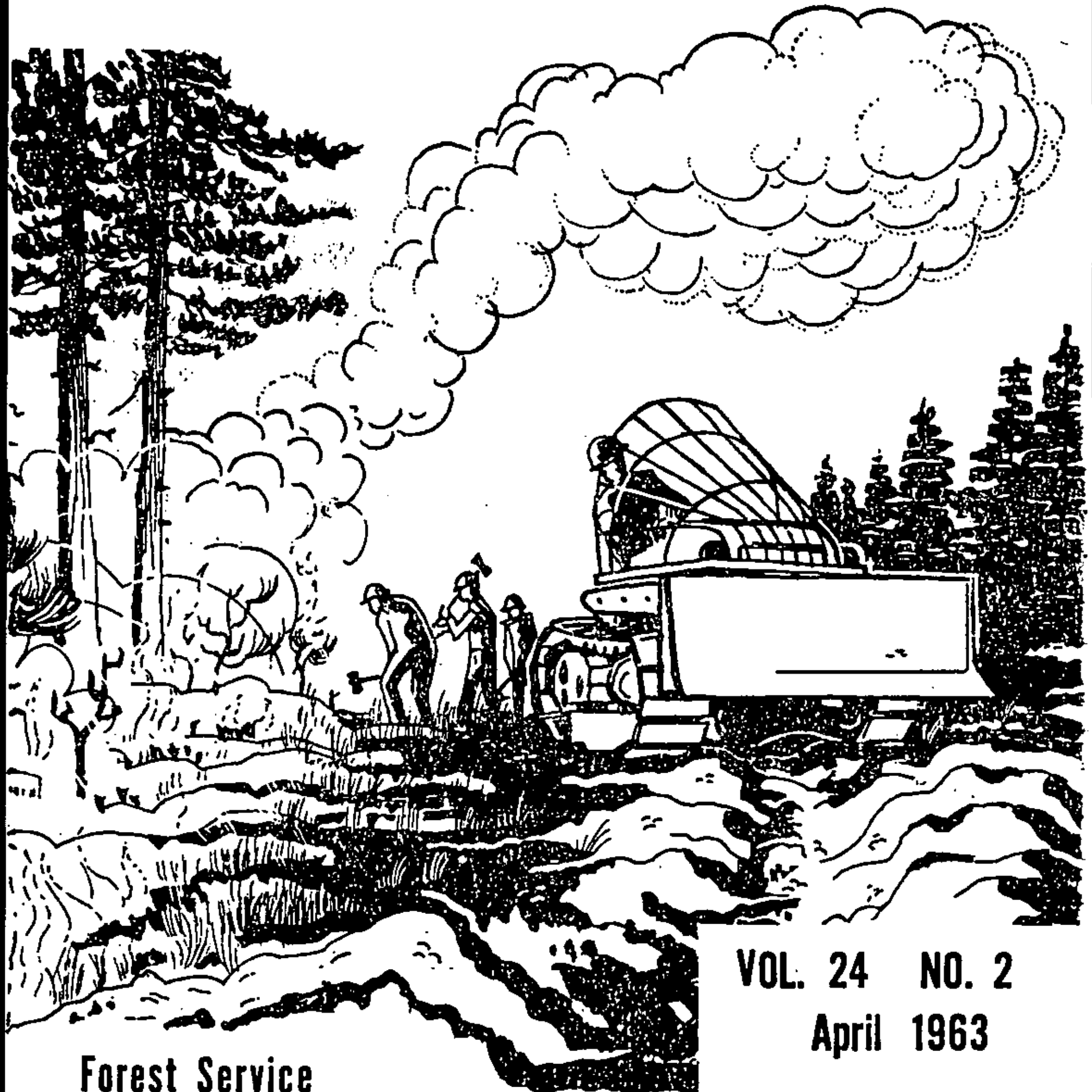
FIRE CONTROL NOTES

A PERIODICAL DEVOTED TO THE TECHNIQUE OF FOREST FIRE CONTROL



VOL. 24 NO. 2
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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 2

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, 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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THE FIRE CONTROL SIMULATOR

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Foresters, Division of Fire Control, Washington Office

Simulation is a watchword in Space Age training. A simulator attempts to represent a real situation in which operations are carried out.

The Forest Service has long been interested in a simulator program that would provide realism in command and staff decision training for campaign fire management. For many years campaign fire exercises have been run using maps, blackboards, and sometimes topographic models. These aids to the training exercise did not provide sufficient dynamics, realism, time pressure, and active trainee participation.

During 1961, the Division of Fire Control explored the possibility of development of a relatively inexpensive simulator that could be used with exercises to train fire bosses and staff, and also initial attack crews.

To be fully effective, the fire simulator needed to provide realistic simulation of:

1. A moving fire perimeter with the flames clearly visible.
2. Burned-over area showing in grey black.
3. Smoke in accordance with wind direction.
4. Movement of fire edge in accordance with wind, topography, fuel type, and effectiveness of command decisions.
5. Aerial and oblique view of fire area.
6. Tankers, tractors, manpower, and other firefighting forces shown by symbols.

Early in 1962 a contract was awarded to the International Electric Corporation, Paramus, N. J., to design a simulator and a command and staff decision-making exercise. The simulator was completed in November 1962, and the first exercise run was made in December 1962.

Simulator

TRAINING ENCLOSURE

The simulator enclosure is a portable, free-form, bell-shaped configuration, 30 feet wide and 24 feet long. There is a light-trapped entrance at the rear of each sidewall. The enclosure is constructed of rigid, lightweight, 4- by 8-foot panels, modularly designed so that assembly, disassembly, and packing may be accomplished quickly and easily. The roof is constructed of lightweight fabric.

The enclosure is divided into two sections: the Trainee Area and the Control Area (a compartment within the enclosure). The Trainee Area consists of four worktables: two side-by-side to the front and two to the rear of the enclosure. (See figure 1). The two forward tables are used for seating up to four trainees each. The two rear tables will normally seat four observers each. However,

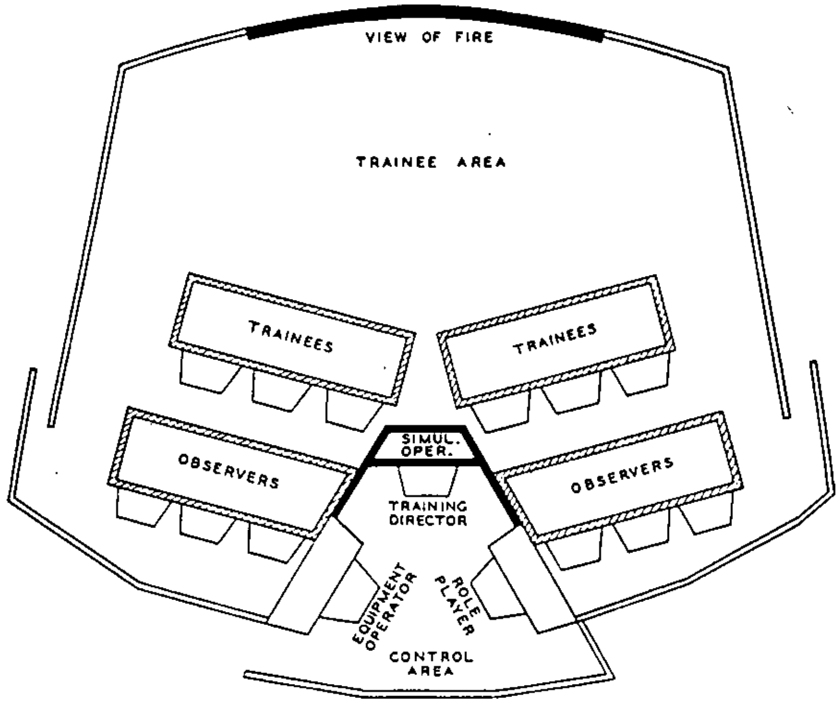

FIGURE 1.—Fire control simulator.

they may be used as trainee positions if a particular exercise requires such additional capability. This seating allows maximum flexibility to train groups of different sizes, or groups with differing operational responsibilities.

The Control Area is situated on the centerline, to the rear of the enclosure, and is wedge shaped. (See figure 1.) At the front of the control area is the Training Director's position. Above this position is the projection booth and the position for the Simulation Operator. To the rear of the Control Area is the Role-player position and the Equipment Operator position, with the audio control console and tape decks.

PROJECTION SYSTEM

The projection booth, at the front of the control area, is elevated 6 feet above floor height and houses three mirror-bounce projectors powered by standard 110-120 volts, 60-cycle. The projection screen consists of a portable snap-together frame and a curved 8- by 12-foot screen. (See figure 2.)

The capability of this equipment includes display of the wildland scene and dynamic reproduction of the flame and smoke. In addition there are two small gimbal-mounted symbol projectors for display of such symbols as air tankers, tractors, vehicles, etc. A standard 35-mm. slide projector is used for briefing (showing fuel types) and debriefing purposes.

FIGURE 2.—Projection system.

COMMUNICATIONS EQUIPMENT DEVICES

The communication console, located in the Control Area, is used for control and switching of communications and tape recording. Communications methods simulated are

1. Intercom (public address—speakers)
2. Telephone
3. Ground-air radio
4. Ground-ground radio.

In addition, two audio tape recorders are available. One may be used for injecting a variety of sound effects or other desired variables into the exercise. The other tape recorder is used during the exercise as an events-recorder to ensure a complete performance record for the debriefing period.

Located on each trainee worktable and at the Role-player's position is a communication unit consisting of 8-button phone and two push-to-talk radio handsets. The base of each communication unit has four standard phone jacks, mounted on the front plate, two on each side. Each pair has jacks marked "G/A" (ground to air) and "G/G" (ground to ground). The phone is coded to permit communications with all other trainees and the Role-player. In addition, the Training Director may monitor all calls on these lines.

TRAILER

All of the equipment is designed to fit into a standard tandem wheel trailer that can be pulled by a 1½-ton truck. Dimensions of the trailer are 14 by 6 feet; weight capacity is 3,000 lbs.

Exercise

The exercise was designed to provide fire control personnel practice in:

1. Evaluating the fire
2. Ordering resources
3. Planning an attack strategy
4. Assigning resources
5. Making decisions as the fire situation changes
6. Dealing with emergency control problems
7. Monitoring and evaluating decisions.

The following is a briefing for a typical exercise:

"The fire is located on the Brush River District of the Green Forest, Region 12. This Forest has central dispatching; all crews and equipment are dispatched through the central dispatcher. You are a Class II fire boss dispatched from an adjacent District. Your orders are to go to the fire and take charge.

"A radio-equipped tanker with a 5-man crew has already been dispatched and should be at the staging area when you arrive. You reach a vantage point in about 30 minutes from the time the fire was reported, which was at 10 a.m., July 1. This vantage point is located near the fire. You have radio communication in your pickup. Telephone lines are nearby, intact and available. All firefighting resources will arrive and check with you via radio at a staging area located on the road below your vantage point."

The Simulator Operator then projects the fire on the viewing area. The fire boss appraises the fire, decides on strategy (fig. 3), and begins his control action which includes ordering resources and assigning crews. He places his calls to the dispatcher, tanker crew foreman, and others in a realistic manner using the radio communications available to him. If he fails to order sufficient men and equipment needed for suppressing the fire, it continues to burn and increase in size. If his actions would reasonably be expected to result in an effective control line, he sees this effect as the fire stops and dies out in the area being effectively controlled.

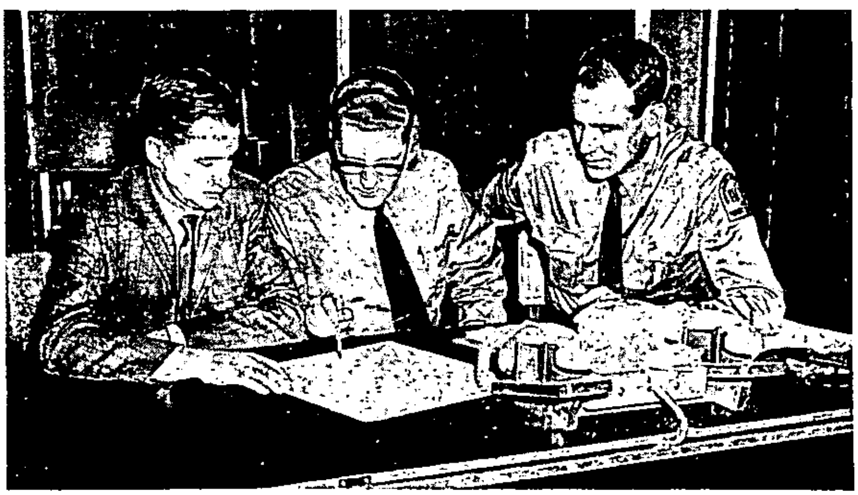

FIGURE 3.—Trainees evaluating a fire.

From time to time the Training Director ensures that realistic messages are transmitted to the fire boss through the Role-player. Some typical messages that might be sent in the early stages of the fire are as follows:

Role	*Message*
Dispatcher:	This is the Dispatcher. The Supervisor wants to know how much fire you got. Will you need a 'copter?
Dispatcher:	Just had a call from the Brushy Creek newspaper. They have sent their photographer and a reporter out to get pictures and a story. They'll arrive at the fire in about 20 minutes. How do you want to handle this?
Dispatcher:	The State Division of Forestry called and wants to know if you need any more tankers. They can have six tankers at the staging area in 1 hour. What name have you given this fire?
Dispatcher:	We've just had a weather report for the fire area. Temperature 85°, humidity 18%, and winds about 2 miles from the South. We've asked for a special forecast. Should be ready in about an hour.
Tanker Foreman:	We had a flareup here in a heavy patch of fuel. Our nozzle man was burned. He needs to be taken off the line. What should I do?

Examples of additional stress situations that might be used by the Role-player as needed are:

"Another fire has started 3 miles down the road, so we won't be able to get you any more manpower or equipment today. In addition, the Supervisor wants you to release three tankers and send them to the new fire."

"The Supervisor is on his way to see you. He thinks you should have more tankers protecting the houses at Panorama Heights."

"The sector boss wants to backfire as soon as possible from the upper road."

"The local TV station wants an interview with you and a short tape recording for showing tonight."

"A traffic jam is blocking the main access road to the fire and threatening delays in equipment delivery."

"A power company official is on the phone asking information on possible danger to powerlines that run to the homes in the fire area. He wants to know whether you feel the powerlines may have to be deenergized."

As he "fights the fire," the trainee has access to those aids he would normally have available to him in a fireline notebook. This includes fuel type descriptions, graphs and charts on rate of construction of fireline by fuel types, and charts on resistance to control. In addition the trainee is given a topographic map of the area, weather forecast, and a tabular log for cost control.

The instruction team keeps a number of forms, including the Training Director's exercise evaluation form and a resource order log. After the fire is suppressed and the fire organization demobilized, a debriefing (fire analysis) is held. Debriefing is essential. It is important psychologically that the trainees receive feedback from the results of their performance. The simulator, with its capability to display fire spread and burned area, provides the trainees with immediate feedback from some of the consequences of their decision-making. However, an approach must be followed that will allow the trainees to review all aspects of the fire management, including plans, service, and finance activities.

Debriefing is as follows:

1. This session takes place immediately after the end of the exercise. It is conducted in the training enclosure with the trainee tables rearranged. The group is seated in a manner that will encourage communication, e.g., circle, semicircle, or conference table, as opposed to a conventional classroom seating.
2. The Training Director starts the debriefing session, using his exercise evaluation form as a guide. His main objectives are to ensure adequate feedback of results and documentation of exercise events.
3. The trainees appoint a debriefing leader and recorder from among the trainees. The debriefing leader guides the discussion to
   (a) Ensure total group participation
   (b) Identify problem areas
   (c) Give constructive direction to the discussion
   (d) Seek resolution of problems
   (e) Make recommendations for use in future training exercises and, more significantly, actual firefighting operations.
4. Each trainee has maintained a decision log of the exercise during the time that he was not serving as the active fire boss. During the debriefing period these logs should be used as a means of reviewing dissenting opinions of actions taken by the active fire boss and also in examining alternative courses of action.
5. Team members and the debriefing leader may evaluate any new procedures tried during the training session and decide whether to continue, discontinue, or modify these procedures.
6. Team members and leader may elect to relate a problem being discussed to other problems and discuss similarities and applications of techniques and methods.

The agenda of a proposed 3-day training exercise calls for a morning session of orientation of the trainees in the simulator operation. The afternoon session is devoted to a series of warmup problems for the trainees. The second and third day is devoted to the actual simulator exercise, preceded by a short pre-exercise briefing of ground rules. The third day's activity ends with a debriefing session.

Summary

The main advantages of the fire control simulator and exercise for command and staff decision-making training for campaign fire management are

1. Maximum individual participation
2. Stress and time pressure on decision-making
3. Easy transfer from exercise experience to job experience
4. Emphasis on teamwork
5. Rapid feedback of results of decisions.

The "heart" of the simulator is a projection system which displays an oblique aerial view of a typical wildland area and a fire starting and spreading across this area. The spread and intensity can be controlled to closely approximate the combined effects of topography, forest fuels, and weather.

The Simulation Operator starts the "fire" and simulates fire perimeter, burned-over area, and smoke.

Through projected symbols such as aircraft, tractors, and fire crews, the sequence of firefighting actions can be simulated.

Information on weather conditions, availability of men and equipment, and other key facts are fed to trainees over intercommunications and public address systems which closely simulate the environment of a fire headquarters. The trainee's commands and requests for information are responded to by fellow trainees, who are members of his firefighting team, or by a role-player instructor.

Two dual-track tape recorders provide sound effects and also permit recording of important aspects of the exercise and the responses of the trainees.

The Training Director gives pre-exercise briefings, directs the start of the exercise, modifies inputs to trainees, and determines success or failure of control action taken by the fire boss.

The Simulation Operator provides the fire, smoke, burnout, and symbols. The Equipment Operator handles the audio and recording equipment to simulate ground-to-ground, ground-to-air, and telephone channels. The fourth member of the instruction team, the Role-player, takes the part of dispatcher, cooperative agency head, Forest Supervisor, and other personnel.

We have found that an adequately simulated fire with provision for immediate feedback of information on the results of performance has significant impact on the trainees. It's a rare person who can shrug off failure when he's practicing his own skill. Although it causes him some pain, he becomes increasingly aware of the need for information about the consequences of his decisions and actions, and he begins to evaluate these consequences critically. Each member of the team rediscovers his ability to think and solve problems.

LIGHT AIR TANKER USE IN NORTH CAROLINA

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Chief Pilot, North Carolina Division of Forestry

With the start of the 1963 fire season the North Carolina Division of Forestry began its sixth year of using air tankers in fire control. Early in 1958 following TBM demonstrations by the U.S. Forest Service and the able assistance of Georgia and U.S. Forest Service TBM's on several going fires, the Division leased a biplane to conduct a series of fire and chemical tests. Results of the tests indicated that 200 gallons could be an effective drop on average coastal fuels. It was recognized from the beginning that both large and small tankers have a place in the complete aerial delivery operation. But primarily because of strip availability and cost consideration, both of which will be explained below, a decision was made to begin with small tankers using mobile base facilities. Subsequently, two surplus N3N's with this capacity were acquired and fitted for training and operational use.

The first year of N3N activity was largely one of training personnel and refining equipment. Lightplane patrol pilots were checked out in the tankers and in lead plane flying. A number of air knowledgeable fire control officers qualified as air attack bosses. All ground personnel received training in loading and servicing the light tankers. On the premise that the tankers were to be working for and directly with them, the ground woods crews were taught how to control and to fully utilize close air support. Seven aerial delivery training sessions were held over the coastal region. Since the inception of aerial delivery, this subject has been stressed at all annual training sessions and will be a continuous training requirement.

Among operational procedures tried and adopted was a standard drop description for radio communication of drop requests. The drop request, as originated by the crew, sector, line, or air attack boss, consists of four basic elements, each stated in one word or phrase of standard terminology:

1. *The type of drop.*—This is covered by the word DIRECT (on the fire) or INDIRECT (ahead of the fire).
2. *The tactical purpose of the drop.*—The terms HEAD, FLANK, SUPPORT, REINFORCEMENT, BREAKOVER, SPOT, SNAG, GROUND FIRE, LINE CONSTRUCTION AND SAFETY (ground crew protection) Drops have each been given a definition. This tells the pilot what the drop is expected to do; and because of the way certain tactical purposes are defined, this phrase also helps to convey the desired target location.
3. *The content of the drop.*—RETARDANT, WATER, WET WATER, DYE, or combinations of these are specified according to the needs of the particular attack.
4. *The target designation.*—This element of the drop re-

quest describes the location of the drop as briefly as possible. Head or Flank locations are localized by using compass point description, i.e., SOUTHEAST FLANK, NORTH HEAD. If the target requires repeated attacks, it may be "designated" by assigning it a code name based on the phonetic alphabet. Advance designating of targets on fire status maps is a timesaver when future targets are known during planning or briefing sessions.

When multiple tank aircraft or several tankers are being used, a fifth element is used. This specifies the number of drops requested on the designated target and, in the case of multiple tank aircraft, the method of dumping, i.e., Single, Trail, Salvo, etc.

A sample call would go out as: "Air Attack to Tanker 5; Drop Call; DIRECT, SUPPORT DROP, RETARDANT, SOUTH FLANK, DESIGNATE TARGET ECHO, THREE DROPS." In practice, several advantages of the drop request sequence are apparent. It serves as a checklist to preclude important elements of the request from being left out of the call. It helps all involved in the drop—on the ground and in the air—to "picture" the type of drop that is to be made. It reduces radio traffic by use of concise language and by providing a "thinking guide" for personnel taking an active part in the drop operation. It is extremely helpful in defining target areas.

A wallet-size card describing the call system was printed and distributed to all fire control personnel for ready reference. The reverse side of the card lists safety precautions for ground crews endangered by low drops.

A Condition-of-Readiness standby plan was also devised to allow tanker crews to adjust their working schedules to current fire danger. Four states of alertness were recognized, varying from a normal "one day's notice" condition to the "5-minute—on standby" situation. Each district uses daily burning index and buildup index information plus local factors as guidelines in computing their fire danger in terms of air delivery needs. Central dispatching is kept informed of any change in district Condition-of-Readiness status.

In order to utilize the flexibility of the small tanker fleet, a concept of remote area landing strips, mobile mixing and support equipment, and universal training in the ground support function is required.

This also calls for a close tie-in with the changing fire danger picture. The air tanker ground service units consist of tractor-trailer tankers and mixing tank and aviation gasoline trailers. One of the tractor-trailer tankers has a capacity of 4,000 gallons; the other three carry 2,000 gallons each. One of the open type 1,000-gallon mixing tank trailers is fitted with an engine-driven agitator in addition to the standard recirculating and loading pump.

An inventory of retardant chemical is packed on pallets with forklift trucks available for easy handling and distributed about the region. Monammonium phosphate, with a corrosion inhibitor added, is being used currently, but recent tests indicate probable

FIGURE 1

change in the near future to one of the higher viscosity mixtures now under development.

The original airstrip check of the region revealed that, of 52 landing areas with runways 2,000 feet or more in length, only 12 were hard surfaced and suitable for air tankers of medium and above-medium capacities. An airstrip development program was begun to encourage construction and proper maintenance of strategic landing strips in the area.

In the past 4 years five additional small tanker strips have been constructed by cooperators with technical assistance from the Division. Facilities such as ponds, permanent pumping equipment, and storage buildings were added as required.

Every year pre-fire season surveys are made of usable strips, and information obtained is used in updating charts in dispatching headquarters.

As operational experience was acquired, many refinements were made in aircraft and ground support equipment. Tanks were

modified on the N3N for better visibility and lower drag. Drop gates were changed for cleaner, more positive drops. Wing area was increased for greater lift, and tailwheel locking devices installed for better control on rollout. Mixing tank bottoms were vee'd for improved agitation. One stationary mixing tank was elevated for gravity-feed loading in the event of personnel shortage at the central base. Pumping equipment underwent constant development and alteration as improvements for faster loading and increased dependability were suggested.

Early in 1962, after a survey of current production aircraft, one of the N3N's was replaced with a 450-hp. low-wing tanker of 300-gallon capacity (fig. 1). This late-model air tanker has proved well suited to Division coastal suppression requirements. Initial cost is in line with the cost of a new tractor-plow unit. In its retardant capacity, short field capabilities, simplicity of operation, and maintenance demands it is a practical air tanker for day-to-day grassroots fire suppression work. Its slow drop speed (75 to 90 m.p.h.), excellent visibility, control simplicity, and cockpit structural design are important safety features.

Present Division plans call for two more of this type aircraft in tanker operations in 1963. Through cooperation between Division and manufacturer, these aircraft will have many improvements beneficial to aerial tanker service, including additional load capacity and a larger engine. Specialized aircraft design is recognized as the prime need in development of the forest fire air tanker program.

FIRE CONTROL HELIPORT

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On the Yakima Indian Reservation helicopters were used for the first time as a suppression tool during the 1961 fire season. The reservation is located in south-central Washington where the average yearly rainfall varies from 8 inches in the grass-brush areas to 40 inches in the higher fir forests. With the forested areas containing some 8½ billion board feet of ponderosa pine and Douglas-fir, and subjected to severe lightning storms, a method of quick initial attack and followup was needed.

The nature of the 1961 season afforded excellent opportunity to test the helicopters in all phases of fire control work, such as reconnaissance, shuttling, rescue, and supply. The favorable results of these initial trials indicated that helicopter use was practical, and a heliport was planned and constructed on Signal Peak. "The Peak," which has an elevation of 5,111 feet, is located in the approximate center of the reservation's timbered area, is served by a good road, and overlooks the area where 75 percent of the timber fires occur.

The heliport was constructed according to F.A.A. specifications, with work having been started in late summer of 1961 and completed in midsummer of 1962. All work was done by summer fire control aids stationed at the Signal Peak Ranger Station.

The heliport is located on the south edge of the summit of Signal Peak and offers a 220° takeoff and approach pattern. Winds are generally from the west, with occasional winds from the east; both of these approaches are unobstructed. The Signal Peak

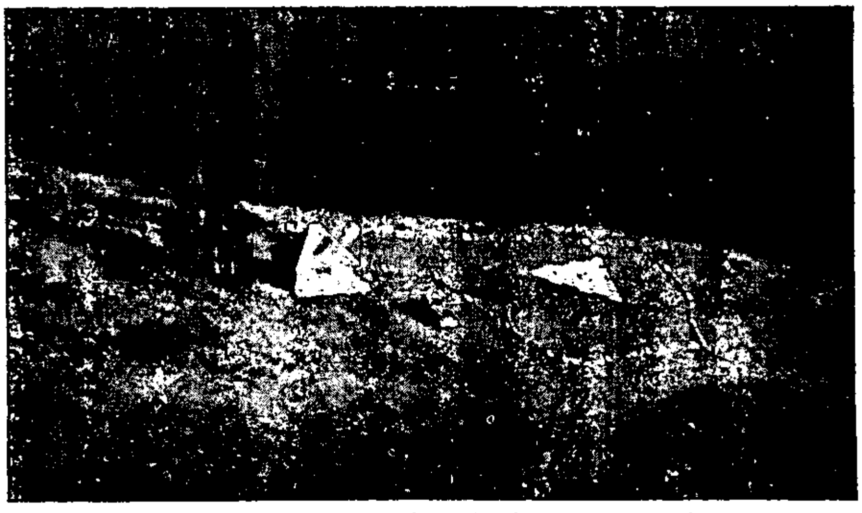

FIGURE 1.—Heliport (from northwest), showing approach patterns.

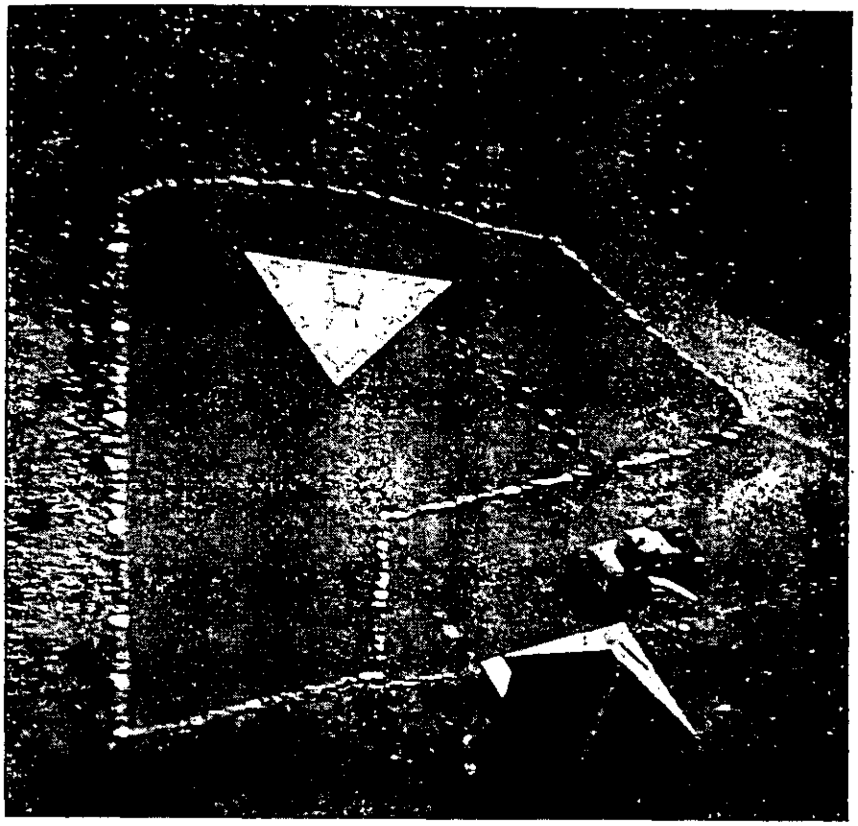

FIGURE 2.—Heliport (from overhead looking south), showing storage shed, parking area, and layout detail.

lookout, lookout cabin, and heliport storage shed, as well as a few trees, block the north approach.

The concrete pad is surrounded by a border of large flat rocks with every 10th rock being painted white, and the area between the pad and border filled with 5/8-inch minus washed gravel to eliminate dust. A graveled parking area large enough to accomodate six or seven pickups or cars, a large storage shed, and a standard wind sock are adjacent to the outside border.

The storage shed, which contains tools packaged for helicopter transport, extra gasoline and oil, and other miscellaneous supplies necessary for helicopter operation, is painted a light gray with the roof international orange. Fire protection is provided with two 25-lb. CO_2 extinguishers.

CABINET FOR LOOKOUT TOWER CAB

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The 79- by 79-inch cab on the Whitmire Lookout Tower imposes a limitation on the size of any cabinet to be used within. Yet, such a cabinet has been designed as a stand for the firefinder, for radio and telephone installation, and for storage of miscellaneous supplies. Because the peak of the fire season is during the colder months, an electric heater was included and housed in the lower compartment of the cabinet.

The cabinet is 23 inches square, 3¾ feet high, and constructed of ¾-inch birch veneer plywood. The writing shelf is 21½ inches square and made of ¾-inch plywood. The drawer below the shelf may be used for a dispatching map or other purposes. The radio compartment has hinged doors on opposite sides to provide ventilation during operation of the radio.

The cabinet is placed slightly off center in the direction of the tower orientation stake with 22 inches between wall and cabinet on that corner. The remaining space on the opposite side is enough for easy operation and use of the writing shelf, firefinder, map, and radio, and for clearance of the trapdoor. The telephone is mounted on the side of the cabinet nearest the trapdoor. Also mounted on this side of the cabinet is the anemometer buzzer and switch controlling it, so that windspeed can be measured direct from the cab (fig. 1). The Osborne firefinder ordinarily has overall dimensions of 24 by 27 inches. To conserve space the tracks were cut down in a metal lathe from 27 to 24 inches. This reduction in size did not hinder the lateral displacement needed for clear observation around the cab corners.

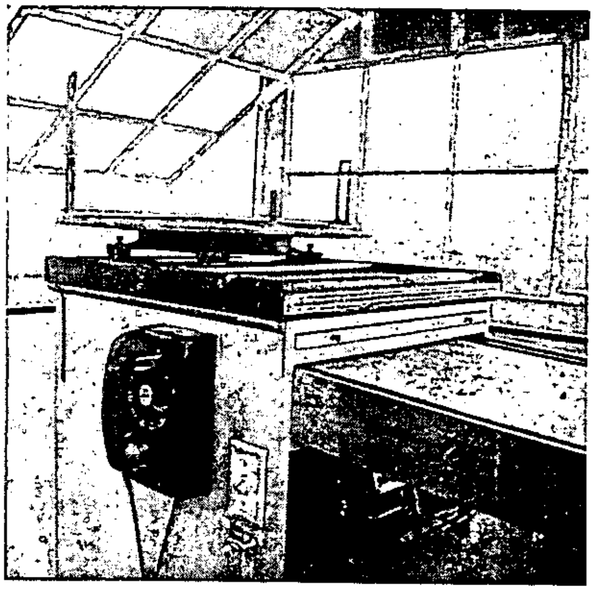

FIGURE 1.—Cabinet, with dispatcher's map drawer extended above radio compartment.

SKID-PAN CARGO CARRIER FOR CRAWLER TRACTORS

MISSOULA EQUIPMENT DEVELOPMENT CENTER
U.S. Forest Service

For several years various makeshift skid-pan cargo carriers have been used with tractors on large fires. Before skid pans came into use supplies and firefighting equipment were often lashed to the tractors for transport to and around the fire.

Missoula Equipment Development Center engineers have designed, constructed, and tested an improved skid pan for use with tractors. Construction drawings (Drawing No. ED-208A-R1) and materials list are available from the Missoula Equipment Development Center.

Field tests of the designed skid pan during the 1961 fire season proved its value wherever used. Comments from field personnel were very favorable. Major improvements over other types are

1. A telescoping pushpole facilitates maneuvering by allowing the tractor to push the skid pan backwards—an important feature in rough terrain. When descending steep slopes the towing cables are slack, and the telescoping pushpole prevents the skid pan from sliding into the tractor. The towing cables absorb all the strain when traveling on level ground, sidehill, or uphill. The pushpole lengthens and takes no strain unless it is telescoped to the stoprings when making turns, backing up, or descending slopes.
2. Wide-channel iron runners control slippage on steep side slopes.
3. The improved skid pan is designed so that the pushpole and towing cables may be attached at either end. Conveniently arranged tiedown loops are provided for lashing down cargo quickly and easily.

Skid-pan cargo carrier. Note arrangement of pushpole and towing cables assembly.

HOSE-FOLDING MACHINE

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The washing, drying, and repacking of firehose used in the control and mopup of forest fires is a time-consuming task. To reduce the man-hours it requires has led to the design of various types of equipment by fire control personnel.

In Alaska portable pumpers are extensively used to control wildfire. Thousands of feet of dirty hose have to be reconditioned almost every day during the peak of the season. Because of the size of the area requiring fire protection (225 million acres) and the lack of roads, our fire control operations are largely aerial. Hose is usually packed so that it can be dropped by parachute. For best handling, hose is folded and placed in packs containing 300 feet each.

By former methods, which involved manual techniques and a jig designed for the purpose, 20 minutes were required to pack 300 feet of hose. We could not afford this much time during peak fire periods. The new hose-folding machine (fig. 1) was designed to cut time. It neatly and firmly folds hose at the rate of 100 feet per minute. It now requires 5 minutes to complete a task that formerly took 20. The saving in time is indeed significant, and the resulting product is better.

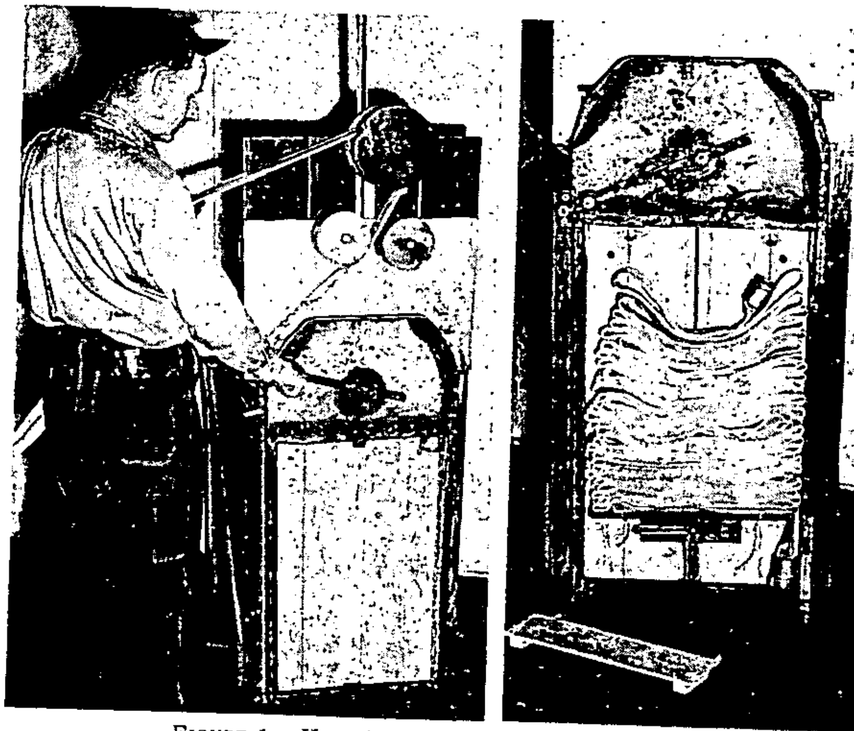

FIGURE 1.—Hose-folding machine in operation.

One- or $1\frac{1}{2}$-inch unlined linen hose is fed into the machine by a simple up-down stroke on the handle of the folding arm. Hose is folded in any desired width of pack. When the last fold of the section is made, an automatic device compresses the section. The folded section is then tied and placed on a hose sacking table. When three sections are stacked on the table, the lengths are then coupled.

The tie cords are then cut, and a pack sack is slid over the hose pile. The hose pack is then pushed off the tabletop into a backpack, and the hose is ready for use.

The material cost of the units is approximately $60 including the sacking table. It can be constructed in approximately 30 man-hours.

Detailed plans and a list of materials needed are available from the State Director, Bureau of Land Management, 6th and Cordova Streets, Anchorage, Alaska.

RECORDING DEW GAGE

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Instrument

The instrument developed by Intermountain Forest and Range Experiment Station to record duration and amount of dew (fig. 1) consists of an expanded polystyrene block mounted on a balance, a clock-driven drum, and a pen geared from the balance to the drum. Changes in weight of the expanded polystyrene block as dew or rain is deposited are recorded on a chart mounted on the drum. This record shows the amount and time of dew formation and dissipation. The instrument also records time and amount of rainfall.

Balance

The balance was developed during the 1930's by personnel of the old Northern Rocky Mountain Forest and Range Experiment Station (now part of the Intermountain Station) to record wind velocity, duff moisture, and wood moisture. Mr. H. T. Gisborne sketched a possible instrument layout in 1932. In 1933 Mr. Dunlap, senior engineer, Forest Products Laboratory, Madison, Wis., completed plans for such an instrument and constructed and delivered one model to the Priest River Experimental Forest. Seven more instruments were ordered and delivered in 1934 at a cost of $331 each. The eight instruments, called anemohygrographs, were used

FIGURE 1.—Dew gage with block of expanded polystyrene in place, and the cover removed for adjustment of the balance: *1*, Expanded polystyrene dew block; *2*, support; *3*, base; *4*, drum and chart; *5*, 7-day-clock drive.

with modifications in forest fire research through 1940. Wartime restrictions prevented their production and none have been produced since. The original eight units are now at the Northern Forest Fire Laboratory, Missoula, Mont.

Dew Block

To measure dew, the fuel moisture sticks originally used on the anemohygrographs were replaced by blocks of expanded polystyrene. The duff moisture indicator and wind recorder, with their pens, were removed. Expanded polystyrene is nonhygroscopic and relatively stable when exposed to weather. This inexpensive material, used commercially as insulation, is readily available in sheets 1½ by 12 by 108 inches at $2.50 each. One sheet contains enough material to make three dew blocks. Hirst[1] in England used expanded polystyrene to measure duration of leaf wetness. He found that a block of polystyrene became wet and dry at almost the same time as the leaves of the crop he was studying.

The dew blocks for this instrument are each 1½ by 12 by 24 inches. They are suspended at three points on the balance. Two points are pivoted at the ends of a T-shaped support that acts as a fulcrum. The remaining suspension point at the other end of the block is connected through pivots and counterweights to a pen. The pen records changes in weight of the dew block on a chart mounted on the 7-day clock-driven drum. The blocks weigh approximately 225 grams, and the frames for their support weigh 75 grams. Dew deposit ranged to as high as 68 grams during a summer night in 1958. Tables were constructed to convert grams of moisture deposited to equivalent fractions of an inch of precipitation. For dew blocks of the surface area used on this instrument, 5 grams of dew would equal approximately 0.001 inch of precipitation.

Calibration

The gages are calibrated by placing successive 5-gram weights at the center of the dew block and marking the deflection of the pen arm on the chart. The variable weights of the counterbalance make it possible to adjust the gage to a zero mark.

Operation

Since the gages are light in weight and the drum is clock driven, the instruments are portable and excellent for field use. The dew block is 12 inches above the base of the instrument. Therefore, when the instrument is on the ground, observations are obtained at 1 foot above ground. For observations at other heights, the instrument can be set on stands mounted on poles. Dew could be recorded at ground elevation by placing the instrument in a 1-foot pit with the dew block at ground level. Apparently, polystyrene has radiational characteristics similar to those of leaf surfaces. A brief test with two gages, one dew block exposed normally and the other covered with green leaves, yielded similar deposits of

[1] Hirst, J. M. A simplified surface-wetness recorder. Plant Pathology 6: 57–61. 1957.

dew. The 7-day clock and chart permit recording of dew deposition for extended periods. However, gusty afternoon winds can blow the dew block from its mounting. Best results are obtained in sheltered locations, or when the instruments can be checked daily after the afternoon wind has died down and prior to dew formation.

The most dew recorded at the Priest River Experimental Forest during a summer night in 1958 was almost 0.015 inch. Although the instrument also records time and amount of rainfall, amounts greater than 0.020 inch extend the pen arm to its limit. Recorded deposits of rain and dew are easily distinguished; dew is deposited slowly and regularly, but rain causes sudden changes in the trace. Figure 2 shows a typical pen trace during two nights when dew was deposited.

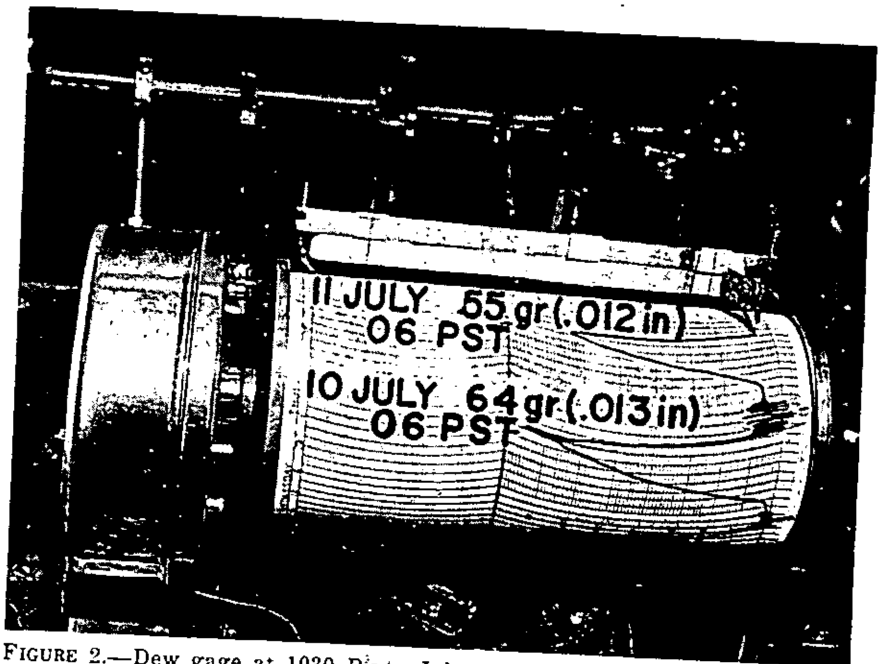

FIGURE 2.—Dew gage at 1030 P.s.t., July 11, 1958. The weight of moisture deposited on the dew block and the equivalent inches of precipitation on the mornings of July 10 and 11 are shown on the chart.

HOW MANY FIRES?

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As forest fuels dry out, the number of fires per day increases. Since most fire-danger meters sort days into classes with different general levels of fuel moisture, there have been reports from all parts of the world on the relation between fire-danger classes and daily numbers of man-caused fires. Sometimes a linear relation has been shown between average fire frequency and danger rating or burning index. But these average numbers include many days with no fires as well as some with more than the average. Accurate description of how often each number of fires per day occurred in the past should help fire control planning by giving a clue to the probability of heavy fire loads as well as to the average level of fire business. A method of preparing such a description will be outlined here.

Examination of fire records from Louisiana and Missouri suggested that the actual frequencies could be closely approximated by negative binomial distributions. These distributions have been found useful to describe many things that are counted in equal units of space or time, such as insects per plant (*1*), seedlings per quadrat (*5*), or accidents per week (*2*). The properties of these distributions have been discussed, and methods of fitting them to observed data have been described (*1, 3, 5*). The purpose of this note is to show how they can be used to describe past fire occurrence in a given area. To do this some of the properties of the distributions will be discussed briefly.[1]

An imaginary model can be described that would give rise to a random frequency distribution of fires in space and time. The space is an area with a nonuniform fuel bed. The time is divided into 1-day periods. The fuel moisture is changed by daily weather conditions which can be classified by a fire-danger rating system. The danger ratings indicate the proportion of the fuel susceptible to ignition by a standard firebrand. A fixed number of these firebrands contact fuel at random locations each day.

The average number of ignitions in large groups of days with a given danger rating will be proportional to the susceptible fuel. On some of these days, none of the random contacts will be in fuels susceptible to ignition; on other days, one or more of the firebrands will start fires. The frequency distribution of number of fires per day in this danger class will be described by a Poisson distribution. For example, if there is an average of two fires per day, there will be no fires on 14 percent of the days, one fire on 27 percent, two fires on 27 percent, and three or more fires on 32

[1] There are two kinds of numbers involved in this. The first is the number of things counted in each unit of time or space—the count. The second is how often each of these counts is made—the frequency.

TABLE 1.—*Partial fire records from Clark National Forest 1946-52*[1]

Danger rating class	Average danger rating	Total number of days	Number of days with no fires	Percent of days with no fires	Total number of fires	Average number of fires per day (*m*)	Estimated *k*
0-1	0.80	2,163	2,146	99.21	17	0.0079	∞
2-6	4.28	1,012	925	91.40	107	0.1057	0.285
7-12	9.57	1,528	1,241	81.22	398	0.2605	0.480
13-24	18.10	1,772	1,176	66.37	904	0.5102	0.970
25-49	32.53	817	413	50.55	797	0.9755	1.007
50+	58.47	72	20	27.78	143	1.9861	1.560
All	11.35	7,364	5,921	80.41	2,366	0.3213	0.298

[1] Based on data furnished by John S. Crosby. See also (*4*).

percent. This distribution has the useful property of being completely specified by the mean. The distribution can be found in tables or computed readily. Since increases in danger rating are accompanied by increases in mean number of ignitions, a family of Poisson distributions will completely describe the fire occurrence for the area.

However, actual fire records aren't described this easily. Days having the same danger rating do not all have the same proportion of the fuel susceptible to ignition. Actual fire-danger ratings are based on windspeed as well as fuel moisture. There are seasonal changes in fuels that are not completely described by danger rating. Firebrands are not uniform in heat output and do not contact fuel at fixed rates in random locations. As a result, there are more days with no ignitions and more days with many ignitions than indicated by a Poisson distribution for any given danger class. There are many "contagious" or "overdispersed" distributions which can describe such frequencies. Of these, the negative binomial is one of the easiest to fit. It is completely specified by two parameters: the average count (*m*) and the exponent (*k*). The larger the exponent, the nearer the distribution approaches the Poisson distribution; the smaller the exponent, the greater the excess of zero and high counts.

Fire-occurrence records from the former Clark National Forest in Missouri for the period 1946-52 (table 1) will be used to show how the frequency distribution of fires can be estimated by computation. These records are for seven Ranger Districts including nearly a million acres of National Forest and another million acres of private land within the protection boundaries. They include the fall and spring fire seasons in the months of October, November, February, March, and April. This gives 1,052 days of record for each Ranger District. Combining the figures for 7 years and seven Districts reduces variability of the frequencies.

Table 2 shows the comparison of actual to estimated fire frequencies in terms of number of days having various numbers of fires in each danger rating class and suggests that the differences are no greater than could be attributed to chance in all classes but danger rating 25-49. Similar tables for 3 years of data from four individual parishes in Louisiana having 352,000 to 430,000 acres of forest land show no more significant differences between actual records and estimates than those in table 2.

TABLE 2.—*Actual vs. estimated days having the indicated fire frequencies*[1]

Danger rating class[2]	Number of fires per day										
	0	1	2	3	4	5	6	7	8	9	10+
	Days	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*	*Days*
0-1	2,146 2,146.0	17 16.9	0 0.1	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0
2-6	925 925.0	72 71.3	10 12.4	5 2.6	0 0.6	0 0.1	0 0	0 0	0 0	0 0	0 0
7-12	1,241 1,241.0	212 209.4	53 54.6	12 15.9	8 4.9	1 1.5	0 0.5	1 0.2	0 0	0 0	0 0
13-24	1,176 1,176.0	394 393.2	135 133.5	43 45.6	18 15.6	1 5.4	3 1.8	0 0.6	2 0.2	0 0.1	0 0
25-49	413 413.0	198 204.6	126 101.1	32 49.8	19 24.6	13 12.1	8 6.0	3 2.9	4 1.5	1 0.7	0 0.7
50+	20 20.0	18 17.5	9 12.6	12 8.3	5 5.3	2 3.3	2 2.0	3 1.2	1 0.7	0 0.5	0 0.6
All	5,921 5,921.0	911 917.0	333 308.5	104 122.5	50 52.3	17 23.3	13 10.7	7 5.0	7 2.4	1 1.1	0 1.0

[1] Based on data furnished by John S. Crosby. See also (*4*).

[2] In each class the upper row shows the actual number of days; the lower row shows the estimated.

To make it possible to estimate probable frequencies for a complete range of danger ratings rather than broad danger classes, graphs can be prepared (fig. 1). The expected numbers of days having each number of fires are converted to percent of the total days in each danger class and plotted as cumulative percent over the average danger rating (from table 1) for the class. Reading from the curves at a danger rating of 25, 59 percent of the days will have no fires and 82 percent of the days will have either one or no fires. Thus, the estimate is that 23 percent of the days will have one fire, 10 percent will have two fires, and 8 percent will

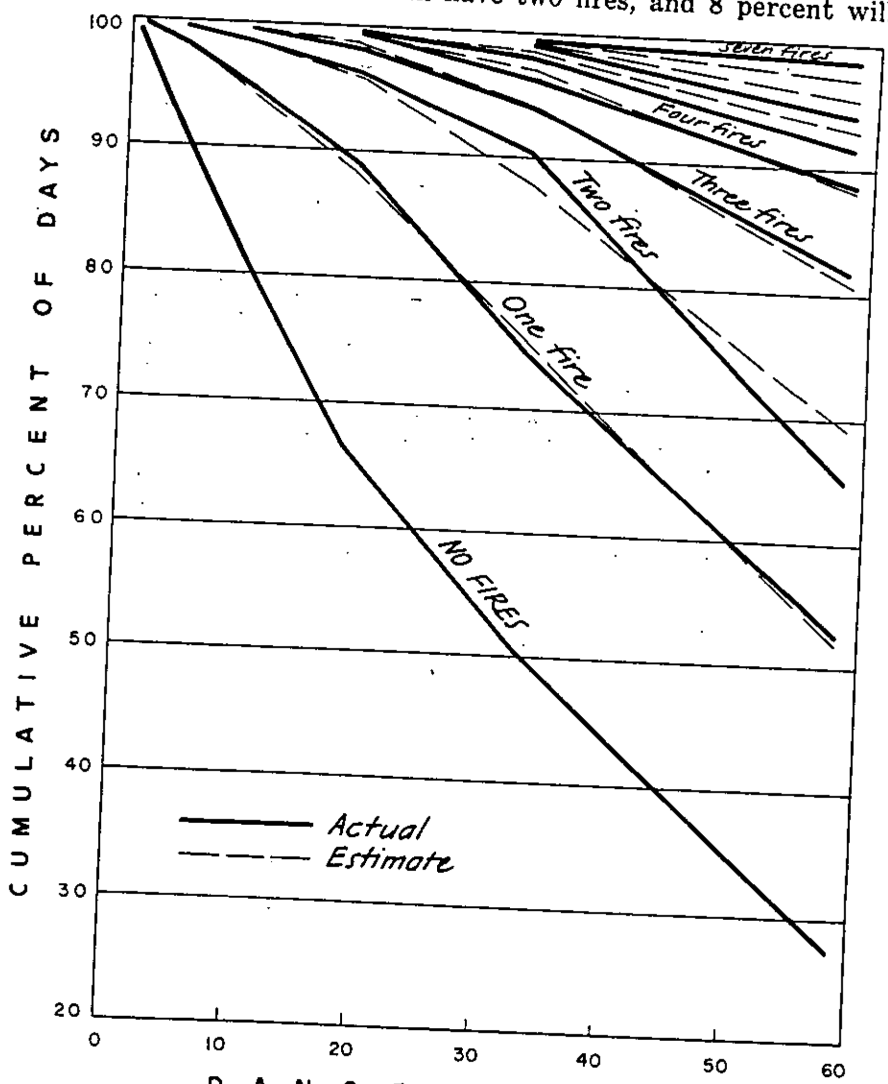

FIGURE 1.—Cumulative percent of days with indicated number or fewer fires per day.

have three or more fires. Graphs like this can be prepared from the actual frequencies, but use of the estimates appears to smooth some of the irregularities in the data.

Use of these estimated frequencies depends on the area and period for which the records are analyzed. The estimates do not tell the whole story because they do not include information about size of fire and fire control expenditures. Although it is tempting to consider combining these estimates with the relation of average area burned per fire in each danger class, this is not likely to be meaningful, because average fire size may be related to number of fires per day within each danger class. Therefore, it seems wise to limit the use of these estimates to suggesting how often the various numbers of fires per day can be expected. Local experience in fighting fire will suggest what disposition of forces can most effectively deal with this many fires on days with these danger ratings.

How to Compute the Expected Frequency

Take danger rating class 7-12 as an example. The necessary values are in table 1. The following method begins by estimating the exponent k from the frequency of days with zero fires.[2] If four significant figures are carried, the total estimated frequency and total number of fires should be accurate to three significant figures. This procedure is followed for each class.

The value of the exponent k is computed from the relation

$$\frac{f_o}{N} = \left(1 + \frac{m}{k}\right)^{-k}$$

where: f_o = frequency of days with no fires (1,241)
N = total number of days (1,528)
m = mean number of fires per day (0.2605)
k = exponent of negative binomial (unknown)

Using logarithms, the equation is solved by successive approximations:

$$\log N - \log f_o = k \log \left(1 + \frac{m}{k}\right)$$

$$\log 1{,}528 - \log 1{,}241 = 0.090351$$

$$\text{try } k = 0.5,\ 0.5 \log 1.5210 = 0.091064 > 0.090351$$

$$\text{try } k = 0.4,\ 0.4 \log 1.65125 = 0.0871232 < 0.090351$$

$$\text{try } k = 0.48,\ 0.48 \log 1.54271 = 0.090376 > 0.090351$$

$$\text{try } k = 0.479,\ 0.479 \log 1.54384 = 0.090337 < 0.090351$$

[2] This method of estimating k will not work where there are no days with zero fire count. In this event, estimates of k and f_o based on the mean, the variance, and the total number can be used (*3*, *5*).

The next step is based on the relation:

$$f_x = \left(\frac{m}{m + k}\right)\left(\frac{k + x - 1}{x}\right) f_{x-1}$$

where f_x is the frequency of days having x fires

$$\frac{m}{m + k} = \frac{0.2605}{0.7395} = 0.35227$$

The second term has to be tabulated for successive values of x. Next, these values are multiplied by 0.35227. Finally, the actual number of days with no fires is substituted for f_{x-1} to obtain the frequency of days with one fire, and other values of f_x are successively computed. For example (from the tabulation below): $f_1 = 0.1687 \text{x} 1{,}241 = 209.4$.

Fires per day (x)	$\left(\frac{k + x - 1}{x}\right)$	$\left(\frac{m}{m + k}\right)\left(\frac{k + x - 1}{x}\right)$	f_x	$p_x = \frac{f_x}{N}$	No. of fires $x \cdot f_x$
0	—	—	1,241	0.812	0
1	0.4790	0.1687	209.4	0.137	209.4
2	0.7395	0.2605	54.5	0.036	109.0
3	0.8263	0.2911	15.9	0.010	47.7
4	0.8698	0.3064	4.9	0.003	19.6
5	0.8958	0.3156	1.5	0.001	7.5
etc.					

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