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FIRE CONTROL NOTES

A PERIODICAL DEVOTED TO THE TECHNIQUE OF FOREST FIRE CONTROL

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 22 Number 4

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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Forest Service, Washington, D. C.

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FOREST FIRE RESEARCH—THE NATIONAL PROGRAM[1]

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Joe West, Elk Creek Zone fire dispatcher, sat before the console of the fire control center and listened to the hum of the computers relaying their information to the dials and viewing screens around him. "Some different from the old days," he thought, "but just as hard on the nerves."

He glanced at the automatic typewriter at his elbow clattering out the stream of weather and fuel data coming in from robot measuring stations around the forest. Some scattered lightning predicted. He knew the airborne cloud-seeding generators had been active since early morning but the electrical field metering system showed him that a charge persisted in some localities. This meant a few strikes for sure.

Suddenly, the receiver for the heat-sensing tower network picked up its signal. Before he could turn his head to view the translucent forest map, the computers had done their work and an illuminated spot had appeared in the head of Pine Creek showing the location of the fire. He was glad the technicians had fed up-to-date information into the memory of the machines last week—it saved a lot of false alarms.

Joe automatically activated the television camera on Pine Mountain and on the screen quickly identified the smoke. He zoomed in for a closeup image of the hillside and verified the serious fuel conditions he remembered there. He checked the travel-time computer which reported immediately the time his first crew could arrive at the nearest heliport to be ferried to the fire. Again he thanked the "brain" of the machine which had been storing the radioed position of the work crews every 30 minutes. It had already selected its answer when the spotting mechanism located the fire on the map.

"Rapid initial spread," Joe thought. "Crews too far to rely on manpower alone." He hit the missile-launching lever for the pad nearest the Pine Creek area. As the missiles rose, Joe knew the quadrant guidance system would see that they reached the target area and then let their heat-sensitive noses home them in on the target. By radio, he set the proximity fuses to activate about 50 feet above the ground; that would be about right for the young growth and slash underneath. "Two loads of that new retardant should hold it," Joe thought.

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[1]Talk presented at Lake States Forest Fire Research Conference, Green Bay, Wis., March 8, 1961.

He radioed his crew, already alerted since the computer automatically signaled them the location of the fire. Nothing like checking on the machines. He filled in the crew on the conditions at the fire and told them the effects of the chemical bursts which he observed as he talked. "Just a routine trip, boys," he concluded as he settled back and punched the time verifier into the automatic daily log. "One minute and forty-two seconds," he mused. "Not bad."

Science fiction? Quite a bit. But not as much as some of you may think. Never before have the opportunities been so great as now for research and the application of scientific knowledge to help us solve some of our most trying forest fire problems. This is why we believe in a comprehensive program of forest fire research. Now, after such a long-winded start, I am going to talk about such a national program.

DEVELOPMENT OF A FIRE RESEARCH PROGRAM

Formal fire research began prior to 1920 in Western United States but it was about 1923 or 1924 when the first full-time fire research specialist was appointed. In the 1930's research was speeded considerably and approximately 15 men were spending full time and $100,000 a year on a variety of research projects from West to East.

As with most forestry research activities, World War II caused a drop in fire research. Even by 1952 there were still fewer fire research scientists on the job than in the 1930's. Since 1955, however, fire research efforts have climbed steadily until today, Federal, State, and private agencies spend an estimated $1,250,000 a year on fire investigations.

Description of the recent rapid growth of fire research in such material terms, of course, is not the whole story nor does it give us a sound basis for judging what kind of a national fire research program we need. Most of the fire research for the first 30 years was observational and empirical. However, great strides were made even though much progress resulted from a "cream skimming" approach. Look at the benefits that have come from fire danger measurement. Think of the many types of fire control equipment that have been developed. Aerial fire control achievements have been outstanding. The techniques of prescribed burning in many fuel types made rapid progress. Use of chemical fire retardants is one of the more recent and spectacular applications of empirical research results.

As beneficial as such research has been, it is not going to satisfy our needs for the future. If we continue to approach the most critical fire problems of the future with the same empirical methods we have used in the past, we are doomed to fail in bringing fire losses and costs to acceptable low levels. You may consider this to be an extreme point of view. Let us examine it further.

Fires are still causing unacceptable losses in many parts of the United States in some years. The risks to long-term management are high even in the South, where opportunities for profitable timber production are more advanced than in most other regions. Threats to other resource values, such as watersheds, are in places intolerable. Encroachment of urban developments and the presence of larger numbers of people who use the forests impose mounting handicaps on the fire control organization and add substantially to the difficulty of fire control. Thus, we see fire control costs steadily climbing to new highs every year. But we are still taking 95 percent of our losses from a comparatively few fires. We have not made progress in eliminating what we call the "unusual fire." Somehow we are going to have to learn enough of the why's and wherefor's to enable us to take strides heretofore impossible.

In research circles one can almost always get up a quick argument on definitions of basic and applied research. It is not my intent to start such an argument here. I do firmly believe, however, that future progress in fire control will require a much stronger emphasis than in the past on the more basic aspects of fire problems. Of course, this is not to say we will no longer need good applied research, utilizing fully any empirical approaches that look promising. Such research will continue to pay off. But to the extent we explore new principles and probe into the basic aspects of broad problems, the more productive will be the application phases of new studies. And the more likely we shall be able to solve the problem of meeting the "unusual" situations.

EMPHASIS IN THE NATIONAL PROGRAM

Then, what kind of research should we be doing in a national program? What should the emphasis be? One could make a long list of fire problems that need attention in such a program. Some of the more important problems are the most difficult and are the ones that we have not adequately attacked heretofore.

Basic research is badly needed to hasten the understanding of forest fire behavior. Knowledge of the combustion process and how various factors influence it is vital to progress in most phases of fire control. There is nothing unusual about the behavior of any fire anywhere. The combustion process is always controlled by environment according to specific physical and chemical laws. We just have not learned to interpret and apply these laws to every situation. When we do understand the factors that control fire behavior we can do a better job of predicting it. Only then can we make any real progress toward whittling down that small but significant group of fires that cause our greatest losses to resources, property, and human life.

Part of this research can be carried on to advantage in the laboratory. Here we can learn basic features of the combustion process and how the many individual factors of environment affect it. We are in this process now. Later through combined laboratory-field studies, scaling laws will be developed. Additional laboratory fire model studies will be needed to provide methods for predicting such things about fire as its rate of spread, spotting and crowning, and other important features of fire and its behavior in natural environments.

Prevention of man-caused fires has been prominently listed as a field deserving systematic investigation. A case study approach has been tried several times in the past. Only in recent years, however, has there been a serious effort to organize research on segments of the man-caused fire problem in a way that may lead to better answers than we have now. In any national program, greatly accelerated research on people is needed—what motivates them to act or not act in certain ways, how do we change habit patterns, what are the most effective and economical ways to achieve favorable results? We need more research on the effectiveness of all the common prevention measures and the development and evaluation of new ones. So far we have not cashed in on the huge background of knowledge in the social science field which has proved so effective in American advertising and other areas where influencing human behavior is involved.

We should not rule out the possibility of preventing lightning-caused fires. Many of you know about Project Skyfire in the northern Rocky Mountains. Here scientists are studying cloud physics and the development of electric fields in the atmosphere with the hope that ways can be found to reduce the potency of fire-starting electrical storms. At the present time, leads are encouraging but a great deal more basic research is needed.

A strong program of research must be started on chemical fire retardants and suppressants. In the past few years extensive use has been made of chemicals to retard fires and many fire control officers are sold on this method in spite of its high cost. We hope this confidence is not misplaced. But as of today, we have no sound method of evaluating the effectiveness of various retardants in controlling dangerous fires. Little research has been done to establish the conditions, timing, and techniques required for maximum payoff. We do not even understand the principle of the retardant or suppressant action in many cases. A lot needs to be done before we can prescribe the fuel coverage required for effective chemical fire control, the chemical droplet size, viscosity, and equipment best adapted to the use of chemicals.

EMPHASIS NEEDED ON APPLICATION OF PRINCIPLES

I could go on and on listing specific fields of research that need attention in a national fire research program. But there is one overriding thought that I want to dwell on for a moment. This has to do with *principles* that can be used in fire control.

It is a human tendency to hold more or less rigidly to the ways in which we usually do things. We have set patterns we tend to use in fire control. For example, robbing a fire of its fuel is a standard and effective way to control it. Thus, we try to improve on this method of control by inventing a better fire rake or fire plow or by using a bigger bulldozer. And I do not slight the great strides we have made through improved fire control equipment, apparatus, and machines. However, we still tend to send men to fires in 200-mile-per-hour airplanes and then give them an ax and shovel to do the job.

As all of you well know, there are three common ways to control a fire: (1) rob it of fuel, (2) cool the fuels below ignition temperature, or (3) exclude oxygen. Application of each of these methods requires energy. What are the various ways that energy can be delivered in time and place using one or more of the fire control approaches? I maintain we have not done a thorough job of examining the physical, chemical, and engineering principles required and available to do the job. How can you rob a fire of oxygen? What kinds of energy would it take? Can ways be found to reduce fuel temperatures? Water, of course, is one way but must it be pumped on in quantities? Are there more efficient ways to use water to contain the fire's energy? And so on and on. We must delve into principles in future research and examine all the newer approaches that such research might turn up.

Musing along these lines brought me to Joe West, the Elk Creek Zone fire dispatcher. Really, I am not talking specifically about all of his gadgets although at least prototypes of every one of them are available today. I do think that our success in meeting necessary future fire control goals will demand imaginative thinking and basic research of a kind we have scarcely begun. The problem of the large or "unusual" fire is not going to disappear. But daring imagination in research will be required to solve it.

The States have recognized that they have a big stake in the fire research field. The State Foresters' Association has passed a series of resolutions recommending a stronger program. Although State forestry organizations are not often staffed to do research themselves, except perhaps in the equipment development field, several States are actively speeding up the research in which they are most interested through joint action under cooperative agreements with the Forest Service and with universities.

Research at State universities has been worthwhile and can be increased especially in some basic physics and chemistry aspects of fire problems. Their social science and psychology specialists can be enlisted in fire prevention research and their engineering departments can contribute in many ways. Private industries have boosted fire research in the past and will continue to do so, especially in perfecting fire equipment.

In the years ahead we are not going to have a truly *national* fire research program unless all responsible agencies and groups —whether they be Federal, State, or private—move ahead on a well-coordinated research program. Such a national program will require good leadership, strong financing, well-trained scientists, good facilities, and worlds of imagination. If we can mix these ingredients wisely and well, we may be recruiting and training a Joe West for Elk Creek before you know it.

RESPONSIBILITIES FOR FUTURE NATIONAL PROGRAM

Who should participate in a balanced national program of forest fire research? Actually, a national program must be one supported by all agencies and institutions responsible for and equipped to do fire research. Fire is a natural phenomenon but one that is no respecter of political boundaries and ownerships. Hence the Federal Government plays a big role in fire research.

The Forest Service is gradually strengthening its fire research program. We have recognized the need for more emphasis on basic research and have been obtaining better facilities to round out this side of the research program. We now have two large and modern fire laboratories: one at Missoula, Mont., and one at Macon, Ga. The latter was constructed with State funds and is staffed and operated by the Forest Service under a cooperative arrangement. A third fire research laboratory will be started in the near future at Riverside, Calif. While the special equipment, instruments, and facilities available at the three large laboratories will provide for a stepped-up basic research program, applied research will continue and be further strengthened. The Forest Service's fire research program will be expanded at other than the three locations mentioned. For example, we expect to continue to build up a fire research program in the Lake States.

☆ ☆ ☆

Label the Hydraulic Track Adjustment Fitting

Some of the newer model fire plow tractors are equipped with a hydraulic track tension adjustment. Adjustment is made by applying grease, with a standard hand grease gun, through a standard fitting. This fitting is in plain view, but it cannot be distinguished from other chassis fittings. Therefore, the possibility exists that someone unaware of this will tighten the tracks while greasing the tractor. Tracks that are too tight result in excessive wear of the track rails and rollers. To prevent this from happening, we have lettered "DO NOT LUBE" at the track adjustment fitting. This requires about 5 minutes of time and a small amount of paint, which is cheap insurance to protect a large investment.

An Allen wrench is needed to release the pressure on too tight tracks, and one of these should be carried in the tractor toolbox at all times.—Howard W. Burnett, *District Ranger, Georgia National Forests.*

SELECTING FIRE CONTROL PLANNING LEVELS BY BURNING INDEX FREQUENCIES[1]

ARTHUR R. PIRSKO
Forester, Pacific Southwest Forest and Range Experiment Station, U.S. Forest Service

How do you pick the base level of burning conditions for planning a fire control organization? Hiring and equipping full-time crews to handle the worst possible situation is obviously not economical, since extreme burning conditions occur infrequently. The more realistic practice is to set up a full-time organization adequate for normal or somewhat above-normal burning conditions and then fill in with emergency crews when the situation demands. The planner, knowing his production goals and values he protects, must decide on a cutoff point for the size of full-time and emergency force he can maintain economically. But selecting the point between normal and above normal burning conditions has always been a problem.

Planning concepts for fire control organizations have long been tied to normal burning conditions.[2] Worse-than-average conditions were recognized to exist, but the severity of burning conditions could not be determined until after the fire season. Then, severity was described by the percentage of fires reaching over 10 acres in size and the total area burned in the most difficult years. Show and Kotok[3] stressed the importance of aiming protection effort at controlling fires under average worst conditions, but they had no burning index to serve as a yardstick. More recent fire control planning, as in Canada, relates organization plans to average burning indexes.[4] The problem in planning, though, is to measure above-average conditions.

One method arbitrarily took the "average worst day" as the planning base for "average bad" conditions. The approach was first to select an "average worst year"—defined as the third worst in the last 10 years as determined by the sum of daily burning indexes. Then, for that particular year the average burning index of the worst 15 percent of the days was computed and taken as the base level. Such a base must not be applied too widely. If it is, it may not allow for geographical variations in climate.

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[1]Issued Jan. 1961 as Pacific Southwest Forest and Range Expt. Sta. Misc. Paper 55.

[2]Dubois, Coert. Systematic fire protection in the California forests. U.S. Dept. Agr. Unnumb. Pub., 99 pp., illus. 1914.

Hornby, L. G. Fire control planning in the northern Rocky Mountain region. U. S. Forest Serv. North. Rocky Mountain Forest and Range Expt. Sta. Prog. Rpt. 1, 179 pp., illus. 1936. (Processed.)

[3]Show, S. B., and Kotok, E. I. The determination of hour control for adequate fire protection in the major cover types of the California pine region. U. S. Dept. Agr. Tech. Bul. 209, 47 pp., illus. 1930.

[4]Beall, H. W. Forest fires and the danger index in New Brunswick. Forestry Chron. 26 (2): 99–144. 1950.

A method of selecting a planning base that will show the probable frequency of a given burning index is reported here. It was devised for use with the California fire danger rating system, in which the burning index is rated on a scale of 0 to 100 and expresses the expected fire spread and intensity as influenced by weather. The index, therefore, is a good measure of relative job size—the higher the index, the more men and equipment will be needed to meet a desired fire control goal in a given period.

The recent revision of the California fire danger rating system[5] showed that an area the size of a national forest could have as many as seven different climatic regimes. When differences in weather, fuel, and topography were considered, the State as a whole had to be divided into 144 fire danger rating areas. Therefore, base levels were computed for fire control planning in each of these areas in the California Region.

The approach chosen was to determine from fire weather records the frequency of occurrence of each burning index. Data used were the daily burning indexes in a 6-year period, for July and August in northern and central California, and for July, August, and September in southern California. Each frequency was expressed as a percent of the total, the percents were cumulated, and the cumulated percents were plotted on arithmetic probability paper.

The resulting charts made it easy to see the frequency of "easy," "normal," or "bad" days. Planning levels can be set to cover a specified percent of the days during a fire season, and the burning index to be expected at this emergency point can be read from the chart. In the California Region, the planning level selected for the fire control organization is 90 percent frequency; the corresponding burning index is called the "area base burning index."

The variability of planning levels can be illustrated by probability curves for four fire danger rating areas (figs. 1–4). In these areas, base indexes range from 12 in the north coast mountains, to 29 in the central coast, and to 17 and 43 in 2 adjacent southern California areas. This means that in the central coast area, for example, 90 percent of the days will have a burning index of 29 or lower, and 10 percent of the days will have a burning index above 29.

Such charts help a planner visualize weather differences between areas. The average burning index, which can be expected half of the time, is not as much alike in adjacent areas as one might expect. In the 2 southern California areas, for example, one averages 11 while its neighbor averages 26. The extreme conditions also differ markedly; in one the burning index is 46, in the other 88.

New charts need not be prepared if management is intensified to increase productivity. As the acceptable fire loss becomes less,

[5]Schroeder, M. J. Development of the California fire danger rating system. Amer. Meteorol. Soc. Bul. 39 (3): 178–9. 1958. (Abstract.)

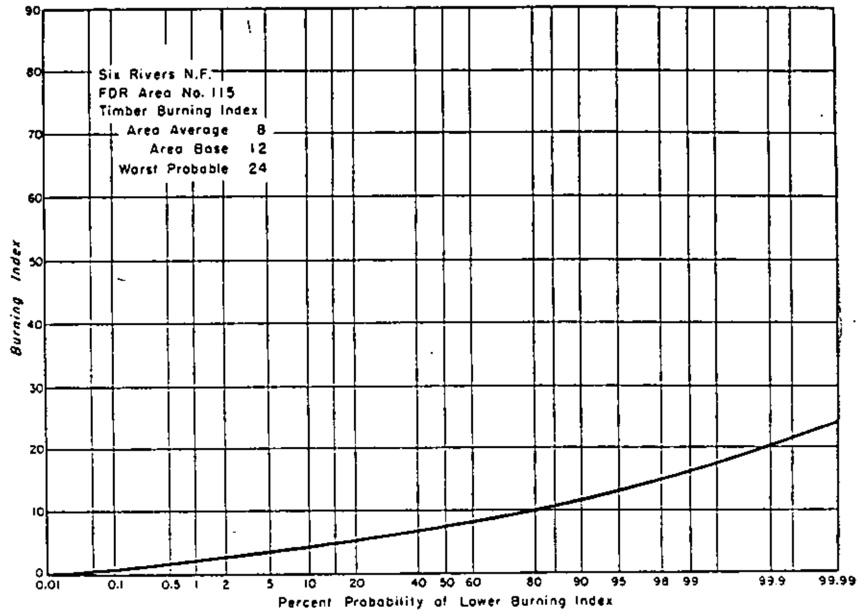


FIGURE 1

the frequency level can be increased—say from 90 to 95 percent—and a new area base can be read from the chart.

Thus, cumulative probability curves give a planner flexibility. He can rate each area on its distinctive weather conditions and

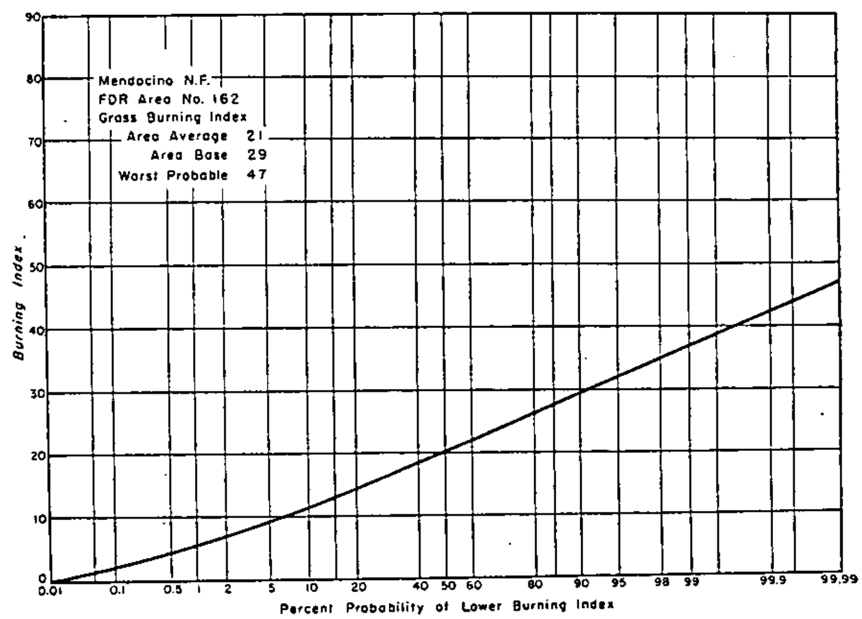


FIGURE 2

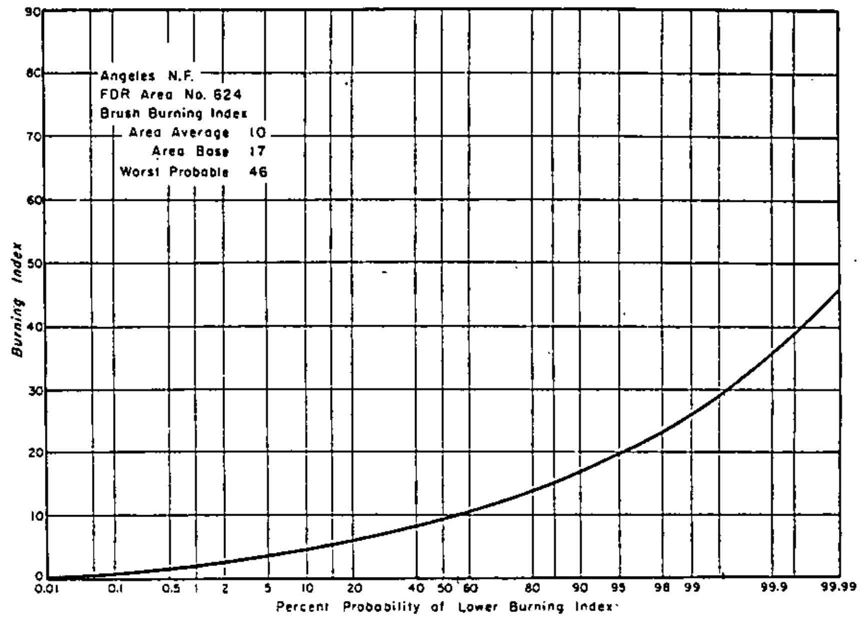


FIGURE 3

easily adapt his organization to future changes in the job load. To produce such curves, good fire weather records are needed, and access to machine data processing is desirable. Frequency analysis by hand computation is a laborious, costly task.

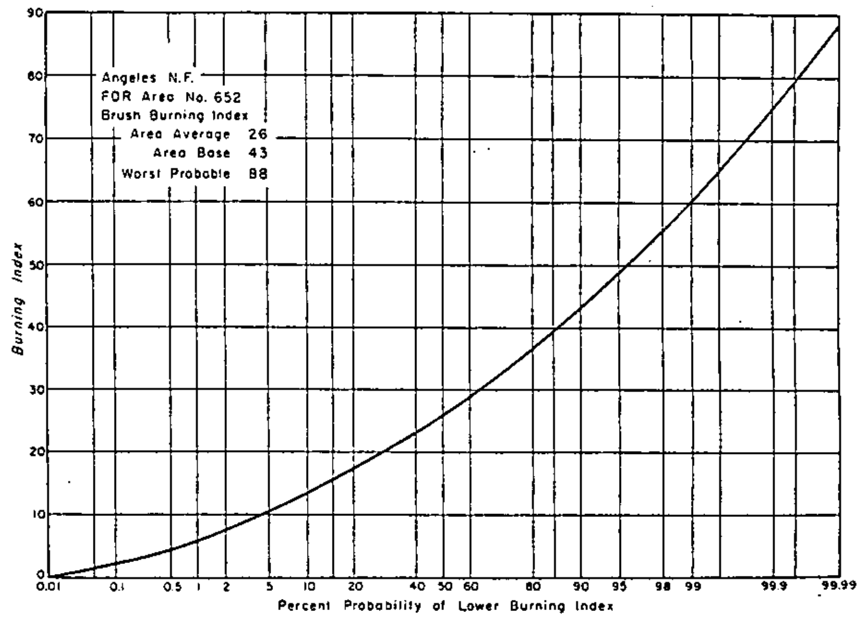


FIGURE 4

TRACTOR-PLOW UNITS ON APPALACHIAN MOUNTAIN FIRES

Robert R. Swiger
District Ranger, Cherokee National Forest

Tractor-plow units have been successfully used for fire control in the South for many years. Development and use were greatly stimulated during World War II when the manpower shortage was keenly felt. Most people felt, however, that the units were for use in the flatwoods and were of little or no value in the mountains. Contrary to popular belief, relatively small tractors with plows can be used efficiently for fire control in the Appalachian Mountains. Such units in operation in Tennessee have proved conclusively that they have an important place in fire control.

The plows presently used with the small tractors are middle-buster-disk type with three point hitch (fig. 1). This plow makes a very clean line about 5 feet wide. In average Appalachian terrain where the plowing is continuous, such a tractor and plow combination will construct about 150 chains per hour. In terrain where the plowing must be interrupted to get the tractor back on top of the ridges to plow downhill, this average may drop to about 45 chains per hour.

It has been determined that the average rate of handtool line construction in the mountains is from 3 to 4 chains per man-hour. This production is gradually reduced as the men tire, whereas the

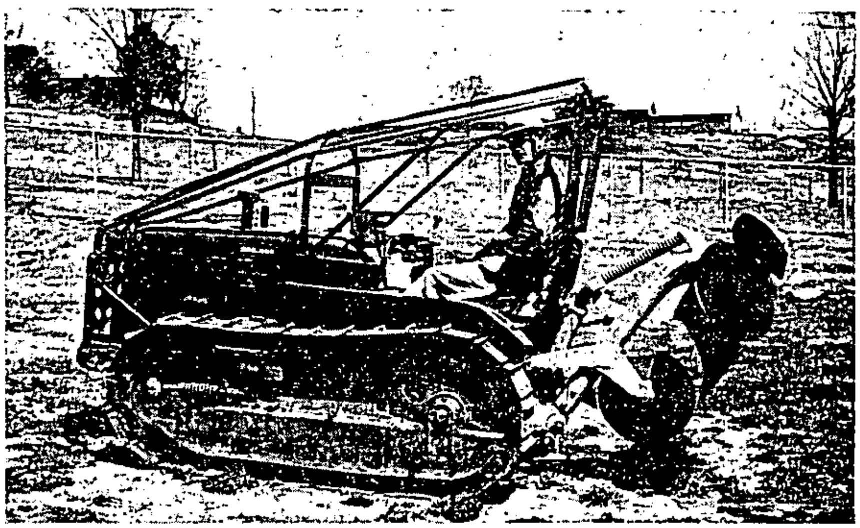


Figure 1.—Tractor with plow in raised position.

plow unit production normally is steady. The hand line is also not as wide nor as clean as that constructed with the plow.

Construction of plowed firelines in the Appalachians differs from that in the flatwoods. Very few of the fires can be controlled by starting in one place and then plowing forward until a complete line has been built at the head or around the fire. In the mountains, steepness of terrain prohibits construction of a plowed line in one direction all the time. On steep slopes the line is constructed downhill whenever possible. In plowing uphill, the line may be started in a favorable location and continued until adverse grade is encountered. Line construction is then discontinued at this point, and the tractor is backed up the slope when necessary, as a safety precaution. It is "deadheaded" up the ridge and put into position to plow down the slope and join into the discontinued line. This means, of course, that the tractor would have to go back up the same ridge again to continue the line for encirclement of the fire.

Under normal conditions it has been found possible to plow safely downhill on slopes up to 65 percent. It is imperative, however, that good scouting precede the tractor-plow unit. On the steeper slopes, if an unplowable area is found, another route must be selected before the tractor starts its descent. Without proper scouting, the plow may get into a situation where it is impossible or unsafe to continue in a forward direction. This might be because of rock ledges, bluffs, thick and large timber, or down logs and snags. It may be impossible to reverse direction and return to the top because of steep ground, loose rocks or rock ledges. Escape to either side will probably also be impossible because of the side slope which would cause the tractor to turn over. The 20-30 hp. crawler tractor-plow units can generally plow safely on a side slope up to 35 percent, as compared with the 65 percent down slope. A mistake in scouting can be time consuming, costly, and dangerous. The scout should be a man capable of operating the unit, and who knows exactly what its limitations are.

An ideal-sized tractor-plow crew for the mountains is three men. Three men can ride in the cab of a plow truck, which means only one vehicle is needed for transportation of the tractor-plow and crew (fig. 2). One man is the operator, one the scout, and the other is the followup man. As mentioned earlier, the scout must be a competent man and preferably an experienced plow operator. He must be able to recognize all the dangers and problems that lie ahead of the plow. The followup man removes any material which is left in the fireline or on turns where the plow is raised. He also helps the tractor operator at any time he is needed, such as when the plow becomes fouled.

There must of course be a followup crew behind the plow crew. They backfire from the fireline and hold it. The size of this crew would depend on factors such as the size of the fire, burning conditions, and type of fuel. One tractor-plow unit could keep as many as 25 followup men busy under some conditions.

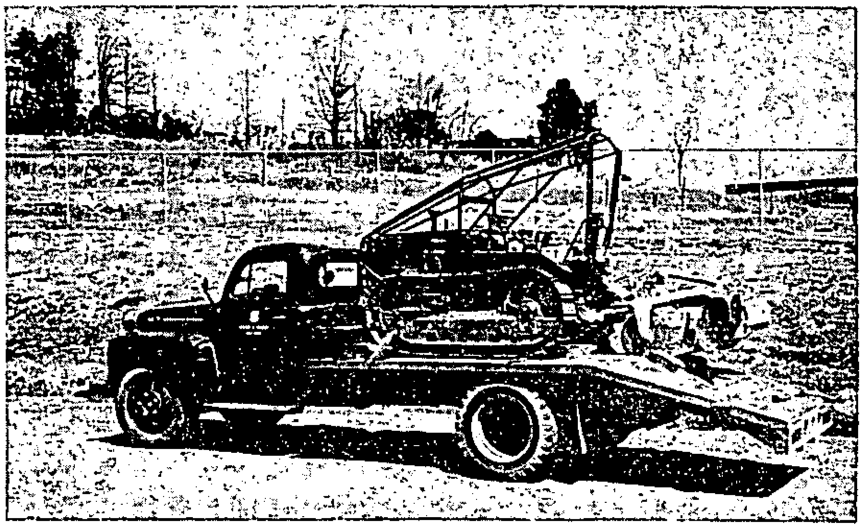


FIGURE 2.—Plow unit on truck ready to roll.

In the Appalachians, the terrain is generally rather steep, and there are many areas which have rather heavy concentration of heavy fuel. Because of these features, mopup is normally very heavy. For example, in recent years mopup on the Hiwassee District of the Cherokee National Forest has averaged about 80 percent of the total man-hours spent on fires. Therefore, in areas where manpower is short, as it is in much of the Appalachians, the tractor-plow unit is used in initial attack action whenever possible.

Some mountain fires occur in terrain where plowing is impossible, or where only partial plowing is possible. In his estimate of needed suppression forces the dispatcher must be able to determine if a plow can be used and to what extent. The secret to successful use of the plow, therefore, is a good plowable area map.

For a long time tractor-plow units were used only sparingly in the Appalachians, or not at all, because it was not known what could be accomplished with them. Now that the tractor-plow units have proved that they can reduce the manpower needs in firefighting, they are used each year on a larger percentage of fires in the Appalachian Mountains.

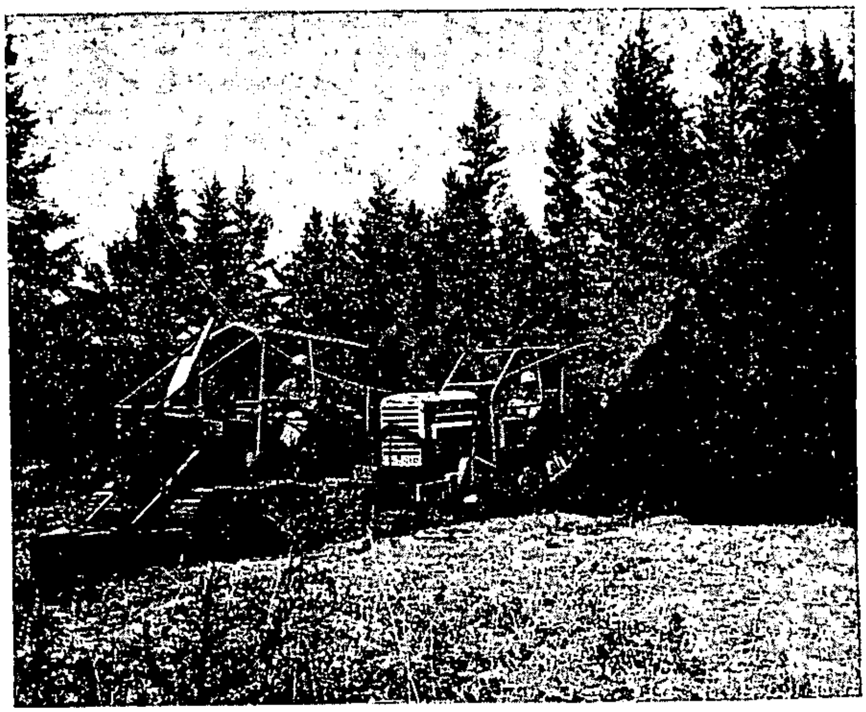
SAND-THROWING MACHINE FOR FIGHTING FOREST FIRES

STEVE SUCH
Supervisor, Forest Fire Experiment Station,
Michigan Department of Conservation

Designed and constructed at the Forest Fire Experiment Station, Roscommon, Mich., as a cooperative effort of the State of Michigan and the U.S. Forest Service, the sandthrower is an experimental development to test the effectiveness of sand or loose dirt in suppressing forest fires.

This machine is intended for direct or indirect attack, and it has shown a versatility still not available in other types of forest fire equipment. It is powered by a 130-horsepower industrial engine, operating through a power train to drive the large, vaned disk at the rear of the machine. The disk removes sand or dirt in a continuous motion; hydraulic controls are provided for directing the "stream" to the area requiring action.

The sandthrower moves through the woods at 1 to 2 miles per hour and it is capable of throwing 2 to 4 yards of sand or dirt per minute at velocities approaching 70 miles per hour and trajectories from flat to elevations of 25 feet. Effective distances



have measured from 20 to 50 feet. Fires are quickly extinguished as the mass of sand or dirt comes into contact with the burning fuels.

Future plans call for the design of a self-contained unit mounted on a D-4 crawler tractor. It is hoped that ultimately a simple, powerful, and thoroughly practical machine will be economically feasible.

CORRELATION OF WEATHER TO FIRE SPREAD IN GRASS AND BRUSH FUELS ON THE SNAKE RIVER PLAINS IN SOUTHERN IDAHO

RICHARD E. TRAYLOR
Fire Control Aid, Bureau of Land Management

Rate of spread of fire in different fuels under varying climatic conditions is the key to many fire control decisions. Controlling factors that govern rate of spread for any particular fire are the fuels and the environment, the latter consisting of air moisture, temperature, wind, and other related factors such as barometric pressure.

There are several ways to approach the study of rate of spread of wildfires. One is to base rate of spread on perimeter increase. The second is to use the concept that a fire generally will move in a particular direction. This direction would be the forward spread of the fire. Using this concept, the rate of spread is measured in a forward movement in chains per hour. I based my study on the forward rate of spread, because of the nature of the fuels involved.

The study, designated as "Project Fire Spread," was initiated in the Boise District of the Bureau of Land Management, with headquarters at Boise, Idaho. Data were gathered for the project within a 75-mile radius of Boise during the 1959 and 1960 fire seasons.

"Project Fire Spread" was designed to determine the effects of weather, slope, and fuel types on the spread of wildfires.

The main fuels were sagebrush (*Artemisia tridentata*) and cheatgrass (*Bromus tectorum*). Fuel types were delineated as follows: (1) Sagebrush—65 percent sagebrush, with the remaining cover scattered cheatgrass and annual weeds; (2) cheatgrass plus sagebrush—55 percent cheatgrass forming a complete cover beneath the sagebrush; and (3) cheatgrass plus other grasses—the cover being cheatgrass and bunchgrasses.

The basic data gathered included dry bulb temperature, relative humidity, dew point, windspeed, burning index, plant species, plant volume and continuity, and forward rate of spread in chains per hour on going fires. Weather measurements were taken on the fireline with a Forest Service Ranger Belt Weather Kit, and a portable, hand-held anemometer was used to obtain windspeed measurements. Rate of spread was measured either by pacing or measuring the distance by tracking the fire with a truck or four-wheel-drive vehicle.

The data were statistically analyzed on an IBM 709 machine. The program used is designated as the BIMD 06 multiple regression program. The data processing work was done by the Western Data Processing Center, Graduate School of Business Administration, University of California.

Output of this program includes the following, for all possible combinations of the variables that were used: (1) Sums, (2) sums of squares, (3) means, (4) standard deviations, (5) cross product sums, (6) cross products of deviations, (7) correlation coefficients, (8) analysis of variance for the multiple regression, and (9) computed F values.

Variables used in this analysis were relative humidity, dew point, burning index, average windspeed, and dry bulb temperature. The variables of fuel type, topography, and fuel type continuity were separated from the other variables for sets of observations.

The study resulted in four regression equations from which four rate-of-spread tables were calculated for the following sets of observations: 1. Fuel type, sagebrush; continuity, uniform; topography, flat to rolling. 2. Fuel type, sagebrush; continuity, patchy; topography, rough to steep. 3. Fuel type, cheatgrass plus sagebrush; continuity, uniform; topography, flat to rolling. 4. Fuel type, cheatgrass plus other grasses; continuity, uniform; topography, flat to rolling.

The final equations do not necessarily represent the ultimate combination of variables, but they do represent the best answers obtainable for the range of data involved.

LIQUID NITROGEN AND SOLID CARBON DIOXIDE AS FOREST FIRE SUPPRESSANTS

ARTHUR R. PIRSKO, *Forester*, and LEO V. STECK, *Consultant in Chemistry, Pacific Southwest Forest and Range Experiment Station*

Fire retardants in current use are effective only on the cooler flanks of fires.[1] Because of this, firefighters have long hoped for a suppressant that will stop the rolling front of a fire in trees or brush. Exploratory tests were made in 1960 of two materials that seemed to offer promise: liquid nitrogen and solid carbon dioxide. Because these two gases are extremely cold (solid carbon dioxide, —78° F.; liquid nitrogen, —195°), it was thought that they might help cool a fire. Storage and handling problems created by their coldness appeared capable of solution by techniques designed by industrial and military users.[2]

TEST PROCEDURE

Liquid nitrogen was poured on test fires from small Dewar flasks or dropped in a polyethylene bag that shattered on impact. It was also allowed to flow down a 10-foot galvanized iron trough, in order to simulate liquid and gaseous nitrogen approaching a forest fire down a hillside.

Solid carbon dioxide was supplied as a 50-pound bag of pulverized material. Much of it had coalesced during storage, and although it could easily be broken up by stirring vigorously with a metal rod, some remained as lumps ¼ to 1 inch in diameter. It was shaken out from a container held above the fires.

For the laboratory experiments, fire test cribs were built according to a pattern described by Fons, et al.[3] The cribs were 6 inches high, 8 inches wide, and 17 inches long, and they were made of ½-inch ponderosa pine dowels on 1¾-inch centers. The dowels were bonded at each junction with resorcinal-formaldehyde resin glue. Cribs averaged approximately 1,350 grams in weight. Their moisture content was not determined, and they were used without ovendrying. These cribs were placed on a 6- by 6-foot iron pan and ignited with burning hexane at several places in the bottom layer of dowels.

A directional radiometer was wired to a recording potentiometer to measure relative radiation from the fire. When radia-

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[1]Miller, H.R. Chemical fire retardants for wild land fire control. U.S. Forest Serv. Forest and Range Expt. Sta. Res. Note 105, 5 pp. 1959.

[2]Anonymous. Pressure's on in cyrogenics. Chem. and Eng. Newsletter 37 (13): 50–51. Mar. 30, 1959.

———— Cyrogeneering. Indus. Bul. 375. Arthur D. Little, Inc. Cambridge, Mass. May 1960.

[3]Fons, W. L., H. D. Bruce, W. Y. Pong, S. S. Richards. Project fire model. U. S. Forest Serv. Pacific Southwest Forest and Range Expt. Sta. Summary Prog. Rpt., 56 pp., illus. 1960.

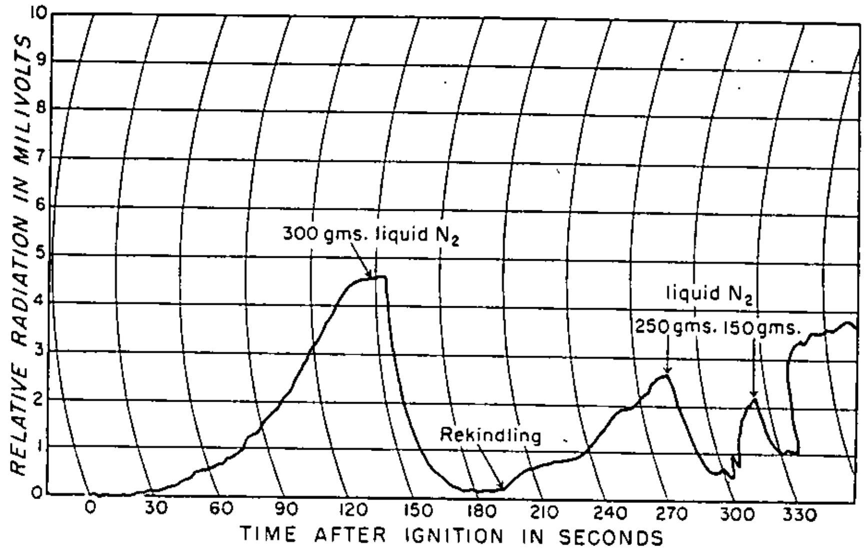

FIGURE 1.—Radiometer trace for application of liquid nitrogen on test fire.

tion was judged from the potentiometer trace to be at a peak, the suppressants were applied to the fire (fig. 1).

For tests outside the laboratory, a large crib was made of acacia bolts 6 inches in diameter and 24 inches long that were split lengthwise. Six bolts were stacked three tiers high with excelsior and small pieces of wood for kindling. At maximum intensity of the acacia fires, liquid nitrogen or solid carbon dioxide was poured directly on the fires from a polyethylene beaker.

EXPERIMENTAL RESULTS

LIQUID NITROGEN

When 300 grams of liquid nitrogen was poured down a metal trough that was 3½ feet from the burning crib in the laboratory, the flames went completely out, but the fire rekindled in a very short time. Fire charring of the dowels became deeper as time passed, and additional applications of 300 grams of nitrogen had no appreciable effect. A similar result occurred with trough application of 750 grams of nitrogen on another crib and with direct application from a flask—the flames were temporarily extinguished until rekindled from deep charring.

With the crib fire of acacia bolts outside the laboratory, results were even less encouraging. Although nearly all the flames were knocked down temporarily, they flared up again within a few seconds.

SOLID CARBON DIOXIDE

About 250 grams of pulverized carbon dioxide was shaken from a container over the laboratory fire. When solid carbon dioxide surrounded the dowels, the flame was extinguished. Other parts of the crib continued burning. An additional 1,000 grams of carbon dioxide extinguished all flame but left glowing embers at one end of the crib. These embers did not rekindle the fire, but they continued to glow until more carbon dioxide was applied.

On the outside fire, 2,000 grams of carbon dioxide was shaken from a container. Only where the chemical hit the logs was the fire extinguished. Wood not in contact with the carbon dioxide continued to burn. A 20 m.p.h. wind dispersed any carbon dioxide gas from the immediate fire area.

CONCLUSIONS

Even though applied to crib fires at the rate of 1 to 2 pounds per square foot of burning area, liquid nitrogen apparently did not absorb enough heat to reduce the temperature of all the burning wood below the ignition point, and the gaseous nitrogen did not reduce the oxygen content of the air below that necessary to support combustion.

Carbon dioxide was better than liquid nitrogen in extinguishing the small crib fire in the still air of the laboratory, but it was poorer than liquid nitrogen when applied to the larger outside crib. It was not possible to extinguish all the flames in the outside crib even with an amount of material far in excess of what could be considered practical for field use.

Handling liquid nitrogen for these tests was about as difficult as handling hot water. Comparable safety precautions were used to avoid spilling on skin or holding uninsulated containers with bare hands. Solid carbon dioxide was more difficult to apply than liquid nitrogen.

On the basis of these tests, further study of liquid nitrogen and solid carbon dioxide as fire suppressants does not seem warranted.

LIGHTWEIGHT LOADING RAMPS FOR TRACTOR-TRANSPORTS

HUGH MOBLEY
District Ranger, Kisatchie National Forest

When beds were built for new tractor-transports on the Catahoula Ranger District, a new lightweight loading ramp was designed and constructed. The old ramps constructed of steel were heavy and cumbersome and required two men to handle. On some transports wooden ramps were used but these were also cumbersome and heavy and continually required repairs.

The ramps had to be strong enough and wide enough to accommodate a crawler-type tractor (approximate weight 5,000 pounds), and the narrow-gage wheels of the plow. In addition, each ramp should be light enough for safe handling by one man (figs. 1 and 2).

The ramps are constructed of three 3-inch aluminum alloy channels (7 feet long) with angle-iron cleats (1¼ by 1¼ inches and 18 inches long) spaced 7¾ inches apart. Angle-iron rather than aluminum cleats are used because aluminum is too soft to withstand the wear of the tractor tracks. The angle-iron cleats are welded to flat steel straps (⅛ by 1½ inches) which are bolted to the top flange of the 3-inch aluminum alloy channels (fig. 3).

The steel straps are welded to a steel plate or strap across the top end of the ramp to keep the tracks from breaking them loose. These steel straps save wear from the tractor tracks to the aluminum alloy channel. A hole is cut in the angle iron at the bolt location, which leaves the bolt head recessed (fig. 3). Another

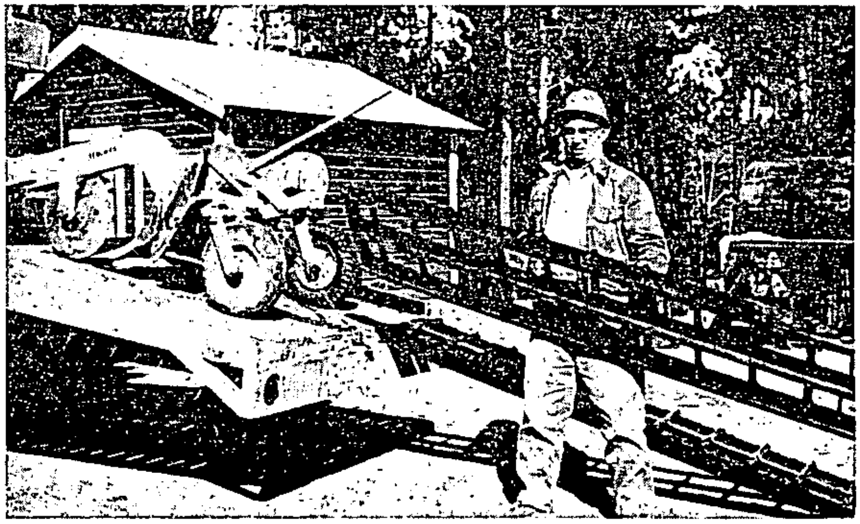

FIGURE 1.—Lightweight aluminum loading ramp easily handled by one man.

method is to bolt the strap to the aluminum channel first and then weld the angle-iron cleats on over the bolt heads. Either way the bolt heads are protected by the angle-iron cleats and are not subject to being sheared off by the tractor tracks. To provide added rigidity to the ramp, two 5/16-inch bolts inside pipe spacers are used between the three channels.

To hold the ramp to the truck while loading and unloading the tractor, a steel plate (1/4 by 3 inches) is bolted to one end of the aluminum channels. This plate fits over two lugs on the truck bed (above license plates in fig. 1) and holds the ramp in place. One end of each steel strap is welded to this plate.

The ramps, 7 feet long by 18 inches wide, can be carried on the bed of the truck outside the plow and held in place by spring clamps. When carried in this position they are not as subject to mud and dirt from the rear wheels as they would be if carried under the bed.

The weight of one aluminum alloy ramp is about 65 pounds compared to approximately 119 pounds for similar ramps with steel channels. One man can safely handle the aluminum ramps. It required two men to handle the steel ramps.

The cost of materials and labor for one aluminum alloy ramp was $94; the estimated cost of a steel ramp was $81. It is felt that the $13 difference in cost is more than made up by the ease, safety, and convenience in handling. Ramps for tractors heavier than those shown here can be constructed by using either larger aluminum alloy channels or I-beams.

These aluminum alloy ramps have been in use for one fire season and have proved very satisfactory and serviceable. One set of ramps has been used an estimated thirty times for loading and unloading with no appreciable signs of wear.

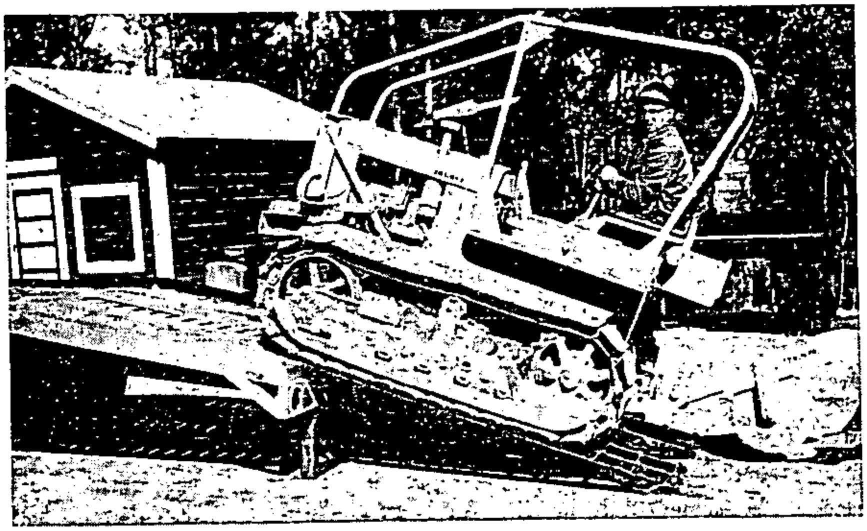

FIGURE 2.—Unloading tractor by means of two aluminum alloy ramps.

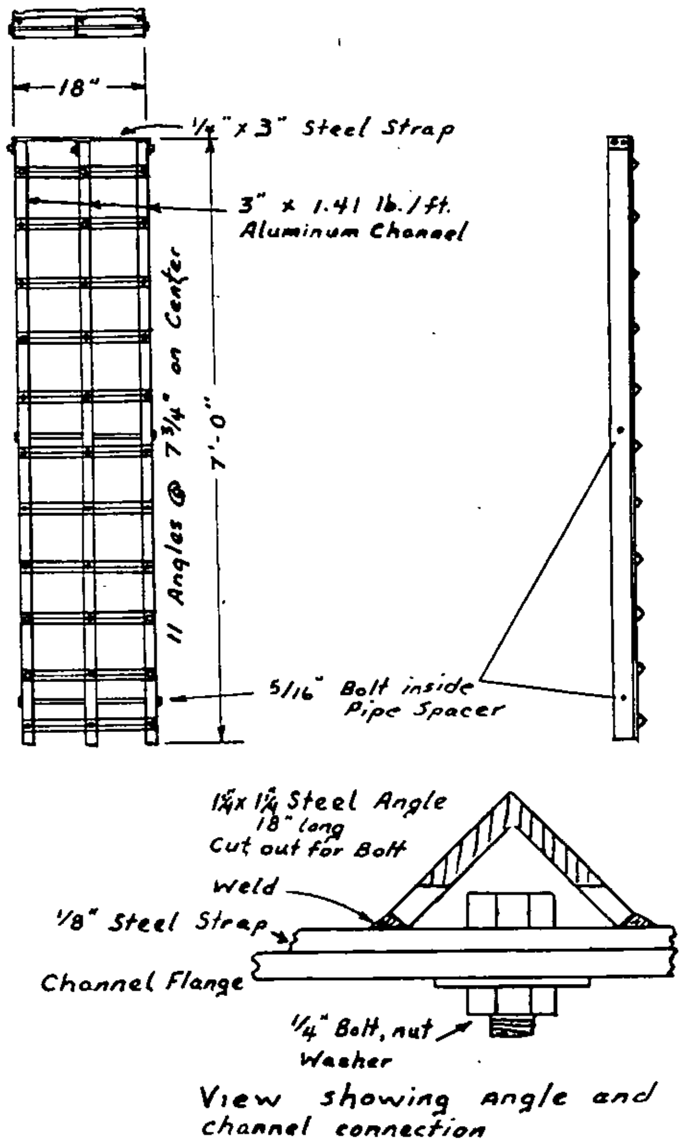

FIGURE 3.—Construction details of aluminum loading ramp.

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[Jan., pp. 1-26; Apr., pp. 27-72; July, pp. 73-102; Oct., pp. 103-130.]

INFORMATION FOR CONTRIBUTORS

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The title of the article should be typed in capitals at the top of the first page, and immediately underneath it should appear the author's name, position, and unit.

Any introductory or explanatory information should not be included in the body of the article, but should be stated in the letter of transmittal.

Illustrations, whether drawings or photographs, should have clear detail and tell a story. Only glossy prints are acceptable. Legends for illustrations should be typed in the manuscript immediately following the paragraph in which the illustration is first mentioned, the legend being separated from the text by lines both above and below. Illustrations should be labeled "figures" and numbered consecutively. All diagrams should be drawn with the type page proportions in mind, and lettered so as to permit reduction. In mailing, illustrations should be placed between cardboards held together with rubber bands. *Paper clips should never be used.*

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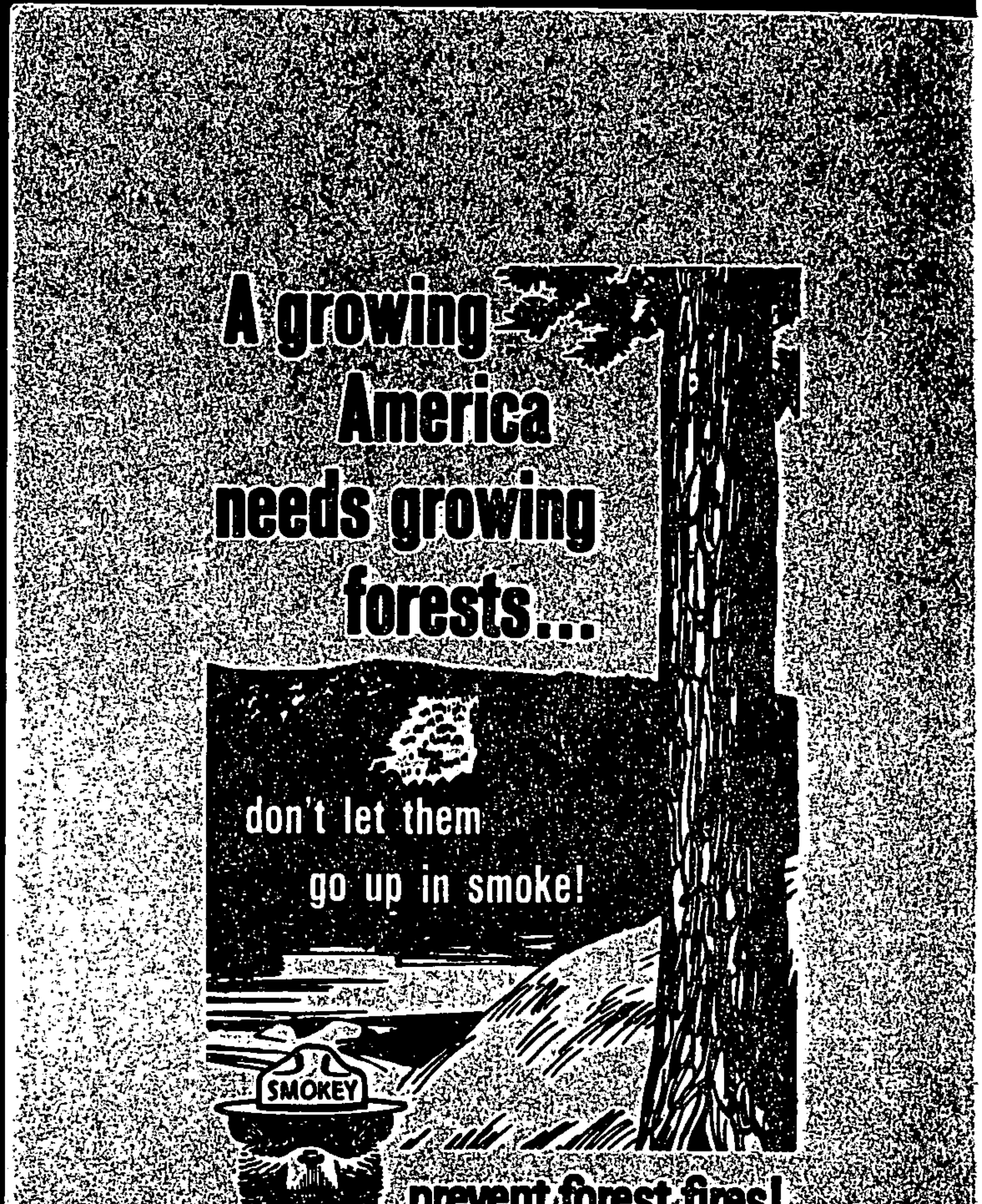
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