are made from new lumber each year. Any one of several species of wood could be used, because here again we are dealing primarily with cellulose. We use ponderosa pine because it is readily obtainable in clear stock at a reasonable price. We use only sapwood because it is the moisture content of sapwood of twigs, branches, logs, and snags in which we are most interested. We can ignore the moisture content of the heartwood of a log because if the outer sapwood is extremely dry the inner heartwood has got to be dry too. We also ignore the effect that bark has on natural wood because if we used natural sticks with bark on them some of that bark would soon chip off and then we would no longer know the true oven-dry weight of our sticks.

To be sure that moisture measurements made at different stations do not differ because of differences between the sticks or because of errors by the danger station operator, we go to a lot of work and incur considerable expense. These sticks now cost from $1 to $1.75 per set to manufacture. In making them they are oven-dried and then cut off at the ends until they weigh exactly 100.0 grams *oven dry*. This is done so that all that is needed to determine their moisture content in percent is to weigh them and subtract 100.0 from the total weight.

As you can see, this difference in weight is not only the weight of the water in the wood, picked up from the air and from rain, but it is also the moisture content expressed as a percentage of the oven-dry weight. Consequently, when you call for a fuel moisture content measurement from any of our stations you can bank on its accuracy probably 95 times out of 100. The other 5 times the scales will be out of balance, which is an operator error, or the operator will have read the scales wrong. Eliminating that error is a job for training and supervision.

Application of Stick Moisture

By the present practice we measure stick moistures at only two to four occupied stations per ranger district. That is not enough under some conditions of spotted weather, wet here and dry there, but under widespread and long continued drouth it is fully adequate. The sticks are exposed on a flat, in the open, but under a shading layer of screen cloth. The reason for this, preparing to meet "average-bad" conditions, is used in all fire control planning in Region 1. The sticks are therefore always exposed alike at all stations so that the results are truly comparable.

The intention in such an exposure is to sample average-bad but not the very worst conditions. By sampling average-bad conditions we are using the sound engineering principle of preparing for the worst probable but not the worst possible. Engineers did not build the Golden Gate Bridge at San Francisco to withstand the worst possible earthquake. They built it to withstand the worst probable. Few ditches, storm sewers, or bridges are built to withstand the worst possible flood. To meet worst possible conditions usually costs more than the resource is worth. It is better economics therefore to accept the risk of the worst possible flood, earthquake, or fire weather conditions, and plan to meet only the average-bad or worst probable. We can get adequate fire control at a justifiable cost by using this principle. We do use it, not only in fire danger measurement, but also in all phases of fire control planning in Region 1.

The double layer of 12-mesh screen cloth under which we expose our sticks provides an amount of shade and a fuel-moisture equivalent to what you would get if you operated two danger stations, one in full sun and one under the half shade left after a moderately heavy logging operation. The stick moistures obtained by this method can therefore be accepted as representing average-bad conditions. Open south slopes will have drier half-inch sticks. Densely timbered north slopes will have materially higher fuel moistures. But when the sticks at our stations have high moisture contents, adjacent areas, both open and timbered, also can be expected to be moist to wet. When our sticks are each day showing lower and lower moistures you can depend on it that both the open areas and the timbered slopes will also be getting drier and drier.

Our present sticks and exposures therefore give you one definite and dependable index to watch. They give you something that you can use in calculating, instead of guessing.

The most significant single feature of stick moistures to watch for is just this: Are they below 5 percent and how long have they been there? Your danger of blow-ups and explosions can be really calculated by getting merely that information. If the sticks at both the nearest ranger station and some nearby lookout have been down below 5 percent for several days you can bank on it that every fuel type in that area is in a truly critical condition. Fortunately this does not happen very often, but it has happened and it will happen again. When it does you will be making the mistake of your life if you fail to know it. You can always find out by consulting the local ranger station fire danger charts or Form 120 R–1. If you are already out on a fire a phone call will bring you the desired information.

If the sticks are reported as at less than 5 percent you should then ask for two more things: a check of the computations to be sure no errors were made, and a remeasurement of the sticks right then. The dispatcher or his assistant can do both of these in 10 or 15 minutes. If these checks verify the original reports you can then *calculate* that every fuel type in the area, on both north and south slopes, and at all altitudes, is in its most explosive condition. You can bank on it that fire will spread in all of these types at the fastest rate, that there will be little difference in rate of spread between fuel types, and that the danger of both spotting and of big whirls will be at a maximum. You can expect a chain reaction at its worst.

Those of you who have never seen fires like the Lost Johnny and Half Moon on the Flathead in 1929, the Freeman Lake on the Kaniksu and the McPherson on the Coeur d'Alene in 1931, and the Pete King on the Selway in 1934, simply cannot fully appreciate the significance and the danger under these conditions. It may be enough to point out that the Freeman Lake Fire, starting at 10:30 a. m. on August 3, 1931, exploded almost from the start to cover 20,000 acres in the next 12½ hours. This is at the rate of 1,600 acres per hour, from a standing start! Both duff and 2-inch-diameter sticks were down to 4 percent moisture content that afternoon. Wind was 13 miles per hour at 10 a. m., and 18 miles per hour at 7 to 8 p. m. Relative humidity was 10 percent or lower from 2 till after 7 p. m. THAT is explosive fire weather.

Differences in rate of spread between fuel types practically disappear under these explosive conditions. The basic laws of chemistry take charge when nature produces such conditions and the molecular chain reaction is actually unstoppable until the wind goes down, the humidity goes up, and the fuels absorb a little moisture. If you have to fight such fires, and you should be mentally ready for it, you will probably do it like Kelley and Ryan fought the Freeman Lake explosion. You will not build much fire line that day, but you will calculate where that fire front will be at midnight and you will then have fire camps and men well distributed around it and ready to begin work at the first crack of dawn. Kelley and Ryan had more than 600 men strung around the Freeman Lake Fire front the next morning after that fire started, and those men never let that fire make another major run. That is a record to shoot for; it has seldom if ever been equalled in this region.

The real difficulties and the most frequent need of skill and understanding by fire bosses come, however, in judging gradations between this explosive condition and that easiest of all conditions when fire will spread, but only so slowly that control is largely a problem of how to do it at the least cost. In between this explosive condition and the easiest condition other factors than stick moisture become more and more important and all the factors become much more involved. It should be evident, nevertheless, that fuel moisture is THE major variable and that if you are to calculate accurately, your first and best bet is to get the stick moistures and other measurements from the nearest danger stations *before* you even start to order men. After you get to the fire you can then see to it that you are informed each day, preferably twice a day, as to how fuel moisture and other factors are changing. There are then three other major variables to watch. These are fuel type, the thermal belt, and wind.

FUEL TYPES

Some men have a misconception about fuel types because they do not understand that our four rates of spread—Extreme, High, Medium, and Low—represent differences only on a class 65 to class 75 day. Obviously, rate of spread will not differ at all in different types when the woods are soaking wet. Also, rate of spread is very nearly the same in all types after several August days with the temperature

at 100°, humidity at 10 or 15 percent, and the afternoon wind at 15 to 20 miles per hour. Hence, we have used the principle of preparing for the average-bad in our fuel type classification, and the rates given on our fuel type maps are those to be expected on an average-bad day. This is about class 70 on our burning index meter. You cannot use those fuel type maps correctly, or dependably, on any other basis.

Our fuel type classes are therefore based on differences in rate of spread, not at the explosive point where we can do nothing about it, but at combinations of moisture contents, wind velocity, and vegetative conditions just short of the explosive point. These begin early in August whenever fuel moisture drops to 5 or 6 percent, the humidity falls to less than 15 or 20 percent, and the wind rises above its normal afternoon average of 6 or 8 miles per hour. After several days of such weather, especially if the burning index rises to 75, as it will with fuels under 5 percent, humidity under 10 percent, and winds of more than 10 miles per hour, differences in rate of spread become less and less as all fuel tyes approach the explosive condition.

A burning index rating is therefore essential to calculation of the probabilities in any fuel type. If it shows class 65 to 75 you can count on the differences shown by the fuel type map, insofar as that map is well made. The weaknesses in these maps are well recognized and steps are being taken to correct them.

In applying the burning index to a correct fuel type map some guides have been worked out, but this is unfortunately a field in which our fire reseach has been woefully weak. Our best contribution is in U. S. D. A. Circular 591, Influences of Altitude and Aspect on Daily Variations in Factors of Fire Danger, by Lloyd Hayes, published in 1941. The outstanding new fact resulting from this research was the discovery and general location of what Hayes called the thermal belt.

THERMAL BELT

The major significance of this thermal belt is that inside a certain altitudinal zone burning conditions change less from daytime to nighttime than they do in either the valley bottoms or on the mountain tops. At Priest River this zone begins about 600 feet above the valley bottom and continues upward for about 1,000 feet. Below and above this zone fuels pick up more moisture at night than they do within it. Within the zone the fuels lose a little every afternoon and pick up a few percent between 6 p. m. and 3 a. m., but the change is very slight. Up on the mountain top, however, the same fuels will pick up 4 percent more at night and lose 4 percent more in the daytime. Down in the valley bottom they will pick up and lose 8 to 12 percent more than within the thermal belt. This is true on both north and south aspects. The only places where it may not hold true are in steep-sided, deep, east and west canyons like that of the Salmon River. In that canyon and perhaps in a few other spots like it, the depth of the canyon and its orientation in relation to prevailing winds combine to interfere with normal air drainage. There the thermal belt effect becomes less pronounced or even disappears. Sometimes going fires will also disrupt this belt, if the fires are large enough, but in most places and under most conditions you should calculate your probabilities on

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the basis of the known difference of burning conditions within this thermal belt.

The next time you have a fire starting in late afternoon or early evening about 1,000 feet up from the main valley bottom, I suggest that you note for yourselves whether or not that particular fire does not run faster and for more hours during the night than a similar fire in the valley bottom. Also note whether or not that fire picks up and starts to run earlier in the morning. I think you will find both of these conditions in almost all thermal belt fires. They are essential elements in the equation required to calculate the probabilities.

These facts also should be highly significant to all fire dispatchers. Other things being equal, more men should be sent, and they should be speeded on their way faster to every fire in the thermal belt. Furthermore, on a going fire, if night work can be done on any sector, it should be planned first on those portions of the front from 500 feet to 2,000 feet above the valley bottom, because this is the zone of the thermal belt. Within this zone you can expect the least benefit from increased fuel moisture at night.

WIND

Although fuel moisture is the critical variable that puts all fuel types in an explosive condition, or reduces them to an easy job of fire control, wind velocity is often the straw that breaks the camel's back. In fact at fuel moistures of 6 or 7 percent up to 20 or 25 percent, wind is often the variable which finally determines what a fire will do. Some basic research by Fons at the California station has shown that with fuel moisture at 8 percent variations of wind velocity are more significant in changing the rate of spread than are variations in fuel temperature, fuel size, compactness, or density.

Whether or not some fire seasons are, as a whole, windier than others I do not know. But we do know that wind is a result of certain meteorological conditions which change periodically at from 3- to 5- or 6-day intervals. If you will watch the wind record portion of any fire danger station chart, particularly for a lookout station, you will see a gradual increase of wind for several days, then a decrease, then another increase. Obviously, by watching this up and down trend you can definitely improve your calculation of the probabilities, even though you cannot forecast precisely.

There are a few general rules of wind behavior which can be used locally in Region 1. First, is a discovery, made by Hayes and described in Circular 591, that the places of greatest wind danger at night are, strange as it may seem, the north aspects at high altitudes. To put it another way: While you can usually count on the wind dying down during the night in the valley bottom, you should not count on this if your fire is up on the high divides between major drainages. Instead, at the higher elevations you should expect the highest winds at night, not in the daytime, and more wind on the north aspects than on the south.

Another general law of wind behavior during the ordinary fair weather of June, July, and August, that is quite well known, is that during the day the wind usually blows up the canyon or creek, while

during the night it blows down canyon. This reversal of direction in the evening usually takes place just a few minutes after sundown. When both the daytime and the night winds are very light—less than 4 miles per hour—this reversal may not be of much significance. However, in topography and on areas which are materially heated by the sun's rays, the afternoon wind created by rising hot air may amount to 8 or 10 miles per hour. When this is the case reversals at sundown may produce a significant down-canyon wind. This condition is most pronounced on south aspects and in watersheds draining toward the south into a big canyon running east and west, like that of the Salmon River. But even under these conditions a large fire may create such an updraft as to upset the normal reversal of wind. Hence, while this generality is worth considering in your calculations there are other factors which also must be recognized before you make your final estimate of rate of spread.

From what has been said it should be clearly evident that "calculating the probabilities" means doing much, very much *more* than just fight a fire with brute strength and numbers of men. It means careful consideration of every available source of information concerning each of the basic factors of fire behavior. But even when that has been done you will still have to use judgment, and perhaps even do some pure guessing. Nevertheless, your batting average is absolutely certain to increase IF you first do the best you can to calculate on the basis of facts and known principles.

EXPERIENCED JUDGMENT

Perhaps I should not close on this point, because if by doing that I cause you to discount *any* of the things previously called to your attention then I weaken my point. However, in fire control there are still a lot of basic factors not yet understood or not yet measured. And even when they are measured the basic facts must still be put together, weighed one against another, and a balanced decision then reached. Worse yet, sometimes that decision must then be modified or even seriously compromised on the basis of what you *can* do about it.

Experienced judgment is therefore the final determinant of what you actually do, both in planning to control a fire and out on the fire line where you try to put your plan into effect. But if you will stop to examine just what is meant by experienced judgment you will come back to the items I have listed above. For what is experienced judgment except opinion based on knowledge acquired by experience? If you have fought forest fires in every different fuel type, under all possible different kinds of weather, and if you have remembered exactly what happened in each of these combinations of conditions, your experienced judgment is probably very good. But if you have *not* fought all sizes of fires in all kinds of fuel types under all kinds of weather then your experience does not include knowledge of all the conditions. In that case some of the facts and principles described above should be helpful to you.

SUMMARY

There are only three things you can do to stop a fire—rob it of its fuel, keep it from being heated to the ignition point, or shut off the oxygen supply.

Library U. S. Forest Service Atlanta

When it comes to fire behavior there are likewise only a few basic variables. The big one is fuel moisture and when our fuel moisture indicator sticks are below 5 percent you can expect your fires to blow up and explode. As that moisture content rises above 5 percent your fires become less and less explosive and you know that they are then more and more influenced by another major variable, wind.

Both fuel moisture and wind are measured every day of the fire season at numerous stations. Those measurements will show you clearly and accurately what the present moistures and velocities are, and how they are changing, whether getting better or worse. These are facts. They are available to you. They were not available to the rangers and supervisors who fought the fires of 1910 and 1919, nor to many men in 1928 and 1929. You therefore have this accurate knowledge that those men did not have.

Furthermore, you have some knowledge of how both fuel moisture and wind velocity differ according to altitude and aspect. The outstanding general differences are known. Very few if any of the most experienced old-time fire fighters knew these things.

And finally you have not only excellent topographic maps to help you visualize your fire area, but you have the major differences in fuel types shown clearly so that you can calculate what you should expect your fire to do on this particular slope in the next few hours.

It is true that you still have to estimate how much different the fuel moisture will be at your fire from what it is at the fire danger station. You also may still have to guess what the exact wind direction and velocity will be on your fire even after you find out what they are at the nearest ranger and lookout station. And it is true that there may be an acre of High-High fuel right near your fire even though the map shows Medium-Medium or even Low-Low. But if you have been on your district very many years and have gotten around, or if you have someone else there who really knows his fuels, you may be able to pick up that important fact.

CONCLUSION

Even though there are some holes in our information, we have much more than our predecessors. Those men had to think of EVERYTHING. They even had to go to town to buy their axes and shovels and grub. Then they had to remember out of their own personal experiences what the topography and timber and brush types were like, up there at the fire. Finally, they could only feel the wind and kick the duff to see how dry the fuels were, right where they stood. Finally they could look at the sky and guess at what the weather might be tomorrow. May be some of them prayed.

But times have changed. Where those old timers had to guess at most everything, today, we have measurements and maps and many other facilities. While we might like to have more, I doubt that anyone ever will be able to sit down to a machine, punch a key for every factor of the situation, and have the machine tell him what to do. Fire control still requires headwork based on knowledge. If we will make a purposeful attempt to use all of the knowledge and all of the facilities that are available to us today we can do one thing the old-timers could not do: We can come mighty close to getting adequate fire control, and at an operating cost far below what it used to be.

SAFE STORAGE OF FIRE TOOLS

R. W. Bower

Fire Control Officer, Modoc National Forest

The Modoc National Forest has two problems in connection with warehouse storage of fire tools. Warehouse space was limited and the method of storage needed to be safe. The ordinary overhead type of rack for shovels and McLeods was dangerous because of possibility of tools falling out of racks. The type of rack for axes that allows the ax to hang by the head is also dangerous because of chance of a person striking an exposed blade.

The tool rack shown in the photo solved both these problems. It is a very compact arrangement with maximum use of available space. It is a very safe arrangement because there is no overhead storage and it is always necessary to reach for the handle of each tool instead of the head or blade. There have been no accidents from handling loose tools in the warehouse since this system was installed.

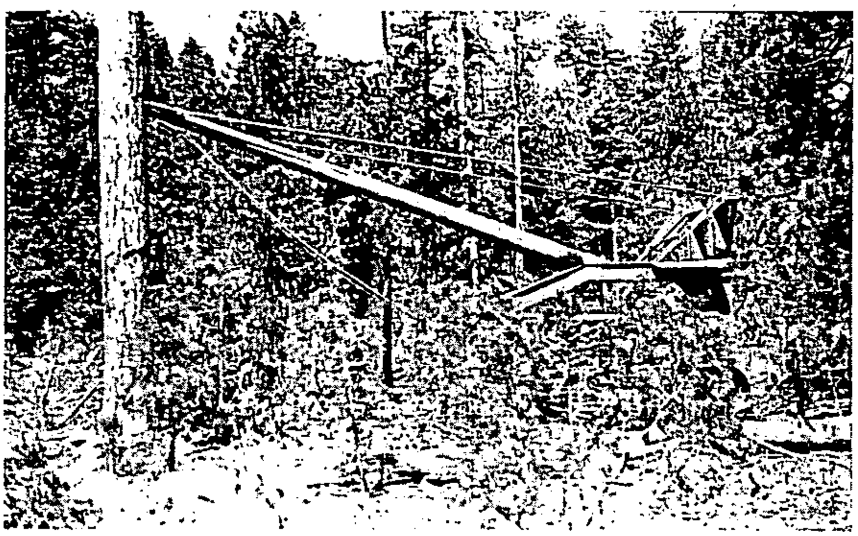
AN EFFICIENT SNAG PUSHER

R. W. Bower

Fire Control Officer, Modoc National Forest

One of the greatest fire hazards in the Northeastern California pine timber type is the presence of numerous snags due to past depredations of the pine beetle.

An analysis of all the class C, D, and E fires on the Modoc National Forest for a 5-year period showed that of all the fires starting in timber type, 70 percent were lost by the initial attack suppression crew because of snags throwing more spot fires than the crew could handle. The standing snags are far more dangerous than slash on the ground.

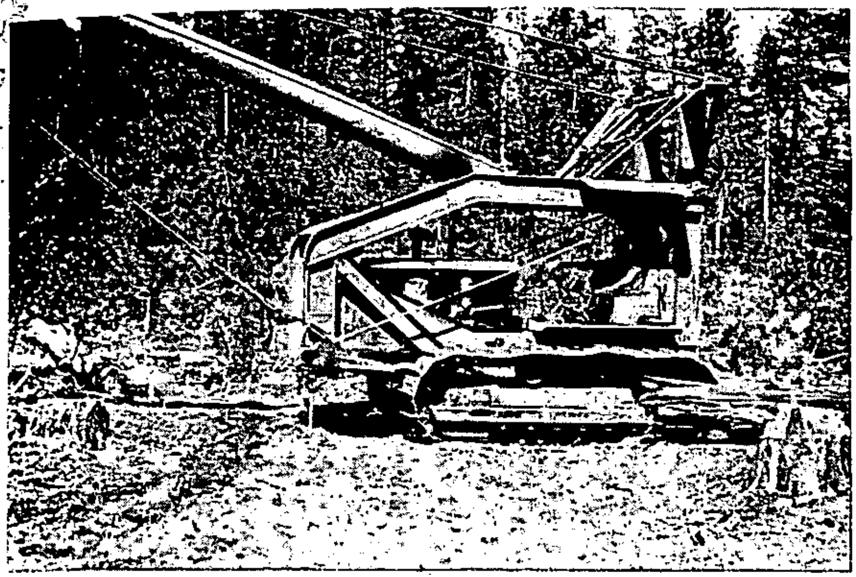


Snag pusher with boom against snag.

For this reason, any fire hazard reduction program must place snag disposal high in priority.

The Finney Logging Co., operating on lands of the Red River Lumber Co., within the Modoc National Forest boundary, has adopted the 100 percent snag falling alternative under the slash disposal requirements of the California State Forest Practice Act. Mr. Ted Finney, manager, has built a snag pusher in order to do the snag-disposal job economically and rapidly.

The main feature of this snag pusher is the 30-foot steel boom connected to a heavy channel iron frame and mounted on a D8 Caterpillar tractor as shown in the photo. Mr. Finney made the frame exceptionally heavy in order to afford maximum safety to the operator. It will stand the full weight of a falling snag if one should break back over the boom.



Arrangement of boom and frame on tractor.

This rig will push well over 300 snags per shift in heavy stands and will average about 200 snags per shift in average stand conditions of about 2½ snags per acre.

The crew consists of an operator and swamper. The swamper tallies the number of snags pushed daily as well as scouts out best route for travel of rig from snag to snag.

Fire Fighting De Luxe.—Region 3 hates to see Region 1 dropping all that water from B–29's so we felt we should go them one better.

A letter has just been received from the Range Developing Co., Phoenix, Ariz., which says among other things:

"It might be interesting to you to know that on Friday afternoon, September 5, the writer discovered a small fire burning in the Prescott National Forest just east of Walker. While bringing about rainfall over the municipal drainage area of the city of Prescott, a thunderhead formed directly above this burning area. I flew into the thunderhead at about 5:15 p. m., dropping approximately 80 pounds of dry ice pellets which brought about an immediate heavy downpour. On circling the area about 6:30 p. m., there was no evidence of fire left. We have no reason to doubt this fire was definitely put out through our efforts alone."

On the same day Assistant Ranger Bill Anderson reports:

"Another man and I went to a small fire east of Walker. We had just got the snags felled when we observed a large cloud which we hoped might bring rain and heard a plane overhead. And in a few minutes, boy! did it ever rain—and hail. We got awful wet but it sure did put that fire out quick and saved mop-up."

The Region's position is obvious. We are certainly going to be much interested in every cumulus cloud—particularly next May and June—and are now considering the addition of raincoats to all our fire caches. No fooling!

Seriously, the Range Development Co. has offered free demonstrations and the region will take full advantage of the offer.—Don Beck, *Region 3, U. S. Forest Service.*

MAKING CONTACTS AND ESTABLISHING GOOD WILL

C. H. Coulter

State Forester, Florida Forest Service

In Florida 99 percent of our fires are man-caused, about 72 percent being deliberately set. This adds up to a tremendous human relations problem—the job of selling fire protection to an indifferent and often antagonistic public.

With this in mind, "Making Contacts and Establishing Good Will" was prepared. It was read, discussed, and taught at our fire control training schools. It is for towermen, assistant rangers, rangers, and others to use in properly approaching the public—the first step in getting their cooperation.

ATTITUDE OF PERSONNEL

In order to successfully sell the program of the Florida Forest Service to individuals and the public in general, it first becomes necessary for the individual employee to believe whole-heartedly in the purposes of the organization and the people in it. In other words, he must first sell himself on the idea that his organization is a good one, and that he has something to offer the public.

From time immemorial it has been proved that nothing is so contagious and stimulating to morale as individual and collective pride. If you thoroughly believe in, and are enthusiastic about your organization, you will soon transfer this enthusiasm to those you come in contact with.

By the same token, nothing will spread so quickly and cause as much discontent and corruption in an organization as a dissatisfied employee—for example, the individual who hangs on merely for the purpose of drawing his pay check, and who is constantly knocking and grumbling about the organization and those in it.

All of us will profit by recalling Elbert Hubbard's adage on loyalty: "If you work for a man, in heaven's name, work for him! . . .—speak well of him, . . . and stand by the institution he represents . . . an ounce of loyalty is worth a pound of cleverness.

"If you must vilify, condemn and eternally disparage, why, resign your position, and when you are outside, damn to your heart's content. But, I pray you, so long as you are a part of an institution, do not condemn it. Not that you will injure the institution—not that—but when you disparage the concern of which you are a part, you disparage yourself.

"More than that, you are loosening the tendrils that hold you to the institution, and the first high wind that comes along, you will be uprooted and blown away . . .—and probably you will never know why."

We are often too prone to speak of, or demand, our constitutional rights, or to say that we are entitled to private opinion. For your information, the following excerpt is quoted from A Pocketful of Pebbles, by Jan Struther:

> Private opinion creates public opinion. Public opinion overflows eventually into national behavior, and national behavior, as things are arranged at present, can make or mar the world. That is why private opinion, and private behavior, and private conversation are so terrifyingly important.[1]

A careful analysis of the above will be of great benefit to all of us and will at the same time not deprive us of our private opinions so long as they *are* private opinions and not used as a subterfuge to stress our point and do harm to an individual or organization.

In our everyday work we must put aside our individual ideas and work for the good of the Service. REMEMBER—what is good for the Service is good for you.

If a particular deed is worthy of praise, it should be looked upon in the light of "WE;" by saying that "WE" accomplished this particular deed the entire organization will receive credit for its accomplishment. After all, we should strive to work together as one big organization, or team, instead of as individuals. Be careful not to develop the "I" complex.

Superiors should be quick to notice and offer praise for outstanding work. Experience has taught us that every person and group of persons will react to kind words and encouragement if properly given out in deserving cases.

PERSONAL APPEARANCE

Much of the success obtained in meeting the public will depend upon your personal appearance. It is not necessary that you be a "white collar dude" or that you appear in formal dress. Just remember to do the best with what you have. No one likes to hold a conversation with a ragged and unclean person. It has often been said that "Cleanliness is next to Godliness."

The occasion may arise when out of necessity you will be forced to talk with persons or strangers immediately after fighting a bad fire or doing a dirty job. Your appearance on this occasion may be explained, and the person you are talking with will understand the circumstances and make allowances for it. He will not, however, overlook your dirty appearance if you are in that state every time he meets you.

Some persons will judge you by the condition of your equipment. Keep your truck and other equipment as neat and clean as possible. REMEMBER—every citizen of the State of Florida has helped to pay for your equipment, and there will be certain persons who will try to find fault with it. Give them no cause for criticism.

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[1] Printed with permission of Harcourt, Brace and Company and Reader's Digest.

MEETING THE PUBLIC

The Approach

There is only one way to meet and greet the Public—the RIGHT way. The RIGHT way will, of course, depend largely upon circumstances and the persons involved.

Meeting the person you know.—If you know this person's name be sure to call him by it. Experience has proved that every person likes the sound of his own name; he has had it since birth, and it is his oldest possession. His name seems to fall softly on his eardrums and leave him with the satisfied feeling that he has at least made an impression strong enough to cause you to remember who he is.

If you do not recall his name, don't try to bluff your way for he will soon learn that you are bluffing and will probably resent it. If you cannot remember his name and yet recall the occasion of your last meeting, then refer to this meeting and ask him his name. When he tells you his name, repeat it several times to yourself, and if possible associate it with some event or other thing which will enable you to easily recall it next time.

Refrain from addressing a person as "Brother." The individual you are addressing may not like you and would not want to be your brother, and in any case, the term sounds insincere and artificial. Nicknames should be used only where you know the individual well enough to take this privilege.

Meeting the stranger.—Remember, first impressions are sometimes lasting. You may be judged by your initial conversation or behavior, and if it creates an unfavorable impression, you may never be able to convince your listener that you were not acting in your normal and usual manner. Also bear in mind that you represent the Florida Forest Service and the State of Florida. You are their ambassador; make them proud of you and endeavor to make the public respect you.

The introduction.—Under all circumstances make your introduction as amiable and firm as possible. Approach the stranger in a businesslike but friendly manner, tell him your name and title, and make certain that he understands who you are. If you doubt that he clearly understands you, then take a few minutes to explain your duties or mission. After you are sure that he understands, start your conversation.

The Conversation

Your conversation will depend, of course, upon the circumstances at hand. If the person is already known to you, this should not be hard. If, on the other hand, the person is a stranger, make reference to his present activities after you have completed the introduction. Try to learn what the person is interested in and converse with him along these lines if you can intelligently do so.

If you are able to get the person talking about something he is interested in, you can later steer the conversation into other channels and probably learn what you want to know. Never dominate the conversation. If he should ask you questions, answer them in a truthful and understandable manner. Don't try to be sly or evasive.

If he should ask you questions which you cannot answer because of your lack of knowledge on the subject, don't try to bluff or guess your way through, tell him you don't know, and he will respect you for it. Wherever possible, tell him who may be likely to have the desired information. If you later learn of information that he wants, go back to him, if possible, and tell him about it. Don't make promises, however, that you can't keep. Always try to leave the person in a satisfied and happy frame of mind. If he should later find that you have given him a false answer, or have been bluffing, he will resent it and will probably judge your entire organization accordingly. You can learn more from listening than telling, and a few well-directed questions may get the other fellow started.

Profane and obscene language.—Many of us are prone to overindulge in the old American custom of swearing. We must be on guard at all times in an effort to eliminate this laxity. There are persons who strongly object to the use of profane and obscene language and are easily offended when it is used in their preseence. Certainly, everyone objects to its use if they are angry, or if the circumstances are such that they are at a disadvantage. Never direct this sort of language at persons, for nothing is proved or gained by its use, and it only tends to brand you as a foul-mouthed person.

Boisterous language.—A boisterous or loud-mouthed and noisy person is thoroughly disliked by everyone; and so is a braggart. In our enthusiasm over a particular subject, it is often easy to fall within this class. Be on the alert, and you will not be guilty of this practice.

Timidity and shyness.—This may on occasions be just as dangerous and damaging as too much conversation. Some persons have a reserve or "outer shell" which is often mistaken for timidity or shyness, but if you are one of these persons, try to overcome it. Avoid being a shrinking violet. Modesty is a virtue but can sometimes be carried to extreme. Don't try to be the "silent type." Don't be reluctant to engage in general conversations, especially if this conversation interests and includes you.

Accusations.—A person will dislike you if you accuse him indirectly of committing an offense. This is sometimes true where the person is directly accused, but at least it gives him a chance to defend himself. If you know of, or have reason to believe that a person is guilty of committing an offense, the wisest method would be to discuss the matter with that person and not with every Tom, Dick, and Harry on the highways and byways. The latter procedure will only serve to make him alert and enable him to build an alibi.

Even if you are certain that a person has committed an offense, discussing it with every person you meet will be of no value and will certainly not strengthen your case or cause in the final analysis. If your facts or evidence are true and complete, take disciplinary or legal action, whichever the case calls for. Don't be a gossip.

Keeping your temper.—Under no circumstances should you lose your temper; nothing can be gained in so doing. And always remember that a person who loses his temper is at the mercy of a cool opponent. There will be occasions when persons will deliberately try to "get your goat," or make you mad. Don't be a victim of this.

Arguments.—For every argument won there must be a loser. A prolonged discussion of differences in opinion will eventually lead to

heated argument and usually proves nothing. Always remember that every person is entitled to his own opinion. You need not try to convince all others that only you are right. There are two sides, and sometimes more, to every story.

It is natural for persons to have different opinions. If a person's opinion or viewpoint is different from yours, you will seldom win him over to your side through argument. If you differ in opinion, never tell him bluntly that he is wrong. Merely tell him that he may be right, that in your opinion you see it thus and so. Remember, you are representing the State of Florida, and it will be for the best interest of all concerned if an argument is avoided. If for some reason you must show him that he is wrong, then it will be best to do so in a way that will allow him to feel he was at least partly right and thus save face.

Flattery.—Never stoop to flattery. Deserving persons will not expect it and others are not entitled to it. Certainly those persons who have accomplished some outstanding feat or act should be commended, but this does not mean they are to be flattered. It has often been said that flattery is a poor substitute for proper and deserving praise.

Don't be a "Yes Man." This type of individual is repulsive to the majority. Be firm in your convictions, without argument, and it will be a great help in making others like and respect you.

Admission of error or fault.—Man is not perfect. He makes mistakes easily and often. Nothing is so difficult for some persons as to admit they were at fault. If you have made an error, or are at fault for any reason, be quick to admit it to the person or persons concerned. Don't be dramatic about it. Others will respect you if you pocket your pride and admit that you have erred.

If you are never hasty in making decisions or statements where they are not needed, there will be little likelihood that it will be necessary for you to admit error. A good rule to remember is, "Do not make unnecessary statements or decisions and it will not be necessary for you to retract them later." In this manner you will demand respect from others, and they will be more likely to believe the things you do say.

THE DEPARTURE

Persons will remember you favorably and will extend a more genuine welcome on your next meeting if you have left them in a pleasant and happy mood.

Many of us are prone to use slang or pet farewells, such as "See you in church," or "Don't take any wooden nickels." These may, or may not, be out of order, but they have no particular meaning. Wherever possible, try to give a farewell which will have a meaning, will linger with the person, and will cause him to remember you pleasantly. Make your farewell sincere and sensible, such as "Hope to see you soon," or just plain "Goodby."

MAINTAINING CONTACTS

So many of us are prone to take our friends and contacts for granted. As a result, these friends feel they are neglected unless we want to get something from them. This feeling often causes a rift in friendships; it is not helpful to goodwill and will not strengthen our cause.

Whenever you can find the time, renew your contacts and acquaintances both old and new. Drop in on them occasionally and spend a little time in pleasant and interesting conversation. Never appear to be in a hurry. Sometimes a hurried contact or visit may do more harm to your cause than no contact or visit at all. But, don't be a nuisance and wear your welcome out. Don't give others the impression you have nothing to do.

One of America's political greats once said that he maintained a book with the names of all his voters; that this book contained information on his voters and their families, and wherever possible the names of their friends, relatives, and families. The politician stated that he studied this book carefully before each visit and tried to call members of the family by name, or to make reference to some incident which was pleasant to their memories. According to the politician, the results obtained were amazing and satisfying.

We cannot hope to set up a similar bookkeeping system for each of you, or to tell you how or when to call on your contacts, but at least the politician's procedure should help form a pattern for all of us.

Magnesium Wedges for Felling and Bucking.—The new magnesium wedges now on the market weigh only about one-fifth that of steel wedges of the same size and only slightly more than hardwood wedges. They combine the durability of the former with the lightness of the latter; thus, they should be superior to both as a fire tool wherever weight and dependability are factors. We have subjected them to a trial of physical tests to determine whether this premise is correct.

Using a 1-pound magnesium wedge, which compares in size to the 12-ounce hardwood wedge and the 5-pound steel wedge (10-inch length), we found it adequate for normal bucking and felling use. In fact, it withstood hammer blows that quickly shattered wooden wedges. With severe abuse, the magnesium wedge can be distorted or shattered more readily than steel, but this abuse was far greater than what should occur on the job. We could produce no "mushrooming," but the magnesium did chip with repeated, deliberate, glancing blows. From a safety standpoint, however, we judged the extremely light metal to be relatively harmless as compared to flying steel. It was our conclusion that, with proper use, the magnesium wedge should have a lengthy life. We believe it to be the tool to use on any bucking or felling job where there is any degree of packing to be done.

Magnesium wedges are now available in a variety of bucking, felling, and power-saw patterns. At present prices they are about 10 percent more than steel and about three times the cost of hardwood wedges.—WALTER J. PUHN, *Forester, San Bernardino National Forest.*

Rust Prevention for Milk Cans.—In using the 10-gallon tinned milk cans to transport and store water for fire camp use, it is necessary to keep them clean and dry at all times, especially when they are stored for future use. Any moisture, even that moisture resulting from condensation caused by changes in air temperature, will cause the cans to rust.

If a piece of zinc about 2 inches square is soldered on the inside of the bottom of these cans, rust on the bottom of the cans will be eliminated. However, no liquid containing an acid can be put in the cans and they should be marked accordingly. Using the zinc plate in conjunction with inverting the lidless cans while they are not in use has considerably increased their life on the Cleveland National Forest.—FLETCHER HAYWARD, *District Ranger, Cleveland National Forest.*

PROGRESSIVE HOSE-LAY IN FIRE SUPPRESSION

STANLEY R. STEVENSON, *Fire Control Officer, and* EDWARD W. SCHULTZ, *Assistant Fire Control Officer, Cleveland National Forest*

A reanalysis of fire control requirements made in 1946 indicated that 70 percent of all fires on the Cleveland National Forest since 1934 (beginning of expanded tank truck use) were controlled at a perimeter of 20 chains or less through the use of tank trucks. This record of effectiveness of the use of water in fire suppression is further substantiated by regional studies. This reanalysis showed that three to five men with power water equipment controlled 5 chains per man-hour control time. This record of control was accomplished under conditions of maximum heat per unit of perimeter. The rate of perimeter control is 15 to 20 times greater than that of similar perimeter units where hand tools were used in line construction.

With this fact as a basis, we proposed to develop a means of placing water over a large and increasing perimeter of a hot brush fire with the same efficiency by expanding the crew.

Preliminary developments determined the problems to be solved in a practical application of the proposition as those of:

1. Organization.—An organization will be required that can function smoothly and fast. This demands that men, whose major experience with the use of water lies in initial attack suppression problems, be trained to operate as a large team on a hose-lay operation where the success of each phase is dependent upon every man.

2. Water supply.—A continuous supply of water must be available to the operation. This recognizes the present inadequacy of source of supply of tanker loads and the limitations of elevation upon delivery of water to a fire.

3. Equipment.—Efficient and modern power water equipment and large amounts of hose, hose-lay fittings, portable pumps, and accessories are needed. Original development of practictal aids will be required as problems are encountered.

4. Strategy.—A determination must be made as to what type of suppression problem the operation is adapted as limited by topography, cover, major sources of water, and burning conditions.

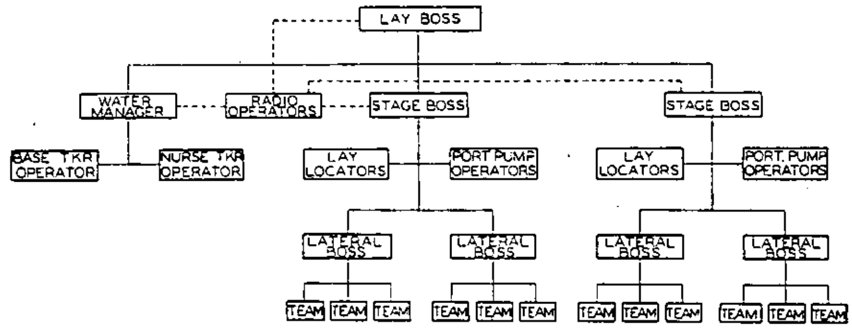
Toward the solution of these recognized problems, a preliminary plan of operations was made and executed in a 2-day meeting of experienced fire control men on the Cleveland National Forest. At this time, 1,500 feet of main-line 1½-inch hose with 100-foot 1-inch laterals every 200 feet, was laid by 7 men in 50 minutes; 2,000 gallons of water was used at an average of 10½ gallons per minute at each nozzle. No progression of manpower was made beyond the point where brush was wet enough to assume theoretical control. Water was available to all laterals, the base pumper being refilled by "nurse" tankers relaying water from natural sources.

The trial gave a control rate of 4 chains per man-hour, approximately the same rate as shown by initial attack tanker crews on small perimeters. The fact that good results were obtained with available equipment and little experience indicates the practicability of the operation.

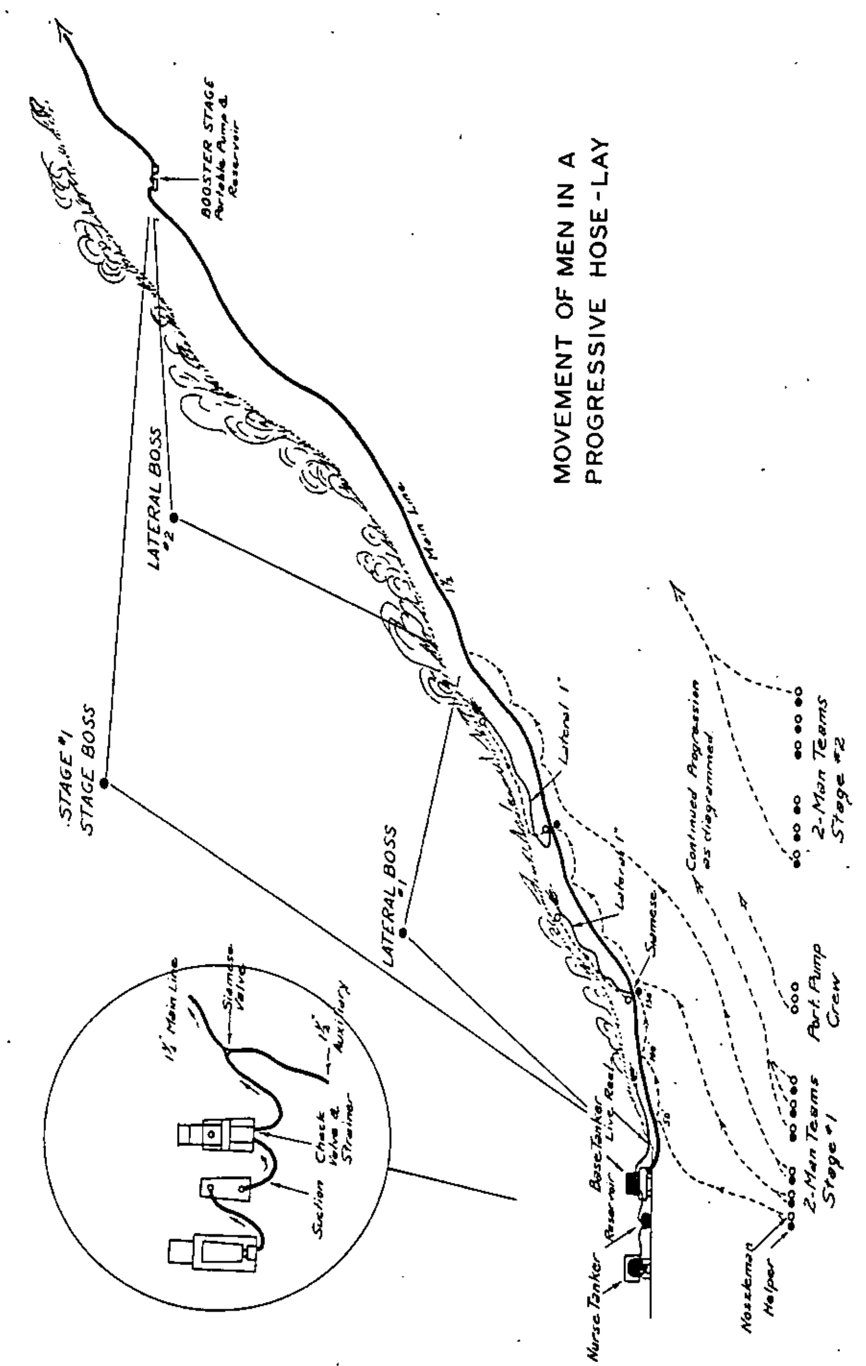
We have called the operation a "progressive hose-lay" and the control line created by it a "water scratch-line." It is fully recognized that this line is a temporary, fast, control line achieved only through progressive application of water to the growing fire perimeter, with control maintained by the lateral lines installed during progress. This line must be followed up with hand line construction to achieve complete and safe control. The hand-constructed line can progress directly on the fire edge with greater speed and without danger and fatigue from heat to the crews. The basic advantage of the progressive hose-lay is the ability to make direct attack on hot line with speed and safety, resulting in faster control. There is also a psychological stimulus to fire fighters in using water in fire suppression.

ORGANIZATION

The organization as shown was developed from trials and use on actual fires. It may be compared to a division organization on a large fire with suitable titles adapted to positions on a hose-lay. It may be expanded or reduced to sector, division, zone, or fire as necessary.



It is possible to place a team organization of this type on both flanks of a fire, progressing to tie in at the head. The lay boss (division boss) is responsible for the operation of one entire hose-lay of any length which has two or more water boosting stages. It is his general function to manage and coordinate all elements of the lay. The stage boss (sector boss) directs the laying of one stage. A stage is that length of hose-lay up to an elevation at which the lower pumping unit is limited in its water output by elevation or number of laterals. He is responsible for determining this point and providing a booster pump for continuation of the progressive hose-lay. The stage boss has several lateral bosses (crew boss), each in charge of three or more laterals as the problem demands. They are responsible for the smooth progression of their teams through the hose-laying procedure. As the size of the job to be done dictates, positions of water manager to coordinate base supply tankers and nurse tankers, lay locators to cut way-trails, lay inspectors to check for leaks and breaks in lay, and others may be added.


MOVEMENT OF MEN IN A PROGRESSIVE HOSE-LAY
BOOSTER STAGE Portable Pump & Reservoir
LATERAL BOSS #2
STAGE #1 STAGE BOSS
LATERAL BOSS #1
1½" Main Line
Lateral 1"
Siamese
Continued Progression as diagrammed
2-Man Teams Stage #2
Port. Pump Crew
2-Man Teams Stage #1
Nozzleman
Helper
Nurse Tanker
Reservoir
Base Tanker
Live Reel
1½" Main Line
Siamese Valve
1½" Auxiliary
Check Valve & Strainer
Suction

As in the performance of a football play, this organization must be keyed by men who know the progressive movements of its operation. When the initial attack crew recognizes that immediate control is not possible with available equipment and manpower, the scheme of progressive hose-lay begins with the decision that such an operation is adaptable to the suppression problem. Without waste of time on the usual lost efforts, they can initiate a main line lay and laterals with the hose and accessories available. Reinforcement crews provide additional water, equipment, and manpower to continue the progress of the lay around the fire edge. The Cleveland Forest has equipped a stakeside on each district with a large water tank and pump to provide the immediate need of a large volume of water, hose, and fittings to first reinforcements.

In the event of fast burning conditions continuing the increase of perimeter, fast dispatching of large reinforcements of manpower and equipment are necessary in Southern California cover types. Upon arrival of reinforcements on a fire reaching major proportions, with a control on the flanks initiated by the first crews, some men are placed in the organization to continue progressive water suppression to a point of control or tie-in with other operations. This procedure was successful on the two class C and two class E fires on which it was operated during the 1947 season on the Cleveland National Forest.

In the diagram the team units, consisting of two or three men, are the hose layers. A team starts their lay of 150 to 300 feet by connecting to the siamese valve at the end of the controlled portion of the fire perimeter. The 100-foot lateral at this point continues along the flank, knocking down the fire and making a water scratch-line. The team is able to lay their main line under the protection of this lateral. When they reach a point where the last lateral cannot protect them, they loop 50 to 100 feet of main line to the rear and install a siamese valve and lateral. The man on the last siamese valve is signaled for water by this team and as the nozzleman of the team receives water at the nozzle, he proceeds ahead continuing the water scratch-line. Manpower coming behind straightens the charged lines out as the nozzleman progresses. This procedure continues with additional teams carrying on in the same manner. Each team, upon completion of their lay, remains on the lateral, holding the fire edge and checking their lay for protection against hot spots. As soon as possible, they shut down and use water only for hot spots and flare-ups to maintain control of their line.

As the fire edge becomes cooler through the efforts of the lateral team and their siamese valve has given water ahead, the nozzleman can maintain control alone and the others return for more equipment to form another team.

Training of personnel for this operation is not one of the big problems. The coordinated progressive movement idea is mastered quickly. The key positions must be filled by men who understand the basic principles of hydraulics as related to hose-lays and are able to calculate and prepare for the limitations of equipment in moving water from point to point, up and down. If key positions are filled by trained men, completely inexperienced men can be used for laying hose with very little prior instructions.

EQUIPMENT

The trials and actual fire experience with equipment for this operation indicate that available equipment, with some adaptions, is adequate. For the base pumper operation the R–5 demountable tanker (Green Hornet) is the most efficient. It is desirable to install a shut-off valve on the 1½-inch outlet to prevent loss of water column in case of shut-down. A siamese valve with necessary adapters on the end of the first length of main line, installed backwards to provide an emergency switch-over to another pumper, is used successfully when the base tanker breaks down or needs servicing after long periods of pumping. This is necessary to maintain the uninterrupted flow of water to the main line.

Stakeside 1½-ton trucks with a 400- to 600-gallon tank and pump are used for nurse tankers; 425-gallon airplane wing tanks, made of rubber and canvas ply, anchored to the bed of the truck are also very successful. They have numerous outlets and with little work can be fitted with a pumping arrangement. These nurse tankers carry an additional empty wing tank, extra hose, siamese valves, nozzles, and a portable pump booster stage set-up. The extra wing tank is rolled off beside the base tanker for a reservoir. This reservoir is kept filled by relay nurse tankers.

The portable pumper stage set-up is available for boosting stages when the hose-lay has reached a point to which the last pumping unit cannot lift sufficient volume of water. It consists of a pump, packboard, canvas reservoir, and accessories. The fittings include a check and a bleeder valve and pressure relief valve.

Team pack units have been devised to solve the problem of men having their hands free to aid teams laying hose and proceed through brush without wrestling with rolls of hose and accessories. Each team has a packboard with separate ties for carrying three 50-foot lengths of 1½-inch CJRL hose and a packsack containing two 50-foot lengths of 1-inch CJRL hose, a siamese valve, and a nozzle with extra tips for the lateral installation.

The 1½-inch hose is double-rolled with male connector lapped by the female connector and double-tied with a one-pull release tie. The 1-inch hose is rolled by starting two separate rolls, side by side, from the middle of the length and tied in the same manner.

The most efficient siamese valves used are those with a single handle, well labeled, and equipped with an inverted cone type, self-releasing central control valve. They are carried with one 1½-inch to 1-inch adapter for the lateral line.

The recently developed Forester Fog Stream shut-off nozzle with its selective control over two streams is very efficient due to its light weight, compactness, simplicity, and double feature of water delivery. In using these nozzles, an in-the-line strainer is used at the base tanker and at intervals along the main line to prevent the fog outlet from becoming clogged with foreign material.

Continued use of the progressive hose-lay for fire suppression will determine the most adaptable equipment and create numerous aids toward its effective operation.

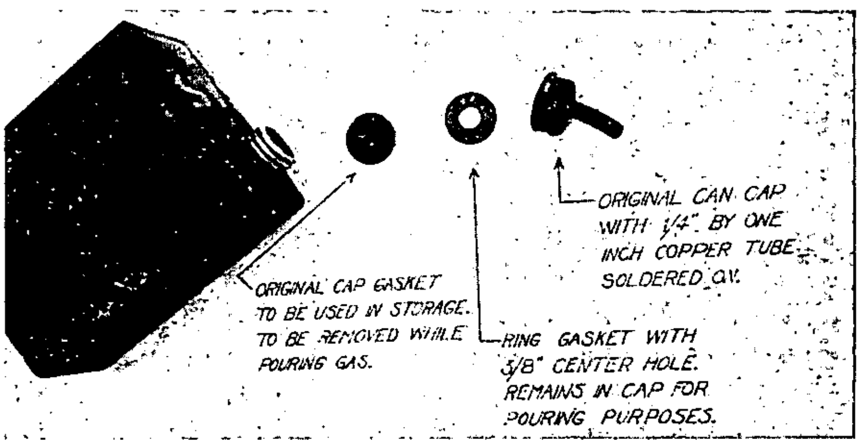
RESULTS ON TRIALS AND FIRES

The accompanying table shows the results of instances in which the progressive hose-lay was used during the 1947 season on the Cleveland National Forest.

Item	Trial 1	Trial 2	Fire 1	Fire 2	Fire 3
Size .... acres	---------	---------	10	623	90
Perimeter .... chains	---------	---------	60	450	200
Total perimeter controlled by progressive hose-lay .... percent	---------	---------	100 + spots	20	15
Length of lay .... feet	1,500	2,700	1,200	5,000	2,000
Elapsed time of lay .... hours	.8	.8	.5	2.0	1.0
Men on lay .... number	7	36	10	15	27
Perimeter per man-hour .... chains	4.1	1.1	12.0	3.0	1.1
Laterals installed .... number	7	18	3	17	14
Water pumped .... gallons	2,000	5,000	4,200	12,000	10,200
Difference in elevation .... feet	+300	+340	Level	+350	+320

Trial 1 was conducted by experienced fire control personnel accounting for the higher rate per man-hour as compared to trial 2 which was conducted for training inexperienced men. Fire 1 was a long narrow fire on which both flanks were controlled by the same laterals. Fire 3 results were attained by an organized "hot-shot" suppression crew who had received only 3 hours training in the operation on the morning of the day the fire occurred. The lay was made up a 65 percent slope covered with very dense brush where hand crews had withdrawn because of heat and danger.

Funnel Attachment for 1-Quart Gasoline Can.—The accompanying photograph shows a device that materially increases the usefulness of a 1-quart gasoline can for filling Coleman lanterns.



Safety rules prevent venting the can. With the funnel and gasket attachment, pressure can be applied to the sides of the can making in a "squirt" can. Anyone who has tried to fill lanterns without the funnel attachment will appreciate the improvement.

The spout can also be partially plugged to apply kerosene on crosscut saws.—CLEO ANDERSON, *Assistant Ranger, Cibola National Forest.*

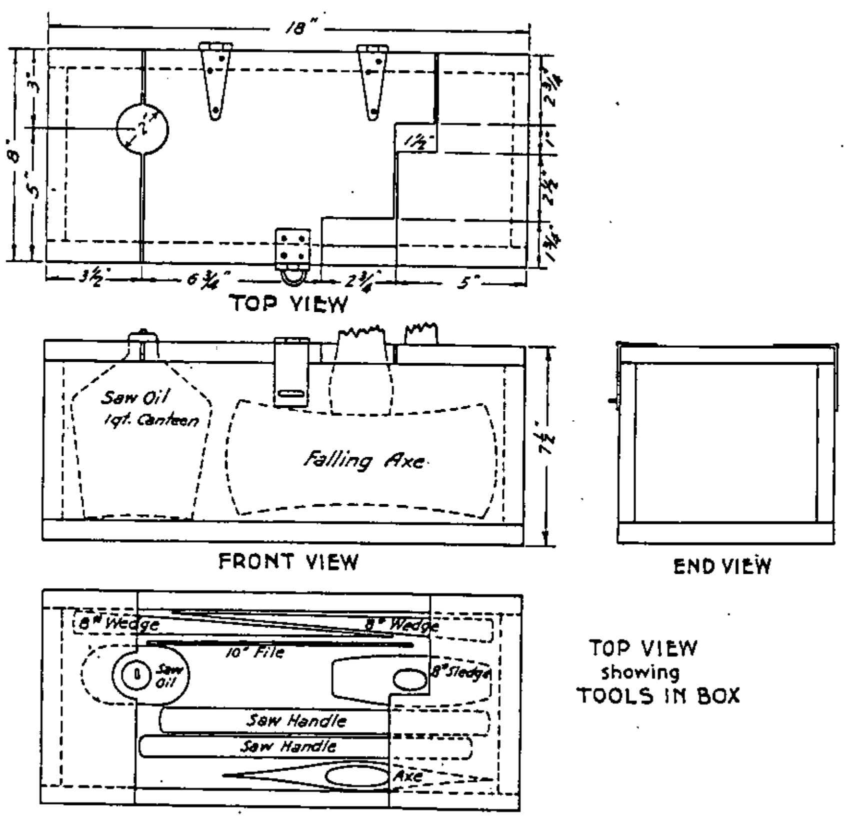
TOOL BOX FOR FELLING OUTFIT

James E. Taylor

Fire Control Assistant, Stanislaus National Forest, U. S. Forest Service

A safe practical box for storing and transporting a felling outfit was designed and constructed on the Calaveras District, Stanislaus National Forest, Calif. The box, which holds all of the necessary equipment except the saw and hard hats, is 18 inches long, 8 inches wide, and 7½ inches deep. The saw and hard hats are kept with it in the warehouse and are shipped to fires so all will arrive at one time and in good working order.

The dimensions of the tool box and method of tool arrangement are shown in the diagram.



FOAM

A. B. Everts

Fire Staffman, Snoqualmie National Forest, U. S. Forest Service

The intriguing characteristics of foam—its rapid expansion rate, its clinging and insulating qualities, as well as its spectacular performance on shipboard and oil-tank fires during and since the war years—stimulate the imagination as to ways and means of how this fire extinguishing agent can be efficiently applied to forest fire control. Manufacturers of foam and foam equipment have, for the most part, given little or no thought to the problems of forest fire agencies. There is a dearth of literature on the subject. D. P. Godwin, in the December, 1936, Fire Control Notes, reported a series of tests on the Monongahela National Forest which pointed out some of the values of foam. T. R. Truax, in the October, 1939, Fire Control Notes, reported the results of further field tests conducted by the Forest Products Laboratory.

However, the rather cumbersome methods of producing foam and the equipment needed, as in the one-powder, the two-powder, and the two-solution methods reported by Godwin, if not obsolete, have at least been greatly simplified by industrial research since 1936. While the author has nothing new to offer as to the practical value of foam in forest fire control he has had the opportunity to experiment with mechanical foam in back-pack cans, tank trucks, and pressure units. The method of application is simple. It remains for field tests to determine the value.

Types of Foam

The two principal types of foam are chemical and mechanical.

Chemical foam is a powder which is introduced into the hose line by means of a hopper or generator approximately 100 feet back from the nozzle. While equipment for its use has improved since 1936, the method of application is essentially the same as that described by Godwin. The quality of the foam is excellent but the employment of a hopper on an advancing fire line creates obvious disadvantages: the hopper must be moved along as the line advances and additional manpower is needed to pack the powder to and keep the hopper full. Other disadvantages are that the nozzle cannot be shut off, since to do so causes the water to back up in the hopper and force the powder out. Chemical foam is not as free flowing as mechanical foam and for that reason seems less desirable.

Mechanical foam is a liquid with a soybean base and other ingredients. It is dark in color and evil smelling, but unharmful to the

skin, clothing, or painted surfaces. It can be used with either fresh or salt water. The writer believes mechanical foam offers the best possibilities for forest fire work and, for that reason, the rest of this article will be confined to its use alone.

Cost of Foam

During the war the cost of foam to the Navy was said to be $11.50 per 5-gallon can. Since the war many hundreds of cans have been sold at $1 and some as low as $0.50 on surplus property sales. At this time the price seems to have stabilized at $22.50 per 5-gallon can. At this price few protection agencies can afford to use it except on those infrequent fires where its use will pay off. Even at this high price, however, which works out at approximately 2.2 cents per gallon of foam produced, it is a matter of record, as we shall see later, that 400 gallons of foam has been responsible for saving at least one and probably three dwellings from burning to the ground.

Characteristics of Foam

The characteristics of foam, which stimulate the imagination, are:

Expansion.—The rate of expansion varies with the pressure and size of the nozzle used. Foam can be produced with as little as 30 pounds pressure but best results are secured at 100 pounds. At 100 pounds pressure, the rate of expansion is approximately 10 to 1. The foam solution is mixed with the water at the rate of 6 gallons of solution to 94 gallons of water, and this mixture will produce about 1,000 gallons of foam.

Delivery.—The gallons-per-minute foam delivery also varies with the pressure and size of nozzle used. Delivery of up to 300 gallons per minute can be secured from 1-inch hose lines and up to 600 gallons per minute from 1½-inch hose lines. Thus a small fire can be quickly covered with a thick foam layer, blanketing out the oxygen.

Insulation.—The clinging characteristic of foam enables one to insulate logs, short snags (40 to 60 feet, depending on the nozzle used), buildings, and other material from the flames. The foam will stand up for an hour or more. The value of this property can best be illustrated by quoting from "The Use of Fog and Foam by Small Fire Departments" by Walter W. Stephen in the January 1946 issue of Fire Engineering. This articles states:

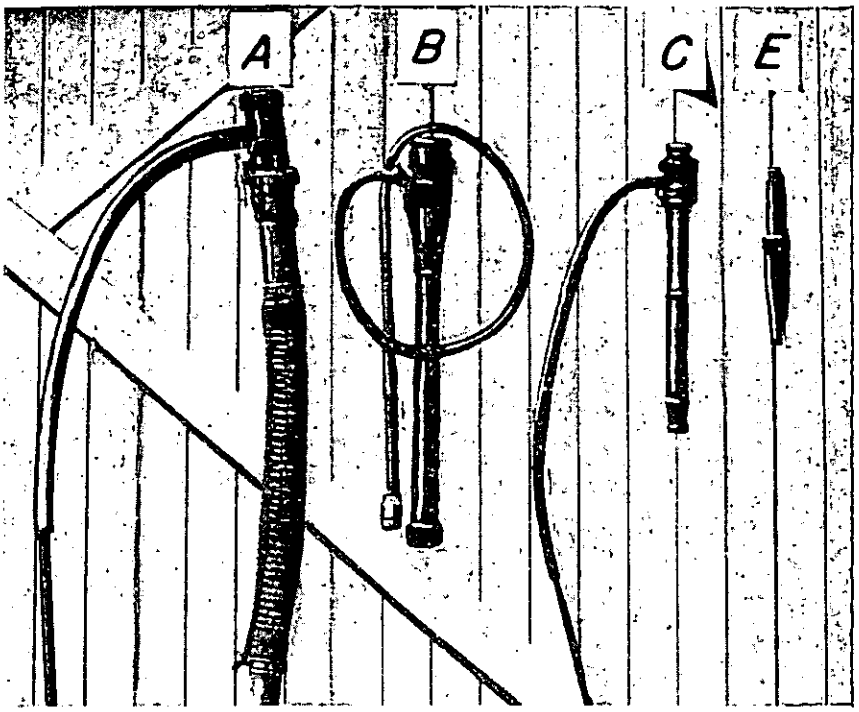
> A hose and chemical truck from an industrial plant went 4 miles out into the country to a crossroads community in response to a phone call. It was found that a fire, starting at one end of a row of five small one-story, frame, shingle-roofed dwellings, had involved two and seemed certain to destroy all of them. There was no source of water nor any apparent way to fight the fire.
>
> There was, on this piece of apparatus, a 40-gallon foam extinguisher. This was operated, and covered the exposed side and half of the roof of the third house with foam; these surfaces were scorching and smoking and about to "light off." The blanket of foam remained in place and protected and saved this house and the other two dwellings beyond it, while the first two that were on fire burned to the ground . . ."

At an expansion rate of 10 to 1, the 40-gallon extinguisher would have produced 400 gallons of foam. It seems very unlikely that these three buildings could have been saved with 40 gallons of water alone.

Methods of Introducing Foam Into Hose Line

There are several methods of introducing mechanical foam into the hose line.

Pick-up tube.—Four different sizes of nozzles are shown in the accompanying photograph. The first three have pick-up tubes. These are simply Venturi tubes designed to pick up the mechanical-foam solution at the proper proportion. The tube is inserted into a can of solution, and the movement of the water through the nozzle draws the solution into the base where it is mixed with air and water and thus produces foam. The disadvantage of this method is that, like the hopper used with chemical foam, cans have to be carried along the advancing fire line.



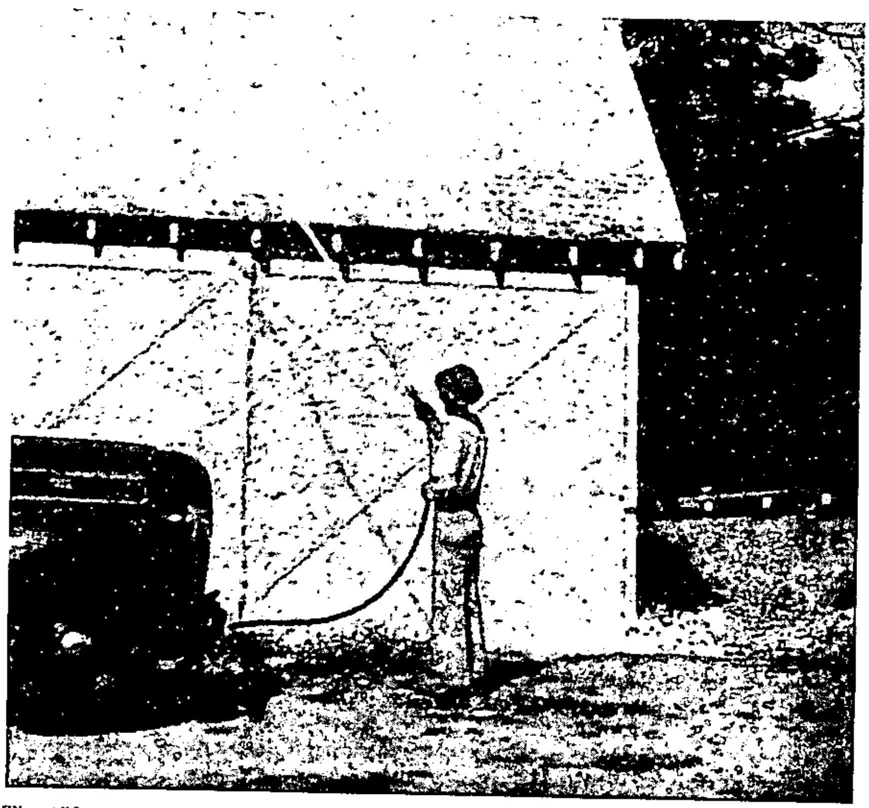
Nozzle *A* produces 540 to 600 gallons of foam per minute, using water at the rate of 56 and solution at 3.6 gallons per minute. Nozzle *B* produces foam at 300 to 500 gallons per minute. Nozzle *C* uses 15 gallons of water to produce 150 gallons of foam per minute. Nozzle *E* takes 2 gallons of water to give about 17 gallons of foam per minute; used on a back-pack can, this nozzle produces 32 gallons of foam with one quart of foam solution and the rest water.

Pick-up at the pump.—This method calls for special equipment and introduces the liquid on the suction side of the pump.

Pressure proportioner.—The proportioner comes in two sizes with capacities of 20 and 50 gallons respectively. Both sizes are dual compartmented so, while solution is being used from one compartment, the other one can be filled. Chief Ranger Rose of Mount Rainer National Park, a former Coast Guard officer, has mounted one of these proportioners on a tank truck and uses it for building protection.

Premix solution.—The fourth method is to mix the solution at the rate of 6 percent with the water in the tank truck. The pick-up tube can then be removed from the nozzle, as is also the case with the proportioner method. The disadvantage of this method is that once mixed the foam has to be used. Since foam will not be used on every fire on which a tank truck makes a run, it is obvious at once that this method is uneconomical. A fifth method is, therefore, suggested for use with tank trucks.

Pressure premix.—Experience has shown that either carbon dioxide (CO_2) or nitrogen gas is a good pressure medium for handling liquids. A light-weight pressure tank of desirable size, 18 gallons for a 300-gallon tanker and 30 gallons for a 500-gallon tank truck, could be mounted in any convenient location on the truck. This tank would hold pure foam solution. From this tank a 1-inch perforated pipe would run the length of the water tank. Connected to the foam tank a cylinder of CO_2 or nitrogen would furnish the pressure to quickly mix the foam solution and water. A pressure gage or pressure relief valve, preferably both, on the tank would provide safety. With this arrangement, a tank truck could quickly convert to foam whenever it was desirable to do so.



The 150-gallon-per-minute nozzle operates from ¾- or 1-inch hose lines and uses 15 gallons of water per minute. Note the insulating and clinging characteristics of the foam produced.

Foam Nozzles

No one has yet designed an adjustable foam nozzle. With the pressure premix method an adjustable nozzle could be used. Otherwise, one must choose the nozzle best suited for the job at hand. This would mean a tanker would need to carry several sizes, a large nozzle for building protection and heavy fuels, a smaller one for light fuels. Even nozzle *C* produces foam too fast for effective application on light fuel such as grass and pine needles. What seems to be needed for this fuel type is a nozzle of about 50-gallons-per-minute capacity. Such a nozzle would consume 5 gallons per minute of water. A 300-gallon tank truck would then operate for 1 hour while producing approximately 3,000 gallons of foam.

Fog-Foam

Fog-foam is produced by passing mechanical foam through a fog nozzle. In this case, the air is mixed with the foam-water solution by the impingement of the fog streams. Contrary to what one might expect the foam is not broken down. The rate of expansion is not 10 to 1, but more nearly 2 to 1. In other words, the capacity of a tank truck is about doubled. The advantage of fog-foam is that it offers the same personnel protection as fog. Its principal use is on airport crash fires and on fires involving volatile liquids. The Navy uses it in sprinkler systems in some cases. Used on light fuels there seems to be no question but that it is more efficient than fog alone. However, there is no proof that it is any more efficient than water fog reinforced with a wetting agent and certainly the latter is much cheaper.

Foam Equipment

As previously stated, manufacturers of foam equipment have given little thought to the forest protection agencies. The equipment that has been built is of a special nature designed for a special purpose. For example, at Midway (between Tacoma and Seattle) a group of citizens have had designed a 150-gallon trailer pressure unit. Pressure is furnished by CO_2. A Y provides two 1-inch hose lines. One line uses fog and the other foam (with the pick-up method). This unit is already credited with having extinguished six fires.

The White River Lumber Co. of Enumclaw, Wash., has a speeder unit also CO_2-pressured and using foam. The tank has a 40-gallon capacity (400 gallons of foam). It is used for patrolling behind logging trains.

This company is now building two 100-gallon CO_2-pressured foam units. These will be heavily reinforced with railroad steel and provided with slings. They will be spotted at skidder settings. If a fire starts at the back end of the operation, they will be hooked on to the skyline and run back to the scene of the fire. Each unit will have 500 feet of 1-inch linen hose and a 150-gallon-per-minute foam nozzle equipped with a shut-off.

Other Possibilities

The writer has proved to his own satisfaction that it is possible to lay a foam line from a moving tank truck, and to backfire this line all in one operation. However, from the economic standpoint it is not feasible. It takes about 1 gallon of foam per linear foot in light fuels. Thus a 300-gallon tank truck could lay only about 3,000 feet of line. The same thing can and has been done with fog and the distance is more than tripled without adding the cost of the foam solution. Application for patent on the latter idea has been made.

And while we are speculating, another idea presents itself. It is not impossible that the future will see helicopter foam tankers. Such a unit might work as follows: The helicopter will take one or two men into a fire. After landing them, the pilot will return to the nearest road where, by prearrangement, he will meet a tank truck. He will land and fasten a canvas reinforced tank to his landing gear. This tank will be filled with water and foam in proper mixture. There will be 250 feet of plastic or linen hose equipped with a foam shut-off nozzle. The helicopter will then return to the fire. The hose line will be lowered and the machine rise to 200 feet. This altitude will be sufficient to provide about 100 pounds nozzle pressure. The ground men will then apply the foam to the fire. Or perhaps water-fog and a wetting agent will be just as effective.

Summary

In conclusion, then, we see that in discussing foam we must not overlook fog, especially wetter water fog. Each type of extinguishing agent has its place. It is a matter of knowing your equipment and what it will do. It should not be too far out of line to say that, considering cost, foam should be of value for:

(*a*) Back-pack cans where the addition of foam solution will produce 32 gallons of foam.

(*b*) Those agencies which, in addition to forest fires, are also charged with the responsibility for rural building protection.

(*c*) Agencies which operate along heavily used truck highways where the danger of large gasoline tankers catching fire can be expected. Fog will handle gasoline fires only if the entire burning area can be covered with fog, or in enclosed places where the effect of the steam produced aids in extinguishment. Foam, on the other hand, can be made to flow over the burning gasoline and bring about control.

Support for Canvas Relay Tank.—The portable tank used in relaying water from one pump to another can be made to stand alone by using one end of the standard folding canvas cot frame. By removing one end of the cot, leaving the other end and the middle legs, two sides and the uprights are formed. The other two sides of the frame can be made from the two end braces by trimming them flush with the sides. The framework folds and can be placed inside the tank before it is folded for storage.—RICHARD RAYBOULD, *Fire Crew Foreman, Cleveland National Forest.*

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