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Thirty-Two Years of Forest Service Research at the Southern Forest Fire Laboratory in Macon, GA

Cover: Constructed in 1958-59,
the Southern Forest Fire Laboratory
was the first of its kind in the world.

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Thirty-Two Years of Forest Service Research at the Southern Forest Fire Laboratory in Macon, GA

Abstract

When completed in 1959, the Southern Forest Fire Laboratory was the world's first devoted entirely to the study of forest fires. Since then the scientists at the Laboratory have: 1) performed basic and applied research on critical fire problems of national interest, 2) conducted special regional research on fire problems peculiar to the 13 Southern States, and 3) assisted other States east of the Mississippi River on fire problems requiring the Laboratory's unique facilities. Some of the research topics included combustion and fire behavior, prescribed burning and fire effects, fire control, weather and fire danger, and smoke management. This brief history highlights some of the important research findings and the scientists that made them. Fire research in the 1990's will focus on ecological processes and understanding the natural environment.

KEYWORDS: Combustion, fire behavior, fire control, prescribed burning.

Introduction

It's the nature of human beings to worry most about the things that are affecting them right now and to devote thought to other things only as the mood dictates. Using this standard approach, Southerners were thinking a lot about forest fires in the mid-1950's. Several years of drought had brought that problem into clear focus. Fires larger than 100,000 acres were common, and the losses of timber and buildings were enormous. A lot of people became convinced that there had to be better ways to protect against forest fires and to prepare to put them out. Those convictions led to the construction of the Southern Forest Fire Laboratory in Macon, GA.

When completed in 1959, it was the world's first laboratory devoted entirely to the study of forest fires. Some fire research had been conducted in the past by the USDA Forest Service,

but this laboratory was something special. It was in and for the Southeast, and research there would be centralized, comprehensive, and intensive. The idea was to combine basic studies of combustion, meteorology, and physics with practical field studies to produce immediately useful findings for the fire managers of the South.

Managed and staffed by the Southeastern Forest Experiment Station of the USDA Forest Service and strongly supported by the Georgia Forestry Commission, the Southern Forest Fire Laboratory has realized much of its potential over the past 32 years. This brief history of the Laboratory highlights important discoveries that were made there. A bibliography at the end lists all the fire research articles published by its staff.

A Special Relationship

When the idea of a laboratory devoted entirely to forest fire research was bandied about, interest in it was greatest in Georgia and in the Georgia Forestry Commission. The story is told that in 1957 the Georgia Forestry Commission Director Guyton DeLoach and his assistant, Leon Hargreaves, traveled from their headquarters in Macon to Atlanta to meet State Senator Wallace Adams, who was Chairman of the Georgia Forestry Commission. The purpose of their discussion was to develop a strategy for getting Congress to appropriate money for a fire laboratory in Georgia. During the meeting, which took place in a hotel room, Governor Marvin Griffin stopped by. Hearing the discussion about the need to get funds from Congress, Governor Griffin is said to have asked how much it would cost to build the laboratory. When he was given a figure, Griffin said, "Forget Congress, I'll finance it." So began the history of the Southern Forest Fire Laboratory and the close association between it and the State of Georgia.

The Laboratory was constructed on State land at the Georgia Forestry Center with $275,000 from the treasury of the State of Georgia, plus $100,000 from the Georgia Forest Research Council. The Georgia Forest Research Council also supplied funds to maintain the facility for the first few years after

construction and to promote some of the research that was taking place. The Southeastern Forest Experiment Station of the USDA Forest Service, headquartered in Asheville, NC, staffed the laboratory and funded most of the research. A close relationship formed then between the Experiment Station and the Georgia Forestry Commission and has survived, benefitting both the State and the Federal Agency and speeding research progress.

Ground breaking for the new Fire Laboratory Annex on April 21, 1972. From left to right are Robert W. Cooper, Project Leader; Stephen Boyce, Director, Southeastern Forest Experiment Station; John J. Flynt, U.S. Congressman; and Edward Ruark, Director, Georgia Forestry Research Council.

Ed Ruark, the Director of the Georgia Forest Research Council from October 1959 to July 1978, also deserves special mention. His organization was a continuing source of funds for fire research, and he frequently testified before Congressional Committees in support of Laboratory programs. His assistance was instrumental in bringing about the expansion of the facility in 1973. At that time, office and laboratory space were more than doubled.

A Research Program

At the outset, the staff of the Southern Forest Fire Laboratory was given three broad missions:

1. To perform basic and applied research on critical fire problems that had national interest and impact.

2. To conduct special regional research on fire problems peculiar to the 13 Southern States, which include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, North Carolina, Oklahoma, South Carolina, Tennessee, Texas, and Virginia.

3. To assist other States east of the Mississippi River on fire problems requiring the laboratory's unique facilities.

Support for the research program sprung from a realization among foresters that they did not understand forest fires very well. Some fires spread in a predictable fashion so that those responsible for controlling them could do their jobs reasonably well. Other fires literally exploded, overwhelming control efforts. It was clear by the late 1950's that excessive buildup of highly flammable fuels on and near the forest floor were a major cause for concern in much of the South. It was also clear that prescribed burning was the most practical way to reduce these concentrations. It was not at all clear what effects these burns would have on the trees that foresters were trying to protect. Under specific sets of fuel and weather conditions, foresters needed to know whether fires would be helpful or harmful. They needed to know how intense fires would be under various conditions, and they needed to know how much heat the trees could stand.

It seemed obvious that a combination of basic and applied studies would be required to supply the information that forest managers required. That approach has been followed to the present, and it has served well.

Through the years, a broad range of fire topics have been explored. In this publication, they are divided in the following manner:

1. Combustion and fire behavior
2. Prescribed burning and fire effects
3. Fire control
4. Weather and fire danger
5. Sea-breeze fronts and Project THEO
6. Pioneering use of computers
7. Smoke management
8. Forestry Weather Interpretations System

Despite the obvious relationships among these topics, each will be described separately. Then a fire research program for the Laboratory in the 1990's will be outlined.

Combustion and Fire Behavior

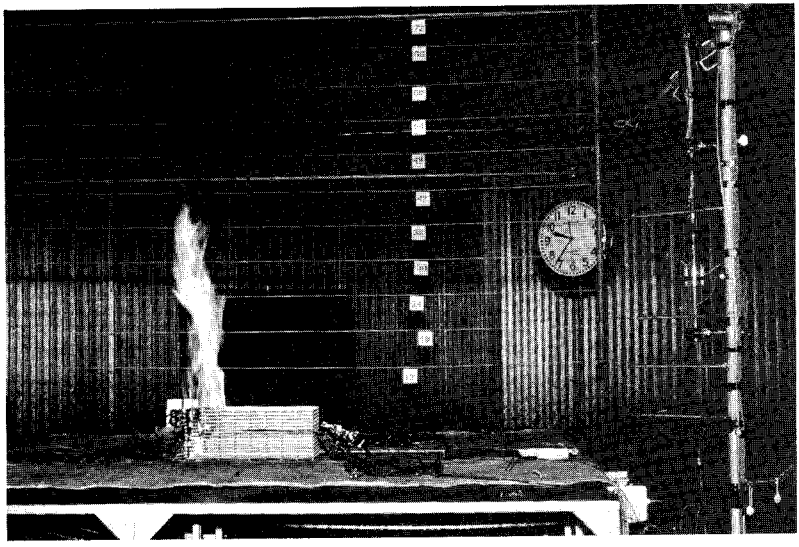
When one first thinks about it, combustion of forest fuels seems like a simple enough process. In the presence of oxygen and sufficient heat, complex carbon compounds ignite, giving off a surplus of heat that ignites additional fuel in a chain reaction that we call "fire."

A closer look reveals that the process is by no means simple or easy to predict. Suppose that we are wondering, as fire managers must, how rapidly fire will spread in a particular arrangement of forest fuels and how intense the fire will get. It is easy to imagine that fire spread and fire intensity will depend on the nature and density of the fuel, its moisture content, the size of fuel particles, the size of the fuel bed, the wind, and the slope. Defining the relationships among these variables with some precision has not been easy. It has required considerable thought and imagination and access to the Laboratory's sophisticated research equipment.

Beds of wood fuel were carefully constructed on the Laboratory burning table. The size, arrangement, geometry, and moisture content of the fuels were controlled, as was the slope of the burning table and the supply of air. The effects of changes in

these variables were monitored. Measured effects included fire spread rate, rate of energy release, distribution of released energy, flame height, flame volume, and temperature, pressure, convection, and radiation in and around the fire. Later, effects on the composition of gases and particulates emitted before, during, and after passage of the fire also were measured.

Out of this work came a fundamental understanding of the combustion of forest fuels and a model of the process. Modeling was started by Wallace L. Fons in 1960, and in 1965 George M. Byran was able to report the effects of wind, slope, and fuel moisture content on the rate of flame spread through specially constructed wood cribs. Of special interest was the observation that the length of time individual fuel particles burned (fire residence time) was the same for backing and heading fires. Even earlier, Byram was able to predict the rate of moisture diffusion in different sizes of woody fuels from such factors as temperature, thickness of sample, and relative humidity.



Fire behavior is influenced by the size, spacing, and moisture content of the fuel.

The combustion model that was finally developed had four essential components: (1) the earth's gravitational field, (2) the earth's atmosphere, which was viewed as a compressible fluid, (3) a boundary surface beneath the atmosphere, and (4) a heat source at or near the boundary surface. This model proved adequate for describing all fires, regardless of their size or intensity.

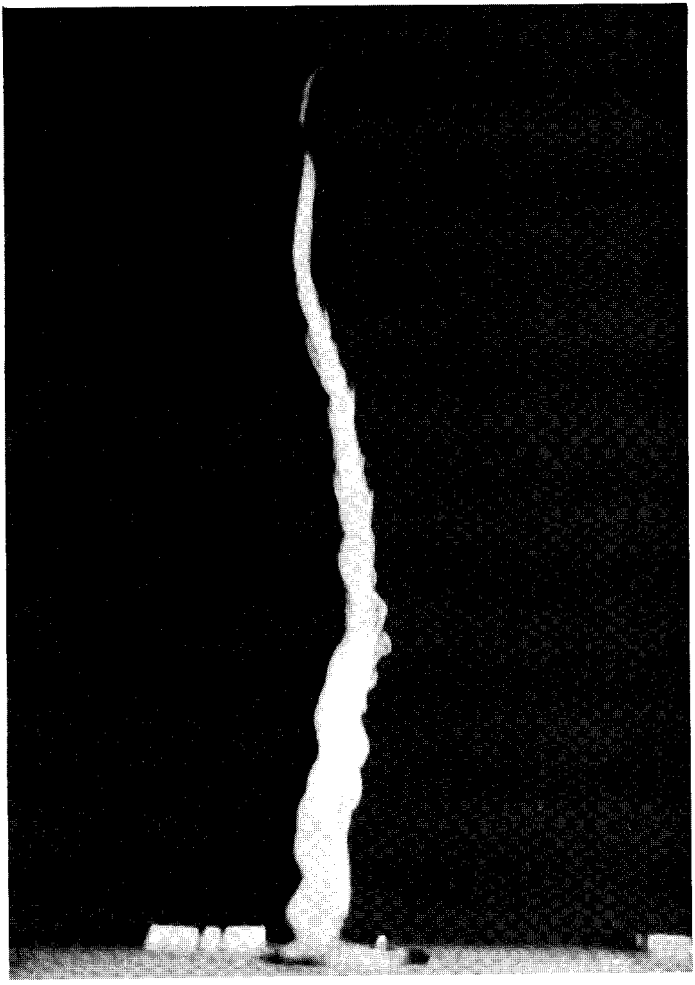
Many of the results of fundamental studies had practical applications. Studies with white fir and sugar maple fuels demonstrated that the rate of fire spread increases rapidly with decreasing fuel moisture content for fuels with a specific gravity under 0.45 and a moisture content less than 10 percent. This information is important because forest litter, bark, moss, and leaves all have specific gravities under 0.45 and dry out rather rapidly when relative humidity is low and rains are widely spaced. In most circumstances, fuels of this type are primarily responsible for the spread of forest fires.

Other important developments included the derivation of scaling laws for modeling mass fires and pulsating fires. Mass fires are of the sort that develop if a shower of embers drops onto a receptive fuel over an extended area. Pulsing fires alternate between periods of slow and rapid spread.

The basic research on ignition and combustion led to important conclusions about fire behavior. And the key variable for explaining the behavior of large forest fires turned out to be convection. The story of high-intensity fires to a large extent is the story of convection. That does not mean, however, that convection or fire behavior is easily explained. Just as a violin string can vibrate in many different ways, so can the convection patterns over a fire have many different forms. These forms are exceedingly complex and depend on the intensity of the fire, the speeds of both the surface and upper winds, the stability of the atmosphere, and topographic features.

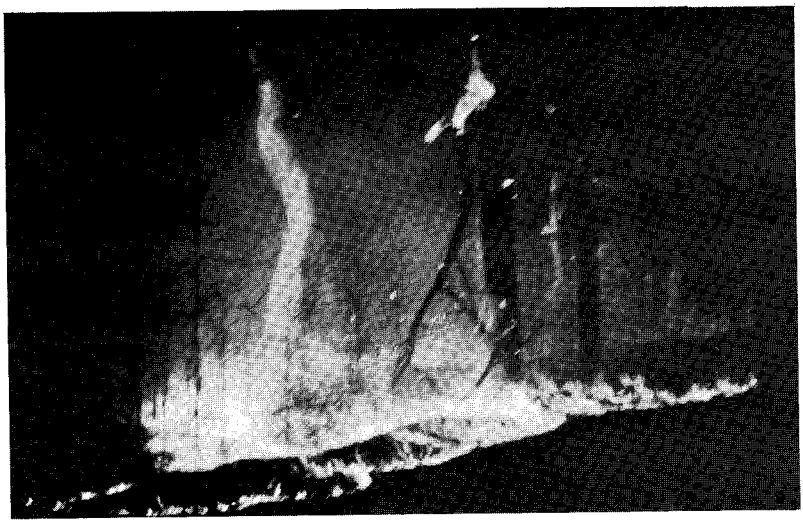
From the time the Laboratory opened, its staff was especially interested in fire whirlwinds. It was well known that these phenomena were responsible for the unpredictable behavior of

many fires. Laboratory convection chambers were specially designed to observe fire whirlwinds. They were able to produce fire whirls to 11 feet in height in the chambers. The horizontal component of wind velocity was between 25 and 30 miles per hour, and the updraft velocity reached 50 miles per hour. Fuel consumption in these whirls was found to be about three times that in areas of normal convection.



Fire whirls are created in the laboratory to understand their effects in the burning forest.

The rapid spread of high-intensity fires depends largely on violent convection in fire whirlwinds. There, whirlwinds can lift logs 8 to 10 inches in diameter and twist off large trees. These winds and other types of violent convection lift burning material and drop it far ahead of the main line of fire. The spot fires in advance of the main front can confound efforts to contain the fire, increase its rate of spread manyfold, and create major hazards for firefighters.



Naturally occurring fire whirls frequently cause fires to escape containment.

Laboratory studies have succeeded in placing numerical values on a fire's ability to burn embers. In general, ember lifting power has been found to vary with the square of the fire intensity and the square of the density of the ember bed.

Research on the burning characteristics of forest fuels has greatly increased understanding of fire behavior. The burning rates of fuels have been found to be closely related to their drying rates. This relationship has been used in the development of fire danger rating systems and in the classification of fuels. Another important factor in fuel classification is their total energy the amount of energy they would release if they were completely consumed by a fire. This factor is used to rate the blowup potential of different fuel types during severe droughts.

A video image analysis system was developed in 1986 and has proven a useful tool for research and practicing fire professionals. The video system was a natural extension of photogrammetric techniques that were first developed by Wayne Atkins of the Macon Laboratory in 1976 to collect fire behavior data from photographs of fires in the Everglades National Park. The prototype video system improved the collection of hard data on fire behavior and provided a permanent record of fire characteristics. The system employs consumer grade video and PC computer technology to scale and measure images of single frame VHS video recordings that are processed into temporal and spatial values of flame length, height, tilt angle, area, and relative position. Rate of fire spread can be computed from elapsed time and relative position.

Prescribed Burning and Fire Effects

Fire is probably the most powerful natural instrument for change in southern forest ecosystems. It was shaping the region's ecosystems long before people walked beneath the trees, so the vast majority of plant species have mechanisms for surviving fire or for reproducing themselves under the conditions that fires leave. There are numerous examples of fire adaptations. Pines have well-insulated bark that protects mature trees from the heat of ground fires. In addition, the seedbeds prepared by fire are excellent for pine seed germination and pine seedling establishment. Thin-barked hardwood stems are killed by fire, but the roots of many hardwood species survive and send up fast-growing sprouts that rapidly occupy areas of burned forest. Grasses and annuals thrive in recently burned areas, providing nutritious forage for cattle and wildlife.

The potential usefulness and the potential danger of fire were well understood by Native Americans, as well as early European settlers. Their concerns, however, were primarily with hunting, grazing, and land clearing. They worried very little about protecting timber and other forest values when they lit fires. Thus, when professional foresters first came to the South, they

launched a crusade against indiscriminate woods burning. Like most crusades, the one against southern woods burning probably went too far and led to excessive fuel buildups in many places.

Finally, with the help of research, prescribed burning assumed its current place as a highly valuable forest treatment. Careful limits were set on prescribed burning to distinguish it from wildfire and simple arson. A prescribed fire must be purposely and purposefully set under selected fuel and weather conditions to meet designated resource management objectives, and the fire must be confined to a predesignated area.

To obtain maximum benefits from prescribed burns, foresters needed to know how fire intensity varied with weather conditions, fuel conditions, and firing techniques. They also needed to know how living plants of different species and sizes responded to various intensities of fire.

At the Laboratory, evaluation of tree stem damage from fire began in 1960. The effects of moisture content and bark density on thermal conduction were studied intensively by Robert E. Martin and were the basis for his Ph.D. dissertation at the University of Michigan. He found, for example, that the lightweight bark of southern pines provided considerably better insulation than the denser bark of oak. The difference undoubtedly accounts for some of the fire resistance of southern pines. His studies also showed that the thermal conductivity of bark is 50 percent greater when the bark is saturated with water than it is when the bark is dry.

Laboratory scientists designed a mobile propane heater for simulating the heat exposures of tree stems to prescribed fires. This apparatus permitted scientists to expose plant stems to precise quantities of heat. In a field prescribed burn, of course, the amount of heat that each stem receives varies enormously. The propane heater removed this source of variation and permitted direct measurement of plant responses.

The effect of prescribed fire on tree trunks was simulated with propane-fueled radiant heaters.

Southern pines, the objectives of industrial forest management in much of the South, are resistant to fire. But there are limits, particularly for young trees. Prescribed burns are usually designed to avoid scorching of needles, and burning is normally not attempted until pines are at least 2 inches in diameter at breast height (d.b.h.). Research results support these precautions. Over a 3-year period after a winter burn in an 8-year-old slash pine plantation, height and diameter growth were carefully observed. Scorching of the needles in the crowns of the trees did not kill them, but it did reduce their growth considerably.

The season of burning was found to strongly affect the responses of loblolly and slash pines. Removal of all loblolly pine needles in the fall to simulate the damage caused by fire killed most of the trees. Trees in which 5 to 33 percent of the needles were left in the fall survived, but their growth was severely reduced. Spring, summer, and winter defoliation reduced growth, but did not kill the trees. These findings suggest that effects of defoliation are greatest in the fall and that burning under southern pines should not be attempted in that season. They also show that loss of up to one-third of the needles is not very harmful.

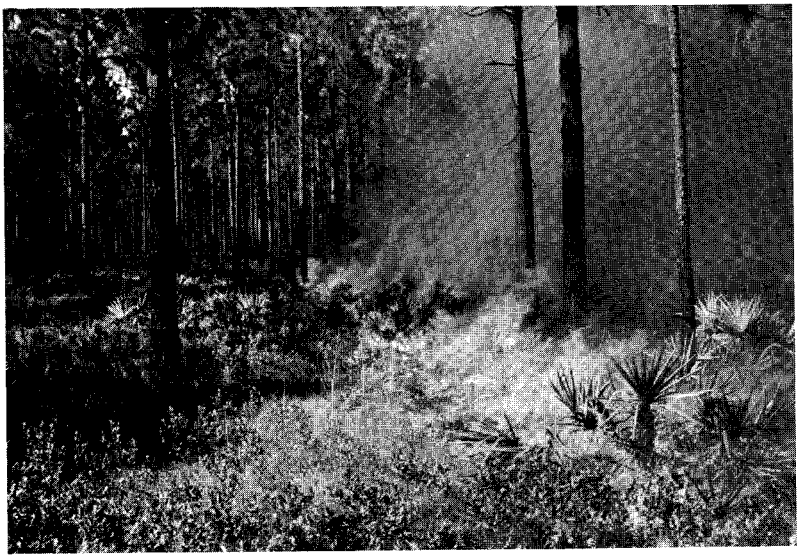
When wildfires severely damage young pine plantations, the forest manager wants to make a quick decision about the need to replant. If the trees are likely to recover, replanting is not necessary. If they are not likely to recover, the quicker replanting is done the cheaper it is likely to be. Research results from the Laboratory are helping foresters to make this painful decision.

Results of a pilot study indicate that relatively cool backing fires have potential for eliminating stems less than 0.5 inch d.b.h. from overly dense southern pine stands. Once loblolly and slash pines reach 2.0 inches d.b.h., a cool backing fire is not likely to harm them if it does not scorch their crowns. Trees between 0.5 and 2.0 inches d.b.h. will suffer some damage. Thus, although the results may be far less than certain, thinning dense pine stands with fire is a possibility.

One of the first research projects at the Laboratory dealt with prescribed burning to reduce hazardous fuel buildups in the South. The pocosin fuel complex of the Carolinas was chosen for intensive study because it had proven to be particularly hazardous. After much sampling at the Hofmann Forest near Jacksonville, NC, 14 distinct fuel types were isolated. These types were placed in five "blowup classes" based on the total amount of available fuel. The purpose was to isolate areas where extreme and unpredictable fire behavior could occur under extreme weather conditions. It had been shown that a minimum of 6 tons per acre of fuel were required before erratic fire behavior occurred. Comprehensive fuel mapping of this kind can be used to produce a fuel reduction plan. Plans of that kind are essential if disastrous wildfires are to be avoided.

Planning for hazard reduction also requires information on the rate of fuel buildup in various forest types. That kind of information has been gathered for a wide range of types. A survey of 374 fires in Florida and Georgia in the late 1950's showed that fires of over 200 acres developed only on areas where the fuel had accumulated for 5 years or more. Those data presented a very strong early case of hazard reduction burning.

Buildup of fuel in the hazardous palmetto-gallberry type in southern Georgia and northern Florida is surprisingly rapid. The understory vegetation recovers to preburning condition in 2 to 3 years. The litter accumulation takes a bit longer, but frequent burning is needed in this type to keep hazard low.



An experimental, prescribed fire in the palmetto-gallberry fuel type in Georgia.

As in other fuel types, the hazard increases as the weight of available fuel increases, but hazard also varies with the season. When the understory vegetation leafs out in the spring, this flush of new growth with its high moisture content essentially fireproofs the vegetation until fall.

A reduction in palmetto-gallberry understory density beneath a pine stand increases pine growth in addition to reducing the fire hazard. Killing the understory plants is pretty difficult, however. A winter fire severely reduces the starch content in palmetto tubers by the following October. A burn in October of the year after a winter burn does kill some of the palmetto population. Combinations of herbicide application followed by winter burning have proven even more effective, but one such combination is only likely to kill about one-third of the plants.

In 1966, a mobile laboratory was outfitted by research personnel to document weather, fuel, fire behavior, and fire effects of large wildfires. It also was used to document all aspects of research-oriented prescribed burns. The 7,400-acre Gaston County Fire in South Carolina was the first of many visited by the mobile laboratory. The presence of researchers on firelines did much to increase their credibility with fire managers and led to many highly productive, cooperative ventures between research scientists and practicing foresters.

With increasing concerns about air pollution from prescribed burns, the number of days each year when burning can be done has declined considerably. As a result, forest managers have become increasingly interested in rapid ignition of large areas on days when fuel conditions and smoke dispersion are satisfactory. Burning large areas requires some combination of heading, backing, and flanking fires, and there is much interest in the variations in intensity and movement of these fires. Studies at the Laboratory showed that a 250-foot line of fire would be 1.7 to 13.5 times faster during the first 10 minutes of spread than a fire of spot origin. On 4- by 4-chain plots, line-ignited heading fires traveled across the plots up to 38 times faster than heading fires initiated from a spot.

The line heading fires ignited in the studies were roughly equivalent to the kinds of fires ignited with a helitorch. The spot fires were like those ignited by the Aerial Ignition Device System, which dispenses ping-pong-ball-sized igniters over a broad area. At least during the early stages of development, fires ignited with a helitorch are likely to be considerably more intense than those ignited by the "ping-pong-ball" system.

Laboratory personnel have done a considerable amount of research on the effects of site-preparation and slash-removal burns on nonwoody vegetation. The fires needed to reduce logging slash often are quite intense, because they typically must consume very heavy fuel loads. Studies show that the number and availability of plants and seeds valuable to wildlife are positively affected by burning. In one area, seed production increased 300 percent and plant abundance doubled in the year after burning.

Fire Control

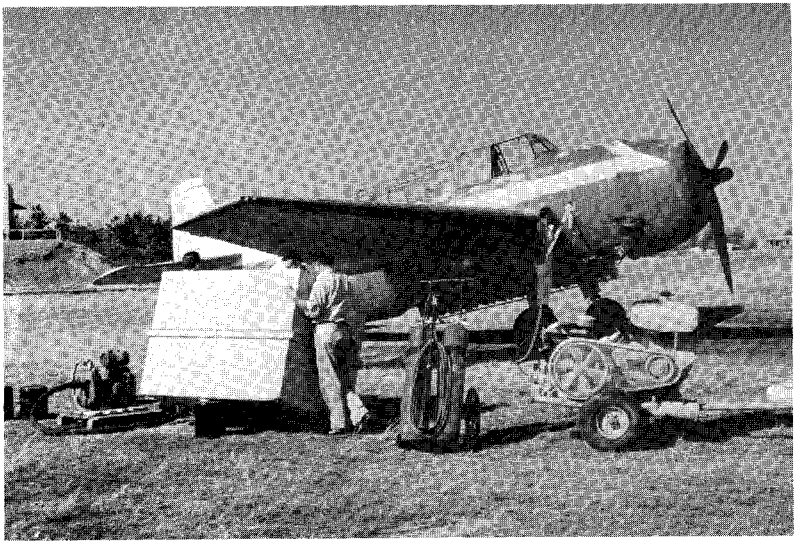
The primary strategy for control of most forest fires has always been to deny fuel to the advancing flames. Where natural barriers and roads cannot be used, people construct fuel-free firelines, backfire from them, and attempt to keep the advancing front from crossing when it arrives. Getting a line around a fire before it has a chance to get large has always paid big dividends by limiting the fire's damage and reducing the number of people needed to build a fireline.

Since World War II, when aerial bombing tipped the balance in many military campaigns, there has been much interest among fire control people in aerial attacks on forest fires. The idea was to attack from the air before ground crews arrived to keep the fire small and to supplement efforts on the ground after the ground crews arrive. In 1959, a major assignment for the Macon Laboratory was to study aerial suppression tactics and materials.

A TBM tanker, which was a modified U.S. Navy torpedo bomber, was used in the studies. It delivered 220- or 440-gallon loads with great accuracy. An early question was whether it was best to simply apply water or to include fire-retardant additives. Since reloading the airplane was not very rapid, including a fire retardant to increase effectiveness seemed like a good idea.

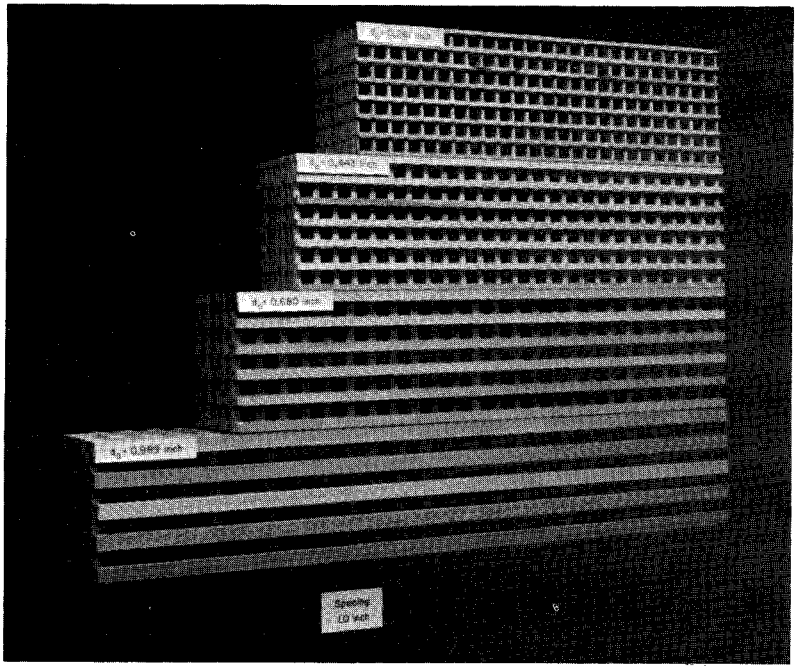
In the first evaluations, a kaolin slurry, a borate slurry, and wet-water solutions were applied to test fires in natural southern pine timber types. Effective lines more than 200 feet long were made in this manner. In 1959, it was determined that ammonium

phosphate solution dropped from a TBM tanker was the most effective combination for use on Coastal Plain vegetation in the South. A 15-percent solution applied at a rate of 1 gallon per 100 square feet was the minimum for slowing a fire's progress.

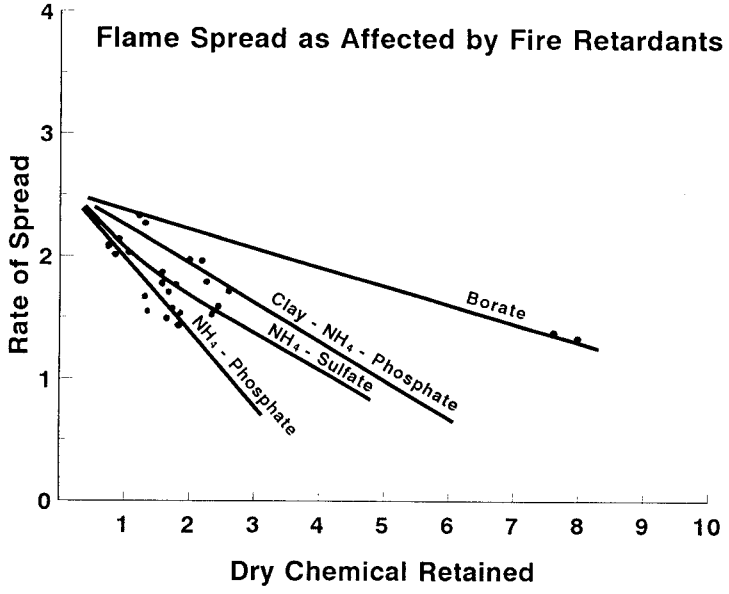


An aerial tanker owned by the Georgia Forestry Commission was often used to evaluate fire retardants. Cooperation between the Georgia Forestry Commission and the Fire Laboratory has been especially close.

Applications of 3 gallons or more per 100 square feet of the fire retardant, sodium calcium borate, killed large trees if their rooting area was covered. They also were shown to prevent germination of pine and sweetgum seeds. These chemicals were rejected because there seemed little point in slowing or stopping the progress of a fire with a chemical that would kill the vegetation in any case. The beauty of ammonium or diammonium phosphate as a fire retardant in forests is that it is also a fertilizer. Two growing seasons after it was applied to slash pine seedlings at rates of 1 to 3 gallons per 100 square feet, the treated seedlings were 50-percent taller than seedlings on untreated areas nearby.



Various combinations and configurations of fuels were burned in the combustion room to estimate fire behavior in the forest.



Fire retardants were rated by burning chemically treated wood cribs and comparing the rate of fire spread with the amount of dry chemicals retained on the wood.

Studies showed that unthickened fire retardant solutions would stop a surface fire running through heavy litter more effectively than thickened solutions because of better retardant penetration. If the fire was being carried in tree crowns, thickened solutions proved better because more of them adhered to the fuels in the crowns.

Solutions of diammonium phosphate were easily thickened with gums, such as sodium alginate, carboxymethyl cellulose, and guar gum, at concentrations of 1 percent or less. Hydrated clays could also be used. Higher concentrations were needed, but costs were much lower.

In 1967, the Laboratory developed a reproducible system for testing the ability of fire retardants to inhibit combustion. In this method, the chemicals were applied to fires burning in preconstructed wood cribs. Results provided reliable estimates of the relative effectiveness of chemical alternatives. Rate of fire spread through the treated portion of the cribs was plotted against the weight of dry chemical present to predict treatment effectiveness.

Foam solutions also were tested, but they did not prove effective for aerial applications. In winds over 5 miles per hour, drift was excessive. They sometimes proved unstable, and drops failed to penetrate dense cover types.

In 1972, the Florida Division of Forestry outfitted two single-engine DeHaviland Beaver aircraft with 300-gallon, interior-mounted tanks to drop water and chemical-retardant solutions on fires. Scientists from the Laboratory worked with the Division of Forestry to determine the distribution of liquids from these aircraft flying at altitudes of 75 and 100 feet. These tankers proved capable of laying effective chemical lines up to 300 feet long and 75 feet wide.

Ground applications of chemicals also were tested, and some proved quite effective. It was shown that a 1,000-gallon tanker pumping a 15-percent solution of diammonium phosphate would lay 10 miles per hour of effective fireline 30 feet wide. The minimum application rate was determined for palmetto-gallberry and wiregrass fuel types.

Use of strip headfires in conjunction with prepared chemical lines was particularly attractive. The combination of a chemical line and a burned out strip could quickly produce a firebreak nearly 200 feet wide. This approach proved highly effective against large fast-moving fires.

In 1976, information on the use of fire chemicals applied from ground tankers was summarized and presented to fire control people throughout the Nation. Advantages and disadvantages of various solutions were reviewed. Environmental effects, chemical handling procedures, fire-fighting tactics, and application equipment were fully described.

The use of plastic-covered primacord for backfire ignition was developed at the Laboratory. The plastic covering reduced the hazard associated with use of the material, and tests showed that it was highly effective for lighting fires in various fuels when the fuel moisture content was below 20 percent.

The Michigan sandcaster was tested in Georgia and Florida.

Tests were also conducted with heavy mesh wire screens to protect tractor drivers working close to a wildfire. The screens, which excluded passage of up to 95 percent of the light striking them, caused similar reductions in passage of heat.

Weather and Fire Danger

Controlling forest fires is comparable in many ways to conducting a military operation. Success depends primarily on the ability to concentrate large numbers of people with appropriate equipment at unknown points and unknown times. Prior planning and preparation pay big dividends. But as the military budget can impoverish a nation, so the budget for fire control could conceivably cripple other activities in a forest management operation.

Ways have been developed for determining the appropriate allocation of resources for fire control. They are based primarily on minimizing the sum of losses due to fire damage and expenditures for prevention, presuppression, and suppression of fires. Forestry organizations have developed flexible staffing schedules in which the number of people available for fire control on a given day depends on the probability of fire occurrence and the probable rate of fire spread on that day. These probabilities are included in a computed variable called "fire danger."

Much effort at the Southern Forest Fire Laboratory and at other fire research laboratories in the Forest Service has gone into the development and improvement of the National Fire Danger Rating System. When the Macon Laboratory was established, John J. Keetch, a Southeastern Station scientist stationed in Asheville, NC, was assigned the job of developing a unified national rating system. Since then, the system has been developed and refined more or less continuously. The Fire Sciences Laboratory in Missoula, MT, had primary responsibility for this work, but scientists in Macon, GA, made some major contributions.

Season of year and weather are obvious determinants of fire danger. In seasons when understory vegetation has green leaves and stems that are conducting water, live vegetation will contribute little if any to the spread of a fire no matter how severe the drought. And in the days immediately after a major rain, it is obvious that the dead fuels on the forest floor will not

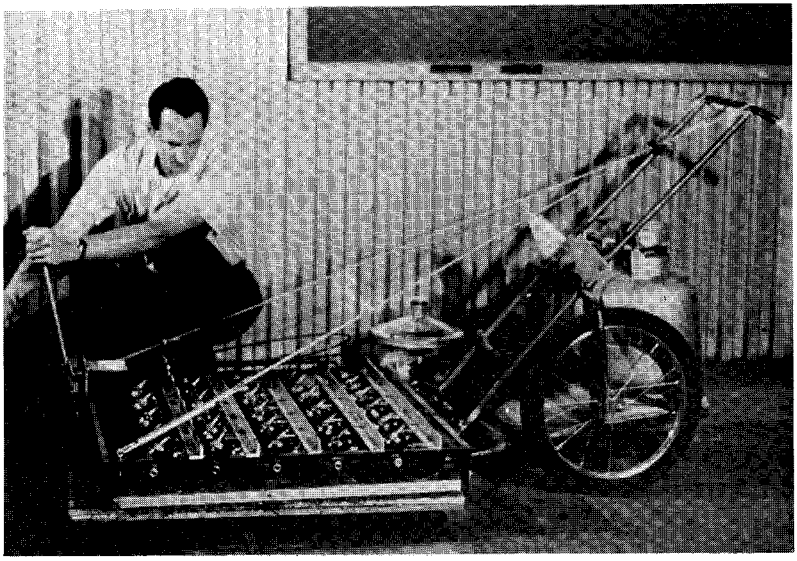
carry a fire very far or very fast. It is also obvious that a fire will spread faster on a windy day than on a calm day. But generalizations like that have only marginal value in determining the staffing needs for a fire control organization. For that purpose, fairly precise mathematical relationships are required.

In 1968, George Byram and John Keetch developed a drought index in which a numerical rating from 0 to 800 was assigned. This index was designed to indicate the water deficit or moisture stress in the upper 8 inches of soil. This drought index has been widely accepted in the forestry community. It is still widely used to estimate physiological effects of drought on plants as well as to determine effects of drought on fire behavior.

In 1969, Laboratory scientists began to measure the caloric output of forest fuels with an oxygen bomb calorimeter. Eventually values were obtained for 75 wildland fuels from the South, Northeast, and Lake States. The measured values indicate the potential release of heat from these fuels.

The rate at which fuels dry is critical to estimation of fire danger. Since drying requires movement of moisture from the fuel to the air, the rate of drying depends heavily on the relative humidity. Research in Macon shows that the rate of moisture movement depends on whether the fuel is passing moisture from a drier atmosphere or absorbing moisture from a humid atmosphere.

The moisture content of fine, lightweight fuels is in almost constant flux. Fine fuels increase their moisture content from late afternoon through early morning and lose it rapidly from early morning to late afternoon. Maximum moisture content can differ from the minimum by as much as 30 percent over a single 24-hour period. These diurnal variations in fine fuel moisture are part of the reason that fires are so much easier to control at night than during the day.



Ignitability was measured by simultaneously dropping 25 fire brands onto litter beds with various moisture contents.

Research with white fir fuel inside the Laboratory established curves relating rate of fire spread to windspeed. Backfires spread at essentially the same rate regardless of windspeed. Heading fires increase their spread rate geometrically as windspeed increases from 2 to 12 feet per second.

To help fire control decision makers to make staffing decisions, Laboratory scientists analyzed historical fire occurrence and fire spread in Georgia. Over a 1-year period they found that 71 percent of 5,000 fires occurred between noon and 5:00 p.m. and that 60 percent of those fires occurred when the calculated Burning Index was 6 or higher. Over a 10-year period, 96 percent of the large fires occurred when the relative humidity was 30 percent or less. A straight-line correlation was found between Burning Index, number of fires per day, and acres burned per day in Georgia. Scientists made the obvious conclusion: Burning Index could be used in Georgia to determine control-staffing needs. Later, a Spread Index, which is part of the National Fire Danger Rating System, proved to be an even better guide to staffing needs.

Weather events are often local phenomena. It rains heavily in one place and doesn't rain at all in another place just a few miles away. To be useful at specific locations, therefore, a National Fire Danger Rating System must rely upon local weather observations. And it is important that the local observers are all measuring the same things in the same manner. In the late 1960's, a survey of fire danger stations in Georgia revealed major inconsistencies in measurement of windspeed. Variations among anemometers led to errors as high as 25 percent at selected windspeeds. As a result, procedures were developed for laboratory and field calibration of anemometers. Even larger errors (up to 50 percent) were associated with the placement of anemometers in relation to firetowers. Tables were devised to correct for differences in anemometer exposure.

Measurement of relative humidity for estimation of fine-fuel moisture content is another potential source of error. In 1963, the Laboratory developed a mortar-board psychrometer, which was then used at all Forest Service weather stations throughout the Eastern United States.

The statistics varied from region to region across the country, but in all regions and states, a rather small percentage of forest fires were accounting for a rather large share of the acreage burned. These fires were making the newspaper headlines and giving fire control specialists a sense of failure. These breakout fires often behaved in peculiar ways, confounding the available rules of thumb for mobilizing control forces. Fire researchers and fire control specialists noticed that meteorological conditions during some of these fires were the same as those required for tornadoes and severe thunderstorms. The similarities suggested a solution that has been adopted across the nation. The methods for forecasting severe thunderstorms and tornadoes have been adapted for forecasting the possibility of unusual and dangerous fire behavior. Fire control people take those forecasts extremely seriously.

Seasonal needs for forest fire control vary widely across the Nation. In Georgia, analysis of fire statistics shows that March is the month with the greatest number of fires and with the largest average fire size. There, debris burning has historically been the largest single cause for wildfires. In recent years, fires caused by hunters, recreators, and tourists have risen. Analysis of such statistics help direct prevention efforts and indicate whether or not fire control efficiency is improving. In addition, causes vary by season and contribute to seasonal variations in fire danger.

Sea-Breeze Fronts and Project THEO

One of the things that makes areas near large bodies of water popular on hot summer days is the sea breeze. In the afternoon, the air over the land has warmed sufficiently to rise, and it is replaced by the cooler air from over the water. Along coasts, the meeting of the cool ocean air and the warm land air often creates localized weather fronts that include events normally associated with weather fronts. Some of these associated events include increased wind velocities, changes in wind direction, and thunderstorms.

Meteorologists at the Southern Forest Fire Laboratory became interested in sea-breeze fronts and associated weather phenomena because of the effects on forest fire control. Fire control people had been reporting unpredictable fire behavior at times near the Atlantic and Gulf Coasts. Similar experiences were also reported near the Okefenokee Swamp in southern Georgia. The swamp, it turns out, has and the area around it create a phenomenon similar to a sea breeze called a "swamp breeze."

Interest in weather along coasts was shared by the U.S. Navy. Its primary concern was about warm fog along the Atlantic Coast, but a joint Navy-Forest Service research effort seemed logical. The Navy was aware of the meteorological research underway at the Southern Forest Fire Laboratory because the Laboratory Chief in 1964, Dee F. Taylor, was also a Naval Reserve Officer. Because of the joint interest, the Navy agreed to provide funds for the establishment and operation of a closely spaced

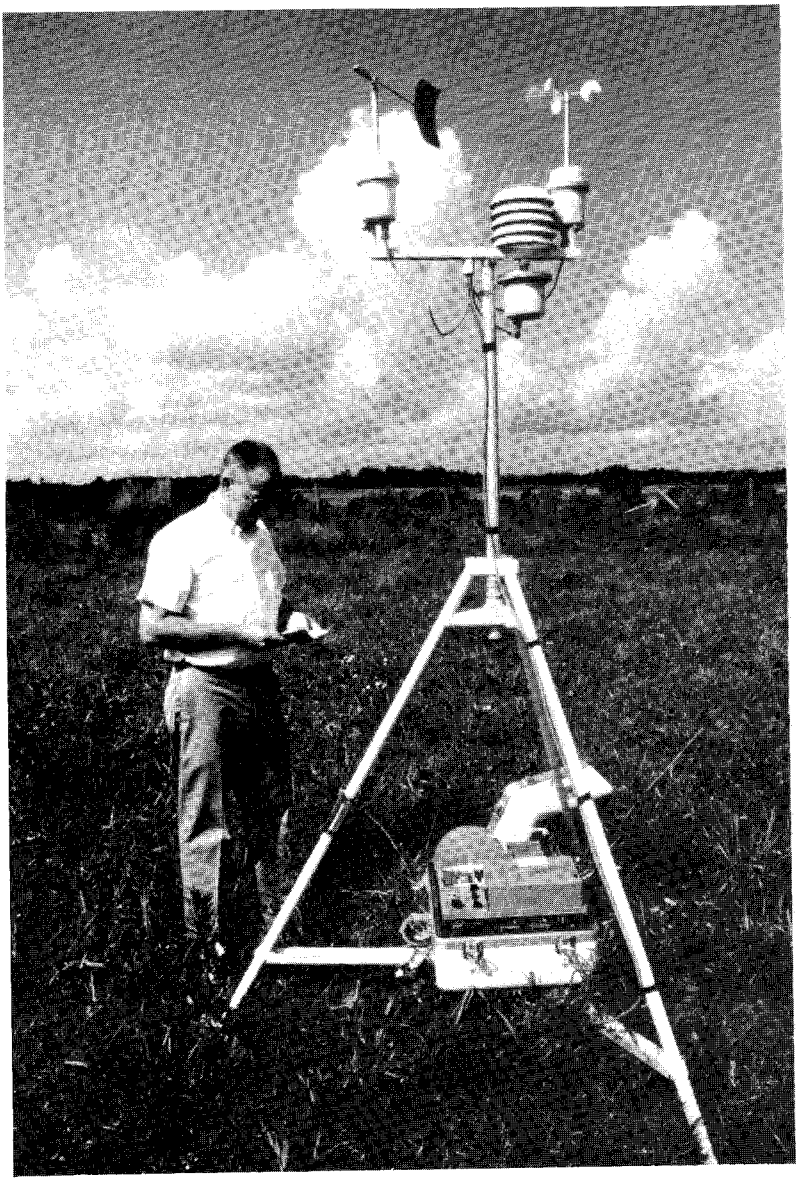
network of weather stations between Savannah and Brunswick, GA stretching from the Barrier Islands to 40 miles inland.

"THEO" was taken as the project name from Theophrastus, a student of Aristotle who succeeded his master as head of the Lyceum in about 300 B.C. During his 35 years of leadership at the Lyceum, Theophrastus influenced the thought of more than 200 students. His name, given him by Aristotle in appreciation of his eloquence, literally means "Divine Speaker." Use of his name in connection with the project may have stemmed from his observation that "flies bite exceedingly hard after rain."

At the weather stations of the THEO network, air temperature, relative humidity, speed and direction of wind, precipitation, and atmospheric pressure were recorded virtually continuously. In addition to documenting the characteristics of sea-breeze fronts, Project THEO can fairly claim some significant accomplishments:

- Insight into the statistical properties of rainfall.
- Development of methods for calibrating tipping-bucket rain gauges.
- Documentation of major variations in fire danger over short distances.
- Development of fog climatology.
- Development of a method for characterizing sites for local climatology analysis.
- Development of techniques for error editing in computerized weather records.

In 1973 a group of the oldest THEO weather stations were moved to Townsend, GA, where they were erected at 1,000-foot intervals in a triangular area that included an open field, a young pine stand, and a mature hardwood swamp. Eighty-eight-foot weather towers were installed at the points of the triangle, and sensors were located at the tops, midpoints, and 4.5 feet above ground on the towers. Near the center of the triangle, a standard Federal Aeronautics Administration transmissometer was set up to measure visibility. Other special instruments were installed



Weather data were recorded in Coastal Georgia for the THEO Project .

to measure dew point and backscatter visibility. This extraordinary array of instruments provided data for assessing meteorological variations in forested and open locations, developing models for predicting visibility, and verifying a variety of theoretical models.

Project THEO also provided a great deal of experience in computerized gathering and analysis of weather data. Assistance in the computer work was obtained from Dr. James L. Carmon, Director of the Computer Center at the University of Georgia. Dr. Carmon took a personal interest in the work and recruited talented and respected scientists to assist. Dr. L.R. Shenton, a meteorologist and international authority on distribution statistics, was recruited. He later published extensively on the statistical properties of rainfall and provided invaluable advice to project scientists.

Pioneering Use of Computers

When the Southern Forest Fire Laboratory was established, major contributions to the use of computers in resource management were not envisioned. The contributions that were made are attributable to the talents and inclinations of some of the Laboratory staff, and to the nature of the data they collected. For 9 years after its establishment, the Laboratory had no computer facilities. All computer support came from the University of Georgia Computer Center in Athens. Data were carried from Macon to Athens—an inconvenient arrangement.

Mark Waters wrote the first program at the Laboratory in IBM-1620 Assembler language for a University of Georgia computer. In the mid-1960's demands for computer time were increasing because new staff members, James Pharo, John Deeming, James Paul, and Robert Lamb, had programming knowledge. Finally in 1968, as part of Project THEO, the University installed an IBM-1052 remote terminal at the Laboratory. It quickly paid for itself in saved trips between Macon and Athens.

Partly on the recommendation of the University of Georgia, the Laboratory began to explore the possibility of obtaining its own computer facilities. Funding did not permit acquisition of new,

state-of-the-art equipment, which was very expensive in those days. Instead, James Paul was assigned the responsibility of scanning Federal Excess Property Lists for suitable hardware that could be obtained essentially for the cost of transportation. The Laboratory's first computer was an IBM 1620 that was obtained in 1968 from the Atomic Energy Commission in Las Vegas, NV. Shipping and maintenance costs were provided by Project THEO. A second IBM 1620 was acquired soon after, and the two systems were used extensively for data acquisition, reduction, and analysis.

The final configuration of the 1620 included: (1) 40K of memory, (2) a 600 card per minute card reader, (3) a line printer, (4) a 1,500 character per second paper tape reader, (5) 9 megabytes of on-line disk storage, (6) 4 magnetic tape drives, and (7) an interface for telecommunication to the University of Georgia. Special software was quickly developed to handle large volumes of weather data.

None of this sounds very impressive, but it was a pretty impressive setup in 1969. In fact, in that year it was so impressive that the Macon Laboratory was asked to host a Forest Service workshop on the use of computers in fire research.

As the years passed, the need for computer capability grew rapidly. The 1620 was replaced with IBM 360, 370, and 4341 mainframes. These mainframes were the property of the Georgia Forestry Commission and were used jointly by the Laboratory and the Commission. The final configuration of the IBM 4341 included 18 megabytes of memory, 10 gigabytes of disk storage, a 1,200 line-per-minute printer, 12 magnetic tape drives, and local terminal access. When they were obtained, these computers were usually one generation behind the state-of-the-art, but they provided the necessary computational power for the cost of electricity and maintenance. Operating system software was usually free. Much of the software was considerably less than user friendly, and a great deal of effort and ingenuity was required to effectively use the systems.

Credit for the idea of getting the Laboratory's first microprocessor must go to Vernon Wiggins, who claims to have made up his mind while waiting for Jim Paul to arrive at a motel in Augusta,

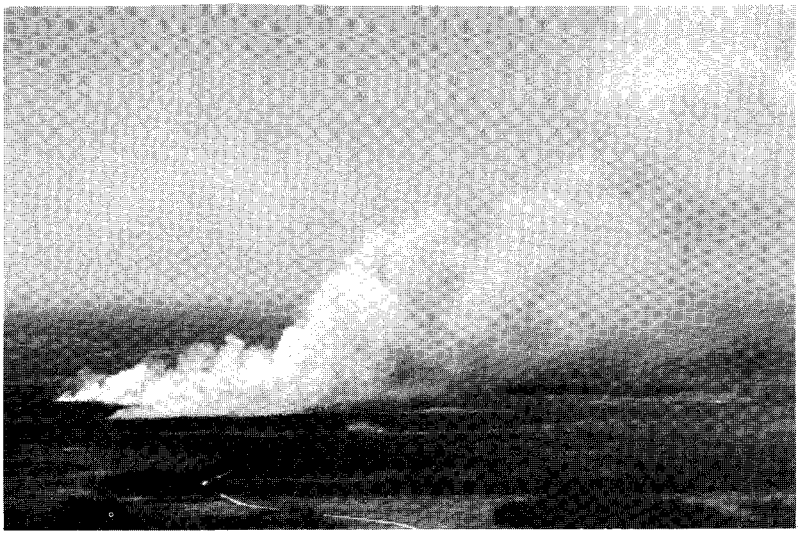
GA, in the spring of 1975. Vernon convinced Jim that microcomputers had a future, and they jointly convinced John M. Pierovich, the Laboratory Program Manager, to purchase an INTEL MDS 800. The machine had a serial number 682, indicating that it was one of the first of many thousands that were sold. At a cost of about $15,000, this microprocessor had 48K of memory and one 8-inch single-sided, single-density disk drive. Access to the processor was through a Model 35 teletype that was already on hand. None of this sounds like much now, when many times the computing power can be obtained at far less cost, but the MDS 800 was quite the machine in its time. Today, all personnel have access to state-of-the-art personal computers.

In the 1980's, the Forest Service decided to establish a national computer network, and Data General was chosen to supply the equipment. The national decision was made largely to provide office automation and electronic communication throughout the Forest Service. Early Data General configurations did not have sufficient memory or disk capacity for the research computing needs of the Macon Laboratory, which continued to rely on its mainframes and microprocessors for research operations. But the operational, maintenance, and programming costs of the antiquated mainframe equipment had been rising, and the price for powerful state-of-the-art RISC workstation equipment had been dropping. In 1991, the laboratory received Departmental approval to purchase HP 9000 Series 700 workstations along with geographic information system software and permission to set up a local area network.

Smoke Management

By 1970, the American public was getting increasingly concerned about air quality. Prescribed burning was a very common and highly effective treatment in southern forests. Burning was used to reduce fuel concentrations and the chances of disastrous wildfires, and it was used to prepare seedbeds for pine reproduction. While it was achieving highly desirable results, it also was producing undesirable smoke. Some members of the

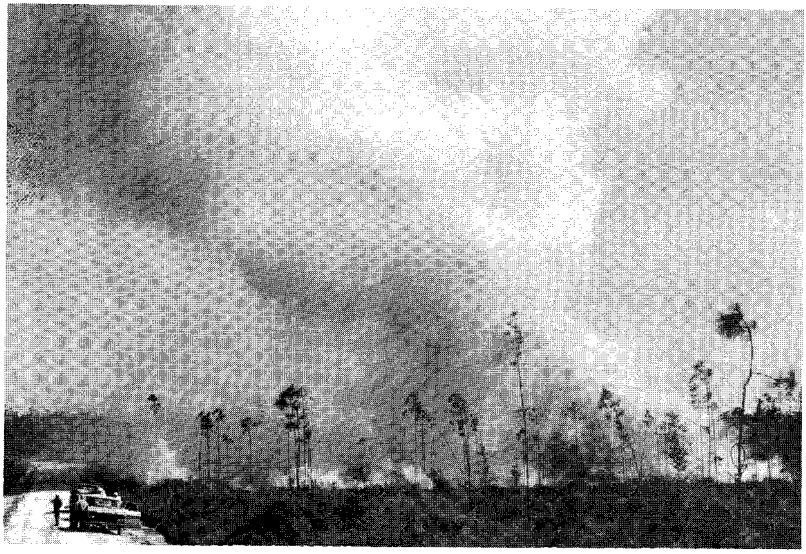
forestry community could see a time when smoke production would preclude prescribed burning if ways were not found to prevent undesirable smoke concentrations over highways and populated areas.



Prescribed burns must be managed to control emissions.

Beginning in the mid-1970's, all of the scientists at the Southern Forest Fire Laboratory directed their efforts solving the problems related to management of smoke from prescribed fires. A 5-year Smoke Management Program was begun, and John Pierovich was appointed Program Manager. The assignment was to produce viable guidelines for the management of smoke in southern forestry. These guidelines were needed to minimize exposure to the harmful effects of smoke from prescribed burns.

For the next 5 years, everyone at the Laboratory felt a special sense of urgency. Land managers tended to see the underlying question as a simple one. For a particular tract, they wanted to know whether or not they could burn on a particular day. A simple "YES" or "NO" would do fine.



Smoke from prescribed burning is studied to evaluate its impact on surrounding areas and to improve fire management techniques.

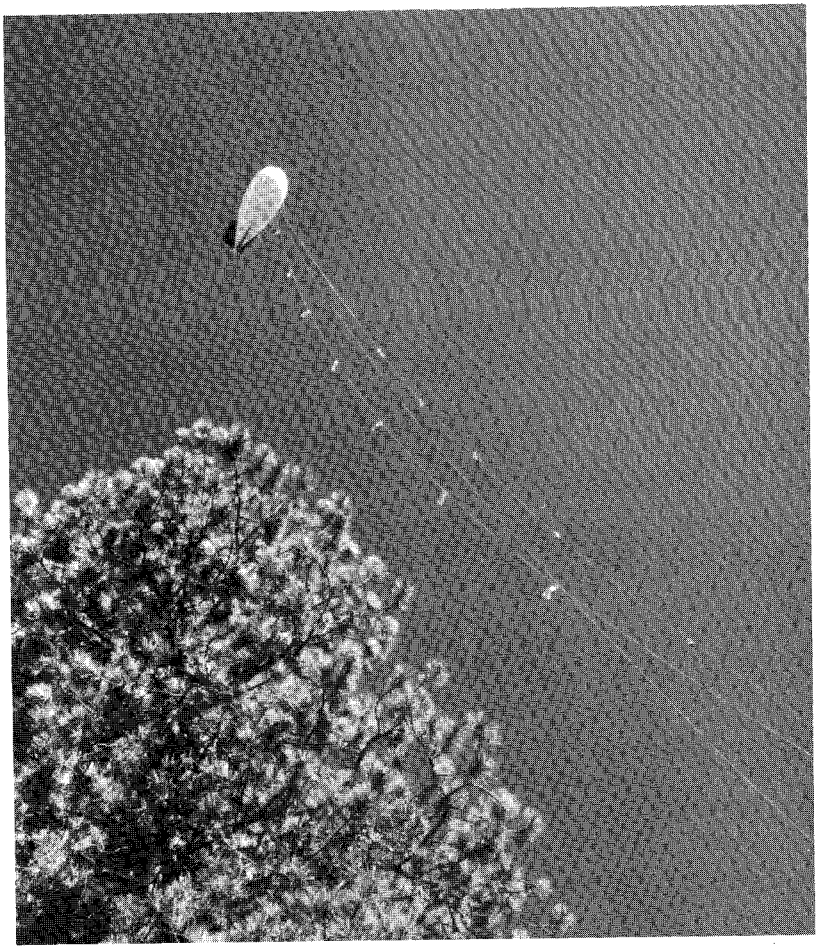
Many land managers were disappointed with the complexity of the answer they got from the Smoke Management Program. Whether it is "OK" to burn a given tract on a given day depends on how much fuel is present, the kind of fuel, its moisture content, the ability of the atmosphere to disperse smoke, and the direction of smoke travel with respect to highways, towns, and other developed areas. The answer also depends to some extent on whether other people in the same general area will be burning at the same time.

Meteorologists were pressed to predict smoke concentrations miles downwind from fires. They needed models to explain the dispersion of smoke in the atmosphere under a wide variety of weather conditions.

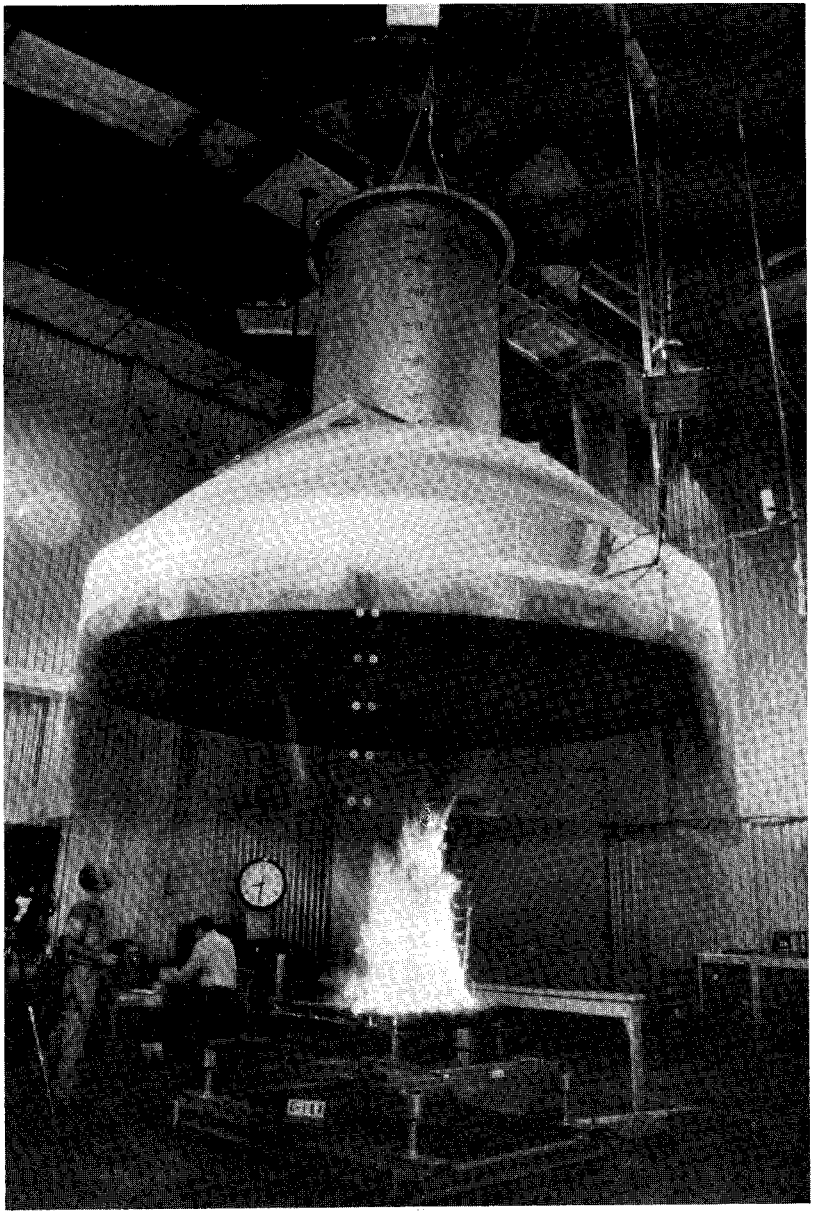
Fuels experts were asked for reliable emission factors – estimates of the amounts of smoke that a given weight of fuel would produce at a given moisture content. They also had to provide land managers with reliable methods for estimating how much fuel was present in the areas they hoped to burn. Combustion

experts were asked to predict the amounts of fuel fires would consume under a wide variety of fuel loadings, fuel moisture contents, and weather conditions.

Models of smoke dispersion in the mountain valleys of the Western United States proved ineffective in the Southern Coastal Plain and Piedmont Plateau. New models had to be developed and tested from observations of dispersion on southern fires.



A tethered balloon with an array of smoke samplers can measure emission to the top of a smoke column.



Smoke emissions from various fuels were measured in the combustion room.

Particulate matter emission factors for various fuel complexes could be derived in laboratory experiments. But they had to be verified with field measurements from full-sized fires. Samples had to be taken from throughout the plumes of smoke from bottom to top. Samples were obtained from low-intensity backing fires burning in steady winds with 30- to 40-foot towers placed along the entire length of the fires. Sampling in smoke plumes on high-intensity fires was considerably more difficult. A 3,500-cubic-foot balloon was purchased and filled with helium to take particulate matter samples from the plumes big fires. It was raised as high as 1,000 feet, and sampling devices were located along its tether. An instrumented aircraft was used to sample plumes at great distances downwind from fires.

Reliable procedures were provided for land managers to estimate how much fuel is left as debris after logging operations in slash pine stands. Estimates could be based on timber cruise data or on the amount of cordwood actually harvested from the area.

Forestry smoke was carefully analyzed for its hydrocarbon constituents. Polynuclear aromatic hydrocarbons (PAH) were of particular interest because some were known carcinogens. Results of those analyses were disquieting. While backing fires produce a lot less particulate matter than heading fires, they tend to produce considerably more PAH for a given weight of fuel consumed than do heading fires. Sampling of the products of combustion in the Laboratory's environmental chamber also showed that pine needle and organic soil fuels form ozone and other oxidants. In the tests, nitrogen oxides were produced in about three times the amounts reported in earlier literature.

Less than 5 years after being created, its mission was completed by publishing the "Southern Forestry Smoke Management Guidebook." Its completion on schedule was a prodigious accomplishment, but, by itself, did not provide the simple answers that forest managers were looking for. To get their answers, forest managers were asked to make a series of rather complex computations.

Research on some aspects of smoke management continued after the program was disbanded. Studies in the mid-1980's showed that burning organic soils produce emissions with high concentrations of complex aromatic hydrocarbons and high quantities of carbon monoxide. These products are the result of inefficient smoldering combustion, which is typical of fires in organic soil. The contents of the emissions are not good news for the people who must inhale them.

Questions were raised about the fates of herbicides, insecticides, and wood preservatives when fuels containing them are burned in the open or in wood stoves. In general, slow, smoldering combustion favored release of the chemicals, while rapid combustion tended to consume them. Depending on the rate of combustion in a wood stove, burning wood treated with chromated copper arsenate in it releases 20 to 80 percent of the arsenic to the air.

Forestry Weather Interpretations System

The Forestry Weather Interpretations System (FWIS) was developed at the Southern Forest Fire Laboratory primarily to fill the needs of southern forest managers for localized weather information and interpretation. The greatest need for weather information was in connection with fire control and prescribed burning, but it also was needed for other forestry operations. The computerized system that was developed also provided the complex computations needed for smoke management decisions.

Lively interest in FWIS was expressed by State Foresters in Florida, Georgia, North Carolina, and Texas, by southern forest industry, and by the Southern Region of the USDA Forest Service. At a summer meeting in Athens, GA, in 1974, interested parties agreed to: (1) seek a formal charter from the research branch of the Forest Service to develop a computerized weather information system, (2) seek cooperation from the National Weather Service, and (3) set up an advisory committee composed of Federal, State, and industrial forestry organizations.

All three objectives were accomplished, and FWIS development began in 1975. Members of the advisory committee were:

John Allen, USDA Forest Service, Region 8, Atlanta, GA.

Richard L. Bailey, NOAA National Weather Service, Washington, DC.

Joe Clayton, USDA Forest Service, Southeastern Area, State and Private Forestry, Atlanta, GA.

Denzil R. Davis, NOAA National Weather Service, ESSC, Auburn AL.

Jack W. Gnann, Union Camp Corp., Savannah, GA.

William D. Marshall, NOAA National Weather Service, WSFO. Birmingham, AL.

Charles F. Roberts, USDA Forest Service, Research, Washington, DC.

Tommy W. Trimble, NOAA National Weather Service, Southern Region Headquarters, Fort Worth, TX.

Stan Winthrow, Florida Division of Forestry, Tallahassee, FL.

The National Weather Service also assigned Aloise Huber to work at Macon full-time to aid in the developmental work.

There were numerous developmental problems. FWIS would have to have direct access to weather information recorded at airport weather stations throughout the South. It would have to provide a spot forecast on request. And it would require some system for readings at airports to estimate local temperature, relative humidity, windspeed, wind direction, current weather, cloud cover, visibility, stability, etc. Modules would also be needed to provide, on request, specific information and computations for smoke management, fire danger, fire behavior, prescribed fire, and fusiform rust.

Developmental work and a pilot test were done on a CDC CYBER computer at the University of Georgia. When the pilot test proved successful, the FWIS advisory committee recommended that the system be placed on a dedicated computer. The Georgia Forestry Commission was a logical choice to operate the system, but neither the Forest Service nor the Commission had the funds to purchase state-of-the-art equipment. A gift to the Commission from the Blue Bird Body Company in Fort Valley, GA; liberal use of equipment from Federal Excess Property Lists; and gifts from other sources got the system started. By 1986, FWIS was delivering daily forecasts and National Fire Danger Rating System indices (both observed and forecast) to the National Forest System in the South and to all Southern States except South Carolina.

In late 1986, the USDA Forest Service withdrew its support for FWIS, citing changes in national budget priorities. The financial contributions of five Southern States were not sufficient to keep the regional system operational. Nevertheless, the Georgia Forestry Commission has continued to operate FWIS using only Georgia data. And there is some interest in other Southern States about expanding the system again.

Future Direction

The direction of fire research is changing in the 1990's. Much greater emphasis is being placed on understanding ecological processes and protecting natural environments. The National Research Council's report on forest research, the Ecological Society of America's sustainable biosphere initiative, and strategic research plans of the whole Forest Service and the Southeastern Forest Experiment Station have recognized obvious deficiencies in current ecological knowledge.

The need for greater ecological knowledge is especially clear with respect to fire in southern forests. The research program at the Southern Forest Fire Laboratory is designed to overcome some of the deficiencies. We know that fire and weather are

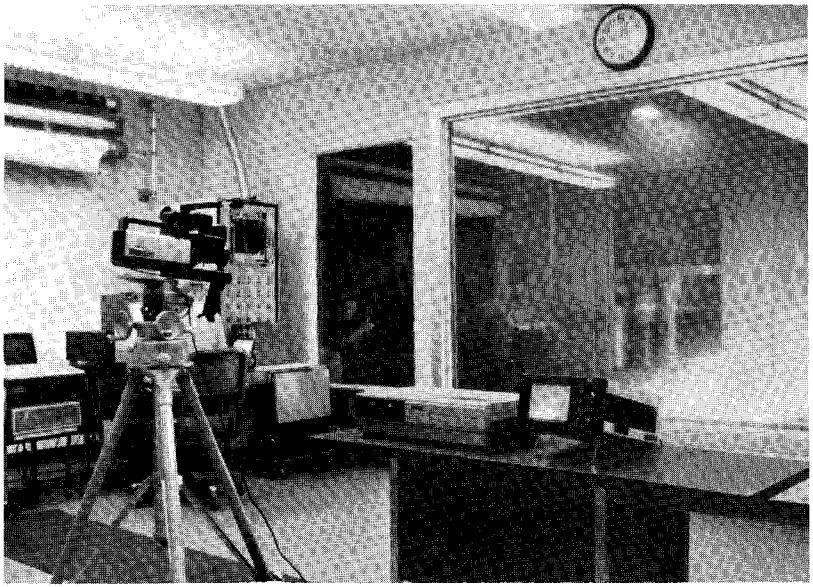
two of the most important forces that shape southern forest ecosystems. Hence, knowledge about fire and atmospheric science will be increasingly important to sound management of southern forests.

Each year, an average of 70,000 wildfires burn about 1 million acres of southern forests. In 1991, these fires destroyed 912 structures, including 145 homes, and killed 10 people. Damage from wildfires and costs for controlling them can be greatly reduced by prescribed burning to reduce fuel buildups. Properly designed prescribed fires also recycle nutrients, improve access, perpetuate fire-dependent species, provide necessary conditions for some endangered species, improve habitat for certain wildlife species, dispose of logging debris, improve access, manage competing vegetation, and prepare sites for seeding and planting of new forests. About 8 million acres of southern forests are burned by prescription each year to achieve one or more of these objectives.

Prescribed fire is critical for perpetuation of the longleaf pine ecosystem on the southern coastal plain. This ecosystem once occupied as much as 92 million acres. Today, less than 1 million acres are left, and loss may be as high as 140,000 acres a year. This ecosystem was once associated with over 100 soil types and contained more than 600 species of flowering plants. Some 230 plant species now considered rare are associated with the longleaf pine ecosystem. It is the preferred habitat of the endangered red-cockaded woodpecker, the endangered indigo snake, and the threatened gopher tortoise. The need for fire to preserve the ecosystem is clear.

Prescribed fire is an ecological as well as an economic necessity. Nevertheless, professional land managers could lose the use of fire if they cannot adequately manage the effects of the smoke that is produced. Numerous highway accidents have been caused by smoke and smoke-enhanced fog. And reductions in air quality in sensitive areas have caused serious problems.

Clearly, there is no shortage of important research problems about fire, its effects, and its management in southern forests. The difficulty at the Southern Forest Fire Laboratory has been to choose the most critical needs to address with the limited resources that are available. The three most pressing management problems are: fire management at the wildland-urban interface, smoke management, and ecosystem management.



Fire Image Analysis System.

Fire physics research will support fire management at the wildland-urban interface. The research will examine the dynamics of combustion and heat transfer during fires in living and dead fuels. Results will help determine risks of structure ignition in various fuel types at the wildland-urban interface. In addition, studies of fire physics will help prescribed burners to estimate the intensities of numerous fires set over a large area when the flaming zones converge. A new fire image analysis system is

being developed in cooperation with SciMeasure, a private enterprise in Atlanta and the Department of the Interior. If the improvements meet expectations, the system should be invaluable for research and operational monitoring of wildland fire behavior.

Meteorological modeling research will support smoke management by more accurately predicting where the smoke from prescribed burning will go, how well it will be dispersed, and whether smoke-enhanced fog is likely to form. Wind models will be developed to better predict the transition from typical daytime to nighttime flows, because windflow and fog formation are especially troublesome at night. Productive partnerships with Federal, State, and private organizations will be essential in this work.

Operations research and landscape ecology research will support ecosystem management. The research will focus on improving fire management operations, particularly in longleaf pine ecosystems. Research methods will include: (1) use of geographic information systems to study ecological effects of fire at the landscape level and (2) applications of artificial intelligence and statistical process control to improve fire management decision making.

Acknowledgments

Many people helped to make this booklet possible. Special thanks go to R.W. Johansen and J.T. Paul for helping to write this history. We also thank Tyne Gonzalez and Janice Lowe for their technical assistance.

The Laboratory Staff

Over the past 32 years, more than 100 people have been on the staff of the Southern Forest Fire Laboratory. All have made significant contributions. These staff members and their job titles are listed below.

NAME	TITLE
Ach, Edward E.	Forestry Technician
Achtemeier, Gary L.*	Research Meteorologist
Adkins, C. Wayne*	GIS Specialist
Altman, April E.	Secretary
Altobellis, Anthony M.	Research Forester
Bailey, Philip M.	Physical Science Technician
Barlow, Doris	SCSEP Enrollee
Bearden, Patsy S.*	Secretary-Typing
Bell, Marvin C.	Forestry Aid
Bennett, Mary Ann	Secretary-Typist
Bishop, Melvin E.	Electronics Engineer
Blackmarr, Winfred H.	Research Forester
Boney, John W.	Statistical Clerk
Brender, Ernst	Project Leader
Burgan, Robert E.	Research Forester
Burgess, Robert K.*	Physical Science Technician
Byram, George M.	Physicist
Calhoun, Henry L., Jr.	Forestry Aid
Chambers, Brenda	Secretary
Cheshire, Karen W.	Secretary
Clements, Hubert B.	Research Physicist
Coffin, James E.	Forestry Aid
Cohen, Jack D.	Research Physical Scientist
Collier, James	SCSEP Enrollee
Colquitt, John	Forestry Research Technician
Cooper, Robert W.	Research Forester
Corey, Margaret H.	Computer Specialist
Cox, William	SCSEP Enrollee
Crawford, Patricia B.	Secretary
Davis, Alisia A.	Computer Clerk
Davis, Lawrence	Research Forester
Deal, Mary P.	Clerk (Typing)

NAME	TITLE
DeCoste, John H.	Research Forester
Deeming, John E.	Research Forester
Dieterich, John H.	Research Forester
Dodds, Lucille, L.	Clerk-Typist
Donaldson, Bryan G.	Computer Programmer
Donaldson, Colleen	Computer Assistant
Dyer, Bertha M.	Business Manager
Edwards, Boyd M.	Research Ecologist
Elliott, Ernest R.	Chemist
Ellis, Thomas H.	Research Forester
Ellison, Irma B.	Mathematics Technician
Everhardt, Gladys A.	SCSEP Enrollee
Fons, Wallace L.	Physicist
Forbus, James K.*	Computer Programmer
Garrett, Grace P.	Secretary-Typing
Garrott, James J.	Electronics Technician
George, Philip M.	Forestry Aid
Gibbs, Hilliard L.	Physical Science Technician
Giddens, Timmy R.*	Electronics Technician
Gladstone, Mary C.	Clerk (Stenographer)
Gonzalez, Tyne E.	Computer Assistant
Griffith, Thelma	Clerk-Stenographer
Hammond, Dianne D.**	Computer Clerk
Harbin, John R.	Electronics Technician
Hardy, Sara*	SCSEP Enrollee
Harms, Mary*	Computer Programmer
Harper, Sidney W., Jr.	Forester
Hauck, Charles A.*	Meteorologist
Hefner, James E.	Research Forester
Heiges, Ann W.	Support Services Supervisor
Horne, Joel M.	Forestry Aid
Hough, Walter A.	Research Forester/Project Leader
Hughes, Oscar	SCSEP Enrollee
Jackson, Arthur T.	Forestry Aid
James, Elnora E.	Physical Science Aid
James, Sophia W.	Secretary
Janney, Clifton E.	Physical Science Technician
Johansen, Ragner W.	Research Forester
Johnson, Horace E.	Electronics Technician

NAME	TITLE
Johnson, Lois**	SCSEP Enrollee
Johnson, Von J.	Project Leader
Jones, Darlene	Secretary
Kitchens, Ruby	SCSEP Enrollee
Lacy, Michael M.**	Maintenance Worker
Lamb, Robert C.	Research Meteorologist
Lavdas, Leonidas G.*	Research Meteorologist
Lee, Robert E.	Forestry Aid
Lege, Frank	Forestry Aid
Lewis, William G.	Forestry Aid
Liston, Sonja B.	Statistical Assistant
Loth, Becky**	Business Management Assistant
Lowe, Janice R.*	Clerk-Typist
MacGregor, Robert B.	Forestry Aid
Martin, Joann C.	Secretary
Martin, Robert E.	Research Forester
McKenzie, Clifford	Forestry Aid
McMahon, Charles K.	Project Leader
McNab, Henry	Research Forester
McNasser, Karl W.	Research Forester
McNeal, Peggy	Clerk-Typist
Mende, Margie*	SCSEP Enrollee
Mitchell, Jamie**	Janitor
Mullis, Kay C.	Clerk Stenographer
Nelson, Ralph M., Jr.	Research Mechanical Engineer
Nicholson, Ernest	Forestry Aid
Offenhauer, David B.	Forestry Aid
Pachence, Anthony M.	Meteorological Technician
Paddon, Robert A., Jr.	Research Forester
Paul, James T.	Supervisory Research Forester
Pharo, James A.	Research Meteorologist
Pickford, Steward	Project Leader
Pierovich, John	Forester
Poss, Patsy K.**	Business Manager
Powers, Gladys	SCSEP Enrollee
Randall, Josephine**	SCSEP Enrollee
Respress, Willie	Maintenance Worker

NAME	TITLE
Rehberg, Cathey	Clerk-Typist
Rodgers, Steven L.	Electronics Engineer
Ryan, Paul W.	Research Forester
Rye, Henry J., Jr.	Forestry Aid
Sackett, Stephen S.	Research Forester
Sanders, Ed	SCSEP Enrollee
Saveland, James M.*	Supervisory Research Forester
Searcy, Andrew	Programmer Systems Analyst
Sechrist, Robert L.	Electronics Technician
Sheffield, Jo Ann S.	Secretary
Shimmel, James W.	Physical Science Technician
Skrehot, Donald J.	Administrative Assistant
Smith, Mary R.	Clerk Typist
Stinnett, Mary J.	Clerk Stenographer
Storey, Theodore G.	Forester
Tangren, Charles D.	Mathematical Statistician
Taylor, Dee F.	Research Meteorologist
Thomas, Charlotte	Computer Programmer
Tidwell, Joan	SCSEP Enrollee
Tkacs, Thomas G.	Forestry Technician
Tossy, Paul G.	Computer Programmer
Tsoukalas, Stevos N.	Chemist
Tribble, Angela M.	Mathematician
Underwood, B. Howard	Forestry Technician
Upshaw, Alvin C.	Forestry Research Technician
Ussery, Mary H.	Clerk
Vitale, Jacqueline	SCSEP Enrollee
Wade, Dale D.	Research Forester
Ward, Darold E.	Research Forester
Waters, Marshall P., III	Forestry Research Technician
Weise, David R.	Forester
Wendel, George W.	Research Forester
White, Jerry D.	Research Chemist
Wittenberg, Dick	Engineer
Wiggins, Mamie	SCSEP Enrollee
Wilson, Paul*	Computer Programmer
Wiggins, E. Vernon	Electronics Engineer

NAME	TITLE
Williams, Dansy T.	Research Meteorologist/ Project Leader
Williams, Debbie	Secretary (Typist)
Williams, Mary	Math Aid
Wright, Willie, Sr.**	Business Management Clerk, General

* Current Fire Project Employee
** Current Administrative Employee

Cooperators Housed in Southern Forest Fire Laboratory

National Weather Service:

Croom, Lowell E.	Meteorologist
Hagerty, Paul H.	Meteorologist
Huber, Alois M.	Meteorologist
Kreuger, Dan	Meteorologist

Georgia Forestry Commission:

Brantley, Julie	Computer Programmer
Donaldson, Bryan G.	Computer Programmer
Gillespie, Clay	Computer Programmer
Perez, Roberto	Computer Programmer
Rippin, George	Meteorologist
Tossy, Paul	Computer Programmer

Region 8:

Mobley, Hugh E.	Forester

Co-op Students:

NAME	TITLE
Bledsoe, Tammy	Computer Clerk
Brown, Lynn	Mathematical Statistician
Goldberg, Steven	Computer Clerk
Mercer, Christopher	Computer Clerk
Mixon, Julie	Computer Clerk
Pickford, Wendell	Computer Clerk
Pounds, Trista	Computer Clerk
Shell, John	Computer Clerk
Smith, Thomas	Lab Aid
Todd, Michelle	Computer Clerk
Tribble, Angela M.	Computer Clerk
Vincent, Wendell	Computer Clerk
Wells, Ken	Computer Clerk

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When completed in 1959, the Southern Forest Fire Laboratory was the world's first devoted entirely to the study of forest fires. Since then the scientists at the Laboratory have: 1) performed basic and applied research on critical fire problems of national interest, 2) conducted special regional research on fire problems peculiar to the 13 Southern States, and 3) assisted other States east of the Mississippi River on fire problems requiring the Laboratory's unique facilities. Some of the research topics included combustion and fire behavior, prescribed burning and fire effects, fire control, weather and fire danger, and smoke management. This brief history highlights some of the important research findings and the scientists that made them. Fire research in the 1990's will focus on ecological processes and understanding the natural environment.

KEYWORDS: Combustion, fire behavior, fire control, prescribed burning.

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When completed in 1959, the Southern Forest Fire Laboratory was the world's first devoted entirely to the study of forest fires. Since then the scientists at the Laboratory have: 1) performed basic and applied research on critical fire problems of national interest, 2) conducted special regional research on fire problems peculiar to the 13 Southern States, and 3) assisted other States east of the Mississippi River on fire problems requiring the Laboratory's unique facilities. Some of the research topics included combustion and fire behavior, prescribed burning and fire effects, fire control, weather and fire danger, and smoke management. This brief history highlights some of the important research findings and the scientists that made them. Fire research in the 1990's will focus on ecological processes and understanding the natural environment.

KEYWORDS: Combustion, fire behavior, fire control, prescribed burning.

The Forest Service, U.S. Department of Agriculture, is dedicated to the principle of multiple use management of the Nation's forest resources for sustained yields of wood, water, forage, wildlife, and recreation. Through forestry research, cooperation with the States and private forest owners, and management of the National Forests and National Grasslands, it strives—as directed by Congress—to provide increasingly greater service to a growing Nation.

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