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FIRE CONTROL NOTES

A PERIODICAL DEVOTED TO THE TECHNIQUE OF FOREST FIRE CONTROL

VOL. 24 NO. 3
July 1963

Forest Service
UNITED STATES 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 24 Number 3

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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, firefighting, 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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MANAGEMENT DESIGNS FOR CONFLAGRATION CONTROL, DUCKWALL TEST UNIT[1]

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The Problem

Many wild land management areas in California contain extensive continuous stands of highly flammable vegetation. These areas have a high frequency of very high to extreme fire danger days each season. Use is high, with peaks of intensive use during the fire season. The combination of fuel, use, and fire danger results in conflagration type fires that quickly overwhelm the normal initial attack organization, cause extensive loss of resources, and require high suppression expenditures—as illustrated in California by the extensive timber losses of 1955, 1959, and 1960.

The cost of maintaining a fire control organization to meet these conditions would be prohibitive; therefore, the problem must be attacked by doing something about the fuels on the ground.

Fuel Treatment

The size, complexity, and cost of a direct fuel treatment program are also prohibitive. Slash disposal on timber sales, firebreaks, prescribed burning, and brush clearing for forage production are some of the programs being effected piecemeal. To secure the desired results, the concept to integrate fuel treatment with all of the multiple use management programs on these high hazard areas on a *complete area management plan basis* was developed.

This concept was entitled "Management Designs for Conflagration Control." It could also be called Integrating Fuel Management with Multiple Use Management.

The Duckwall Test Unit

To determine how this concept could best be carried out, a test area was selected. The Duckwall Unit on the Stanislaus National Forest met the criteria for an active multiple use program, high hazard fuels, and a history of severe conflagrations. Extensive high-value timber stands and recreation areas lie within and contiguous to the area. The Duckwall Unit consists of about 40,000 acres clearly defined by the middle fork of the Tuolumne River on the south, Clavey River on the east, Duckwall Ridge on the north, and the north fork of the Tuolumne on the west. Elevations vary from 900 feet in the canyons to 5,800 feet on Duckwall Ridge.

Cover types consist of annual grass on the lower river slopes; woodland-grass on the upper canyon slopes and lower spur ridges, with dense brush fields taking over nearer the timber belt. Timber

[1] The concept and program for the test unit was worked out by a management team from the California Region, Pacific Southwest Forest and Range Experiment Station, and the Stanislaus National Forest.

types range from young pure ponderosa pine stands to mixed conifer in the intermediate elevations and to some sugar pine-fir areas at higher elevations. Some small patches of oak are interspersed with the conifers.

Soils range from Bandarita, which has a low vegetative capability (annual grass and light brush) ; Mariposa, with a capability for hardwoods, heavy brush, and some pockets of conifers in the deeper soil areas; and Josephine soil, with a high capability for coniferous timber.

Precipitation amounts to 20-25 inches of rain annually, normally occurring from November to April. There is some snowpack on the upper elevations. Summer climate is hot and dry. Temperature often exceeds 100°, and humidities fall to 5 percent. Daytime winds are normally strong enough to result in many days of high to extreme fire danger.

About 20 percent of the unit is in private ownership. Most is commercial timberland, some tracts are patented mines, and some are small homesteads.

Management history shows two grazing allotments with some range revegetation done on both Government and private land, three public campgrounds, and some wildlife habitat improvement on the winter deer range. Most of the private timber has been cut over. There have been some small sales of National Forest timber. Fire history indicates that since 1910 about 83 percent of the Duckwall Unit has burned at least once, 25 percent has burned twice, and 10 percent has burned three times.

Conflagration Control Program Procedure

The first step in the program was to have a complete pre-attack survey and plan made for the area. The completed pre-attack plan shows the firelines, fuelbreaks, and other facilities needed by suppression forces for an adequate, safe place to make a stand on any fire that escapes the initial attack on a high fire danger day. The general guide for the layout was to break the area into about 2,500 acre blocks with continuous firelines and fuelbreaks or natural barriers. All available resource inventory and multiple use maps were used as references.

The next step was to overlay the area pre-attack plan with maps of current management operations and operations planned for the immediate future, such as the 5-year timber operating plan. Highest priority went to a major continuous fuelbreak and fireline at the general line of demarcation between the heavy brush on the steep river slopes and the high-value timber on the gentler topography of the ridges and basins above the river. A soil survey was made of this area.

Every multiple use operation that could contribute to this priority program was examined and, if feasible, was scheduled for early start. Areas where the multiple use program could not contribute were identified, and the work scheduled as direct construction out of fuel treatment funds.

The following programs were used in first unit development:

1. *Range revegetation.*—Conversion of brush areas to perennial grasses. One unit on National Forest land and one on private land were already done. These were tied into the plan, and the new work on both private and National Forest land was designed to extend the fuelbreak as far as possible.

2. *Wildlife habitat.*—Some work had been done on deer browseways in the winter feed areas on the river slope and spur ridge brush fields. This work was tied in and new work programmed to contribute to the high priority fuelbreak.

3. *Recreation.*—Rehabilitation of one campground adjacent to the general fuelbreak location included a fuel reduction plan for fire prevention.

4. *Timber sales.*—A 3,000,000 board feet timber sale included about 1 mile of the primary fuelbreak location. The portion of the sale area included in the fuelbreak was designated as a "fuelbreak cut unit." Marking was modified to remove a large portion of the mature overstory and thin out the intermediate-size class in order to get proper spacing of the trees on the fuelbreak and still maintain shade on the low ground cover. All slash is disposed of on the fuelbreak cut unit.

5. *Stand improvement.*—Stand improvement funds are used to thin the material under merchantable size up to point justified for silvicultural practice. Additional work needed for fuelbreak purposes is paid out of fuel treatment funds. All trees on the fuelbreak are pruned so as to completely eliminate the continuous vertical distribution of fuels. All stand improvement slash is eliminated by chipping or piling and burning.

6. *Timber plantations.*—On good timber soils, there is a regular program of stripping brush for planting of commercial trees. One such unit is contributing to the primary fuelbreak. Current work is underway on the proper plantation design to get nearly full production on the timber soil and yet maintain the efficiency of the fuelbreak.

7. *Fire control-fuel treatment.*—Handlines on the steep canyon slopes have been put in by fuel treatment funds in order to effectively tie the fuelbreak into unit boundary natural barriers. Helispots and water source improvements are being carried out concurrently with the fuel work.

8. *Watershed management.*—All work is checked for erosion control, such as water-breaks on firelines and surface ground cover to be maintained on fuelbreaks.

9. *Other activities.*—There will not be any major engineering projects in this test unit. Management designs for conflagration control are needed in connection with major highway construction, powerline locations, reservoir clearing, and similar projects.

Private Land

The Duckwall area land ownership pattern requires work to be done on the private lands to make the program totally effective. The area plan and purpose of the program were explained to the land owners, county officials, and adjacent communities. Com-

plete endorsement of the program resulted. In one case the private landowner was interested enough to do all the work at his own expense with the advice of the project leader. This included ½ mile of main fuelbreak, one helispot, and ½ mile of secondary fuelbreak on a spur ridge.

Other landowners doing work for range conservation were able to qualify for financial aid under the Agricultural Conservation Practice Program for brush conversion and firebreak practices authorized by the State and county conservation committees. One mineral land patent owner having no interest in the surface values, which were low, gave the Forest Service an easement to do the work across his property.

A problem yet to be explored is how far commercial timber landowners whose lands are now cut over can go in participation in the plans.

Cooperation with Research

Research personnel from the Pacific Southwest Forest and Range Experiment Station have been on the management team and have been delegated the major responsibility for physical and economic evaluation of the work. They are working on such aspects of the program as determination of the volume of fuels before and after treatment, effect of the treatment on the microclimate on the fuelbreak, effect of the fuelbreaks on fire behavior under various weather conditions, best types of low ground cover

FIGURE 1.—Some 450 acres of fuelbreak were cleared along the Paper Cabin Ridge. The brush from the cleared break was burned. The brush-cleared areas were planted to perennial grass. Groups of oak and pine were thinned and pruned.

to maintain on the fuelbreaks, and best methods of disposal of fuels to be removed.

The findings from these investigations will make it possible to prepare more complete specific management guidelines for the application of the conflagration control concept to the multiple use management programs throughout the Region.

Progress to Date (fig. 1)

Work was started on the pre-attack plan in January 1962. By January 1963, the following have been accomplished:

1. Pre-attack plan for 40,000-acre Duckwall Unit completed.
2. Fourteen miles and 1,056 acres of major fuelbreak completed by the following:
   a. Two miles by timber sale and plantation preparation.
   b. Two miles on private land by owners.
   c. Two miles on private land by Forest Service under easement.
   d. Six miles accomplished by range revegetation and wildlife browseway work supplemented by fire funds.
   e. Two miles of handline out of fuel treatment funds.
3. About 3,000 snags felled in and adjacent to the fuelbreaks.

First Fire Test

On July 3, 1962, a fire on a very high-danger day built up too fast for initial attack to handle, crowned upslope, and hit the Paper Cabin Ridge fuelbreak. The fuelbreak stopped the head of the fire and made the suppression job much easier. Conservative estimate places the suppression cost savings at $25,000, which is about double what has been spent on the Paper Cabin Ridge fuelbreak.

Summary

Progress to date indicates that it is feasible to integrate fire fuels management into the multiple use management program on an area plan basis.

Some modification of treatment may be necessary on specific fuelbreak areas. This can be done with a small increase in costs and without reducing the productive capacity of the land.

Multiple use management measures must be supplemented by fuel treatment funds to make the program fully effective.

THE FIRE BEHAVIOR TEAM APPROACH IN FIRE CONTROL

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[*Editor's note.*—The authors of this article have been leaders in the development and application of the fire behavior officer job in the fire suppression organization. They present a very strong case for a team approach to the fire behavior officer's work on major fires. Although the organization proposed here has not as yet been adopted as standard for the Forest Service, it points a way to the possible organization of the future. It is important to integrate the fire behavior work with cooperation by the Weather Bureau under the National Plan for Fire Weather Service.]

"The weathermen just don't understand our problems." Perhaps many of you have heard this or similar complaints by the fire boss faced with a new fire problem when some unexpected and seemingly unusual wind pattern carried a nearly controlled fire completely out of control again. Nearly as common is the answering complaint of the fire weather forecaster: "We could give the fire control people more information, but they don't know how to use what we give them now."

Perhaps both complaints are greatly exaggerated, but they also contain much truth. The growing value of wildland resources and the encroachment of manmade improvements into wildland areas have greatly complicated the fire control problem. No longer is it possible to wait for the fire to "come out" to a position where control can readily be attained. Instead, even hot-burning, aggressive fires must be attacked and controlled where they are. His margin of safety greatly narrowed, the fire control man now needs much more precise and detailed fire weather information. He must have an accurate evaluation of the integrated effect of weather and fuels on fire behavior, often sector by sector.

To provide this information, we need people with training in both fire behavior and meteorology. Only thus can we make full and efficient use of the data provided by the weather forecaster. It is the primary responsibility of the fire control agency to furnish its organization with personnel of such skills. This is the purpose of the fire behavior officer in the Forest Service fire control organization.

Development of the Fire Behavior Officer's Job

Although the fire behavior officer or fire behavior specialist has been used occasionally on fires for a long time, it was not until 1957 that the job received formal recognition by the Forest Service. The position was adopted on the recommendations of a task force set up by the Chief of the Forest Service to study major fire disasters in wildland areas. Looked upon at first by field men as a sort of "super" safety officer position, the job has gradually evolved toward its proper purpose—that of predicting fire behavior resulting from changes in the environment surrounding the fire.

The evolution of the fire behavior officer's job has probably been more rapid in California than in any other part of the country. The long and critical fire season and frequent large fires focus the need for the specialized services of the fire behavior expert. Since 1959, three successive drought years in California accelerated development of the fire behavior officer position.

Organization of the Fire Behavior Team

The growth of the fire behavior officer's job has been largely a trial-and-error process. Each fire presented some new problems and new situations that the current procedures, equipment, and organization of the job did not fit well. As a result the operational base of the job has been constantly revised and broadened to take care of as many different situations as possible. The magnitude and complexity of the fire behavior officer job has also grown as fire bosses became aware of the kinds of service the fire behavior officer can provide.[1] Thus, he is not only used on many more fires but also to a much greater extent on each fire. To meet the obli-

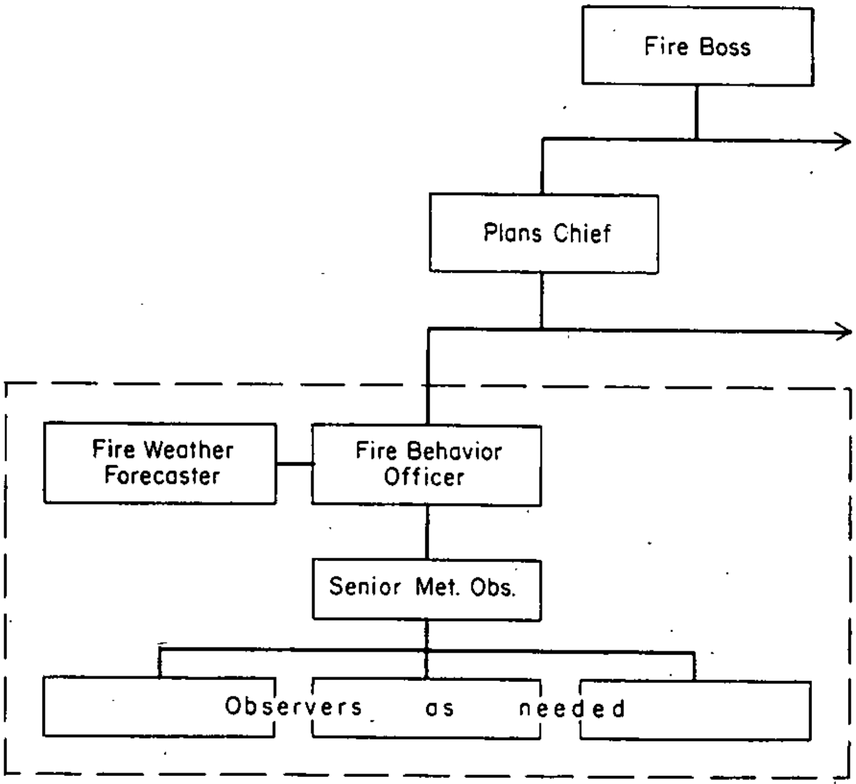

FIGURE 1.—Section of fire fighting organization showing fire behavior team.

[1] Chandler, Craig C., and Countryman, Clive M. Use of fire behavior specialists can pay off. Fire Control Notes 20(4): 130-132. 1959.

gations of the job, we now believe that the position cannot be adequately filled by one man, but requires a team approach. A fire behavior team was tried operationally during the 1961 fire season and proved to be highly successful. Organization of the team, as we see it now, should be as shown in figure 1.

Duties of the Fire Behavior Team

Fire Behavior Officer

The fire behavior officer is an adviser to the plans chief and the fire boss. He has final responsibility for localizing the general fire weather forecast for specific sectors of the fire. He must integrate information on weather, fuels, topography, and anticipated fire control action into a forecast of probable fire behavior. This forecast should be as specific as possible, while fully recognizing any forecast uncertainties. It must be written and provided in time for each shift, special forecasts being made whenever needed for unexpected changes. The fire behavior officer is specifically responsible for apprising the plans chief and the fire boss of any planned line location or fire control operation that he regards as unsafe because of probable fire behavior.

Although the fire behavior officer may provide assistance for specific line jobs on request, he must weigh the probable value of such assistance against the probable loss of contact with the fire situation as a whole. There is always a strong temptation to dash off to "where things are doing" with a resulting neglect of situations developing on other sections of the fire.

The fire behavior officer is responsible for securing local weather measurements and observations of fire behavior. He arranges for the necessary help and special equipment to make the measurements and observations. He is responsible for communications between himself, the various members of his team, and the plans chief and fire boss.

Senior Meteorological Observer

The senior meteorological observer is responsible to the fire behavior officer for obtaining and compiling accurate and complete meteorological observations in and around the fire area. To do this he needs to be thoroughly familiar with all types of meteorological equipment and with procedures for computing and compiling pertinent weather variables. He should make sure that the meteorological observers under his supervision are competent in the use of the necessary instruments and forms. Experience in collecting and compiling data is essential—often research men can fill this position very well. It is also a good position for a fire behavior officer trainee.

The senior meteorological observer prepares such summary graphs and tables of meteorological elements as may be requested by the fire behavior officer, or as experience dictates. He prepares and delivers current summaries of all observations to both the fire behavior officer and the meteorologist in ample time for their study before the preparation of fire weather and fire behavior forecasts.

He maintains fire weather equipment, including both manual and recording types of instruments, in good operating condition. He may also supervise special observations, such as pilot balloon runs and helicopter soundings.

Clearance for balloon runs and arrangements for helicopters or fixed wing flights are obtained *only* by the fire behavior officer. Senior meteorological observers should not deal directly with line or air operations overhead.

Meteorological Observer

Meteorological observers are under the direction of the senior meteorological observer. They should be familiar with common weather instruments and their use to measure temperature, humidity, and wind at times and locations specified by the senior meteorological observer. They should be capable of obtaining accurate and neatly recorded information with a minimum of supervision. They may also assist in special measurements such as pilot balloon observations or helicopter soundings. Usually these men can be drawn from the fire control force, often using men with minor injuries, such as blisters, to advantage.

Gains from Team Effort

In a fire behavior team organized as described, the meteorologist or fire weather forecaster is relieved of the responsibility for making observations in the fire area and thus has more time for weather analysis and preparation of detailed forecasts. When a fire behavior team is at a fire, the weather forecaster does not necessarily have to be there, but can set up shop wherever he can best obtain information needed for his forecast. This freedom of movement is particularly advantageous when there is more than one fire in the forecaster's area of responsibility. Adequate communication with the fire behavior officer is absolutely essential, and two or more conferences per day are necessary.

The Future

The organization of the fire behavior team does not mean that the fire behavior job has reached its ultimate goal and peak of performance. As more experience is gained, the operating procedures (see Checklist) and duties for the various members of the team will doubtless be revised for better performance of the entire team. New positions may need to be added. During difficult fires, for example, the fire behavior officer is more and more frequently called on for "on the line" help and advice. As this type of service increases, a fire behavior specialist may need to be added to the team so that the behavior officer can fulfill his duties to the fire as a whole.

Perhaps the most important implication of the increased use of the fire behavior officer is recognition by the fire control agencies of their responsibility in bridging the gap between the fire boss and the fire weather forecaster, thus enabling the fire boss to make full use of the service the forecaster can provide.

A Checklist of Operating Procedures

Fire Behavior Officer

Dispatch:
- Leaves immediately with fire weather trailer.

Arrival at fire:
- Leaves itinerary with plans chief.
- Arranges operating procedures with fire weather forecaster.
- Establishes observation routes and schedules.
- Sets up recording stations.
- Arranges for specialists and equipment as needed.

As soon as possible:
- Briefs senior meteorological observer on personnel, observation routes, schedules, safety plans, and any special observations needed.

Daily:
- Maintains contact with fire weather officer.
- Prepares fire weather (when no Weather Bureau forecaster is at the fire) and fire behavior forecasts.
- Holds briefing session with senior meteorological observer.
- Attends planning sessions.

Senior Meteorological Observer

Dispatch:
- Sets up transportation arrangements with meteorological observer.
- Inventories equipment.
- Leaves for fire.
- Arrival at fire.
- Checks with plans chief.
- Meets with fire behavior officer.
- Goes over ground with meteorological observer.
- Trains extra observers.

Daily:
- Collects observations.
- Prepares summary graphs and compilations.
- Conducts or supervises special observations.
- Inspects stations.

Meteorological Observer

Dispatch:
- Contacts senior meteorological observer for travel arrangements.
- Leaves for fire.

Arrival at fire:
- Checks equipment.
- Receives route and safety instructions and goes over ground with senior meteorological observer.

Daily:
- Makes and records observations.

CONNECTICUT FIRE WEATHER SEMINAR

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The Connecticut State Park and Forest Commission, in cooperation with the Hartford Weather Bureau, arranged and held a fire weather seminar at Bradley Field, Windsor Locks, Conn., on March 9, 1963. As far as we could determine, this was the first of its kind ever held, if not in the nation at least here in the East.

The primary purpose was to indoctrinate the forest fire personnel in basic weather, in the relationship between weather and fire danger prediction, and in the use of specialized fire weather forecasts in forest firefighting and control.

Jack Rimkunas, a meteorologist, described the various pressure systems with their associated weather and wind circulations. He stressed the various weather types that affect Connecticut during the spring, summer, and fall. In addition he explained the causes of local wind conditions and reviewed the concept of humidity.

Warren Silverzahn, Fire Weather Meteorological Specialist, related the basic weather concepts to the prediction of fire danger.

He explained how long- and short-range planning could be formulated by use of the Weather Bureau's 30-day and 5-day forecasts. He pointed out that the Hartford Weather Bureau is now forecasting rainfall in terms of probability or number of chances in 10 for rain in any area. The information will be used this fire danger season as an additional guide for the fire danger prediction. Fog, wind, adverse wind profiles, inversion, and fronts were explained and related to forest firefighting and control.

Larry Mahar, meteorologist in charge, summarized the preceding papers and explained the excellent communications set up for dissemination of the fire danger predictions.

After the showing of a fire weather film and a tour of the Hartford Weather Bureau facilities, the group was taken to an outdoor demonstration held with the cooperation of the airport management and the Bradley Field Fire Department. A mockup aircraft was set on fire in the woods; fire department personnel then quickly rescued the "pilot" and extinguished the blaze with foam.

Over 100 persons attended this seminar, including Harry Swift, chief fire weather forecaster from Weather Bureau headquarters in Washington, D. C., and D. C. Mathews, Director, State Park and Forest Commission of Connecticut. The rangers and patrolmen indicated by general comment that they now had a clearer understanding of the weather and could now better appreciate its effects in forest firefighting.

In a meeting of this type a closer relationship is established between the weather specialists and the forest firefighting organization. This can only result in better cooperation, better understanding, and better control of our larger forest fires. Such a fire weather seminar would be of advantage to any fire control operation.

HELITACK STUDY PROJECT ON CUMBERLAND NATIONAL FOREST

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Due to forest improvements and the increased value of forest land on the Cumberland National Forest, it has been necessary to step up forest protection proportionately. During forestwide planning in 1959, it became apparent that the cost of ensuring adequate protection by increasing the number of standby crews would be prohibitive. As an alternative, use of new equipment was considered. The helicopter, which provides quick access to remote areas, seemed to be the answer.

The situation.—Topographic conditions are unique on the Forest, since Cumberland County is on an eroded plateau. Erosion has resulted in vertical sandstone and limestone cliffs 50 to more than 200 feet high. In places there are three levels of cliff lines between a river channel and the upper plateau. The topography has long restricted use and development of the natural resources of the Cumberland, and similarly has posed many problems in protecting the Forest from fire. Some of the problems are:

1. Limitation by the terrain of vehicular and foot travel.
2. Frequent restriction of communication between the various land levels.
3. Usual limitation of visibility from fire towers to upper plateau or exposed upper slopes. Most lower slopes, coves, and shores of lakes and rivers receive only indirect detection coverage from fire towers. Actually less than one-third of the forested area within the protection zone may be seen.
4. Frequent movement of smoke, by wind, down into canyons and out of sight of the towermen.

Forest fuels are flashy—both coniferous and Appalachian hardwoods. Timber harvesting, mining, recreation, and land clearing is continuous on the numerous private holdings intermingled with National Forest land. Two-thirds of the land area within the proclaimed boundary is privately owned.

Area of the study.—Four southern Ranger Districts, containing the most consolidated public ownership on the Forest, were selected for the study. Within these Districts there are 424,065 acres of protection area, composed of 254,334 acres of National Forest and 169,731 acres of private holdings. During the past 5 years fire occurrence on the southern unit has averaged 45 fires per year. Recreation is expanding, and risks are increasing with more intensive use.

The helitack study plan.—The study plan was developed after an analysis of the situation and fire control problems on the area being considered. In brief, the objective of the study was to investigate the operational and economic feasibility of using a helicopter to transport men, equipment, and supplies in the initial

attack phase of fire suppression and support of conventional ground forces. Initially, a crew leader and five firefighters were trained to serve with the helicopter at the headquarters heliport; later, several men were trained on each of the Districts.

The operating plan.—An operating plan was prepared to guide the project officer and to acquaint Forest Service personnel with the pertinent details of the helicopter operation. In brief, the operating plan included the following details:

1. Concept of operations with outline of the study area.
2. Arrangement for maps at the central heliport headquarters, at the dispatching offices, and for use by the helitack crew.
3. Dispatching procedures for single and multiple fires and crew travel.
4. Safety precautions and responsibility.
5. Organization and individual responsibilities.
6. Equipment.
7. Training.
8. Fire records.

Study equipment.—Study equipment included a three-place helicopter (fig. 1), conventional handtools, and, at the start, miscellaneous radio equipment from various sources. In the fall of 1962, the Cumberland acquired its own air-net system of radio communication. During the first two fire seasons of operation, lack of adequate communication was one of the most serious handicaps to satisfactory helitack operations. The helicopter was

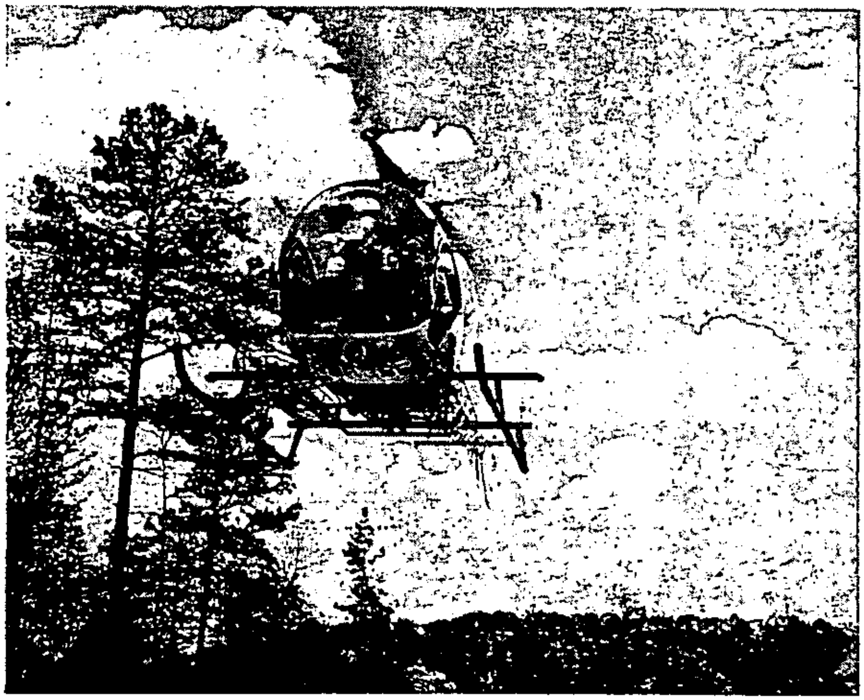

FIGURE 1.—Type of helicopter used in helitack study.

equipped with a wire litter basket which held handtools and supplies for the crew. Cargo-carrying equipment included a bomb shackle and cargo rack with a sling—electric release—for cargo handling. Standard 10-foot cargo chutes were included and have been used in several training exercises. No provision for training or use of jumpers has been provided in our helitack plan.

Summary of Operations

1. Helicopter transport of men and equipment has proved quite satisfactory during the 2-year study. Many thousands of acres in half-hour-control zones were reached within the time limitation by the helicopter crew, whereas 1 hour or more is required by ground crews going to the same fires.
2. Small crews of two to six men have achieved control of more than 85 percent of our fires with the aid of the helicopter.
3. Initial attack by helitack crews costs less than 5 cents per acre of protected land, and it is believed they could have been effective on a larger percentage of fires if more helispots had been available.
4. Only two to four men are needed at the base heliport during medium fire danger, provided extra crew members are available near helispots, where the helicopter may pick them up. These extra men in work status need ready communications with the dispatcher.

The dispatcher at headquarters must have sufficient information to provide the helicopter pilot with compass headings, or azimuth bearings, and distance to landing spots and fires. Helispots may be located by similar bearing and distance information.

5. During planning stages and early operation of the helitack unit, we considered the desirability of securing a four-place helicopter; however, because of higher operating costs, we were unable to finance a larger unit. Actually, experience shows that the smaller unit is adequate during average fire weather. Other helicopters could be hired during critical fire periods. Perhaps increased efficiency in operating procedures will enable one helitack unit to protect one-half million acres with minimum ground support.

PRESCRIBED BURNING FOR HAZARD REDUCTION ON THE CHIPPEWA NATIONAL FOREST

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An unusual combination of fuel types on the Chippewa National Forest, northern Minnesota, has resulted in annual prescribed burning in marsh meadows as a fire prevention technique. Vast areas of marsh meadows constitute a high-hazard fuel when in the cured stage. These meadows contain primarily grasses, rushes, and sedges. Woody shrubs are not uncommon, particularly along meadow perimeters and on natural levees adjacent to watercourses. During the spring months meadows are frequently flooded during years of normal or above-normal precipitation. This frequent flooding is a factor that contributes to the continuance of the meadow cover type.

Because of the elongated patterns formed by this vegetative type, a wildfire can quickly increase in perimeter and enter adjoining timber at several widespread locations. Figure 1 shows a meadow which is recognized as having an exceptionally high fire hazard. A fire on this meadow could quickly expand to 25 miles of perimeter. A rate of spread of 400 chains of perimeter per hour can occasionally be expected on meadow fires. Thus, in the case

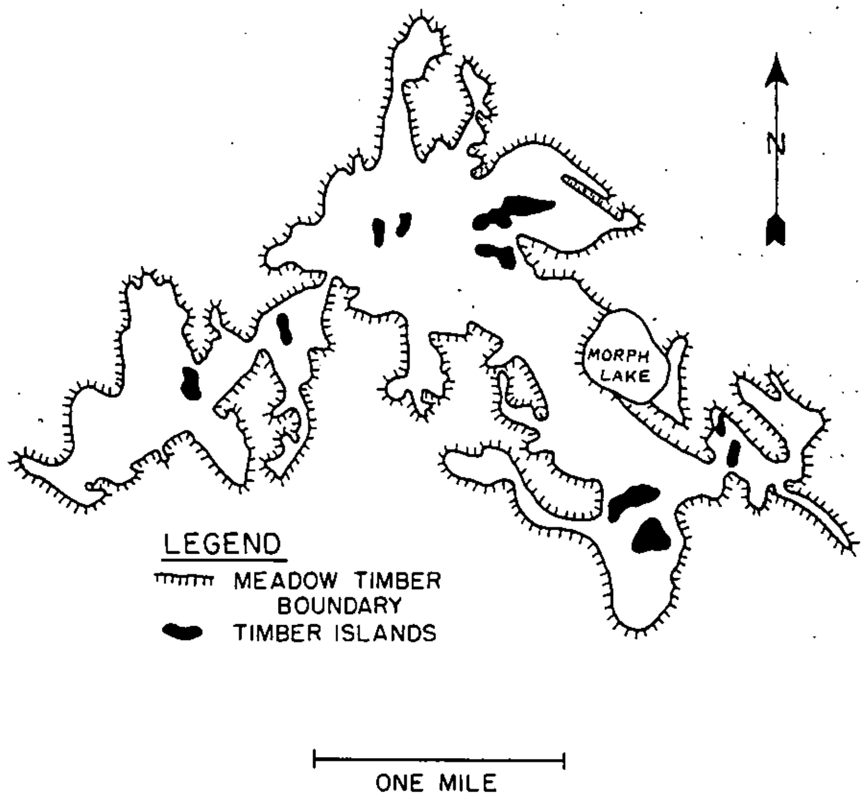

FIGURE 1.—Morph Meadow, Blackduck District.

illustrated, a fire could reach 25 miles of perimeter in 5 hours. Inaccessibility and difficulty of rapid travel are also part of the fire control problem. Incendiary fires are common and during the past 5 years (1958-62) accounted for 23 percent of all wildfires on the Chippewa National Forest.

In addition to the physical features of the land, the sociological aspects are also significant in fire prevention. Public education in fire prevention is an important part of fire control activity. The problem of public education in fire prevention is similar to that in the Southern States.

In northern Minnesota a long tradition of meadow burning exists, perhaps beginning in the early use of meadows for hay production because annual burning was thought to produce better hay. Meadow hay is known to have commonly been cut as late as 1950. Prescribed burning of meadows has been a management tool for approximately 35 years on the Chippewa National Forest. The objective has been to reduce the hazard by burning under safe conditions. Safe conditions for prescribed meadow burning exist throughout an approximate 3- to 4-day period in the spring. At this time snowmelt exposes marsh vegetation and dries rapidly in the open. Under the cover of adjoining timber snowmelt lags, and residual snow provides an efficient firebreak. The date of burning may vary by several days from meadow to meadow, depending upon latitude, orientation, and snow catch.

Meadow burning is frequently done individually or by two-man teams. During the 3- or 4-day period when conditions are optimum, several thousand acres must be burned by the four- or five-man staff of each ranger district. Table 1 shows the area burned by each ranger district and total acres of meadow available by district. A meadow burning team will commonly burn a river meadow 5 to 10 miles long in a day. Burning is usually done in the same manner as backfiring; wooden matches or drip torches are most commonly used for ignition. The fire is usually set so that the wind will carry flame across the meadow to be burned. No attempt is made to control the fire, since residual snow under adjoining timber provides an adequate control line. Because of river oxbows and snowdrifts, burning is never uniform; neverthe-

TABLE 1.—*Meadow type available and acreage prescribed burned by ranger districts*

Ranger district	Available*	Prescribed burned annually*
	Acres	*Acres*
Bena	20,000	12,500
Blackduck	5,500	3,545
Cass Lake	3,300	1,600
Cut-Foot Sioux	11,285	3,050
Dora Lake	5,540	1,650
Marcell	313	45
Remer	10,240	5,760
Walker	22,000	4,837
Totals	78,178	32,987

* Varies with annual water level.

less, breaking the continuity of fuel conditions suffices to prevent wildfire from spreading unchecked.

The need for prescribed meadow burning has often been evaluated and discussed by forest personnel. Generally the conclusion has been that burning is necessary for effective fire prevention, particularly in light of the incendiary fire problem. It is better to burn when conditions in the woods are safe than to take a chance on the area burning during periods of high fire danger.

WIND MEASUREMENT WITH HYDROGEN-FILLED BALLOONS

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Wind velocity is an important variable to be measured during test fires and many other investigations in forest fire research. This report describes trials of hydrogen-filled balloons, tethered to the ground, and used to measure the speed and direction of light air currents (0-5 miles per hour) near or around experimental fires. The hypothesis was that when a tethered balloon is displaced by a certain wind speed, the angle between the tether and the vertical ("angle of lean" of the balloon) can be correlated with the speed of the wind. This hypothesis was investigated at the Petawawa Forest Experiment Station at Chalk River, Ontario, in the summer of 1962.

Balloons for studying air movements are common in meteorology and have been employed to a lesser extent in climatology. MacHattie[1] used captive balloons for studying low-level winds, including their variation from point to point. Use of tethered balloons for measuring wind velocity was suggested for prescribed burning experiments, where a relationship between indrafts and ambient winds was sought. It was later thought that tethered balloons might also be used to determine air movements on other occasions, such as the observation of 2-minute test fires. In view of the importance of wind measurement in fire research, anything that may permit the measurement of speed and direction of light winds in a simple and direct manner should be investigated.

Various balloons were tested; these included toy balloons of different shapes and standard 3-inch meteorological balloons. The latter were more satisfactory as they retained their shape and stayed inflated longer than the toy balloons. Balloons were tethered to the ground by a No. 8 linen thread fastened to short blocks of two-by-four. Angles of lean were measured with protractors of 2-foot radius and graduated in 5-degree intervals, and made from quarter-inch plywood.

Preliminary observations revealed that the displacement, and consequently the angle of lean, induced by a certain wind speed was dependent on the size (degree of inflation) of the balloon and the amount of lift caused by the hydrogen (fig. 1). Displacement also varied with the length of the tether. The larger the balloon, the stronger the wind needed to produce a given displacement; also, the longer the tether, the stronger the wind required to give a comparable angle of lean. These determinations meant that each combination of balloon size and length of tether would require a separate conversion table to relate angle of lean to wind speed.

Conversion tables were constructed, and a hot-wire anemometer was used to measure wind speed. Fifty to 60 measurements of angle of lean and corresponding wind speed were taken for sev-

[1] MacHattie, L. B. Study of meteorological drying effects on forests. Unpublished report. Department of Northern Affairs and National Resources, Forestry Branch, 34 pp. 1954.

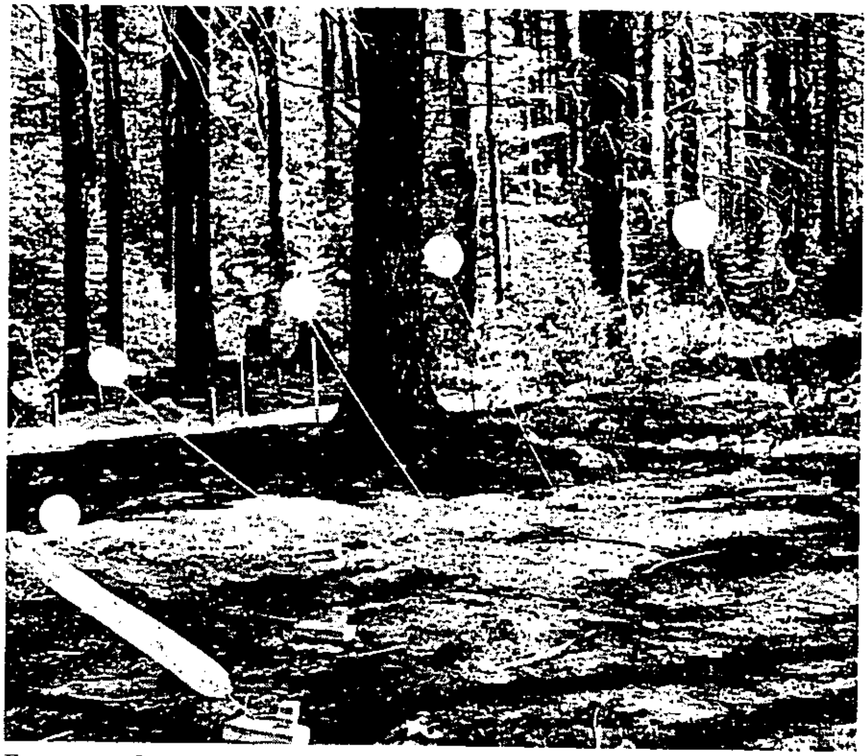

FIGURE 1.—Same wind speed induces a different angle of lean when balloons of different sizes are used. From left to right the diameters of the round balloons are 6, 7, 8, 9, and 10 inches.

eral combinations of balloon size and tether length. When angle of lean was plotted over wind speed for each combination, a linear relationship was indicated. Straight lines were fitted to the data using the method of least squares, but the correlation was not good; there was considerable scatter about the line. Wind speeds in feet per minute corresponding to angles of lean (0° to 80°) were then read from the line and tabulated. Observations of several sizes of balloons, 7 to 14 inches in diameter, tethered 2 to 10 feet above ground were "calibrated" in this way. No balloons smaller than 7 inches in diameter were tested owing to insufficient lift to pull the tether reasonably straight. Balloons larger than 14 inches showed little, if any, relation between wind speed and their angle of lean.

Balloons were tested during fire observations three times: twice at small bonfires of piled slash and once at a small-scale prescribed burn in a plantation. The bonfire tests were conducted to determine whether the balloons would be useful for detecting and measuring indrafts, caused by the fire, in relation to ambient winds. At the first bonfire test, pairs of balloons, 7 inches in diameter and on 4-foot tethers, were placed on each of the four cardinal directions; one balloon of each pair 10 feet from the fire, and the other 20 feet from the fire. An attempt was made to measure simultaneously the angles of lean of the balloons in each

pair. It was hoped that comparison between the angles in each pair would permit the detection of any effect of indrafts on the balloon nearest the fire. Also, wind direction was concurrently estimated. At the second bonfire the same procedure was followed, with 10-inch-diameter balloons on 6-foot tethers. During the plantation fire the angle of lean of a single balloon, 10 inches in diameter and on a 4-foot tether, was measured every half-minute. This record was compared graphically to measurements taken with a cup anemometer (fig. 2).

The following facts became evident during the development of the conversion tables and the field tests of the balloons at fires:

1. The angle of lean of the balloons was very difficult and often impossible to measure with any precision because they were rarely sufficiently steady; they "bobbed" and "weaved" in all directions, even when the wind was relatively steady. This constant motion was probably caused, in part, by turbulence and by eddies and swirls in the air flowing around the balloon. It was once thought that a small vane, attached to the thread below the balloon, might have a steadying effect, but this was disproved.

2. When angle measurement was possible, it was found that for a specific wind speed, size of balloon, and length of tether, the angle of lean was not consistent. Thus, the angle of lean is not a reliable indication of wind velocity. The range of angles for a given wind velocity increased as the size of balloon increased.

3. Estimation of wind direction as indicated by the balloons was no more accurate than the age-old method of holding a dampened finger in the air and feeling which side is coolest. The constant swinging in a horizontal plane made the determination of wind direction at any instant practically guesswork. Also, as wind speed decreased and the tether thread assumed a more nearly vertical position, estimation of wind direction became even less positive.

4. There was no discernible correlation between indrafts and ambient winds. Also, sparks and the heat of the fire exploded several balloons, and tether threads often became entangled in low vegetation.

5. The record from the plantation test fire, when compared graphically to measurements taken with a cup anemometer, showed roughly the same trend of wind velocities throughout the fire (fig. 2). The balloon record, with measurement every half-minute, showed the distribution of the gusts of the wind, whereas the anemometer readings gave average velocities over 1-minute intervals. Although measurements of gustiness may be important when evaluating factors of fire behavior such as rate of spread, in light of (1) and (2) above, the record of balloon observations has to be interpreted with some reservations as to the absolute reliability of the wind speeds recorded.

These tests indicate that the use of tethered, hydrogen-filled balloons cannot be expected to provide reliable and accurate measurement of wind speed or direction near the ground. However, for qualitative assessment of general air movements around

test fires, and where more precise or elaborate instrumentation is not possible, the balloons are useful when tethered at various positions and heights around areas to be burned and then observed or photographed at desired time intervals.

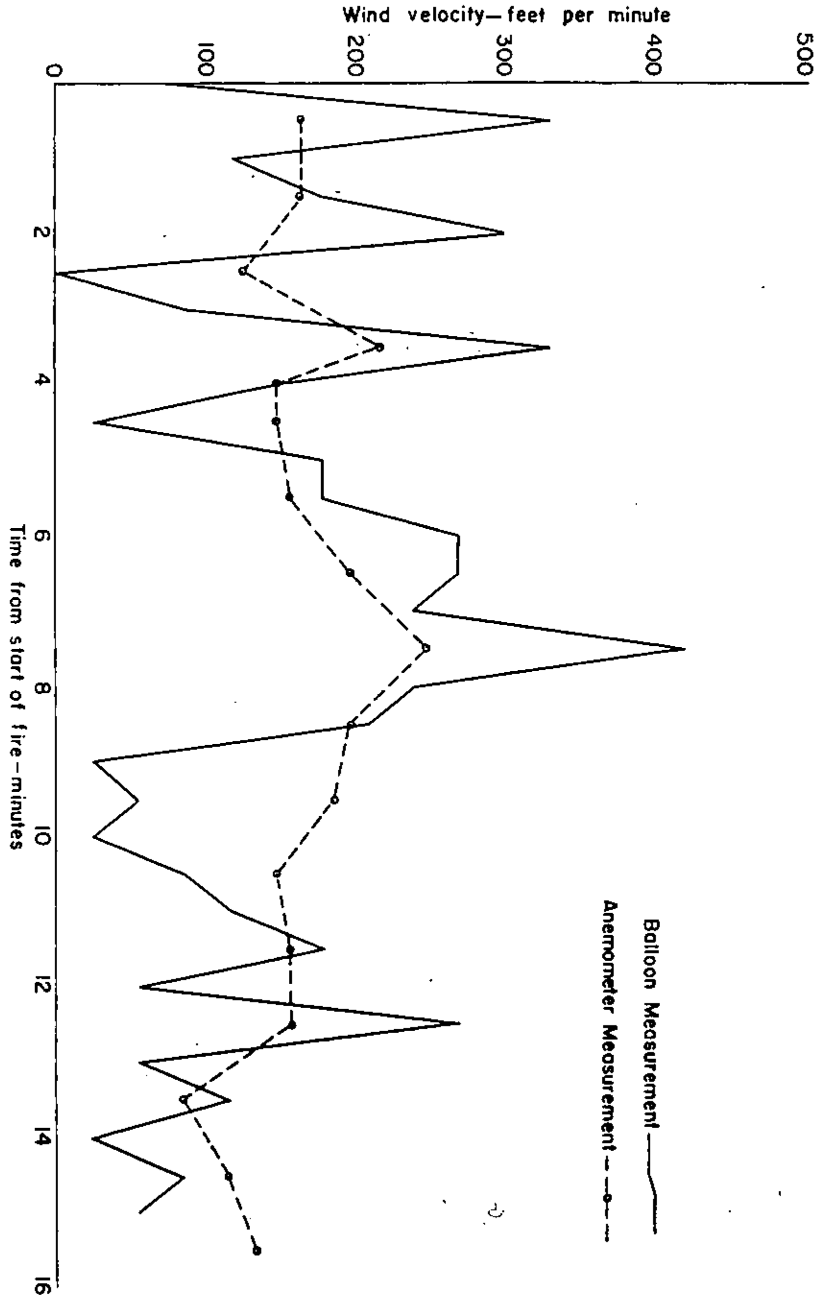

FIGURE 2.—Comparison of wind measurement by balloon and cup anemometer at plantation test fire.

PROTECTING THE TRACTOR-FIREPLOW OPERATOR FROM RADIANT HEAT

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Tractor-fireplow operators working close to wildfires are often exposed to high-intensity radiant heat. Although it generally causes only discomfort, painful burns may be inflicted. For efficiency as wll as safety, some form of protection seems desirable.

Enclosed cabs would be expensive and would probably require air conditioning in hot weather. Visibility and maintenance might be troublesome. Proper wire screens, on the other hand, may provide inexpensive protection from heat without the problems of complete enclosure. Wire screens[1] were found to be effective heat shields capable of reducing the amount of transmitted heat in proportion to their metal area. Thus, if 25 percent of a screen consists of openings (75 percent metal area), transmitted radiant heat would be reduced to approximately 25 percent of that without protection.

The screens could be mounted directly on the tractor. The screen behind the operator might be installed permanently, while those on the sides and front could be rigged to be raised overhead when not needed. On most fires, only the screen on the side toward the flames would be lowered, thereby permitting free air circulation from the other sides. Mounted in this manner, the screen shields should provide protection against branches and snags, in addition to being versatile and easily maintained radiant heat reducers. Screen of varying metals, wire size, and mesh is available from several manufacturers.

The author solicits comments from tractor operators or others interested in this idea or who may have had occasion to use shields.

[1] Downs, L. E. and Bruce, H. D. Attenuation by window screen of thermal radiation from nuclear weapons. Tech. Rpt. AFSWP-341, Forest Products Laboratory, 1957.

HANDY RIVET PUNCHER

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Cutting rivets can be time consuming and dangerous. The Virginia Division of Forestry used the cold chisel and hammer system to cut rivets in repairing fire rakes until an enterprising Division employee developed a better method. Armed with a cutting torch, electric welder, drill press, scrap metal, a few bolts, and odds and ends, Porter Caldwell, Chief Forest Warden of Botetourt County, assembled a little hand-operated machine (fig. 1) that punches out old rivets and "brads" new ones. The punch is only a common high-quality steel punch, and the "brader" is a 3/8-inch studbolt. These items, when mounted as shown in figure 2, will permit an efficient and safe operation.

FIGURE 1.

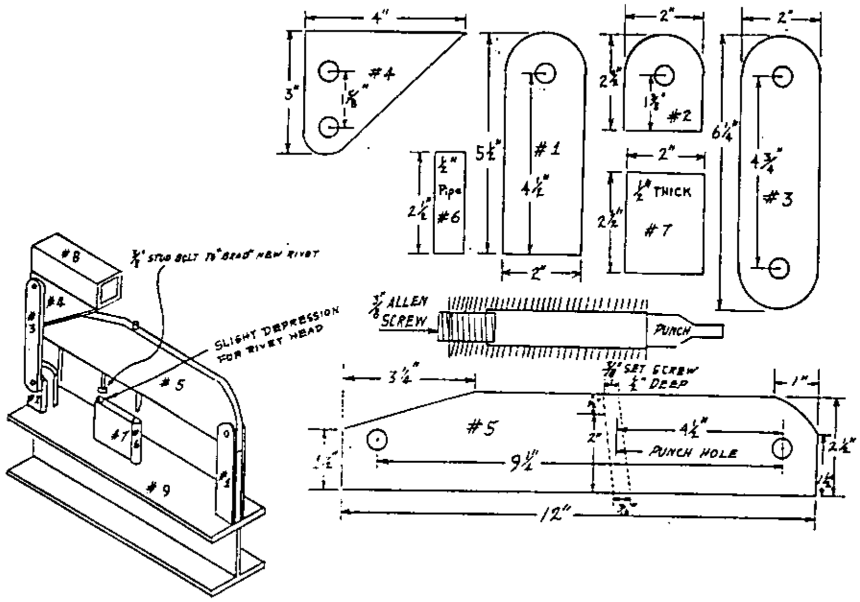

FIGURE 2.

Referring to figure 2:

1. All boltholes are five-eighths inch.
2. Two of each of parts #1 through #4 must be made.
3. Lower hole in #4 and left hole in #5 must be riveted to permit clearance with part #3.
4. Hole under #6 is cut to permit rivets to drop out.
5. Part #8 is constructed from two 4-inch-long pieces of angle iron (1¼ by 1¼ by ¼ inches).
6. Removable handle, made of pipe, axle, or drill bit, inserts into #8.
7. Part #9 is an I-beam 12 inches long.

A TABLE FOR CHECKING THE REASONABLENESS OF ENTRIES ON FIRE REPORT FORMS

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When fire reports (form 929, later revised as form 5100.29) were analyzed in a rate-of-spread study in 1959, a number of discrepancies or impossible combinations of entries were noted. For example, one fire report showed elapsed time from origin to attack as 1.5 hours, rate of spread or perimeter increase as 3 chains per hour, and the area attacked as 4 acres. If the time and acreage figures were correct, the reported rate of spread was less than one-sixth what it should have been.

Since this type of error or discrepancy seemed fairly common, table 1 was developed to aid in checking the reasonableness of certain entries on fire report forms. It is solely a means of checking and is not for use in computing acreages or perimeters. It shows the probable acreage of a fire spreading at various rates for varying periods of time. It can be used for any period in the fire's history for which data are available between any two of the following times: origin, discovery, attack, and control.

The probable acreages were computed from what was believed to be a normal-shaped fire and, although subject to adjustments, seem quite representative—at least for fires in the East. Of course fire shapes do vary, and figures computed for perimeters will frequently differ from those derived from this table.

These differences are limited when the perimeter computed from data on the fire report is less than that derived from table 1. A difference of 25 percent less would indicate a circular or near-circular fire, and this is the maximum possible difference. In general an error should be suspected when this difference reaches 20 percent, unless the fire is very small (1 acre or less).

On the other hand, there is no specific limit to the extent to which a fire perimeter may exceed that derived from the table. A fire may be extremely long and narrow or may have a very irregular margin, resulting in a very high perimeter-area relationship. However, when a computed perimeter exceeds that derived from the table by more than 30 percent, an explanation should be required. Such a difference indicates a fire of unusual shape or an error in the report.

How to Use the Table

First, this table can be used to check the reasonableness of the final perimeter and area-when-controlled entries. For example, suppose a report shows the area when controlled as 10 acres and the final perimeter as 24 chains. Are these figures reasonable and compatible?

A glance at the table shows that they are not. In the table both

TABLE 1.—*Probable acreage burned, in relation to rate of fire-perimeter increase and elapsed time*

Elapsed time	Area burned when perimeter increase in chains per hour is—														
	2	3	5	10	20	30	40	50	60	70	80	90	100	120	140
Hours	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
0.1	....	....	....	....	....	....	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.7	1.0
.2	....	....	....	....	0.1	0.2	.4	.5	.7	1.0	1.3	1.6	1.9	2.6	3.5
.3	....	....	....	....	.2	.4	.7	1.1	1.6	2.1	2.6	3.3	4.0	5.7	7.7
.4	....	....	....	0.1	.4	.7	1.3	1.9	2.6	3.5	4.5	5.7	7.0	10.1	13.4
.5	....	....	....	.1	.5	1.1	1.9	2.8	4.0	5.4	7.0	9.0	11.0	15.0	21.0
.6	....	....	....	.2	.7	1.6	2.6	4.0	5.9	7.7	10.0	12.6	16.0	23.0	30.0
.7	....	....	0.1	.3	1.0	2.1	3.5	5.4	8.0	10.2	13.4	16.6	21.0	30.0	41.0
.8	....	....	.1	.4	1.3	2.6	4.5	7.0	10.0	13.5	17.5	21.5	27.0	38.0	53.0
.9	....	....	.1	.4	1.6	3.3	5.7	9.0	12.3	17.0	22.0	27.5	34.0	48.0	66.0
1.0	....	....	.1	.5	1.9	4.0	7.0	11.0	15.0	21.0	27.0	34.0	41.0	59.0	80.0
1.1	....	0.1	.2	.6	2.2	4.8	8.5	13.0	18.5	25.0	32.5	40.5	49.0	72.0	98.0
1.2	....	.1	.2	.7	2.6	5.7	10.1	15.0	22.0	29.5	38.0	47.5	59.0	86.0	117.0
1.3	....	.1	.2	.9	3.0	6.7	11.8	17.5	26.0	34.5	44.5	55.5	69.0	100.0	136.0
1.4	....	.1	.3	1.0	3.5	7.8	13.4	20.5	30.0	40.0	51.5	65.0	80.0	115.0	157.0
1.5	....	.1	.3	1.1	4.0	9.0	15.0	23.5	34.0	46.0	59.0	75.0	92.0	132.0	179.0
1.6	0.1	.1	.4	1.3	4.5	10.1	17.2	27.0	38.5	52.0	67.0	85.0	104.0	151.0	204.0
1.7	.1	.1	.4	1.4	5.1	11.2	19.7	30.0	43.5	58.0	75.0	96.0	117.0	170.0	230.0
1.8	.1	.2	.4	1.6	5.7	12.5	22.0	33.5	48.5	65.0	84.5	107.0	130.0	191.0	258.0
1.9	.1	.2	.5	1.7	6.4	13.7	24.5	37.0	53.5	72.0	94.5	119.0	146.0	212.0	287.0
2.0	.1	.2	.5	1.9	7.0	15.0	27.0	41.0	59.0	80.0	105.0	132.0	163.0	234.0	318.0
2.1	.1	.2	.6	2.1	7.7	16.8	29.5	45.0	65.5	88.0	115.0	145.0	179.0	260.0	350.0
2.2	.1	.2	.6	2.2	8.5	18.5	32.0	49.5	72.0	96.5	126.0	158.0	196.0	285.0	385.0
2.3	.1	.3	.7	2.4	9.3	20.0	35.0	54.0	78.5	105.0	137.0	172.0	213.0	310.0	420.0
2.4	.1	.3	.7	2.6	10.1	22.0	38.0	59.0	85.0	115.0	150.0	189.0	233.0	337.0	457.0
2.5	.1	.3	.8	2.8	11.0	24.0	41.5	64.0	92.0	125.0	163.0	206.0	254.0	364.0	495.0
2.6	.1	.3	.9	3.0	11.8	25.5	44.5	69.0	99.0	135.0	176.0	222.0	273.0	395.0	535.0
2.7	.2	.4	.9	3.3	12.6	27.5	48.0	75.0	107.0	145.0	189.0	239.0	294.0	425.0	577.0
2.8	.2	.4	1.0	3.5	13.4	29.0	51.5	80.5	115.0	155.0	203.0	256.0	316.0	457.0	621.0
2.9	.2	.4	1.1	3.8	14.2	31.5	55.0	86.0	123.0	167.0	218.0	276.0	340.0	490.0	666.0

TABLE 1.—*Probable acreage burned, in relation to rate of fire-perimeter increase and elapsed time* (Continued)

Elapsed time	Area burned when perimeter increase in chains per hour is—													
	2	3	5	10	20	30	40	50	60	70	80	90	100	120	140
Hours	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*	*Acres*
3.0	0.2	0.4	1.1	4.0	15.0	34.0	59.0	92.0	132.0	179.0	234.0	296.0	364.0	524.0	712.0
3.1	.2	.5	1.2	4.3	16.0	35.5	62.5	98.0	140.0	190.0	249.0	315.0	387.0	560.0	760.0
3.2	.2	.5	1.3	4.5	17.2	37.5	66.5	104.0	150.0	202.0	265.0	335.0	413.0	597.0	811.0
3.3	.2	.5	1.4	4.8	18.5	40.0	70.5	110.0	160.0	215.0	282.0	357.0	438.0	635.0	862.0
3.4	.3	.5	1.4	5.1	19.7	43.0	75.0	117.0	169.0	229.0	300.0	379.0	466.0	673.0	914.0
3.5	.3	.6	1.5	5.4	21.0	46.0	80.0	125.0	179.0	244.0	318.0	402.0	495.0	712.0	968.0
3.6	.3	.6	1.6	5.7	22.0	48.5	84.5	132.0	189.0	257.0	335.0	424.0	522.0	755.0	1,025.0
3.7	.3	.6	1.7	6.0	23.5	50.5	89.0	139.0	200.0	271.0	353.0	447.0	551.0	798.0	1,083.0
3.8	.3	.7	1.7	6.4	24.5	53.0	94.0	147.0	211.0	285.0	372.0	472.0	580.0	841.0	1,142.0
3.9	.3	.7	1.8	6.7	25.5	56.0	100.0	155.0	222.0	300.0	393.0	497.0	613.0	885.0	1,201.0
4.0	.4	.7	1.9	7.0	27.0	59.0	105.0	163.0	234.0	318.0	414.0	524.0	646.0	929.0	1,263.0
4.25	.4	.8	2.1	8.0	30.5	66.5	118.0	184.0	264.0	359.0	468.0	591.0	732.0	1,050.0	1,425.0
4.50	.4	.9	2.3	9.0	34.0	75.0	132.0	206.0	296.0	402.0	524.0	662.0	817.0	1,174.0	1,597.0
4.75	.5	1.0	2.6	10.0	38.0	83.0	147.0	229.0	329.0	448.0	583.0	737.0	910.0	1,310.0	1,780.0
5.00	.5	1.1	2.8	11.0	42.0	92.0	163.0	254.0	364.0	495.0	646.0	817.0	1,007.0	1,450.0	1,970.0
5.25	.6	1.2	3.1	12.0	45.5	101.5	179.0	279.0	401.0	545.0	712.0	892.0	1,110.0	1,597.0	2,167.0
5.50	.6	1.3	3.4	13.0	50.0	111.0	197.0	307.0	440.0	599.0	783.0	987.0	1,215.0	1,750.0	2,378.0
5.75	.7	1.5	3.7	14.0	54.5	121.0	215.0	334.0	480.0	654.0	853.0	1,080.0	1,330.0	1,910.0	2,599.0
6.00	.7	1.6	4.0	15.0	59.0	132.0	234.0	364.0	524.0	712.0	930.0	1,174.0	1,450.0	2,070.0	2,831.0
6.50	.9	1.8	4.7	17.8	68.5	155.0	273.0	424.0	613.0	835.0	1,090.0	1,375.0	1,695.0	2,440.0	3,322.0
7.00	1.0	2.1	5.4	21.0	80.0	179.0	316.0	495.0	712.0	967.0	1,260.0	1,597.0	1,970.0	2,831.0	3,853.0
7.50	1.1	2.3	6.2	24.0	92.0	205.0	364.0	565.0	817.0	1,110.0	1,450.0	1,830.0	2,256.0	3,249.0	4,422.0
8.00	1.3	2.6	7.0	27.0	105.0	234.0	414.0	646.0	929.0	1,260.0	1,695.0	2,070.0	2,567.0	3,697.0	5,032.0
8.50	1.4	2.9	8.0	30.5	118.0	258.4	466.0	730.0	1,050.0	1,425.0	1,850.0	2,347.0	2,898.0	4,174.0	5,681.0
9.00	1.6	3.3	9.0	34.0	132.0	294.0	522.0	817.0	1,174.0	1,597.0	2,070.0	2,632.0	3,249.0	4,679.0	6,369.0
9.50	1.7	3.6	10.0	37.5	147.0	329.0	583.0	910.0	1,310.0	1,780.0	2,317.0	2,932.0	3,620.0	5,213.0	7,096.0
10.00	1.9	4.0	11.0	41.5	163.0	364.0	646.0	1,007.0	1,450.0	1,970.0	2,567.0	3,249.0	4,012.0	5,776.0	7,862.0

10 and 10.1 acres are found in several places. By multiplying the rate of perimeter increase for the column in which these entries appear by the elapsed time in hours for the row, we get an expected approximate perimeter of 47.5 or 48 chains. The 24 chains shown on the report is approximately 50 percent less than that obtained from the table, indicating an error in the report. A little computing shows that a 24-chain perimeter, even in the form of a circle, would enclose an area of only 4.6 acres. A circle would require a perimeter of approximately 36 chains to encompass an area of 10 acres. Of course the chances of a fire burning in a perfect circle are rather slim, so the perimeter of a normal 10-acre fire would have to be somewhat greater than 36 chains, probably 45 to 50 chains as indicated by the table.

Now assume a 61-acre fire. No 61 is found in the table, but 59 appears in several places. Multiplying the chains per hour by the elapsed time in hours for any of these entries gives 120 chains as the expected perimeter of a 59-acre fire. By interpolating we would get approximately 122 chains for a 61-acre fire. In this way the expected perimeter of any fire can be computed, up to the maximum acreage shown in the table.

A second and probably more important use of the table is in checking the rate of spread from discovery to attack. This is the one item that seems most subject to unreasonable entries. The elapsed time from discovery to attack is definite. In general, the estimate of area-when-attacked is fairly good, but in many cases there is some doubt concerning the figure shown for perimeter increase per hour.

The use of the table for computing rate of spread differs slightly, depending on whether the origin and discovery times are approximately the same, or whether the fire had already attained a reportable size when discovered.

Consider a simple case in which origin and discovery times are the same, time from discovery to attack is 2 hours, and size at attack is 20 acres. First, we locate the elapsed time of 2 hours in the column at the left; then reading across to the right, we find 15 acres in the 30-chains perimeter-increase column and 27 acres in the 40-chain column. By interpolation we see that 20 acres would fall approximately at 34-chains-per-hour perimeter increase.

In a fire report actually checked, the following data were given: Elapsed time from discovery to first attack, 1.2 hours; area when discovered, 0 acres; perimeter increase in chains per hour, 15; final perimeter, 90 chains; area when attacked, 18 acres; and area when controlled, 26 acres. The table indicates a perimeter of approximately 78 chains for a 26-acre fire, but the 90-chain entry is well within acceptable limits and would not be questioned. However, the perimeter increase of 15 chains per hour is obviously low if the size at time of attack and elapsed time from origin to attack are correct. Reading to the right from 1.2 hours in the elapsed-time column of the table, we find 15 acres in the 50-chains-per-hour column and 22 acres in the 60-

chains-per-hour column. Interpolating for 18 acres, we would get 54 or 55 chains per hour as the rate of spread, rather than 15 as indicated. Thus, in 1.2 hours elapsed time the perimeter would be 65 or 66 chains, which is reasonable for an 18-acre fire. Where such large discrepancies are found, it is probable that the report would be returned to its source for correction.

A slightly modified procedure is required where a fire has attained a reportable size at time of discovery. The first step is the same as above—locate the elapsed time from discovery to attack in the column at the left. Then read to the right to obtain the rate of perimeter increase that gives the area when discovered, and subtract this figure from the rate of perimeter increase that gives the area at first attack. The difference is the rate of spread from discovery to attack.

This table will be useful to anyone responsible for reviewing fire report forms.

MEASURING HUMAN EFFORT AND FATIGUE

Missoula Equipment Development Center
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An important criterion of the worth of a machine, handtool, or work technique is the amount of human effort required to use it. Frequently the adoption or rejection of a machine or work technique, or the acceptance of one of several similar machines or work techniques, is contingent upon the answer to this question: which one is less tiring to use?

Heretofore, Missoula Equipment Development Center engineers have determined human fatigue or stress in an informal manner. Men testing new tools or work techniques would be asked how tiring it was to perform a task in a prescribed manner or to operate a particular machine, or which of several machines was less tiring to operate. The opinions of men actually doing a job will always be important in the evaluation process. For comparative purposes, however, results obtained subjectively are of little use. Such data cannot be plotted on a graph or a chart. A project has been started to develop objective methods for measuring fatigue or stress produced when performing physical tasks common to forestry activities.

A method of measuring energy cost, fatigue, or stress must meet these requirements:

1. The apparatus must not hamper the test subject's normal movements while performing tasks such as hiking, running, digging, chopping, or sawing.
2. The apparatus must be rugged enough for field use.
3. The measuring technique must not require extensive training or special knowledge on the part of the operator.
4. Equipment must be inexpensive.
5. The method should follow accepted practices and be a valid index of human stress.

Methods of Measuring Human Energy Costs, Fatigue, or Stress

A search of pertinent literature disclosed two accepted methods of measuring energy expenditure:

Analysis of waste respiratory gases.—Test subjects wear a closed-circuit breathing apparatus; gases expired during a prescribed exercise period are collected and analyzed. A person's oxygen consumption per minute is calculated from the volume of oxygen remaining. Oxygen consumption is then converted to energy expended, expressed as calories per square meter of body surface per hour (calories/m.^{2}/hr.). One liter of oxygen consumed is equivalent to 5 calories of energy or 3,086 foot-pounds of work. This method is best suited to laboratory experiments.

Monitoring Heartbeat.—Human fatigue and stress can also be evaluated by monitoring the test subject's heartbeat prior to, during, and after exercise. The degree of fatigue is indicated by the time it takes the test subject's heart rate to return to the pre-exercise level. Instruments for monitoring heartbeat include the common stethescope, heartbeat totalizers, and audio and

photo-electric counting devices. Heart rate analysis seems most promising. Some monitoring devices of this type are small, do not hamper the test subject's movements, and are rugged enough for field use. A photocardiotachometer, which measures the rate of heartbeat by recording blood pulsations in the test subject's ear lobe, is now being assembled by our electronic technician. Data obtained by monitoring heart rates shows excellent correlation with those obtained through gas analysis.

Our engineers have completed a mechanical treadmill (fig. 1), a device widely used as an exerciser by physiologists wherein temperature, humidity, workload, and type of exercise must be closely controlled. It is expected that this exerciser, the photocardiotachometer, and gas analysis equipment will enable us to obtain objective data on fatigue, stress, and energy costs incurred while performing various types of Forest Service work both in laboratory tests and in the field.

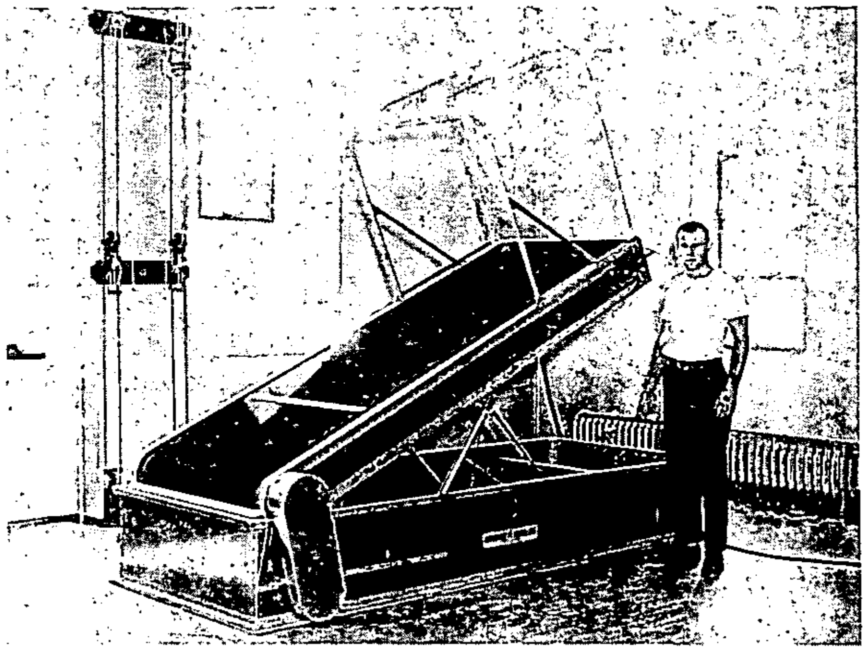

FIGURE 1.—The treadmill is a standard exerciser for calculating human fatigue.

Experiments to Determine Fatigue

Tests were conducted to determine the practicality of using heart rate and monitoring devices to validly indicate fatigue and stress.

Test Procedure

The time interval required for the rate of heartbeat to return to normal following exercise is an indication of physical fatigue. The primary factors affecting the subject's rate of heartbeat are

environment and workload. Environment includes temperature, humidity, and clothing. Heavy workloads increase the rate of heartbeat and lengthen recovery time. Lighter workloads result in lower heart rates with faster recovery time.

Four tests were run with two independent variables—environment and workload. A bicycle ergometer (fig. 2) was used as an exerciser. Varied workloads were established. Ten 5-minute work periods were established for each of the four tests, for a total of 50 minutes per test.

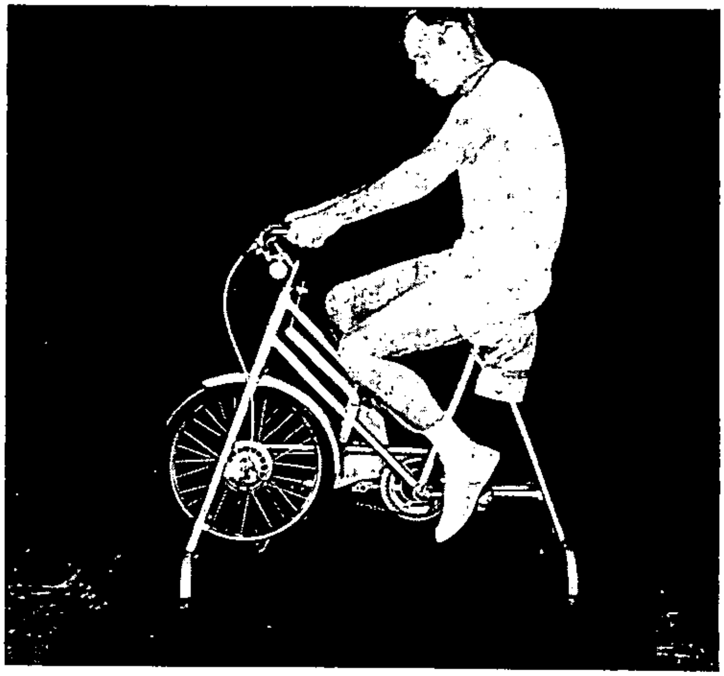

FIGURE 2.—Bicycle ergometer used in experiments to determine human fatigue.

Heart rates were measured with standard stethescope and stopwatch at controlled room temperature. Blood pressure readings were taken to reinforce and supplement the measurement of normality.

Fatigue and stress indicators were curve plotted and evaluated by finding the sum of the ten 5-minute exercise period *partial* recoveries and the time elapsed from the moment exercise ceased (end of the 50-minute work period) until recovery was restored.

Heart rate tests in the laboratory have substantiated this method as being practical for measuring fatigue in the field. In future tests a motor-driven treadmill will be used as an exerciser, and a phototachometer will be the monitoring instrument. Further experiments will measure the energy cost and fatigue incurred by firefighters operating two types of motor-driven fireline trenchers. Also, the energy cost and fatigue of backpacking a load will be compared with wheeling it.

CHILDREN-CAUSED FIRES ARE INCREASING

E. S. Bliss
Forester, Southwestern Region, Forest Service

[*Editor's note.*—This article presents a new and somewhat revolutionary proposal to help prevent fire caused by children. Some may argue over the practicality of this suggestion, but it points to a problem that is not being adequately handled. Other ideas and suggestions are invited for publication in Fire Control Notes.]

Analyses of wildfires started by children in the Southwestern Region, U. S. Forest Service, indicate that they are increasing. Such fires occur most frequently where cities or towns encroach upon the forests. Also, children-caused fires have often occurred near campgrounds and not so often at picnic grounds. There is no record in this Region of fires started by girls, but some were started by boys only 4 and 5 years of age. Considerable thought has gone into preventing children-caused fires. Close cooperation with city fire and police departments has helped. Intense patrolling of critical areas has also prevented many fires. Public appeals to parents have not been fruitful. One based on personal danger to the children yielded no apparent result. Parents seemed fatalistic, at best, about the welfare of their children.

In legal jargon any attractive nuisance that will burn, such as brushpiles, stacks of papers, etc., seems an open invitation to children to set it afire. Unburned brushpiles in the near vicinity of a camping area were the indirect cause of eight wildfires in 1962, all started by small boys. Piles of fuelwood at campgrounds are also an attraction to children, but usually are too difficult for them to light. Preventive measures should include disposal of all needless hazards before the fire season starts. "Fireproofing" critical areas has also been found reasonably effective if most dead flammable material is removed from the ground, dense growth thinned, and lower branches of larger trees pruned. Young trees growing where they could carry fire into the tops of mature trees should also be removed.

Most States have parental responsibility laws similar to those of Arizona and New Mexico—that parents are liable to some degree for the wrongs of their children if the children's acts are motivated in malice. Making these laws ineffective are the criminal laws of most English-speaking jurisdictions that children under 14 years old are not responsible for their criminal acts unless it can be clearly shown that the child knew the wrongfulness of the act at the time it was committed. (On this basis children under 14 committing such acts are not usually considered malicious.) As children seldom have estates in their own right to satisfy court judgments, and under 14 are almost immune to criminal law, legal measures to prevent children-caused fires are largely precluded.

Where laws do not prohibit publishing the names of youthful offenders and their parents, publicity has been found effective in curtailing youthful depredations. Encouraged by lawmen, sev-

eral States are considering repeal of existing juvenile probation laws that prevent publicly naming young offenders and their parents. Most of these laws were passed about 50 years ago, sparked by Judge Ben Lindsay and his followers who openly declared that there were no bad children, only bad parents and bad environments. Children must be protected against public censure for bad acts for which they should not be blamed. The fallacy of this argument is now evident to any thoughtful person, and it has resulted in great increases in juvenile delinquency.

This article submits for consideration a measure to curb children-caused fires in very critical fire areas. Where authority exists or can be obtained, these areas should be closed to children under 14 years of age unless accompanied by their parents or other responsible adults during critical fire conditions. Patrolmen would be needed to enforce this measure, but their efforts would then be more effective. Probably less patrol time would be needed than at present, when a patrolman must frequently follow a gang of boys for hours to make sure their activities do not include fire starting. The gang would be put out of the closed area, and—after making sure they were not returning—the patrolman could go about other business. Curfew laws have been effective in some States and England in preventing this and other juvenile offenses. The cost of preventing and controlling fires has mounted to the point where new and possibly restrictive measures seem justified.

INFORMATION FOR CONTRIBUTORS

It is requested that all contributions be submitted in duplicate, typed double space, and with no paragraphs breaking over to the next page.

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.*

When Forest Service photographs are submitted, the negative number should be indicated with the legend to aid in later identification of the illustrations. When pictures do not carry Forest Service numbers, the source of the picture should be given, so that the negative may be located if it is desired.

India ink line drawings will reproduce properly, but no prints (black-line prints or blueprints) will give clear reproductions. Please therefore submit well-drawn tracings instead of prints.

THE FUTURE OF OUR FORESTS

IS IN YOUR HANDS!

Follow Smokey's A-B-C's

A*lways hold matches till cold —then break in two!*

B*e sure you drown all fires out—cold!*

C*rush all smokes dead—in an ash tray!*