FIRE CONTROL NOTES

A quarterly periodical devoted to forest fire control

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COVER—This U.S. Marine Corps HR2S helicopter is dropping 450 gallons of water. See story on page 4.

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DOUSING SNAGS WITH CHOPPERS

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On May 5, 1966, lightning struck a ridge and started the Scorpion fire on the Tiller District of the Umpqua National Forest (Oregon). When fire control personnel arrived, the fire was burning in a snag patch on a north aspect in the center of the old Beaver Creek burn. It covered about 35 acres, was 40 chains long, and was 2,900 to 3,300 feet in elevation. The top of the fire was on a ridge, while the bottom was 300 to 400 feet above the creekbed. A south aspect snag patch was just across the creek, which was about 2 feet wide and 6 inches deep. The fire was spreading from snag to snag; as the snags burned and fell to the ground, ground fire began below. There was little if any spread on the ground. There were 42.5 snags per acre, averaging 2.85 feet in diameter, and most of them were broken topped Douglas-fir with top rot exposed in the breaks. The fire was spreading erratically, driven by gusty winds from local thunderstorms, and was spotting downhill from the top of the ridge, where the fire had started.

From our vantage point, a heliport 600 feet horizontally and 300 feet vertically east of the east edge of the fire, we could see 40 percent of the fire area and could observe firespread and wind currents fairly well. A previously constructed helispot was 800 feet below the fire on the "stinger" of Scorpion Ridge. The heliport, which was on an adequate road, was about 1 hour's drive from the Tiller ranger station.

Since the spread was entirely by snags and ground control was not a serious problem, we concentrated on putting a fireline around the area the first night. Then at daybreak we planned to stop the spread of the snag fires by using aerial retardants and by falling the snags within the fire area. We had to fell the snags while we still had cloudy weather with 40 to 60 percent humidity accompanying the lightning and gusty winds. However, it was necessary to change our plans when we found that fixed-wing tankers and retardants would not be available.

We had one Hiller 12E helicopter on the fire, and the pilot had saddle tanks available. He said he could put water on a snag or a flareup without difficulty at our elevation. We requested a set of saddle tanks and were sent a second helicopter equipped with such tanks. We also ordered the supply pumper for the helicopters, and the saddle tanks for the first helicopter were received with the pumper.

We began snag felling at 6:30 a.m. on May 6. We immediately faced the normal problem of felling Douglas-fir snags. The snags were on fire, and the falling embers had piled up around the base until the fellers couldn't get close. The lack of retardants required that additional snags be felled around the fire perimeter to stop the fire spread.

We then began our helitanker operation; we put 80 gallons of water on both helicopters and dropped the water on the snags. The felling crew then moved in and cut the snags. More water was available if it was needed to cool the area. The loading time for each chopper was 2 minutes, and the flight time averaged another 2 minutes. During the first hour of operation the two helicopters, with plenty of targets, dropped more than 2,000 gallons of water on the fire. We added detergent to the tanks as they were being filled, providing wet water for the operation. With 20 sets of snag fallers being supplied by two helicopters, most of the approximately 2,000 snags on the fire were felled the first day. In addition to time spent moving personnel and observing the fire, the choppers were used for almost 9 hours of flying time on water-dropping operations. They dropped 10,730 gallons of wet water on the fire. The cost per gallon of water, which was dropped very accurately on the fire, was a little less than 10 cents. The operation was very safe because flying speeds were low and visibility was good from the low altitudes used. The water dropped was not hazardous to ground crewmen because the small volumes dropped impacted at low speeds. The accuracy was excellent but could be improved with larger tank openings. The choppers couldn't hover with loaded tanks, so the drops were made at a forward speed of about 5 miles per hour.

In summary, using helicopters to drop wet water is a feasible, efficient, and fairly inexpensive method of putting water on selected portions of fires. It is especially effective on snag fires in rough country. Its efficiency would be less at higher elevations, but the severity of the problem would be less, so use of choppers with reduced loads could be considered up to 6,000 feet.

MASS HELITACK ON LARGE FIRES IN CALIFORNIA

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Since helicopters were first positively used on a forest fire, on the Bryant fire, on the Angeles National Forest in southern California in 1947, more and more of these aircraft have been used in fire control. Until 1964, most helicopter attacks have been rather small. Generally, one or two helicopters have ferried crews to otherwise inaccessible firelines, transported supplies to spike camps, dropped water or retardants, and scouted firelines. More than a half-dozen helicopters have rarely been used on one fire or project.

However, in 1964 large-scale attacks by helicopters were used to support firefighting by ground crews on two major fires in southern California. Twenty-six helicopters were used at the peak of the Cozy Dell fire on the San Bernardino National Forest. Nineteen helicopters were used on the Coyote fire on the Los Padres National Forest. These aircraft performed well during both fires and were of great value in their control. An old concept in forest fire control—close air support of ground personnel—was proven applicable to large-scale operations. This paper describes the use of helicopters on these fires and the research planned to make mass helitack even more effective.

THE COZY DELL FIRE

The Cozy Dell fire swept across 18,265 acres of watershed cover from July 21 to July 26.

Both military and civilian helicopters were used.

The U.S. Marine Corps Base at Santa Ana provided the military helicopters. They were used according to a joint program developed by the Marine Corps and the California Division of Forestry. On July 24, the Marines dispatched four HR2S (S-56) helicopters and nine HUS's (S-58's) (fig. 1). One HUS led the other helicopters into the drop area. On July 25, the Marines sent four more of the medium HUS's and one more of the larger HR2S models. During the 2 days these aircraft dropped more than 55,000 gallons of water during 231 drops.

The base heliport was in a large pasture about 3 miles from the fireline. A well in the pasture contained an adequate water supply. Two California State Disaster Office pumper trucks boosted water from the well through 2½-inch hose lines into the helicopter tanks at four fill points. Marine Corps landing officers directed landings and takeoffs, flight patterns, and traffic control to fill points and service areas. Liaison with fireline personnel was handled by California Division of Forestry personnel at the base heliport and in the lead helicopter.

While the Marine helicopters dropped most of the water, commercial helicopters transported per-

TABLE 1.—*Helicopters used on Cozy Dell and Coyote fires*

Helicopters	Designation	Passenger capacity	Weight when empty	Maximum takeoff weight[1]	Retardant carrying capacity
Commercial:		*Number*	*Pounds*	*Pounds*	*Gallons*
Bell	47G-3B1	2	1,772	2,950	100
Do	204B	9	4,600	8,500	320
Hiller	12E	2	1,755	2,800	100
Do	E4	3	1,813	2,800	100
Hughes	300	1	910	1,600	-----
Military:					
Sikorsky	HUS (S-58)	14-20	7,630	13,000	180
Do	HR2S (S-56)	30-36	20,960	31,000	450

[1] Actual figure depends on individual model and accessory equipment.

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[1] The author is on assignment to the Forest Fire Laboratory, Pacific Southwest Forest and Range Experiment Station, Forest Service, USDA, Riverside, Calif.

sonnel, hauled cargo, and scouted the firelines. Seven small private helicopters were used on the fire. A larger Bell 204B carried up to eight men per trip to critical spots on the fireline (table 1).

There were some problems in tactics and coordination. A few retardant drops were made far ahead of the ground crews. These drops were flanked or burnt through before the hand crews could take advantage of them. Also, some crews were too slow in following up the knockdown of hot fire when drops were made right in front of them.

THE COYOTE FIRE

The Coyote fire started on September 22 near Santa Barbara; it was contained on September 30. It burned 67,000 acres of watershed cover and destroyed 161 buildings and damaged 27 others. A high powerline near the origin of the fire limited the initial attack by aircraft. But as the fire spread uphill away from the powerline, "air attack became very effective."[2] If the air attack had not been stopped by darkness, the fire probably would have been held to 250 to 300 acres.

Privately owned helicopters under contract to the Forest Service, the National Park Service, and the California Division of Forestry were used on the Coyote fire.

Most of the helicopters operated were from four base heliports. The main base—a polo field east of Santa Barbara—provided ample space for helicopter operations as well as for the main fire camp. Adequate water was available. Turf designed for polo ponies eliminated the dust problem and seemed to hold up under helicopter traffic. Forest Service helitack crews handled traffic control, landing direction, and loading of cargo and retardants.

Every phase of helitack was used. Some of the operations follow:

1. Small portable pumps were used to pump water from tanks set up on ridges.
2. Water was flown to the ridges by helicopters (helipumpers).
3. Manpower was ferried to remote sections of the fireline.
4. Spike camps were ferried in and supplied with food and water.
5. Fire spread and control line construction was scouted and mapped.
6. Retardant was dropped in close support of ground personnel.
7. Wire was layed for emergency telephone communications.

Much of the retardant (Gelgard) was mixed and loaded at the polo grounds. A 1½-inch hose line, split into two lines with a "Siamese," supplied water to retardant mixing and loading stations. Aardvarks — lightweight eductor-type mixers — mixed 2 pounds of fire retardant in each 100 gallons of water. The retardant was premeasured into coffee cans with snap-on plastic lids. When a helicopter landed, crewmen turned on the water and poured a can of retardant into the Aardvark. The helicopter was usually in the air within 2 minutes. However, the helicopter could not reach the fireline for 15 to 20 minutes.

Retardant mixing and loading were done near the fireline where feasible. Cisterns on ridgetops were used. Tank trucks provided water where roads permitted access to a ridge or other suitable helispot. From these locations, a loaded helicopter would be at the fireline within 2 or 3 minutes after takeoff. A two-man mixing crew with an Aardvark mixer, a lightweight portable pump, and an 80-pound bag of retardant could be flown by helicopter to meet a tank truck on a ridge. The helicopter could be loaded with fire retardant and take off within 10 minutes after landing the mixing crew beside a tank truck or cistern (fig. 1). Eighty pounds of retardant is usually sufficient for the daily mixing needs of two helicopters because retardant drops may be intermittent and the helicopters are often diverted to scouting or crew ferrying.

CONCLUSIONS

Although helicopters have been used in the control of some forest fires since 1947, only a few were generally used on each fire. In 1964 massive air attacks by helicopters were used on major forest fires for close support of ground crews.

(Continued on page 16)

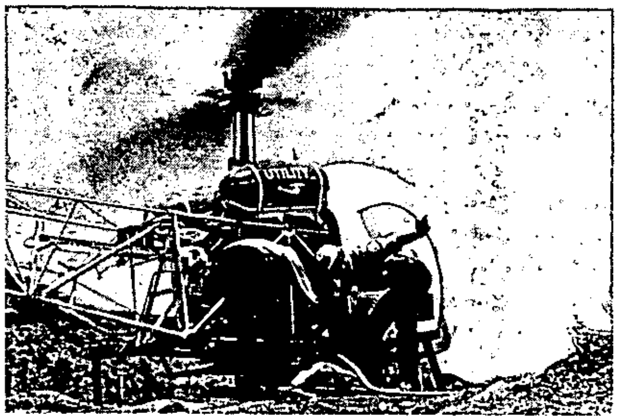

Figure 1.—This Bell 47G helitanker is being loaded at a ridgetop heliport.

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[2] Administrative Fire Analysis, Coyote Fire, September 22-October 1, 1964. Los Padres National Forest, Santa Barbara, Calif.

PHYSIOLOGICAL FACTORS AFFECTING NIGHT HELICOPTER FLIGHT

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Editor's Note: Small helicopters will probably soon be operational at night on forest fires. This assertion is based on the results of 3 years of tests and development work at the Missoula Equipment Development Center and the Pacific Southwest Forest and Range Experiment Station. See Fire Control Notes vol. 27, No. 3, July 1966, pp. 12-14.

Have you ever thought of flying over mountains in a helicopter after dark? Studies conducted recently in Montana and California show that night helicopter flying can be fairly safe if trained personnel use specific procedures.

Three of the reasons why firefighting agencies may want their personnel to fly after dark follow:

1. Fire control is likely to be more effective because of reduced fire intensity and rate of spread.
2. Density altitude and air stability are usually more favorable.
3. Helicopters do not have to compete with fixed-wing air tankers and cargo planes for airspace.

Even if you are not a helicopter pilot, the chances are good that in the next 2 or 3 years you will be a passenger in a night operation. What you do in the helicopter can make a big difference in the safety of the operation. Besides having a thorough knowledge of daytime safety rules, you should also be aware of some of the physiological factors that may affect both you and the pilot at night. This paper summarizes the latest aviation and medical information on these factors.

NIGHT VISION

Special ways of using the eyes at night are necessary because vision then is not as clear or as effective as during the day.

The part of the eye that senses light is the retina (in the back of the eye). It is composed of two types of sensory cells: the cones, which are only sensitive to fairly bright light but produce a distinct image; and the rods, which are sensitive to dim light but do not give a very clear image (fig. 1).

The cones are usually clustered in one small section of the retina; light from objects in the center of the field of vision is focused in this section. In fairly bright light, it is best to look directly at an object to take advantage of the sharp image that cones give.

The rods are usually spread out in the area around the section containing the cones; light from objects toward the edges of the field of vision is focused in this area. In dim light it is best to look just to the side of an object to take advantage of the greater sensitivity of the rods. If you lose sight of the object, move your eyes in a circle, always focusing them to the side of the spot where the object was.

In searching a broad area, scan a small area carefully and then shift the eyes to the next area. Move the eyes often but slowly in dim light; the eyes can perceive little while in rapid motion, but they are sensitive just after movement. If the image becomes blurred, blinking may help.

Rods contain a chemical called visual purple, which breaks down in the presence of light. When this breakdown occurs, a message is sent to the brain as light hits each rod. In bright light, much visual purple breaks down, and the rods lose most

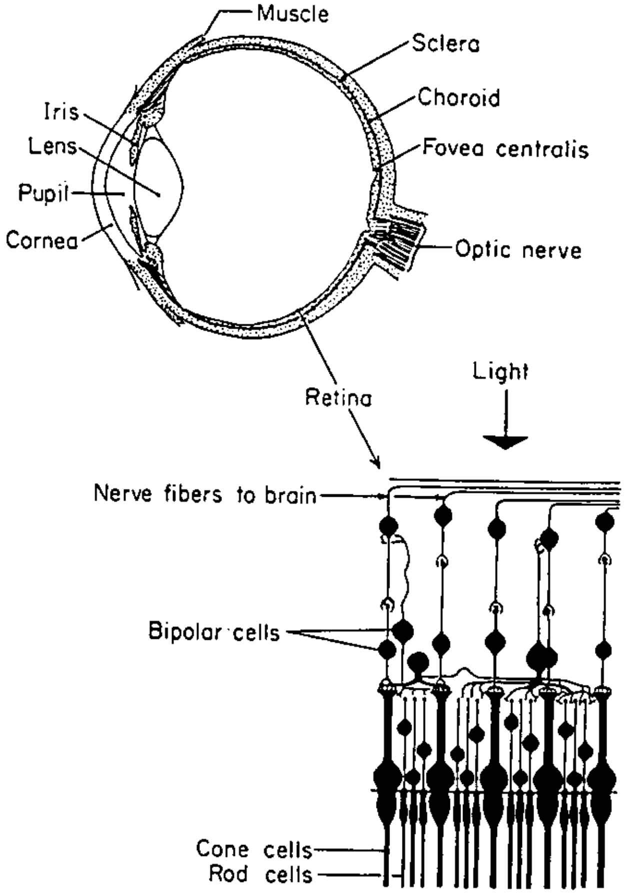

Figure 1.—The retina is the part of the eye that senses light. One group of its sensory cells, the rods, are sensitive to dim light; the other group, the cones, are only sensitive to fairly bright light.

of their usefulness. When dim light returns, the visual purple begins to build up again, but there may not be a useful amount for 15 to 30 minutes. Thus, during night flying, it is important to avoid any exposure to bright light, such as the beam from a flashlight.

ILLUSIONS OF VISION

The pilot's vision is his most vital faculty. But even the best eyes can play unexpected tricks on the most experienced pilot. Some illusions may be quite unexpected.

If you keep your eyes fixed on a single light on a dark night when no other light is visible, that light may appear to move after 10 to 20 seconds even when you know it is stationary. If you stare at the light long enough, you may become almost hypnotized by it, and it will absorb all your attention. The apparent but false movement of a light is called autokinesis. The exact cause of this illusion is not known, but it may be prevented or removed by continually shifting fixation from point to point and by switching on other dim lights in the field of view, such as cabin instrument lights.

Another very confusing illusion is the sudden apparent splitting of light. A single light against a dark background may abruptly appear to split into two or more lights. The muscles that control the movements of the eyeballs have suddenly lost coordination. Closing the eyes briefly or looking at other objects may restore the proper muscle balance—unless the eyes are considerably fatigued.

A pilot sometimes believes that lights or objects in his field of vision have changed their motion or position, and he may not realize that his speed or direction has changed. When instruments are available, the pilot should use them to determine his motion. When they are not available, he will find known stationary ground objects (such as buildings, hills, etc.) to be useful references. Most pilots will try to avoid flying when no known sources of reference are visible, such as during fog, because direction and motion become almost impossible to determine. Do not ask the pilot to fly in visibility conditions he believes are or may become hazardous.

At high speeds, the pilot's normal sense of direction and motion may not be effective.

Illusions are aggravated by physical fatigue, alcoholic hangover, hunger, excessive flying, and monotony.

FLICKER VERTIGO

Flicker vertigo results from exposure to intense light flickering at frequencies of 10 to 30 per second. They can be produced by an idling propeller or rotor in the path of sunlight or by any other source of intense flickering light, such as an unauthorized night marker light.[1]

Flicker vertigo may come suddenly, but there is usually a brief warning, such as uneasiness or intense feeling of discomfort. The first impression is that a light source has suddenly increased in intensity, or that it has expanded so quickly that it fills your entire field of vision. If the condition becomes worse, you may develop a mental blank and then rapid progressive confusion and inability to speak. You may lose muscular control and your head and eyes may quickly and irregularly jerk to one side. Abrupt loss of consciousness and even convulsions may follow.

In trying to counteract flicker vertigo, you should keep your eyes open; closing them causes intense white light to filter through as red light, which is most effective in causing flicker vertigo. Instead, you should turn your head away from the path of light or block the light with your hand or forearm, being careful to avoid pressure on the eyes themselves.

Sensitivity to this condition is greatly increased by emotional excitement, fatigue, and stimulants or sedatives.

MOTION VERTIGO

Mechanisms in your inner ear detect tilt, movement, and rotation of your body and send this information to your brain. Under most circumstances, these organs give accurate reports when movements are not extremely slow or extremely abrupt, when turns are 90° or less, when accelerations and gravitational forces are normal, and when body support is stable. However, accurate reports are often not given. For example, if you are tilted or turned slowly, you may not be able to detect the motion accurately, if at all.

After receiving information on motion, your brain sends a message to your muscles. This signaling normally results in quick adjustment of your body to changes of its position in space. If this adjustment cannot be made, either because your detecting mechanisms are not working properly or because your body cannot make the proper adjustments, dizziness or motion vertigo will probably result. The symptoms of motion vertigo are sweating, nausea, vomiting, inability to stand, and a feeling of spinning or other motion. Ability to adapt to motion varies among individuals. Some people become sick and dizzy on planes and boats while others do not.

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[1] Various flash frequencies are being carefully studied by personnel of the Pacific Southwest Forest and Range Experiment Station, and any lights that may be approved for operational use by the Forest Service will not, in themselves, produce flicker vertigo.

THE CONCEPT OF FIRE ENVIRONMENT

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Webster[1] defines "environment" as "2: the surrounding conditions, influences, or forces that influence or modify".

This definition applies to "fire environment" very well. For fire environment is the complex of fuel, topographic, and airmass factors that influences or modifies the inception, growth, and behavior of fire.

Fire environment may be represented by a triangle (fig. 1). The two lower sides of the triangle represent the fuel and topographic components of fire environment. The top side represents the airmass component; this is the "weather" part of the fire environment.

INTERRELATIONSHIPS OF COMPONENTS

Fire environment is not static, but varies widely in horizontal and vertical space, and in time. The fire environment components and many of their factors are closely interrelated. Thus, the current state of one factor depends on the state of the other factors. Also, a change in one factor can start a chain of reactions that can affect the other factors.

For example, consider the simple topographic factor of slope aspect. The amount of heating of fuel by the sun on a slope depends partly on aspect. A slope facing east begins to warm first, and its maximum temperature occurs early in the day (fig. 2*A*). A slope facing south reaches its maximum temperature about 2 hours later, and it is higher than the maximum of the east-facing slope (fig. 2*B*). A slope facing west reaches its maximum temperature still later, and this maximum is higher than those of the east and south slopes (fig. 2*C*). The north slope also has its distinctive diurnal trend (fig. 2*D*). The data illustrated in figure 2 were obtained from observations taken on a clear day on 45-degree slopes early in July at 42° N. For a different combination of cloud cover, slope, time of year, and latitude, a different pattern would be observed. This differential heating of different aspects affects the probability of fire starts, and also fire growth and behavior.

When the surface of a slope is heated, it transmits this heat to the air above it by conduction, convection, and radiation. The resulting increase in air temperature changes the relative humidity. In addition, local winds also are often strongly affected by the differences in air temperature resulting from the differential heating of slopes of different aspects. These winds are further modified by the configuration of the topography and by the surface fuels. Since the moisture content of fine dead woody fuels depends primarily on the relative humidity of the

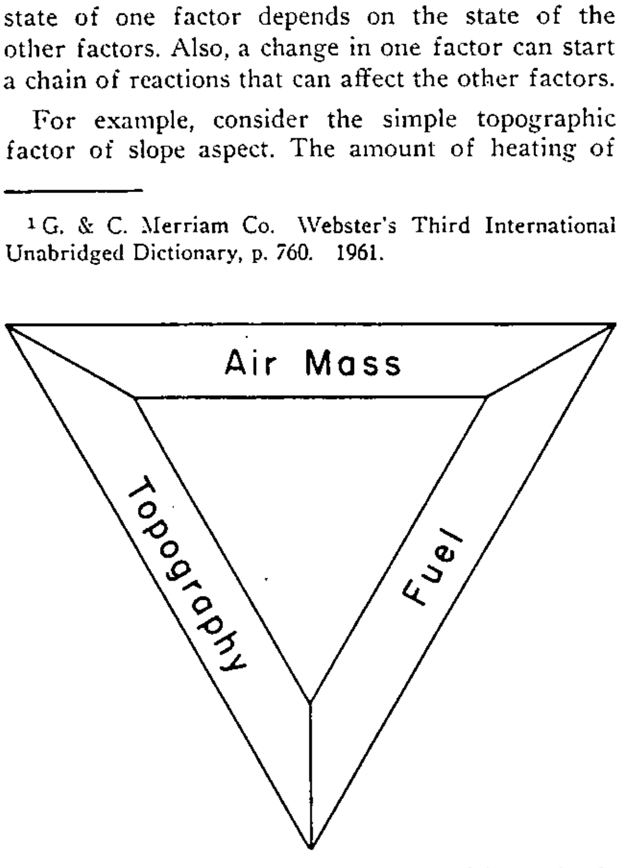

Figure 1.—Fire environment may be represented by a triangle. Each side represents a component of fire environment.

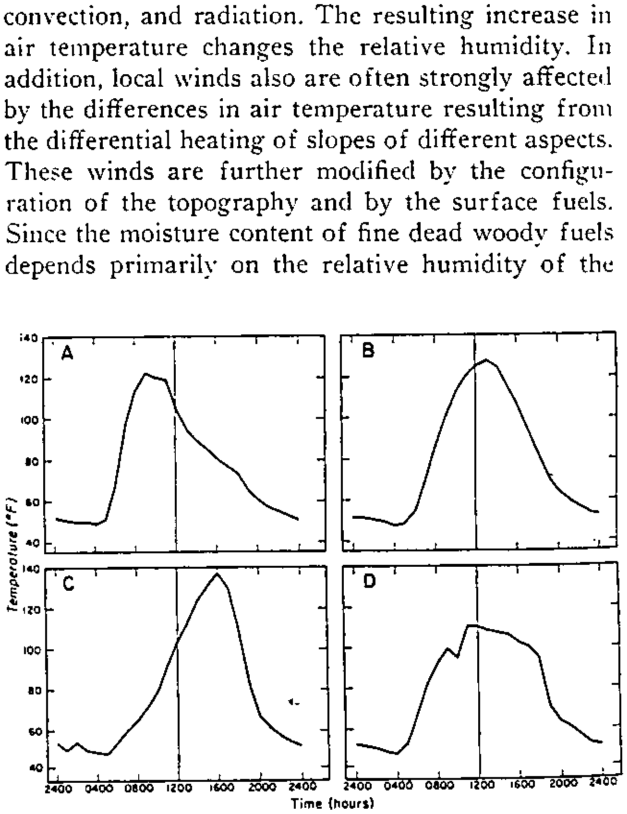

Figure 2.—Relationship of temperature to time of day on 45-degree slopes facing in four directions: *A*, East, *B*, south, *C*, west, and *D*, north. Data were taken on a clear day early in July at 42° N.

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[1] G. & C. Merriam Co. Webster's Third International Unabridged Dictionary, p. 760. 1961.

air, the differences in heating of slopes can affect both fuel moisture content and fuel temperature. The amount of heating of fuels, vegetative or urban, on the surface is affected by airmass conditions such as clouds, moisture content, and windspeed.

FIRE AND FIRE ENVIRONMENT

Where does fire fit into this picture? In an environment without fire, radiant energy from the sun is almost the only source of heat. This energy heats the earth's surface and to a minor extent the air above it. Most of the energy that directly and indirectly modifies the airmass and fuel components of fire environment comes from the heated earth surface. Because of differences in slope, aspect, and ground cover, heating by the sun is not uniform—some areas become much warmer than others. This variation in the local heat sources creates the variability in local weather and fuel conditions.

Perhaps we can most simply consider fire as just another local heat source. As a heat source it reacts with its surroundings in the same way as other local heat sources: interacting with the airmass to create changes in local weather, and with the fuel to modify fuel moisture and temperature. Because of the high temperatures in a fire, however, the reaction can be much more violent.

By adding fire to the center of the fire *environment* triangle (fig. 1), this symbol becomes the fire *behavior* triangle. It is the current state of each of the environmental components—topography, fuel, and airmass—and their interactions with each other and with fire that determines the characteristics and behavior of a fire at any given moment.

FIRE ENVIRONMENT PATTERNS

Because fire behavior and fire environment are interdependent, changes in one will cause changes in the other. To understand or predict fire behavior, we must look at the fire behavior and the fire environment at all points of the fire. Thus, both fire behavior and fire environment are pattern phenomena.

The scope of the fire environment depends primarily on the size and characteristics of the fire. For a very small fire, the environment is a few feet horizontally and vertically. For a large fire, it may cover many miles horizontally and extend thousands of feet vertically. An intensely burning fire will involve a larger environmental envelope than one burning at a lower combustion rate.

OPEN AND CLOSED FIRE ENVIRONMENTS

From a fire behavior standpoint, fire environment can be separated into two general classes: (1) closed environment and (2) open environment. Inside a building, for example, the fire environment is nearly independent of outside conditions. Fuel characteristics are determined by the construction of the building and by its contents. The climate, and hence, the moisture content of the hygroscopic fuels, is controlled by the heating and cooling systems. Air movement and topographic effects are nearly nonexistent. This is confined or 'closed" environment. However, the environment outside buildings is not confined. Current airmass characteristics vary with the synoptic weather patterns and local conditions. Wind movement and topographic effects prevail. This is "open" environment.

Fire burning inside a building is controlled by the fire environment within the building. The outside environment has little effect. As long as the fire remains within the building (fig. 3*A*), there can be no spread to adjacent fuel elements. The fire is confined.

If the fire breaks out of the building, it is no longer burning in a closed environment. Outside conditions can influence its behavior, and the fire can spread to other fuel and grow in size and intensity (fig. 3*B*).

Closed and open environments also exist in wildland fuels; however, the boundaries between the two environments are not as clear as they are in urban areas.

For example, a fire burning under a dense timber stand (fig. 3*C*) is burning in an environment that may be much different than that above or outside the stand. Fuel moisture is often higher, daytime temperature is lower, and windspeed is much slower. In this situation the fire is burning in a closed environment.

If the fire builds in intensity and breaks out through the crowns of the trees (fig. 3*D*), it is burning in an open environment and can come under an entirely different set of controls. Fire behavior and characteristics can change radically.

Open and closed environments exist in other fuels as well as timber, such as grass and brush. Because of the short vertical extent of these fuels, the probability of fire burning entirely in a closed environment is much less. But the closed fire environment in a fuel bed influences fire behavior, even if only part of the fire is burning in a closed environment.

The most obvious use of the concept of fire environment and fire behavior patterns is probably in understanding and predicting wildfire behavior, but the concept can also be used in prescribed burning. In fires of low or moderate intensity, which are usually desired in prescribed burning, the fire environment pattern largely controls the behavior pattern. Thus, by knowing the fire environment pattern for the area, the fire behavior pattern can be predicted. And by selecting the proper environment pattern, the desired type of behavior can be obtained and dangerous points can be alleviated.

SUMMARY

Fire environment is the complex of fuel, topographic, and airmass factors that influences or modifies the inception, growth, and behavior of fire. It is the current state of these factors and their interrelationship with one another and with fire that determines the behavior and characteristics of a fire at any given moment. Fire environment is not static, but varies widely in space and time. Both fire environment and fire behavior are pattern phenomena, and both patterns for the area of the fire must be considered in order to understand and predict a fire's behavior. Because of the difference in the fire environment patterns, the behavior of fire burning in a closed environment may be vastly different from one burning in an open environment. The concept of fire environment and fire behavior patterns is useful for the understanding and prediction of fire behavior for both wildfires and prescribed fires.

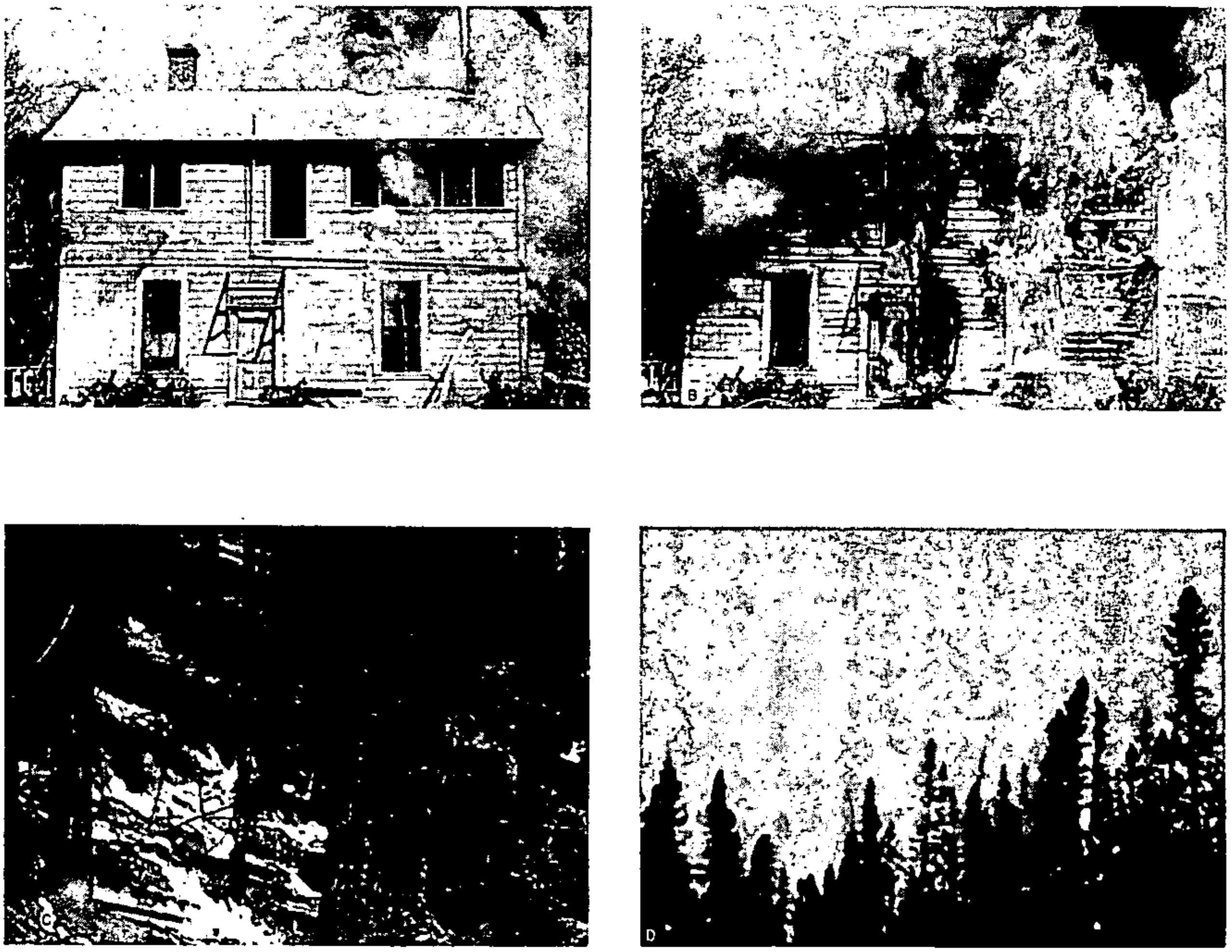

Figure 3.—These fires are burning in the following fire environments: A, Closed urban, B, open urban, C, closed wildland, D, open wildland.

QUALITY CONTROL IN FIRE DANGER RATING

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Fire control officers need accurate data to develop, execute, and evaluate their procedures in fire control management. One of the most valuable sources of data for the fire control officer is the fire danger rating. But to use the ratings with confidence, it is imperative to establish and maintain uniform standards of measurement and effective methods of data verification. These are the functions of quality control.

Quality control is much more than a rigorous check of the observer's record sheets. It must start with the fire danger station network and continue through a series of checkpoints to the final computations on the daily record. To clearly define quality control, and what must be done to implement it, this tool is discussed in the following six sections: Site, installation, maintenance, operation, recording, and computation.

SITE

Professional judgment is needed in site selection and equipment installation. Both checkpoints must be standardized so there is a uniform fire danger rating system instead of a series of systems.

The general location and specific site of a station must assume first priority. Readings from instruments that are incorrectly located are wrong and cannot be counterbalanced by the work of the most meticulous observer. If airport-type exposures could always be found, proper site selection would not be difficult. But there are few ideal sites in areas where fire danger stations are needed. Obstructions or unwanted reflecting surfaces are usually present on sites that are convenient for observers. Topography, surrounding woodland, and nearby manmade structures must be carefully considered for their probable effect on each fire danger element to be measured. Also, a thorough understanding of the instrument exposure standards and the basis for them is necessary.

The instructions in chapter 600 of the Forest Service National Fire-Danger Rating System Handbook are the best guides for proper placement of fire danger stations. Specialized training in site selection is also necessary. Experience in site evaluation is vital; therefore, site selection should be a Regional responsibility, and should be made by one qualified staff man.

INSTALLATION

When a good site has been selected, adequate equipment must be properly exposed and correctly installed. The exposure part of the problem is the most difficult, particularly the anemometer installation. At substandard stations where instruments are improperly exposed, the measured elements will, in effect, be weighted differently than was intended in the design of the system.

Only qualified staffmen should give final approval to the placement of instruments, both for the existing network and for new stations. This responsibility includes their recommendations for upgrading or relocating stations that were already approved, but where the immediate environment has changed because of tree growth or the addition of structures, roads, parking areas, or irrigation systems. The standards for installation in chapter 600 are somewhat easier to follow than the rules for site selection, even though acceptable equipment varies somewhat.

MAINTENANCE

Inspection sampling of stations in several Regions has clearly shown that prompt and effective maintenance is one of the most important factors in quality control. Maintenance includes the routine cleaning, minor adjustment, and repair of instruments and their supporting devices according to the guidelines in chapter 800 of the National Fire Danger Rating Handbook. Alertness, mechanical proficiency, and knowledge of the instruments and their mechanisms are required. High maintenance standards are easily achieved; mistakes are almost always due to carelessness rather than to lack of knowledge. Unadjusted anemometer contacts, a reduction in cup rotation because of dirt or lack of oil, unmatched thermometers, dirty wicking, or leaky rain gages inject inescapable errors into the basic fire-danger record.

The professional judgment needed in site selection and installation is not necessary. The primary responsibility is local rather than Regional because effective maintenance requires frequent checking. The network of stations on a National Forest should be checked at least twice each year (see section 890). The results of the semiannual visits will determine which stations require more frequent visits from the local staff officer or designated technician.

OPERATION

When an adequate training program is in effect, the observer must continue correct daily operational procedures. The measurement routine is simple and easily understood. The source of error is

(Continued on page 16)

GET THE MOST FROM YOUR WINDSPEED OBSERVATION

John S. Crosby and Craig C. Chandler[1]

Surface windspeed is often the most critical weather element affecting fire behavior and fire danger. It is also the most variable and, consequently, the hardest to evaluate.

Air moving across the surface of land is constantly changing speed and direction. Standing still, one observes a series of gusts and lulls. Because of gusts, trying to measure windspeed is much like trying to measure the speed of a car on a winding mountain road. It slows on the turns, speeds up on the straightaways, and slows to a crawl on bumpy stretches. To obtain a reliable average speed, one must determine the time required to travel at least 2 miles. And the rougher and more crooked the road, the longer is the distance required to obtain a reliable average. This same principle applies to wind measurements. The greater the gustiness (the ratio between the range in momentary windspeeds and the average speed), the longer it takes to determine a reliable windspeed. [illegible]

Peak windspeeds that persist for 1 minute can affect gross fire behavior, including rate of spread and fire intensity. For example, a surface fire in pine litter spreading at 10 chains per hour with the wind averaging 5 miles per hour would spread 11 feet farther than expected during a minute when the wind was blowing at 9 miles per hour. During that minute it would burn with twice its average intensity and would be nearly three times as likely to jump a prepared fireline.

Momentary gusts have little effect on the overall rate of fire spread and intensity, but they do produce large fluctuations in flame height and can easily trigger crowning or throw showers of sparks across the fireline when other weather factors are in critical balance. Gusts will usually be close to the average value and will rarely exceed the maximum value.

Gustiness is caused by mechanical and thermal turbulence.

Mechanical turbulence is produced by friction as the air flows over the ground surface. Its magnitude depends on the height above the ground where measurements are made, the roughness of the ground surface, and the windspeed. The maximum mechanical turbulence is found close to the surface in rough topography on windy days.

Thermal turbulence occurs when horizontal wind meets convective currents produced by unequal heating or cooling at the ground. Its magnitude depends mostly on topography, ground cover, solar radiation, and atmospheric stability. The maximum thermal turbu-

Table 1.—*Wind gust estimating table*[1]
(Miles per hour)

Standard 10-minute average	Probable maximum 1-minute speed	Probable momentary gust speed	
		Average	Maximum
1	3	6	9
2	5	8	12
3	6	11	15
4	8	13	17
5	9	15	18
6	10	16	20
7	11	17	21
8	12	19	23
9	13	20	24
10	14	22	26
11	15	23	27
12	17	25	29
13	18	26	30
14	19	28	32
15	20	29	33
16	21	30	35
17	22	32	36
18	23	33	38
19	24	34	39
20	25	35	40
21	26	37	42
22	27	38	43
23	28	39	44
24	29	40	46
25	30	41	47
26	31	43	49
27	32	44	50
28	33	45	51
29	34	46	53
30	35	47	54

[1] All readings were taken in the afternoon 20 feet above the ground.

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[1] Respectively, Research Forester, North Central Forest Experiment Station, Forest Service, USDA, Columbia, Mo., and Assistant Chief, Forest Fire Research Branch, Division of Forest Protection Research, Forest Service, USDA, Washington, D.C.

lence occurs above rough topography with patchy ground cover during sunny afternoons in unstable air.

Gustiness is a serious problem for both fire researchers and fire-control planners. Because of gustiness, wind measurements at two locations cannot be compared unless they are taken at the same height above the ground and for the same length of time. For maximum comparability, measurements should be taken as high above the ground as possible and for as long as possible. But high towers and long observations are expensive. Therefore, for fire-danger rating we have established a standard anemometer height of 20 feet and a standard observation time of 10 minutes.

While these standards are fine for fire-danger rating, they often confuse the firefighter on the ground. Rapid changes in fire behavior are determined by rapid changes in the wind blowing on the burning fuel, and not by changes in the long-term average windspeed 20 feet above ground. Often the firefighter loses confidence in his meteorologist or his weather station, or both, because he is told to expect a 16-mile-per-hour wind and found the fire fanned by 35-mile-per-hour gusts. He often must estimate the variations in windspeed that may be expected for the average speed that is reported.

To help firefighters estimate gustiness, we determined the 10-minute average speed, the probable fastest 1-minute average speeds, and the probable average and highest momentary speed or gust during the fastest 1-minute speed (table 1). The table values were determined from several hundred noon and afternoon observations made at Salem, Mo., during fire seasons. They were taken when gustiness was likely to be greatest, as it often is on difficult fires. Thus, the estimates are most accurate when they are needed the most.

It is difficult to convert windspeeds taken by firefighters to the standard windspeed. In preparing spot forecasts for project fires, wind measurements are often made with a hand-held anemometer. This instrument indicates gust speed accurately, but it is almost impossible to accurately determine average speed with it. Consequently, the windspeed reported from the fireline almost invariably is the average gust speed rather than the accepted 20-foot, 10-minute standard. Therefore, another table was developed to convert gust speed 5 feet above the ground to the standard 20-foot, 10-minute speed for stable, neutral, and unstable conditions (table 2). This conversion should be used when fire-danger indexes are determined from fireline observations or when wind information consists of a mixture of hand-held and tower observations.

TABLE 2.—*Standard windspeed estimates based on maximum gusts*[1] *(Miles per hour)*

Fastest gust observed on hand-held anemometer[2]	Standard windspeed when atmospheric condition is:		
	Stable[3]	Neutral[4]	Unstable[5]
0-3	0	0	0
4-6	1	1	1
7	2	1	1
8	2	2	1
9	3	2	2
10	4	3	3
12	6	4	4
14	8	6	5
16	10	8	7
18	12	9	8
20	15	11	10
22	17	13	12
24	19	15	14
26	22	17	16
28	24	19	18
30	27	21	20
32	29	23	22
34	32	25	23
36	34	27	25
38	37	29	27
40	39	31	29

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[1] Standard windspeed is 10-minute average speed 20 feet above the ground.

[2] Readings were taken 5 feet above ground. For best results observations should be made for several minutes.

[3] This column usually should be used for observations between 8 p.m. and 8 a.m.

[4] This column usually should be used for observations between 8 a.m. and noon, and between noon and 8 p.m. on overcast days.

[5] This column usually should be used between noon and 8 p.m. on clear or partly cloudy days.

ONTARIO TESTS A NEW TYPE OF FOREST FIRE HOSE

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Ontario is one of the largest users of forest fire hose in Canada. The Ontario Department of Lands and Forests maintains approximately 31,000 lengths of hose at its various headquarters strategically located in the Province.

The capital investment for this hose is approximately $1 million. Also, much of this hose must be replaced each year because of various causes of failure. Replacement costs are almost half of the annual expenditure for fire suppression equipment.

This high rate of replacement has stimulated an endeavor to find hose with a longer useable life. Requirements include resistance to burning, ability to transmit water with low friction loss, and durability and mobility.

Two types of forest fire hose are used in Ontario:

1. Lined hose is used to deliver water to the fireline. It has low friction loss and withstands high pressures, which is desirable for this part of the hose-lay. Lined hose is not resistant to burning if exposed to direct heat and flame.
2. Unlined linen hose is used at the fire perimeter. This hose with its weeping characteristic does not burn under pressure.

An ideal hose should incorporate these features:

1. Low friction loss
2. High resistance to burning under pressure
3. Ability to withstand high pressures
4. Resistance to abrasion in handling and storage
5. Flexibility when dry or wet

Figure 1.—This self-wetting or percolating type of lined hose can withstand fire.

A percolating lined hose (fig. 1) that meets most of these requirements has been manufactured. It is a composite of natural fibres and synthetics.

In 1964 this new type of forestry hose was supplied to the Ontario Department of Lands and Forests for evaluation tests. Test results indicated that the friction loss ratio of the new hose was approximately 50 to 70 percent of the difference between standard types of unlined and lined hose. Its weeping capacity provides resistance to damage by heat or flame. Its weight and flexibility correspond with standard types. Its flexibility is satisfactory for handling and packing procedures now used.

This initial investigation resulted in a recommendation to purchase a certain quantity of self-percolating hose for field testing. Some hose was tested during the 1965 fire season, and initial reports appear favourable. All field establishments will have this hose during the 1966 fire season. Therefore, data on its performance and durability will soon be available.

This new type of percolating lined hose is a major improvement. However, the search for a better type of forest fire hose is being continued in Ontario.

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OFFICIAL BUSINESS

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Mass Helitack—Continued from page 5

Close ground support by helicopters speeded control. Effective retardant drops knocked down hot spots just ahead of the crews. They greatly reduced the hazard to the firefighters, particularly when flareups on slopes below the crews could have forced a retreat. Often the crews did not have to battle hot fire to put in control lines. Also, hot spotting ahead of the crews by the helicopters slowed the fire spread and shortened the control line that did have to be built. However, the crews still had hard work in heavy brush and on steep, rough topography.

The mass use of helicopters in the control of both fires emphasized problems that need further study. Foremost among these are:

1. The use of helicopters at night. Air conditions then are more favorable, and because fires usually are not as intense at night, control would generally be easier.
2. The close coordination of helicopters with other aircraft, ground equipment, and ground crews. Research in systems analysis is needed to help develop the optimum balance among all types of firefighting forces.

Studies on both problems are now being conducted by the Forest Service.

Quality Control—Continued from page 11

usually carelessness and intermittent lack of attention to detail in the day-after-day routine.

The selection and training of observers and followup is primarily a local responsibility. Almost daily contact may be needed for some time, especially with new observers. Thus, the district in which the station is located should have direct responsibility for correct operation.

RECORDING

The accurate and legible recording of observed data may be considered a part of operation, and the level of responsibility is the same. It is discussed separately, however, because an excellent record taker may be a poor record keeper. Even when a station is perfectly installed, maintained, and operated, a record with indistinct or uncertain entries is useless as a source of future information. Observers must understand that their work is of permanent value.

However, observers, in their zeal to make clear and legible records, have sometimes hand copied or typed the original data from a scratch sheet. This, most emphatically, should not be done. Mistakes in copying are easily made, and many such errors have been noted. Exactness in preparing the original record, with use of carbon for copies that are needed, is all that is required.

COMPUTATION

When the data are in order, the buildup index, spread index, or other operational indexes must be correctly computed. Errors in computation are not as serious as mistakes in previous sections because corrections can be made. For example, poor exposure or a faulty anemometer may result in the recording of windspeed as 10 m.p.h. instead of the correct 15 m.p.h.. Moreover, such an error would probably not be detected in a review of the record. But the same error in computation, resulting in an incorrect spread index, could easily be found by recomputing. Thus, the final step in quality control should be to completely recheck all computations.

This computation should be done at the district level because any sizable error will adversely affect preparedness action. Moreover, any questionable items can be discussed directly with the observer, and it is a good training measure.

The records from a National Forest network should be cumulated in the Supervisor's office and spot checked. Comparative checking at the Forest level may reveal inconsistencies that were not apparent at the source.

Fire danger data forwarded from the Supervisor's office, either to the Region, Fire Research Center, U.S. Weather Bureau, or other cooperators, should be as free from error as is possible if all six steps in quality control have been successful.