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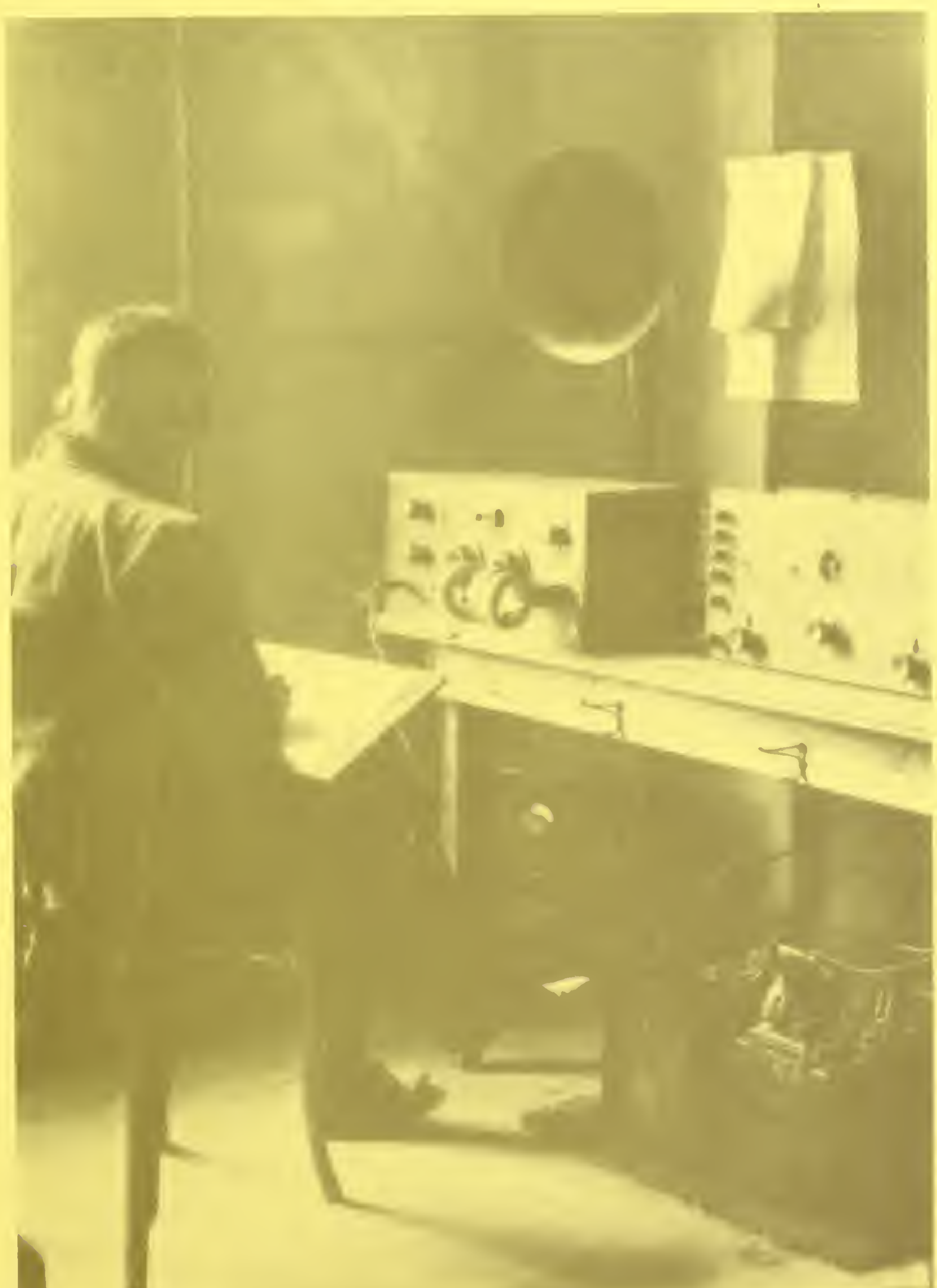
Legacy of a Pioneer



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The Gisborne Era of Forest Fire Research

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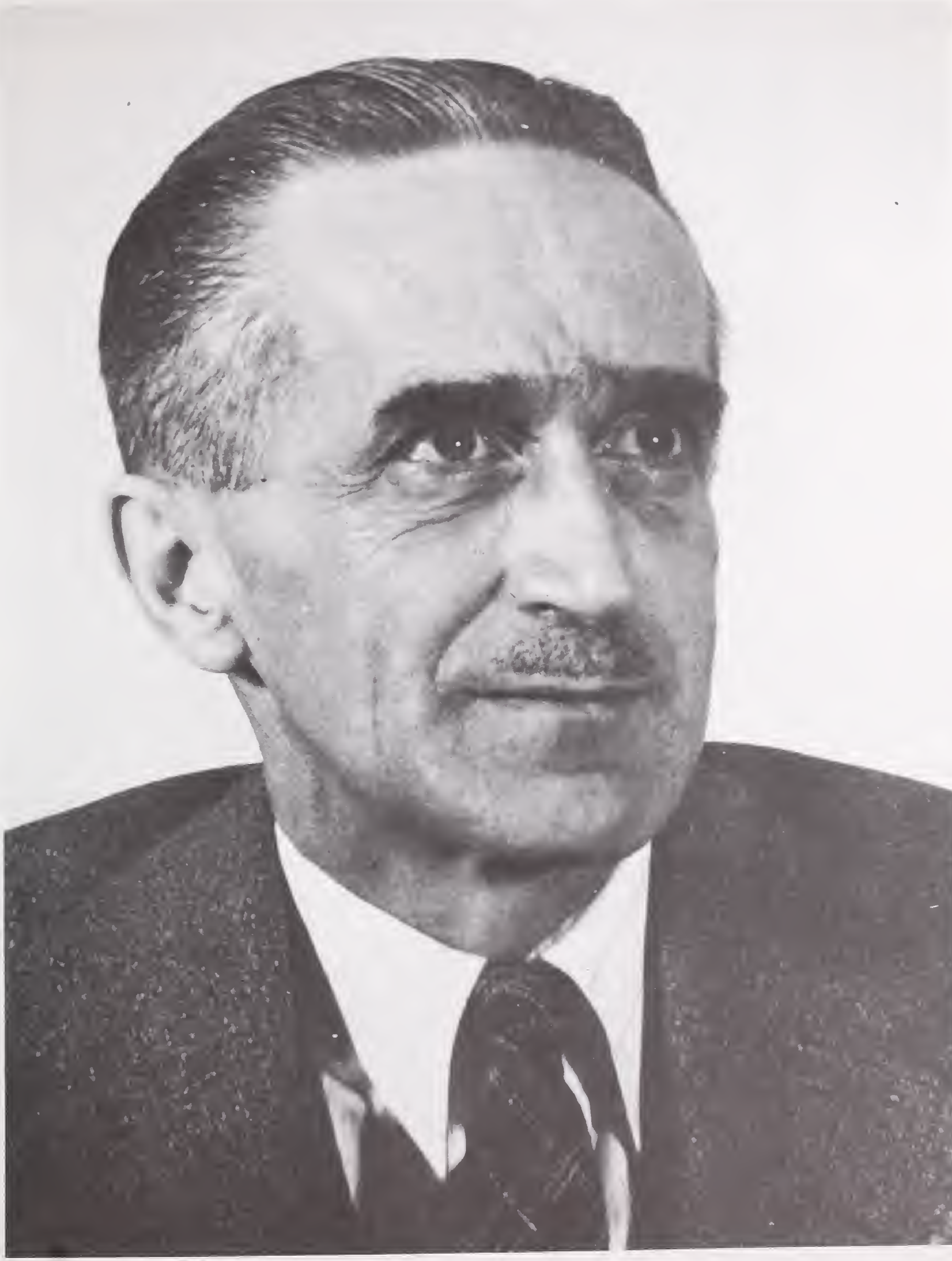

Harry T. Gisborne

Preface

In 1951, I transferred from the Kaniksu National Forest to a new assignment. I spent most of the next 22 years refining the fire-danger rating system, a complex mechanism for predicting the likelihood and potential severity of forest fires at any given time and place.

Like a second-generation laborer on a monumental cathedral, I found myself continuing a work begun by a great designer. In the case of the fire-danger rating system, indeed of much of our approach to research on forest fires, the architect whose creativity inspired and guided all who followed him was Harry T. Gisborne. Much of what we know today about the origins and behavior of forest fires is his legacy. And the fire-danger rating system, although repeatedly modified over the years (as he desired that it should be), is Gisborne's own monument.

As my career at the Northern Forest Fire Laboratory drew to a close, it became apparent to me that few of my younger colleagues knew of Harry Gisborne or fully appreciated the extent to which they were indebted to him. I felt called upon to record for others his role in the history of forest fire research and the tradition of excellence that he established for his followers.

This account of the "Gisborne Era" has been a labor of pleasure. It is not one, however, I could have accomplished alone. I wish therefore to acknowledge the many people who provided information and documents for my research. Those who consented to interviews are identified in the Reference Notes.

But special mention needs to be made here of the contributions of Charles A. Wellner, a lifelong friend of Gisborne and custodian of his private and professional papers; George M. Jemison, Gisborne's first full-time professional employee who later became Deputy Chief of the Forest Service for Research; and his other associates, including G. Lloyd Hayes, Jack S. Barrows, Arthur A. Brown, Charles L. Tebbe, William G. Morris, the late Clayton S. Crocker, Vincent J. Schaefer, and Robert R. Johnson. Without their contributions, this history would not have been possible.[1] I am especially pleased to thank Mabelle Hardy, my wife, for her part in this story--her suggestions, admonitions, editorial work, and most of all, her patience.

Finally, I acknowledge the technical and financial support of the Forest Service's Northern Forest Fire Laboratory, Missoula, Montana, and the History Section, Washington, D.C. This history was prepared under a Working Agreement to the June 6, 1958, Master Memorandum of Understanding between the Forest Service and the University of Montana. The Working Agreement is dated June 30, 1975. The university's School of Forestry and the Montana State Forest and Conservation Experiment Station contributed to and cooperated in this study. The first and more detailed and anecdotal version of this history was completed in February 1977. It is twice the length of this version. Copies are with the Gisborne Papers in the University of Montana Library Archives[2] and the files of the History Section, Forest Service.

Charles E. (Mike) Hardy
Missoula, Montana

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Dawn of an Era
1893-1922

I chose forestry as a profession because I loved the woods and hills and wanted to work with them. I went to the Vermont summer school of forestry in 1911 to make sure that I knew what I was getting into. I liked it, but actually gained hardly an inkling of what was to come. I can't remember that anyone ever mentioned research.[2]

Harry Thomas Gisborne was born September 11, 1893, the son of a lumberyard and planing-mill owner in Montpelier, Vermont. His association with forest resources grew naturally from that of his father, and he worked during his school years in the family business in capacities ranging from teamster to assistant shop boss. His family was not wealthy, so Gisborne interrupted his education between high school and college and again during a full college year to work for his father. He entered the University of Michigan School of Forestry in 1912 and graduated in 1917. In between he worked as an assistant to Professor Leigh J. Young and spent one season (1915) manning the Tip Top Lookout on the Wenatchee National Forest in Washington.

Immediately upon graduation, Gisborne entered the Forest Service as a Timber Cruiser on the old Santiam (now part of the Willamette) National Forest, Oregon, only to find his career again interrupted--this time by world events. On August 1, 1917, he enlisted in the 10th Engineers (Forestry), and served in France as a corporal during World War I. Upon his discharge in February 1919, Gisborne resumed his work for the Forest Service in the Northwest.

He was energetic, and his ability to master challenges led at first to frequent reassignments to places where his skills were needed. He began on the Service's Sitka spruce research study under N. L. Terry and worked on a number of other projects including two assignments to the old Wind River Forest Experiment Station, on the old Columbia (now Gifford Pinchot) National Forest in Washington, on research projects directed by J. H. Tolmann and Julius V. Hofmann. But just as it appeared that he was destined to be a roving researcher, he received, in April 1920, a permanent assignment to the Whitman National Forest, Oregon, where he worked for nearly 2 years on the staff of Supervisor Robie M. Evans.

Gisborne's abilities attracted the attention of other professionals during his travels around the forests of the Northwest. He received offers to transfer to forest fire research work in the South, where man-set fires were a critical problem, and to join the teaching staff at the University of Syracuse Ranger School in New York, the latter at a 50-percent increase in salary. But his satisfaction with Forest Service employment, together with confidence in his eventual promotion, led him to decline the invitations.[3]

He was not wrong, for the opportunity of his lifetime was in the making. Protection of the forest from fire was the agency's number one priority. Determined to more effectively control forest fires, the Forest Service began to focus its attention on basic and readily applicable fire research. In 1921, the headquarters of the Priest River Forest Experiment Station, founded in Northern Idaho in 1911, was moved to Missoula, Montana. The Station received a substantial increase in budget and a new Director, Robert H. Weidman.[4] The Priest River Office was about to concentrate on forest fire research in a major way, and Gisborne was the logical candidate for the job. In January 1922, Assistant Forester Earle H. Clapp, head of the Service's Branch of Research in Washington, D.C., who later became Chief of the Forest Service, requested Gisborne by name for assignment to Priest River. For Gisborne, Clapp suggested, the new position would be a great opportunity to demonstrate his initiative and use his administrative experience in studying the subject of fire in the northern Rockies. The development of practical means to attack the Service's major resource protection problem would bring, to people like Gisborne, the highest kind of national recognition, for, Clapp concluded, the men who entered fire research were destined to "become the leaders of the most important forest research activities in the country."[5]

Gisborne and his superiors agreed. On April 1, 1922, he transferred to the Priest River Branch of the Northern Rocky Mountain Forest Experiment Station with the title of Forest Examiner and a raise in pay.[6] The "Gisborne Era" of forest fire research had begun.

Figure 1.--Gisborne, as a young forest lookout, operating double tripod heliographs on Tip Top Mountain, Wenatchee National Forest, Washington, in the summer of 1915. The Forest Service experimented with them for a few years. Messages were received from men on fire patrol and relayed by telephone or other means to Ranger District headquarters. The devices, which reflected sunlight in mirrors with shutters attached, had been successfully used by the Army in its Indian campaigns in the sunny Southwest but were found not to be reliable in most National Forest areas because of the difficulty of operation and the irregularity of bright sunlight. Messages were exchanged in Morse code or in special codes.

(Gisborne collection)

Figure 2.--Harry Gisborne as Forester on the staff of Robie M. Evans, Supervisor, Whitman National Forest, Baker, Oregon, in 1921. He wears the newly prescribed Norfolk uniform, a British military style with breeches and leather puttees.
(Gisborne collection)

The Early Years 1922-1929

The purpose of forest fire research is to discover the fundamental causes and effects which vary in such a way as to cause variable demands on the forest protective organization. When we know accurately all the controlling causes and their effects we should be able to expand the protective organizations sufficiently to give adequate protection during the abnormal years, and to reduce expenses as much as possible and still provide adequate protection during the fire seasons that are less dangerous than the average.[7]

Gisborne entered forest fire research well suited in temperament to explore new areas of knowledge and translate his findings into practical tools for the forester. A small, meticulously dressed man who regularly wore, according to an associate, "chokebore pants and boots," Gisborne was "[not] afraid to get his hands dirty.... He never shunned hard work or dirty work at all."[8] Nor did he back down from danger. He was, in fact, indefatigable and remained so despite later health problems. Arthur A. Brown, retired Forest Service Director of Fire Control, recalled that "everyone that worked with Harry was impressed with his industry and how efficient he was in getting things done. He carried out a good many experiments singlehandedly that I'm sure we would do only with a good-sized crew today."[9]

Gisborne's frenetic pace was driven by an unbounded inquisitiveness regarding everything around him, especially the wonders of the natural world. To Brown, "He was one research man who never lost his little boy's curiosity."[10] And yet, he kept his curiosity within tight, practical bounds, consistently opposed to "research for research's sake."[11]

To Gisborne, research that was not intended to produce results for immediate application to forest management problems was merely a waste of effort. To determine the realities of problems in the field, he and his associates traveled ceaselessly; wherever possible, they conducted their experiments under field conditions rather than in the laboratory. To maintain a good rapport with men in the forests, he learned their needs, solicited their judgments, tailored his research to their immediate requirements, and in the process, sold the value of research to the pragmatic field Foresters.[12] "Harry was a prolific writer, an eager and effective salesman of fire research," recalled Brown. "Many have criticized many of his publications as being too empirical and much of his research as too localized in significance. But most of his research was a real pioneering job. He had no encouragement. He had to sell his program to the practitioner. He had to develop technical standards which would command respect among other researchers."[13]

Fire, the subject to which Gisborne devoted his career, has preoccupied Foresters perhaps more than any other subject during the entire history of the Forest Service. In the early years, all fires were considered bad. Later, it was learned that many major tree species owe their continued existence to fire; but for many years, fires were regarded chiefly in terms of their damage to timber, land, water, wildlife, fish, and esthetic appearance. Fires were, therefore, always officially considered destructive. The prevailing view was that forests could not be managed (for production of timber, protection of forage, soil, water, and wildlife, and provision for livestock grazing and public recreation) without the prevention or control of as many forest fires as possible. A series of catastrophic burns covering millions of acres in the Northwest late in the summer of 1910 seemed to confirm the worst fears of the newly established Forest Service. Within a year, Congress gave the Service a leading role in the control of forest fires on State, Federal, and private lands.[14]

Despite the seriousness with which Service Foresters regarded fire, they soon discovered that they knew relatively little about its predictability and behavior, the nature of its effects, and means to control it. A strong back and a few handtools were their only weapons at first. It is not surprising that such a "technocratic" agency ordered fire research studies within its first decade. Although Gisborne entered an area where little was known and much needed to be done, he soon discovered that a few tentative steps had already been taken in the quest.

Some Basic Data on Hand

Much of the work that preceded Gisborne involved collecting basic information on fires and their environments. As early as 1913, Julius Ansgar Larsen began work at Priest River gathering weather and climatic data for silvicultural studies and soon appreciated their value for understanding fire behavior. Within 3 years, he established a number of research projects to develop a scientific basis for evaluating fire hazard and likelihood of occurrence. His work, and that of Walter C. Lowdermilk and Station Director Donald R. Brewster, focused on the relationship among climate, current weather, and forest fuel inflammability. Larsen established four weather stations and through them detected significant differences in temperature and humidity of valley bottoms and mountain slopes. In 1922, he and C. C. Delavan presented the results of an analysis of information collected between 1909 and 1919 related to climate and forest fires in Montana and northern Idaho. Larsen wanted to establish more weather stations but could find no one "with the right attitude" to operate them. He also wanted to establish a laboratory but could not locate an adequate facility.[15]

Meanwhile, others had been working farther afield. In 1914, the US Weather Bureau initiated its fire-weather service in cooperation with the Forest Service. It began with daily wind forecasts and soon added other data to the exchanged reports. The project lacked a specific appropriation, however, and was interrupted during World War I.[16] In California, Stuart B. Show and Edward I. Kotok were able to relate the ignition point of pine-needle duff in sunlight and in shade[17] to seasonal evaporation, surface-fire rate of spread, and various wind velocities.

This was not enough, however. In 1916, Assistant Forester Clapp appealed to the Forest Service's Experiment Stations to expand their research on forest fires. He suggested a general program to divide forest areas into climatic units to study weather, climatic conditions, and the rate of fire spread under different weather conditions and various types of forest fuels, topography, and cover. He especially wanted to develop a means of predicting the likelihood of fires.[18] But World War I intervened, and neither people nor dollars were immediately available for expanded fire research.

But after the war, perhaps impelled by numerous large fires in 1919, the fire research budget began to grow. By 1920, the Priest River Station was determined to increase its studies of fire--with emphasis on the economics of fire protection, origin and behavior of fires, techniques of fire control, and statistical analysis of data and problems. The Station Director believed that with sufficient data and proper review, one factor or a convenient combination of factors might be discovered that would constitute a warning to increase manpower before fire emergencies actually occurred.[19]

The Service's interest in fires was so strong, and its call for financial support so favorably regarded, that it considered all possibilities--including the use of airplanes and dirigibles, aerial grenades, gas bombs, cloud seeding, lightning detectors, and even electrified sand dropped from the sky--to fight or retard fires.[20] More importantly, as it turned out, Gisborne was added to the Station staff and assigned to fire research. For many years, however, he worked alone.[21]

Gisborne's first task was to sort through previous studies and establish a course for the future. A visit from his California colleague, Show, in the summer of 1922 helped him get his bearings. Gisborne believed that the results of earlier studies, although primarily statistical analyses of past fires in relation to weather, would enable him to deal directly with effects of current weather on inflammable conditions. He hoped to eventually discover how to predict dangerous fire periods. By the end of the year, he had established most of the fire research projects that he actually pursued for more than a decade. Two years later, the Administrators of Research and those of the National Forests agreed on the order of priority:

(1) measuring and forecasting fire conditions;
(2) lightning and fires; and
(3) statistical forecasting of rainfall.

They were as interested as Gisborne was in the applicability of his findings.[22]

To measure and forecast fire conditions, Gisborne knew that he must have a sound understanding of the fuels that fire consumes. It had been known for centuries that most inflammable materials burn more readily when dry than when wet. And the direct materials in a forest are commonly (but not always) those that are dead--chiefly duff, the natural detritus on the forest floor. To determine the potential for fire in a forest, therefore, Gisborne believed that he would need to know the moisture content of its duff.

Three Field Weather Stations

In 1922, Gisborne established three fire-weather stations on the Kaniksu, Clearwater, and Nezperce National Forests in northern Idaho. The data provided by those stations persuaded him that for the local station the Bates evaporimeters then in use had no value for predicting the evaporation to be expected the next day. He also learned that the relative humidity of air is not a good index of the moisture content or inflammability of duff and other forest materials. Temperature is an important variable in moisture content determinations, and he found duff moisture content significantly lagged behind the constantly changing air humidity and temperature. Gisborne

Figure 3.--Weather station, right, on Looking Glass Mountain at Priest River Branch, Northern Rocky Mountain Forest Experiment Station, on the Kaniksu National Forest, northern Idaho, in the mid-1920's. Original lookout house built in 1917 is at left (note four-cup anemometer close by).
(Gisborne collection)

Figure 4.--Gisborne receiving fire-weather information over his prized radio receiver at the Priest River Station, 1924. Radio transmitter is at right.

(Gisborne collection)

also compared duff moisture content with weather forecasts radioed from the Pacific Coast, hoping to predict fire conditions a few days in advance. He measured and compared rates of moisture absorption and evaporation by the duff, the atmosphere, and the soil and studied their relation to precipitation. He determined that the distribution of rainfall over an area was more crucial than the total amount of rainfall in producing dangerous fire conditions.[23]

Gisborne soon learned that he would never find one single factor that could be used to measure or predict forest inflammability. He needed some convenient way to integrate all weather and fuel condition variables. Duff moisture appeared to offer hope for such an instant analysis of multiple complexities. So he worked during the next few years to learn how duff moisture relates to weather conditions. The principle he followed, as he stated in 1923, was that of measuring the prevailing moisture content of fuels and applying a detailed weather forecast to determine forest inflammability several days in advance. He selected the average moisture content of the top 1/4- to 1/2-inch layer of duff as "the index of inflammability of all the important materials which burn in the Western white pine type [forest]."[24]

Measuring duff moisture content by weighing and ovendrying was impractical for field use. In 1923, Gisborne and Matthew E. Dunlap of the Forest Products Laboratory in Madison, Wisconsin, devised and tested a "duff hygrometer." It was composed of a rattan strip inserted into a ventilated hollow spike. A gage attached to one end of the strip measured changes in length caused by the rattan's hygroscopic reaction to changes in humidity. The spike was inserted about 1/4 inch below the duff surface, where the rattan responded to the relative humidity of the air within the duff layer with a readout scale interpreted in terms of duff moisture content. The instrument was calibrated by inserting the spike into cans containing duff of known moisture content. By the end of the year, the device was used at a number of forests. Although the duff hygrometer was used for nearly two decades, it was difficult to calibrate and never achieved the success that was hoped for it at the beginning. It was, however, a start toward Gisborne's objective of finding a simple system for determining fire danger.[25]

The inflammability of duff was only part of the combustion problem. A fire became a serious matter when it actually consumed wood; therefore, Gisborne looked for a way to measure

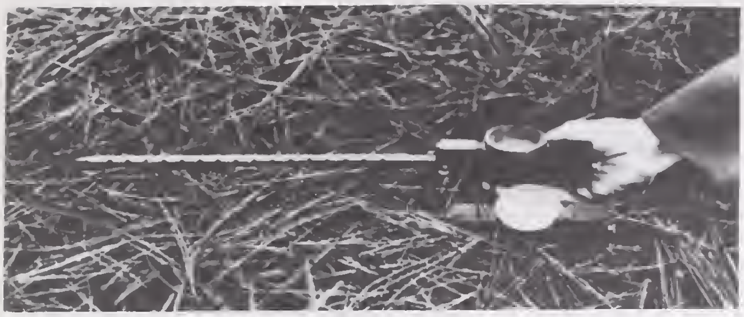

Figure 5.--Two types of duff hygrometers developed by the Forest Service in the 1920's and 1930's and used for nearly 20 years to measure relative humidity of detritus on the forest floor. At top is early model; at bottom, later model. (NA:95G-185774, 337092)*

Figure 6.--Gisborne taking duff sample in heavy timber stand at Priest River. (Gisborne collection)

the moisture content of slash and branchwood. By coincidence in 1923, just as the final touches were put on the duff hygrometer, Larsen returned from a tour of European forest experiment stations. In Denmark, he had seen a simple device that might prove useful to them. "At Clampenborg at or near Copenhagen," he later recalled, "they showed me in the plot a block or cube of even-grained wood. When I asked questions about it, they told me it did absorb vapor at night, lost it again during the day, and indicated or reflected atmospheric humidity. This I conveyed to Mr. Gisborne...."[26]

Gisborne evidently welcomed the idea of standardized wooden moisture indicators, especially since he was then struggling with the vagaries of the rattan strips. The next year, he began developing what became known as his "wood sticks." He decided to try round wood sections rather than cubes because the round wood more nearly represented natural fuels. But tests with calibrated pieces of natural branchwood were unsuccessful; they were too erratic in their response to temperature and humidity changes. In 1925, he settled on turned dowels, and by 1929, he had developed a series of experimental dowels as small as 1/2 inch in diameter. It was but a quiet portent of bigger things to come.[27]

Predicting Fire Danger

By the middle of the decade, Gisborne believed his research had come far enough along that he could begin to seriously consider the prediction of fire danger--enough so that he authored a bulletin on the subject.[28] But he knew that his understanding of fires was only preliminary. When he was given a Field Assistant in 1925, he gained more time to visit fires in progress, a habit he continued for the rest of his life. He described his observational method during a fire as:

> *...very simple. It consists of getting inside the fire and as close to the main front as possible, or else on a promontory from which I*

* "NA" numbers printed near photos are National Archive photo reference numbers. "95G" is Forest Service file.

can see all fronts, and then measuring everything I can measure, including the weather elements and the spread of the fire according to timber type, slope, and kind, size, amount, and arrangement of fuels. Results are something else than simple, however.... I'll admit that although I worked on four big fires last summer, I did not get any consensus of facts. Contradictions were more common than agreements. The variety seemed unlimited. And worst of all, there were too many factors, such as the fuel arrangements, volume, etc., which I could not measure. I learned a lot about fire behavior, but not much about how the weather affects it. It is a good experience because it makes a fire research man see the ultimate application of some phases of his work.... Actually, I haven't any method in this work.[29]

Figure 7.--The round, 1/2-inch wood sticks developed at the Priest River Research Station to measure moisture content of forest fuels as an indicator of fire danger. These daily readings were later incorporated into the early fire-danger meters. Charles A. Wellner, Fire Researcher at the Station, holds the doweled sticks, wired together here in a group of four, an arrangement that became standard in 1942.
(Gisborne collection)

Gisborne was not satisfied. He knew that what he had not yet learned far outweighed what he had. He believed that his basic research must be amplified by direct comparisons of weather conditions and fire behavior, and by 1927, he was working toward this with Richard E. McArdle of the Pacific Northwest Forest Experiment Station at Portland, Oregon. (McArdle became Chief of the Forest Service in 1952.) As he told a friend regarding their work, "The field is so new that we have nothing to help us except our own imagination and what little ingenuity we possess. I've been at this fire research for five years now and, while I'm becoming more and more convinced that there is nothing revolutionary in it, I am also becoming more certain that by better knowledge of details we can tighten up in both prevention and suppression very appreciably."[30]

By the end of the decade, Gisborne conceded that many more measurements were required to find relationships among fire danger and behavior factors than anyone had realized in 1922. His goal was still to integrate the effects of all or at least several of the weather and fuel factors into a single measure of resultant inflammability. He accomplished much, and the results of his work gained wide acceptance, but his dream of a simple way to forecast fire conditions was still unrealized.[31]

When he joined the Station staff in 1922, Gisborne lost no time starting his second-priority research project, a study of the relationship between lightning and forest fires. Since it was well known that lightning can ignite fires, Gisborne turned his attention to means of predicting the occurrence of lightning storms. As approved on June 24, his project plan focused on such areas as the effects on lightning occurrence of different soils, rocks, forest cover, and topography; the study of lightning by instruments; and possible ways to control lightning.[32]

The project began with 1,300 storm reports from 146 stations. Admitting that 1 or 2 years' records were insufficient because of the variations in atmospheric conditions from one year to the next, Gisborne nonetheless learned the surprising (at the time) fact that lightning storms in the northern Rockies do not generally occur as well-defined single storms following definite paths, but as numerous isolated storms occurring more or less simultaneously over a wide area of atmospheric disturbance. By 1924, the conclusions of his initial work were reflected in the Forest Service's District One Fire Manual--the first incorporation of fire research results into an operating manual.[33]

Gisborne entered data from 1924 and 1925 onto punchcards, which were analyzed in Washington, D.C., on the Service's Hollerith automatic data processing machine. By 1926, he had begun to report the results of his interim analysis, stressing the value of prompt reporting of a lightning storm and immediate preparation for fires, the identification of probable fire-starting storms, and the value of the Service's work for the Weather Bureau in producing long-range forecasts.[34]

In 1929, Gisborne compiled and analyzed 14,754 storm observations taken since 1924. He retrieved data from 344 observation stations (chiefly fire lookouts) in three Forests Service Regions and in British Columbia. The results were used to improve the level of protection from lightning fires by increased surveillance; to gain knowledge of the difference between a "fire-starting" storm and a "safe" storm; and to arrive at more accurate 36-hour forecasts of storm occurrence. But Gisborne warned that the work must be continued, because no atmospheric phenomenon can be completely accounted for in such a short period as 5 or even 10 years. In fact, the volume of data was beginning to overwhelm the handling capacity of the Weather Bureau and the Forest Service.[35]

Rainfall Forecasting Proves Elusive

Gisborne's third-priority project, forecasting rainfall and--by extension--fire-weather conditions, was the most amorphous and the most frustrating. From the beginning, he was fascinated with the possibility of very long-range weather forecasting, and over the years he pondered the occurrence of 11-, 22-, and 44-year precipitation cycles and their possible relation to sunspot cycles. He also studied varves in clay deposits around Priest River as a possible record of ancient yearly fluctuations in rainfall.[36]

Somewhat shorter range predictions of fire-weather seemed more practical, however. In 1923, the Weather Bureau began to offer telegraphed forecasts from San Francisco as a "fire-weather warning service." But mountain weather was generally unknown, and the Bureau's sources of information were only a few big city stations. Therefore, the forecasts were of limited value. Gisborne and others hoped that dependable 6-hour, 36-hour, and even longer range forecasts might be devised, but some people in the Forest Service believed that there was no scientific foundation for the belief that an abnormal season could be predicted months in advance.[37]

Gisborne, however, was more optimistic. In 1924, with a part-time assistant, he developed a statistical method of showing the relative probability that the following spring or summer would be wetter or drier than the previous one. He claimed that his system proved

86 percent correct for the previous 14 years of record analysis. In 1925, he reported on a system for predicting rainfall for each month from April through September, based on 44 years of precipitation records.[38]

But effective forecasting depended upon acquiring immediate data, which could be measured against the historical record. Prior to 1926, the Weather Bureau had been able to assign only two employees, on a part-time basis, to the fire-weather service. But that year, Congress first appropriated money for the program, and representatives of the timber industry, the Forest Service, and the Weather Bureau met at Portland, Oregon, to hammer out a new and detailed plan of operations. Beginning almost immediately, weather observations were transmitted from a number of Forest Service field locations to the Weather Bureau at Spokane, Washington, where they were processed with information from various Weather Bureau facilities in order to produce forecasts of fire-weather conditions. The Weather Bureau provided instruments and onsite training to Service personnel, and the program continued to grow over the years. Nonetheless, there never seemed to be enough personnel or money for the truly comprehensive reporting and forecasting system that Gisborne wanted.[39]

Gisborne devoted most of his energy during the 1920's to the three avenues of research that he hoped would lead to a means of predicting fire danger. Since he often worked without an assistant, he was able to devote little effort tc other aspects of the forest fire problem. He remained current with the work of others, however. In particular, he assisted in the wide-ranging projects of the Northern Region's Chief of Fire Control, Howard R. Flint. Flint was seriously concerned with the economics of fires and fire controls, especially with the effects ("damages") of forest fires. During the course of the decade, he developed a theoretical order of susceptibility to fire damage for various species, the accuracy of which the Station was able to prove.[40] Flint and Gisborne cooperated intensively in

Figure 8.--Half Moon fire seen from Desert Mountain Lookout, Flathead National Forest, near Glacier National Park, Montana, summer of 1929. In 1940, tests made here confirmed earlier tests at Priest River Station concerning the weather variabilities of altitude, aspect, and time of day and their effects on fire-danger calculations.
(Gisborne collection)

fire control planning, which included preparing "fire surveys" of a number of forests that experienced frequent burns.[41]

By 1929, Gisborne had made great progress in identifying and analyzing the hundreds of factors that enter into the ignition, behavior, and control of

Figure 9.--Buildings at Priest River Branch, Northern Rocky Mountain Forest and Range Experiment Station, in the early 1920's as the clearing was being expanded (note blackened stumps in foreground). Early "weather tree" in center background was stripped of all branches and equipped with wind gages. Attached spikes formed a ladder to the sawed-off top. House at right was the original 1912 office, lab, and home of the Director. Bungalow and gambrel-roof house at left were staff residences. Small barn in center background was the shop. (NA:95G-256189)

a forest fire. The more the range of factors broadened, the more complicated the subject appeared. But at the same time, he grew ever more sure that he could eventually synthesize from the forest fire universe some systematic way of predicting when and where fires were most likely to erupt. With such a system, the Service would be able to confront the fire problem before it arose and reduce it significantly.

One of the worst fire years since the beginning of organized fire control occurred in 1929. Gisborne could feel some satisfaction that his research since 1922 had been extremely valuable, because firefighters were better prepared to meet the emergency than ever before. But those involved knew that the research accomplished so far was insufficient. The Regional Forester joined with the Station Director, therefore, in asking for an accelerated fire research program. The list of their interests had grown considerably beyond the three areas first outlined by Gisborne in 1922--a reflection of Gisborne's own expanding awareness of the complexity of the fire problem. Of the original three research areas, Gisborne's work on lightning had proven most productive and immediately usable, and the cooperative work with the Weather Bureau had given the greatest return for the effort. But the first priority, the study of the predictable essentials of inflammability, while the most fundamental, had proven to be the most difficult.[42] For Gisborne, and for fire research, interesting times lay ahead.

The Boom Years 1930-1937

The so-called "Forester's" policy of control [of a fire] by 10 a.m. undoubtedly rates either a milepost or a tombstone. If and when that policy becomes clearly recognized as a temporary expedient, I believe that it will rate a milepost. If, however, it has already become or ever does become the death knell of all previous objectives based on damage, then it rates a tombstone executed in the blackest of black granite. Fires can be caught small and cheaply, most often without controlling them by 10 a.m. tomorrow. If one function of research is to assemble and array all the significant facts, it seems more than possible that it might contribute something here.[43]

By 1930, Gisborne had produced and analyzed enough information to make real fire control planning appear possible. Central to planning was his first objective--to synthesize all pertinent information into a workable system for predicting the danger of fire. He felt ready at last to give it a try, knowing that refinement of any such system would require an enormous amount of work. All he needed was the opportunity.

The events of the Great Depression seemed to offer just such an opportunity, for they brought a sudden infusion of money and capable researchers who significantly widened the scope of fire research. But as suddenly as they had arrived, the boom years departed, and Gisborne once more was on his own.

In 1928, as the result of much preparatory effort directed by Earle Clapp, Chief of Research, Congress passed the McSweeney-McNary Act, which authorized an expanded Forest Service research program with special emphasis on fire and fire-weather research.[44] Gisborne expected increases in his research budget under the legislation, and they began to appear in 1931. But at the same time, the Depression caused Congress to reduce the Federal budget across the board in 1931; regular appropriations were held down thereafter. Nonetheless, Gisborne received a regular budget of $18,900 in 1932. Although it fell steadily to a low of $13,625 in 1937 and stabilized at $15,000 by the end of the decade, it was considerably higher than his largest budget during the 1920's: less than $5,000.

The separate emergency appropriations of the New Deal brought the biggest increase in research support. Fire research at the substation received $4,630 in emergency funding in 1934 and three times that amount in 1935. The richest year was 1937. Gisborne benefited from $18,220 in emergency fund allocations that year, only to have the amount suddenly drop to zero in 1938.[45] But money was not the only means of support, because New Deal programs--especially the Civilian Conservation Corps (CCC)--made available great masses of manpower for construction of roads, trails, bridges, and administration and recreation structures; fire control; forest planting and improvement; and major research projects. It was a short-lived, yet fruitful era, and for the Forest Service things became possible that before had been only dreams.

As might be expected, Gisborne had to become something more than a solitary researcher during this period. He donned the cloak of the bureaucrat--administrator of programs and facilities and Staff Supervisor. It was not a role for which he was perfectly suited, but considering the uncertainties caused by wildly varying budgets, he acquitted himself adequately--much to the benefit of the research mission.

Gisborne found much of his attention diverted to physical plant during the 1930's. As his staff and his program grew in numbers and sophistication, he was able to acquire more adequate laboratory facilities and equipment. The total reconstruction and expansion of the facilities at Priest River Experimental Forest, as the site was renamed, consumed a substantial amount of his time between 1935 and 1938, and he fought for and won additional laboratory space in the new Federal Building at Missoula, Montana, in 1936. Despite an equally prodigious expenditure of energy, he was not able to have built during his lifetime an environmentally controlled wind tunnel-forest fuel combustion chamber that he had planned in detail. Gisborne regarded this structure as essential to his study of the complex problems of forest fire behavior--rate of spread and similar factors--that are influenced by many natural variables. It would allow each factor to be held constant in turn, as repeated trials were held to doublecheck results, thus reducing the complicated interaction of many variables to manageable terms. Gisborne considered this project to be of nationwide significance and wanted it placed at the Forest Products Laboratory in Madison, Wisconsin. However, within a decade, in 1939 or 1940, he was able to have a small portable wind tunnel built by summer student employees in the Missoula building. He used it primarily to calibrate repaired anemometers, and this use continued until the 1970's. Gisborne's foresight was finally rewarded nearly 30 years after his first proposal, and 10 years after his death, when the Northern Forest Fire Laboratory at Missoula built a

Figure 10.--Northern Region weather station of Forest Service atop the new Federal Building, Missoula, Montana, in 1936. Note rain gages in foreground, weather vane and anemometer on pole in background.

(Gisborne collection)

Figure 11.--The new office-laboratory of the Priest River (Idaho) Branch, Northern Rocky Mountain Forest and Range Experiment Station, Forest Service, August 1937.

(NA:95G-350673)

wind tunnel that almost exactly fulfilled the requirements he had described in 1931.[46]

Funds were available, however, to erect structures and acquire equipment for specific major projects.

Talented Researchers Hired

Fortunately, Gisborne was able to hire researchers for his projects. Although he was not an easy man to work for, he had a knack of selecting good people and inspiring them to do well. Many of them went on to prominent careers. A case in point is George M. Jemison, who in 1930 was a forestry student at the University of Idaho. Deeply inspired by a series of lectures Gisborne delivered on fire research, Jemison passed up a seasonal job as a fire lookout to work for the summer under Gisborne, then returned for permanent employment after graduation in 1931. By the time he left Gisborne's staff in 1937, he had begun a career that eventually took him to the top of the research organization, Deputy Chief of the Forest Service for Research.[47] A number of other important figures in the history of fire research also began their careers under Gisborne's guidance. Lloyd G. Hornby spent his last and finest years in association with Gisborne. In all, Gisborne directed as many as eight scientists at the height of the boom times in 1937.[48]

Gisborne was most enigmatic as a supervisor. In describing his dealings with other people, his former employees and associates used the word "sarcastic" frequently. Gisborne was certainly outspoken, frequently irascible, and nearly as demanding of perfection from others as he was of himself. And yet, he inspired a legacy of devotion and fond memories that is truly remarkable; one suspects that his crustiness was simply crust-deep. What he lacked in diplomacy, he more than compensated for with example.

Clayton S. Crocker recalled that Gisborne "argued to beat the devil," and would do so with "most anybody most anywhere if the occasion merited debate." Gisborne once told Charles A. Wellner, "I'll fight you on anything I want on a professional basis, but it has nothing to do with our personal relationship." To Wellner, Gisborne's willingness to go to the mat on any issue was good for the profession, for honesty, and for the Service.[49] According to Lloyd Hayes, "He told me I accomplished more when I was mad. So he deliberately irritated me at times. He set himself up as an irritant to others all his life. I heard him say in meetings that the group needed to have a burr under their tails to keep them moving along, and he is that self-appointed burr."[50]

But, however abrasive his method, it worked. As Hayes said, "We had the kind of encouragement and training that was needed to get us going. Gis' enthusiasm was very contagious, affecting everyone around him. When he looked at something you could see his eyes expand if he recognized a potential significance."[51]

Nearly all of Gisborne's employees described his supervisory method in the same terms. He gave very close watch and supervision at first, gradually relaxing to the point of agreement on principles, with the actual direction of work finally left to the employee. But he would inspect their labors periodically, and review them very critically.[52] And yet, Gisborne was not invariably a hard taskmaster. He held frequent gatherings at his home, where the musical members of the staff formed an orchestra with Gisborne's wife, an accomplished pianist.[53] Beneath his hard veneer, Gisborne held a personal regard for his researchers that helped to cement strong personal relationships with them. As in later years, they emulated his scientific methods (if not his outward personality) and looked to him for lifelong inspiration.

Gisborne was his own harshest critic. Recognizing his shortcomings as a supervisor and bureaucrat, he said privately, "I am not a good administrator. I may see things needing doing but it does not follow that I have the ability to get men to do that. I am too erratic. When the work does not go very well I worry. When I worry my heart goes fast. I wouldn't last long in a Washington Office job."[54]

His essential philosophy remained clear, however, as he once wrote, "To some people advancement in pay or position is a controlling guide in all their actions. To them, doing good work is secondary when they can get the advancement without doing good work. They have achieved their goal. To others this order is reversed. The control of all their actions is to do a good job. If from this they obtain advancement, they are more pleased, of course, but they are satisfied with having done a necessary or helpful job and done it well."[55]

But despite his volatile nature and his critical judgment of his own supervisory abilities, Gisborne proved an effective supervisor in the balance. George Jemison, his first assistant, felt that:

> *he was an extremely fine person to work for, although he was highly critical and could be very sarcastic and caustic if a person working on something with him or for him didn't do well or didn't try as hard as he thought he should.... He would go at length to point out why or how you could have done better and would break his neck to help you do better.... He also was one of the few bosses I had in the Forest Service who really went out of his way to recognize good work. He would get so excited and so exuberant. Gisborne would glow when he'd praise--not for the work particularly, but trying to make you feel like you'd really done something; he was really stimulating in that respect.... I've thanked my lucky stars many times in my career for having a chance to start with a man like Gisborne.[56]*

Timber Inflammability Stations

Armed with a growing budget and an expanding staff of energetic young researchers, Gisborne worked to improve upon the foundation he had established in the previous decade. He began with typically systematic studies of the effect of shade and canopy on fuel moisture, during which he refined the system of dowels used as fuel moisture indicator sticks. In 1930, he established the Half-Timber and Full-Timber inflammability stations on Benton Flats across the county road from the Priest River Office, thus completing a research trio he had begun in 1926 with the Clearcut station. The three stations--actually small, fenced plots--were within a radius of a few hundred yards and differed only in the density of their forest cover (eliminating variables of aspect and topography). Jemison's first assignment at the station in 1930 was to set up the Full-Timber station--hack it out, fence it, and install the

Figure 12.--The Clearcut inflammability station at the Priest River Research Station, set up in 1926-27.
(NA:95G-350653)

instruments in sturdy shelters that he also built. Thereafter, he took weather measurements at all three stations and at a control station next to the office three times a day and summarized the data. The central part of this work was observation of the reaction of moisture content of 1-, 2-, and 1/2-inch wood cylinders to the different degrees of shading. Jemison pursued this for so many years that he could still remember the numbers of the wood sticks four decades later. By comparing the cylinder moisture contents with temperature and humidity records, he learned that their correlation was weak.[57]

Figure 13.--Gisborne studying fuel moisture at Clearcut station, Priest River, Idaho.
(Gisborne collection)

Nonetheless, the small 1/2-inch sticks did indicate fuel moisture--an important element in developing a fire-danger rating system. By 1935, Gisborne was producing "triplets"--sets of 1/2-inch by 18-inch round dowels pinned together at one end and cut to 80 grams oven-dried--for field use as fuel moisture indicator sticks. The idea of joining the sticks together for use as sets had originated at the Pacific Northwest Station, where McArdle and associates pursued similar work with square sticks. Considerable testing (and debating of philosophies) went on until the present indicator--four 1/2-inch dowels pinned together and cut to 100 grams--was decided on in 1942. Regardless of those changes, Gisborne had acquired an important addition to his fire-danger equipment that was conveniently usable anywhere.[58]

Even before the sticks were grouped into triplets, they had proven valuable in reflecting fuel moisture--a key element of inflammability. Since they were easier to use than the rattan duff hygrometers, the sticks were more practical for wide field use. Early in 1931, with the triplets in hand, Gisborne set to work on what he later called his "major research contribution"--the development of the fire-danger rating meter.[59]

Figure 14.--Full-Timber inflammability station at Priest River, set up in 1930. Photo taken in May 1932.
(NA:95G-270725)

Figure 15.--Half-Timber inflammability station at Priest River, set up in 1930. Photo taken in August 1937.
(NA:95G-350654)

Jemison believed that Gisborne began to conceive of the idea of a fire-danger meter as a result of Earle Clapp's visit to Priest River during the summer of 1931:

I remember...listening to a conversation between Gis and Earle Clapp over this question of how to correlate the various inflammability factors like fuel moisture and wind, how to express these into a numerical rating that would be more meaningful to the fire protection official than just giving him an abstract reading of fuel moisture like 10 percent or 8 percent and a wind rating of 5 or 10 miles per hour. Such figures didn't give him anything that he could translate consistently... into some uniform expression of the actual inflammability.... It was, I think, out of that discussion that there arose in Gis' mind the idea of developing a fire danger meter. The following winter he began playing around with various devices to put these factors together and to express them into a single numerical rating scheme.

Figure 16.--The round, 1/2-inch fuel sticks being weighed to detect changes in moisture content. This was one of the first new basic indicators of fire danger developed by the Priest River Research Station under Gisborne. The practice of pinning three sticks together was begun in 1935.
(NA:95G-350666)

However he started out, Gisborne revealed the nature of his thinking at the end of 1931, when he reported that the work of measuring the weather elements and their effects on fire danger had produced a large volume of records permitting the comparison of duff and wood moisture content with any combination of weather factors. He suggested that fuel moisture and weather conditions must be fitted into their proper places with respect to other factors that affect fire danger, such as activity of the fire-starting agencies and visibility. All factors must then be integrated so the result of any combination could be expressed in terms of justifiable control action.[60]

Devising a Fire-Danger Meter

Gisborne's next step was obvious: he must devise a simple and readily usable means of expressing in one figure the results of the integrated factors, rather than depend on several charts (one for each factor). Taking a clue from a simple type of exposure "meter" then in use for photography, Gisborne prepared a little cardboard envelope with windows and two slides marked "A" and "B." On the device he entered the fire-danger factors he regarded as most important: fuel moisture percentage (from the 1/2-inch sticks), wind velocity, relative humidity, normal or abnormal number of people or lightning storms, and period of land clearing or peak brush burning activity. Taken together, the factors produced six classes of fire danger in terms of both rate of fire spread and administrative action needed to cope with probable danger. According to Jemison, Gisborne "drew columns and rows on the slides, but left them blank." He asked six people from the Region and the Station to separately fill in a rating of one (no danger) to six (extreme danger) for what they thought various combinations meant in terms of fire danger. "Gis, of course, filled one out, too. He took all of these and harmonized them. He then discussed the major variances that appeared among the individual ratings and smoothed out the differences. This became the first Fire Danger Meter."[61]

Since Gisborne had thus obtained the blessing of Regional officials in advance, his device won ready acceptance when first distributed to the field in May. By July, the Regional Office reported, "The first issue of the forest fire danger meter...has created such a demand for inflammability stations that the Experiment Station has utilized all the wood cylinders and duff hygrometers available and has not been able to equip all the stations for which requests have been received." By that time, Gisborne had established 18 fire-danger stations on National Forests and two in National Parks.[62]

True to form, Gisborne was dissatisfied with his creation and set about improving it. Model 2 of the fire-danger rating meter carried a description of fire behavior according to fire-danger classes to help users in the field. Model 3, which was in use by 1934, featured a number of changes. Land-clearing activities were eliminated, and amendments were made for treating lightning within the previous 2 days, visibility, and interpretation of humidity. There were now seven, instead of six, danger classes and a description of protective organization according to fire-danger classes.[63]

By the end of 1933, Gisborne had established 30 more inflammability stations throughout the Region.[64] The idea that the likelihood of fires could be determined in advance by such a simple procedure was exceedingly popular. But the reliability of Gisborne's device remained to be demonstrated. During the summer of 1934, Mother Nature entered the argument and provided the most frightening kind of test.

The Selway National Forest in Idaho had long had a reputation for serious forest fires. It had accordingly attracted considerable notice from Gisborne over the years. In the process, he formed a close relationship with the acting supervisor, Clayton S. Crocker. That experienced firefighter had a native understanding of factors influencing fire behavior and became Gisborne's sounding board for new ideas.[65] Gisborne established several inflammability stations on Selway. Those at Pete King and O'Hara began to

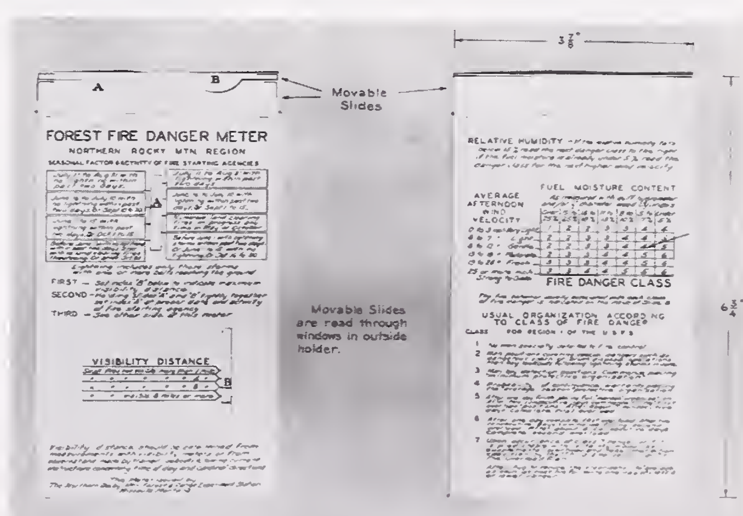

Figure 17.--Model 2 fire-danger meter, the second meter ever devised. Northern Region, Forest Service, 1931.
(Gisborne collection)

indicate critical conditions in 1933. By early 1934, readings at Pete King persuaded Gisborne that the danger of a major fire was extreme. According to Jemison, "Gisborne was screaming to everyone that 'Boy, we really got a blowup situation on the Selway!' Crocker was extremely concerned and very much in touch with Gisborne and sensitive to the fact that the measurements at Pete King and O'Hara were showing evidence of very critical conditions."[66]

Crocker importuned his superiors to release firefighting funds so that he could hire enough men to prepare for a big fire. But at the time, Service policy limited the use of money for what was called "presuppression." Crocker's (and Gisborne's) worst fears were realized on August 10. A dry lightning storm that day started a dozen fires. Ten of them were caught early and put out by that night. But the other two, originating near Pete King and McLendon Butte, got away. Eventually they joined together, and burned over a quarter-million acres of some of the most rugged landscape in North America. Firefighting crews were utterly overwhelmed as they fought the blaze for nearly 6 weeks. Nature, which had started the fire, finally put it out with a snowfall on September 22.

Selway Fire Triggers Policy Changes

The Selway fire led to major changes in Forest Service policy. Crocker maintained that he could have prevented the big burn if he had been granted the funds he had requested. The next year, accepting the reliability of Gisborne's fire-danger rating system, the Service started allocating presuppression budgets as determined by fire danger. But the fire also sparked a Service debate over the virtue of fighting every fire, even in difficult country, without regard to the values threatened by the flames. Those who believed that <u>every</u> fire should be suppressed, regardless of costs or the relative value of the resources it fed upon, won out. In 1935, the Service, under Chief F. A. Silcox, officially instituted its "10 a.m. policy." Its objective was to extinguish every fire before 10 o'clock on the morning following its discovery.[67]

Gisborne's fire-danger rating meter was a success. It permitted the revisions of Forest Service fire control policies; in fact, its use became integral to fire control procedures. But although the change in presuppr032ion allocation was a tribute to Gisborne's ideas, it is ironic that the adoption of the rigid 10 a.m. policy--equally dependent upon use of the meter--violated his basic principles of fire control. He never stopped criticizing the policy. He argued loudly and persistently for a return to a more economical and rational way to weigh relative costs and values in fire control planning. He believed that, although the Service vindicated his major contribution to fire control planning, it nevertheless took a major step backward with its new policy. The policy relied on the availability of large budgets and masses of manpower, both of which proved to be temporary and chiefly limited to the New Deal period. Gisborne, who had inherited the frugal instinct of a native Yankee, was convinced that this was a wasteful and shortsighted policy.[68]

With the fire-danger rating meters institutionalized in Forest Service procedures, Gisborne continuously improved his device.[69] He also improved and expanded his system, which depended upon the establishment of fire-weather (inflammability) stations throughout the Region. Each station was composed of not only the fuel moisture indicators and fire-danger rating meters provided by the Forest Service, but also an anemometer, wind direction vane, rain gage, psychrometer, hygrothermograph, and thermometers provided by the Weather Bureau.

Each of those instruments was expensive, and Gisborne wanted to establish

Figure 18.--Gisborne computing the daily fire-danger rating in August 1937 at Priest River Research Station. Note radiophone at right.
(NA:95G-350647)

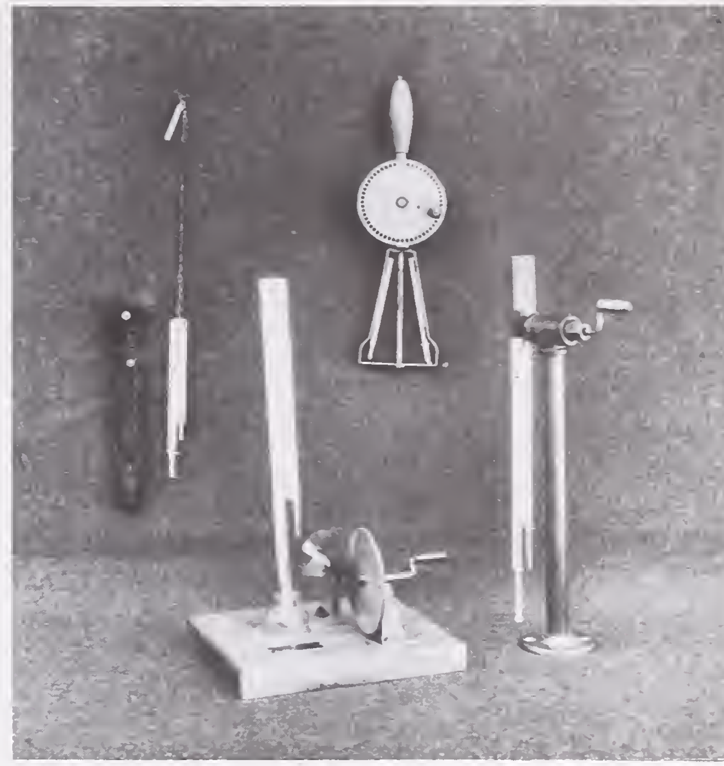

Figure 19.--Four psychrometers used at the Priest River Forest Research Station at various times to measure atmospheric relative humidity. The small hand-crank model, developed at the Portland, Oregon, Research Station of the Forest Service in 1934, was very easy to use and accurate and was used widely in the Forest Service until recently.
(NA:95G-309726)

more stations than the Weather Bureau could equip. As a result, during the 1930's he and his associates and their colleagues at the Pacific Northwest station developed a number of inexpensive, locally produced anemometers, psychrometers, hygrometers, rain gages, wind vanes, visibility meters, scales for weighing the fuel moisture sticks, and a large-log moisture meter they called a "Blinkometer."

Gisborne developed a notable and quite remarkable instrument for its day called the "anemohygrograph." Jemison said that it measured and recorded fuel moisture, duff moisture, and wind speed. It was to be placed at the scattered fire-danger stations in the field, which had been found practical and were being steadily increased in number about 1930. Not enough men were available at the desired locations to record the various readings, so an automatic instrument was needed. Gisborne went to the Forest Products Laboratory to work on the design with Matt Dunlap, who had helped him with the duff hygrometer. The new gadget was called "Robot" for short by the staff. A number of them were produced, and they worked fairly well. "However," recalled Jemison, "the Robot never got past the research use stage since it took a full time technician to keep [it] in accurate operating condition, and the cost of a unit was over $300."[70]

Figure 20.--The first homemade S-curve galvanized wind gage designed by Gisborne at the Priest River Forest Research Station about 1933. It was inspired by a metal sign advertising motor oil and was very inexpensive, yet useful. Many were made for field weather stations throughout the Northwest.
(NA:95G-314970)

In 1935, and again in 1940, Gisborne offered training for Forest Service, Weather Bureau, and National Park Service personnel in the use of the instruments, operation of the stations, and fire-danger rating techniques.[71]

Gisborne also perfected his system by continuing research into the factors affecting fire ignition and behavior. In these boom times, he now had a capable staff to work on the problem. Jemison's first project was the study of the effects of stand density and cover at the Full-Timber, Half-Timber, and Clearcut stations at Priest River. During several years of observation, Jemison learned that timber cutting:

(1) increased the average maximum air temperature, soil temperature, and maximum temperature of surface duff;

Figure 21.--S-curve wind gages for field stations being calibrated in number of turns for various wind speeds in miles per hour, using anemometer, at the Priest River Forest Research Station.
(Gisborne collection)

(2) lowered relative humidity;
(3) increased wind movement;
(4) doubled the rate of evaporation; and
(5) lowered fuel moisture content.

His conclusion was that removal of the forest canopy significantly increased fire danger: "A full forest cover eliminates 90 percent of the critical days during July and August, while half-cover cuts out more than one-half." Also during the course of the work, he was able to confirm Gisborne's earlier finding that absolute humidity exerts a greater influence on the moisture content of fuels than either relative humidity or number of days since the last rainfall.[72]

Jemison also studied the effects on fire danger of the progression of lesser vegetation from green to cured. He believed that some bad fire seasons had been preceded by a lush growth of grasses, weeds, and shrubs. Working with Leon W. Richards, a chemist from the University of Montana, he searched for "indicator plants" by studying the fiber, wax, and oil content of various species. He also studied color changes, the effects of cumulative maximum

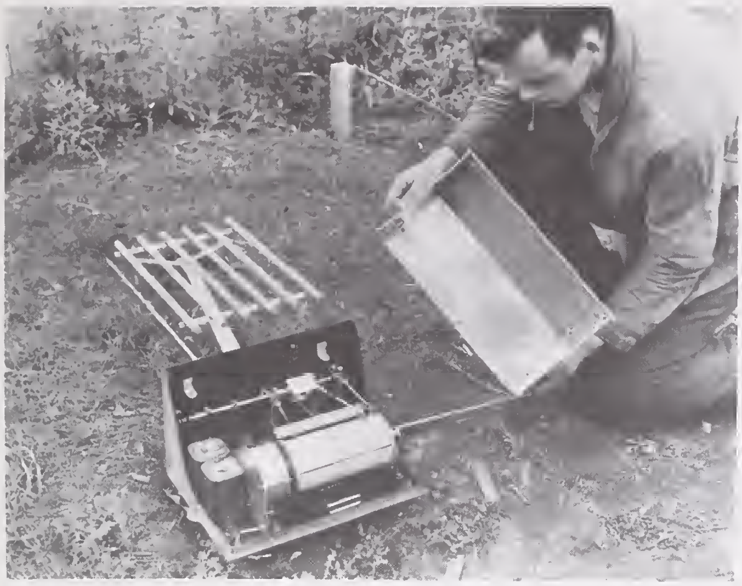

Figure 22.--One of several "anemohygrographs" developed by Gisborne with Matthew Dunlap of the Forest Products Laboratory of the Forest Service at Madison, Wisconsin, in 1930-31. It measured and recorded on graph cylinders wind velocity and the moisture content of forest fuel sticks and duff. Checking the apparatus is George M. Jemison, who later became Director of the Northern Rocky Mountain Station, and finally Deputy Chief of the Forest Service in charge of Research.
(Gisborne collection)

temperature on curing, and experimental burns of plots with varying live vegetation contents.[73]

Other contributions from Jemison included a 20-year climatological summary for the Priest River Forest Research Station area and a modification of the Beaufort Scale of Wind Velocity for use in forestry, especially in fire-danger rating.[74]

The "Weather Trees"

About 1923 at Priest River, Gisborne topped a live larch tree (3 feet in diameter at breast height) at about the 150-foot level, removed all the branches, and hammered in a ladder of spikes all the way up. To the top of this "weather tree" he attached a number of weather instruments. For several years, he climbed to the top every day and gathered information on winds and weather in the forest. But by about 1927 or 1928, the tree had become unsafe, so Gisborne topped another live larch nearby for a second "weather tree," which he also equipped and climbed daily.[75] However, by 1934, this tree had also deteriorated dangerously and was no longer sufficient to support all the instruments Gisborne now needed for his detailed studies of fire-danger factors.

So, in 1935, Station Director Lyle F. Watts, who later became Forest Service Chief, alloted funds for a steel frame structure for the following year. With the CCC labor, a 150-foot "meteorological tower" was erected. (See figures 9 and 24 to 28.) Over the next 2 years, Gisborne arranged for the installation of various wind and weather instruments at different levels of the tower.[76] Since it extended up through and above the surrounding trees, it gave Gisborne an opportunity to compare unobstructed air conditions with those influenced by the forest canopy. He learned that wind is not uniform across all topo-

Figure 23.--Gisborne using one of the atmospheric visibility meters he and his staff designed in 1935 as a fire-danger indicator.
(Gisborne collection)

graphic or fuel-type situations. Even during the windiest periods, a fire on the ground under a dense forest canopy will not be greatly affected by the wind. He also learned at what time during a day to expect the highest and lowest winds, temperatures, and humidities, and applied this information to fire-fighting procedures.[77]

Responsibility for gathering much of the data from the meteorological tower during the 1930's fell to G. Lloyd Hayes, who came to work for Gisborne in 1934. Like Jemison, Hayes expanded the scope of Gisborne's fire-danger research into a number of important areas. One of them was the effect on fire danger of north and south slopes and elevations. Some work on the subject had been done before, but in Gisborne's estimation, it was not enough. He determined that Hayes would become his resident weather expert and directed him especially to slope and aspect studies. The anemohygrograph (Robot) proved to be indispensable for this work.[78]

Taking measurements hourly around the clock, with the full complement of weather and fuel moisture instruments, Hayes produced the first systematic study of the daily variations of fire conditions and behavior as influenced

Figure 24.--Making a "weather tree" of a living western larch at the Priest River Forest Research Station about 1927 or 1928. Top is shown being cut off at 5 inches in diameter, 156 feet above the ground. Installed on the new top were a recording anemometer, wind vane, and a sunshine duration transmitter, which was wired to the office. (Gisborne collection)

Figure 25.--The "weather tree" with equipment and the control station in place at its base at Priest River Forest Research Station, May 1932. (NA:95G-270719)

by altitude and exposure. Gisborne gave him no written study plan, and since the work was new, he was on his own. He cleared six paired sites on the north and south sides of a ridge at Priest River, used the Clearcut and Half-Timber stations as valley bottom locations, then placed three others at different elevations near Looking Glass Lookout. Each station was fitted with a complete range of instruments. He kept his observations current throughout the 1930's; in the 1940's, he established stations elsewhere and proved that his findings were applicable throughout the northern Rockies.

Hayes' prodigious labors produced equally prodigious, and very important, results. He quantified and precisely defined the thermal belt principle, previously understood only in general terms. But, in keeping with Gisborne's philosophy, it was the applicability of his findings that made them most important. As he noted in one of his reports,

Figure 26.--Meteorology tower, 156 feet high, built by CCC labor in the woods at Priest River Research Station in 1936 to replace the weather tree at the edge of the clearing. It was instrumented at five levels and began full operation in 1938. Access was by a metal ladder.

(NA:95G-350676)

"The fire dispatcher does not need to act on the basis of guesses only. By use of charts showing the degree of class of danger on north and south aspects at all ordinary altitudes and for each hour of the day and night, it is now possible to interpret measurements made at an individual station into data more dependably applicable to a

Figure 27.--Lyle F. Watts, Director of the Northern Rocky Mountain Forest and Range Experiment Station at Missoula, Montana, 1931-36. He later became Chief of the Forest Service.

(Gisborne collection)

Figure 28.--Fire-weather control station at Priest River Research Station, with metal weather tower in background. Photo taken in August 1937. Weather records have been kept there continuously since October 1911.

(NA:95G-350649)

larger part of the adjacent topography." Hayes' data are still employed; dispatchers incorporate them into their calculations of fire danger, fuel, and rate of spread to estimate their manpower and equipment needs before sending forces to a fire. When fire control demands tax available resources, Hayes' system is used to establish priorities.[79]

Hayes had an affinity for long range research. Among the more important projects he initiated for Gisborne was the study of moisture content of large logs. Gisborne and his associates had previously investigated the moisture content of all fuels from grass to 2-inch wood cylinders. In 1935, he assigned Hayes to a study of moisture changes in seasoned 10-inch and 12-inch western white pine logs, using a device called a "Blinkometer" to measure electrical resistance between copper spike electrodes driven into the logs to various depths. He continued the measurements until 1943, using them in his Master's thesis, but neither he nor Gisborne was satisfied with the approach. In 1942, therefore, he began a modified large-log study based on weighing. The work continued through 1960, and the results were not formally published until 1975; but as with Hayes' other study, the data were employed by Gisborne in his fire-danger work as they were obtained.[80]

Although the studies by Gisborne, Hayes, Jemison, and others represented signifi-

Figure 29.--G. Lloyd Hayes, who became a Fire Researcher at the Priest River Research Station in the mid-1930's and directed altitude and aspect studies.
(Gisborne collection)

Figure 30.--Altitude and aspect study station at 5,500-foot level, close to Looking Glass Lookout at Priest River Research Station. This was one of a pair at that level on either side of the ridge, one on the north slope and one on the south slope, running up from the headquarters. A second pair of stations were at the 3,800-foot level along the same ridge, a third pair were at the 2,700-foot level of the ridge, and two more were on the valley bottom at 2,300 feet. All used anemohygrographs. Photo taken in August 1937.
(NA:95G-350660)

cant achievements in their own right, their chief importance for Gisborne lay in the collected data that he used to continually refine his fire-danger rating system. But it is fair to say that, in devising the system during the early part of the boom years, he achieved the first priority he had set for his research in the 1920's.

Lightning and Weather Forecasting

For Gisborne's second priority of the 1920's--the study of lightning and fires--there were few momentous developments during the boom years. He published a 5-year analysis of lightning storms in 1931 and believed that further analysis was fruitless until at least a decade of records had been accumulated.[81] He did engage in correspondence with academic and industrial electronics specialists on various questions related to the detection of lightning before occurrence. With the help of General Electric Company engineers, he erected static detection equipment at Priest River and Looking Glass Lookout, but he gained little from the apparatus beyond a few minor shocks. Gisborne also entered current debates about whether red or white lightning was the real fire starter, without indisputable result.[82]

Figure 31.--Testing moisture content of a large dead and seasoned white pine log with the "Blinkometer," developed at the Priest River Research Station in 1935 and used until 1943.
(NA:95G-350651)

The story for his third research priority, fire-weather forecasting, was similar--continuous work but few outstanding events. For the most part, the fire-weather service operated by the Weather Bureau was plagued by shortages of funds and personnel. The reporting system grew steadily, chiefly because of the expansion of the fire-danger rating system through Gisborne's establishment of inflammability stations. The Forest Service constantly prodded the Weather Bureau to provide better long-range forecasts, but the state of the art was still comparatively primitive. In 1936, however, the Bureau began to provide 10-day weather summaries, making more localized forecasts and tentatively forecasting probable departures from normal weather during an entire fire season. That same year, the Bureau began to equip and assign mobile fire-weather units to the scenes of fires in progress, a major boost to firefighting.[83]

Finally, Gisborne learned of a finding by Robert W. Strong, of the old Cabinet National Forest, that the severity of a dry season was closely related to the amount of precipitation during the preceding November. Eager to seize any opportunity to improve his fire-danger forecasting, Gisborne directed Jemison to compile maps and figures relating the two phenomena; the results appeared to support the theory. Gisborne found that bad fire years were frequently preceded by Novembers with between 50 and 65 percent of normal rainfall; easy years were preceded by Novembers with less than 50 percent or more than 65 percent of normal precipitation. Using that formula, he began in 1933 to publish annual forecasts of "average inflammability" based on November precipitation. The system had a fair degree of accuracy, but it was not foolproof and

Figure 32.--Gisborne and Wellner weighing large logs on a heavy-duty platform scale. The logs were used in fuel moisture tests from 1935 to 1939. Another study ran from 1942 to 1961.

(Gisborne collection)

never served as the basis for serious planning.[84]

And it was planning that Gisborne believed essential to a rational fire control policy. His fire-danger rating system had finally made seasonal planning possible, but only in a tactical way: by knowing where fires were most likely to break out, foresters could more effectively arrange the forces required to fight them. But that was founded on the assumption that all fires must be fought, a belief that Gisborne did not share. His idea was that the expense of fire control must be justified by the level of damage that would be sustained if the fire were not controlled. "Each service of the land protected, subject to loss by fire, must be rated," he said in 1932. "To say that we have satisfactorily determined the probable damage to wood products, recreation, wildlife, water, soil, and climatic influences, and to the social benefit attached to these values, would be gross overstatement."[85]

Throughout the boom years, he argued for funds for a serious study of the economics of fire control. But his pleas fell on deaf ears, especially after the adoption of the 10 a.m. policy. Calling for a reduction of fire-control costs at the end of the period, he pointed out that while the law of diminishing returns could be applied to fire control in high-value areas, no principles existed to determine how much effort should be expended in noncommercial, little-used, low-value areas. The application of the 10 a.m. rule to both areas did not make economic sense to Gisborne. Nevertheless, he still lacked the resources to make economic studies that could pave the way for change.[86]

Short of tampering with the sacred doctrine that all fires must be extinguished by 10 a.m., Gisborne's basic

Figure 33.--New Looking Glass Lookout tower built at Priest River Research Station in 1933, site of lightning experiments by Gisborne. This tower was replaced in 1958.
(Gisborne collection)

economic principles for fire control were applied to planning, even without the benefit of the economic research that he thought essential. In 1931, the Regional Forester, Evan W. Kelley, decided to institute a comprehensive fire control planning system for the Northern Region. To undertake the work, he assigned Lloyd G. Hornby, Supervisor of the Flathead National Forest, and a continuing flow of Regional money, to the Station. Gisborne then entered into a close partnership with a man of congenial spirit, of whom he later said, "[Hornby] brought to the task a background of training, experience, and inherent ability that was as unique as it was well suited to the opportunities of this work. His training in both engineering and forestry, his 15 years of field experience from smokechaser and ranger to supervisor of three National Forests, and his exceptional ingenuity practically assured a researcher that would make a major contribution to forest fire control."[87]

Figure 34.--Lloyd G. Hornby, Chief of the Fire-Control Planning Project of the Northern Rocky Mountain Forest and Range Experiment Station at Missoula, Montana, in the 1930's. He developed the first basic principles for fire control planning.
(Gisborne collection)

Early Planning by Hornby

After Hornby's death, Gisborne called the energetic planner a major pioneer of forest fire research and said his work formed a major "milepost" in the history of the whole subject. Hornby's "most outstanding contribution," as Gisborne averred, "was his analytical approach to the planning problem and his reemphasis on physical conditions on the ground as the proper starting point for all fire plans. His concentration on fuel types, rate of fire occurrence, rate of spread, and fire danger as fundamental, measurable factors of the fire job everywhere constitutes a sound basis for future progress. Fire control planning work is not new, but Hornby systematized that planning."[88]

The two men lost no time in laying the groundwork for the comprehensive plan. In 1931, 14 foresters from around the Region were detailed to the Station where, under the joint supervision of Gisborne and Hornby, they began an analysis of 12,056 fire records gathered between 1921 and 1930 in the Region. Gisborne and Hornby then spent the spring of 1931 in Washington, D.C., processing the data on the Service's Hollerith machine.[89]

By the year's end, although they were at a preliminary stage in their analysis, the two had learned a lot about discovery time in relation to attack time, burned areas, suppression costs, detection coverage, man-caused versus lightning-caused differences, visibility, type and moisture condition of fuels, cover types, topography, aspect, and efficiency of the fire detection force. Their data were already supporting a Regional manpower placement and transportation study to determine the need for more complete detection ability, depending on fuel type and maximum allowable blind spots. The findings also permitted calculation of allowable distance (travel time) in respect to smokechaser location, fire protection standards, and fuel and weather conditions.

Since the analysis showed that effective planning could not be based on average conditions, the Region contemplated a fire organization prepared to handle the worst 10 percent of fires, with due allowance for short periods of extreme danger. The analysis also suggested that if allowable burn standards could not be met with reasonable costs, a decision would have to be made whether to increase the organization or expand the allowable burn area according to the use for which a given forest cover is grown.[90]

The analysis completed, Hornby (advised by Gisborne) started to prepare plans in 1932. His attention went first to the Region's 10 western high-hazard "fire forests" west of the Continental Divide, then to the eastern forests. Concurrently, he began two massive field projects--fuel-type mapping and seen-area mapping. Fuel-type mapping described fuels in terms of rate of fire spread and resistance to control and ranked each as low, medium, high, and extreme. Seen-area mapping was conducted at all lookouts and other locations where lookouts or fire patrol points might be established. By manually arranging and rearranging seen-area map composites, the project produced a combination of the fewest number of lookouts giving the greatest surveillance of the forests. Hornby, Gisborne, and their team also investigated transportation planning, actual road routes, and resource valuation zones.[91]

In 1936, Hornby finally released his complete report on fire control planning. It was greeted with much enthusiasm. "Comments indicate that it evidences a breadth of view and an approach that provide scientific precision which is in balance and keeping with available basic data and the elusive character of forest fire danger," said Ferdinand Silcox, the Chief of the Forest Service who had ordered the 10 a.m. policy. "This publication constitutes an outstandingly successful instance of cooperative effort between the Regional Office and the Experiment Station, of which I sincerely hope there will be many other examples in the future."[92]

To make the document more useful, Hornby began a shorter summary report. But in 1937, he was transferred to the Washington Office. When he returned to the Region for a visit in late summer, he found the opportunity to observe a fire on the Clearwater National Forest too great a temptation. It was to be his last, for on August 21, 1937, he suffered a heart attack and died, in Gisborne's words, "as he probably would have chosen, with his boots on, in the field, actually on the fireline, studying methods of getting more efficient fire control at less cost."[93]

Gisborne had lost a friend and a respected colleague. He was determined to continue Hornby's work and eventually codified his associate's findings as "Hornby's Principles of Fire Control Planning":

1. Held line must be built faster than the fire makes perimeter.

2. Fuel-type classification is necessary to show the two basic factors, rate of spread and resistance to control.

3. Plans must be made for first-attack control before the fire commences to spot or crown except under class 6 or greater danger in the extreme fuels.

4. Fuel type, occurrences of fires, and values at stake must be coordinated for most economical yet adequate fire control.

5. Lookouts, firemen, and crews have the dual responsibility of detection and smokechasing.

6. Transportation and communications planning should follow and be based upon fire control planning and other forest use requirements for multiple use.

7. Fire control for the "worst first" automatically simplifies the process.

8. The conditions creating a fire problem are not static; fire control planning is therefore a continual process of revision and refinement.[93]

Gisborne's testament to Hornby was also a monument to his own work, for Hornby's principles represented the practical application of years of careful research. For Gisborne and for the Forest Service, the boom years were good years. Whatever Gisborne thought of the 10 a.m. policy, he had made it possible for the Service to finally come to grips with the problem of fire in the forests. Policies, plans, and actions were thereafter to be based on the kind of systematic assessment of inflammability that Gisborne had developed with his fire-danger rating meter.[94]

The Discouraging Years 1938-1945

> *I want to keep my eye on the ball--the two main balls are fire danger rating and fire control planning--and, if possible, to have these two big projects neatly packaged and pretty well sewed up by the time I retire. The Forest Service should make me do that if they want to come nearer getting value received out of [the] salary already invested in me as a fire researcher.... I have to hurry and keep my eye on the ball or I will not make it. My fear is that we will not even get half the funds asked for. Then we will not make it.[95]*

The heyday was over. Allotments shrank, emergency crews and budgets vanished. Projects terminated and vacancies went unfilled. A series of easy fire years reduced the Forest Service's interest in fire research. After the flush times of the New Deal, Gisborne found the tight period that began in 1938 distressing. But after the significant advances he had already made, the hiatus forced him to consolidate his gains. Although he conducted a few projects during the World War II period, for the most part it was a time to review the record of the past and plan for the future. Again he found that he must do most of his work alone.[96]

Most of Gisborne's major projects simply came to an end for want of people to pursue them; others were reduced to sporadic trickles. A little additional field checking of Hayes' altitude and aspect study was done in 1940, but an attempt to extend the study with a large "mountain transect" that was cleared in 1940 came to naught. Hayes' large-log fuel moisture measurements, however, continued throughout the period.[97]

Gisborne took over Hornby's planning project in 1938. That year, 10,000 fire reports were punchcarded to support intensified analysis, but without personnel to handle the work, it remained unfinished. In 1939, the Region assigned Chalmer K. Lyman, a recent forestry

Figure 35.--Harry Gisborne with Stephen N. Wyckoff, who was Director of the Northern Rocky Mountain Forest and Range Experiment Station at Missoula, Montana, 1936-39.

(Gisborne collection)

graduate with practical fire behavior experience, to the Station to take actual measurements of rate of spread and other behavior factors of fires in important fuel types and in different danger conditions. During the summers of 1939 and 1940, he took measurements of 74 fires and used the results to verify estimates established in Hornby's planning project. He also used his data to prepare charts showing not only the average rates of spread but also the variation that could be expected in a specific fuel-type/class-of-danger condition. The results were troubling to Gisborne. "Obviously," he commented in 1940, "either the present concept of fuel type requires refinement or the weather factors influencing fire behavior are not being adequately measured, or both."[98]

Figure 36.--The "mountain transect," a 100-yard-wide clearing made in 1940 at the Priest River Research Station from the top of South Ridge down the slope and up North Ridge to the top. Monitored with fire-weather instruments, it allowed comparative measurements of fire danger data for changes in elevation at different times of day and night in a mountain valley.
(Gisborne collection)

In 1944, Colleen McCarthy, a forestry student specially trained for the job, undertook a study to determine the heat content of slash and other debris in the forests resulting from fires, windthrow, and other disturbances. There had been some disagreement for years over the extent to which such materials contained latent heat that could be liberated in a fire. The results showed that the heat content of dead fuels could range up to 10,000 Btu's per pound (in a 57-year-old ponderosa pine top) and significantly modified earlier approaches to fuel typing. Weight now had to be considered. The study terminated in 1945, as soon as it had demonstrated that the potential heat of slash was significant. The demands of the times would not allow the kind of detailed, long-range projects that Gisborne preferred.

Similar short shrift was allowed for a parallel project which Lyman returned to the Station to conduct in 1944 and 1945: weighing the costs and benefits of fuel reduction, especially in slash and related inflammable debris. Although inconclusive, the study did replace opinions with facts and suggested postwar work on the reduction of hazardous fuels in the forests.[99]

Other projects yielded even fewer results. Among them, Gisborne provided technical direction in 1944 and 1945 for a study of rate of fire spread in grass, during which he modified an "Asman" aspirator psychrometer to measure humidity at the root crown in low vegetation. But he never prepared a formal plan for the work, and although readings were taken for 10 years, the only lasting effect was to fill a big gap in Hornby's rate-of-spread tables. Paul Stickel extended Jemison's previous work by preparing a 30-year summary of weather at Priest River Station, but it was never published. Meanwhile, Gisborne continued to request support for research on fire economics but still met with opposition.

Figure 37.--Gisborne using the Asman aspiration psychrometer that he modified for grass cover.
(Gisborne collection)

His Ideas Adopted in Other Regions

Gisborne could not even make headway in planning for the future. He had participated in a 1936 national meeting of fire research and fire control personnel at Shasta National Forest in northern California, during which he had become impressed both with the extent to which his ideas had been adopted in other Regions and with the need for national coodination and planning of fire research. He joined in another such meeting at Ogden, Utah, in 1940, then hosted yet another symposium at Priest River in December 1941. This last meeting supported his beliefs by proposing national programs of research on fire economics and on fire prevention. But his hopes were immediately dashed, for the day after the conference adjourned, Pearl Harbor was attacked. New programs were postponed for the duration of the war.[100]

Anticipating growth in the research budget after the war, Gisborne prepared a detailed analysis in late 1944 of the major research areas that he believed needed action to support Regional and national goals of adequate fire control at the least cost. The research program he proposed would cover the fields of economics, fire effects and use, fire control planning, and fire-danger measurement. He outlined a combined program to extend over a decade, costing $145,000 a year for the first 3 years but decreasing to $43,000 a year by the tenth year. As early as 1946, he hoped to make an all-out attack on fire control planning, follow up the fuel reduction study with a manual of fuel reduction practices, define "adequate control at the least possible cost," and resume several of the studies dropped since 1937 that would lead to a fire dispatcher's guide.[101]

The Last Years
1946-1948

> *Foresters throughout the country are beginning to appreciate the fact that all the techniques of silviculture, in fact of all phases of forestry, are less important than policies which will express and determine where and how much of those techniques should be used. Techniques are a means to an end--what bothers us in Fire Control is where the hell are we headed? Which end or ends? ...This is a perfectly natural period we are going through; a transition from an even-aged stand of one species--silviculturists--to a mixed-age stand with a few more species. One thing we seem to be scrapping about is: which if any of the new species are 'weeds'?[102]*

Gisborne's grand plan for the postwar period did not materialize. He did, however, receive an increase in his research budget, some hope of a growing program in the future, a lot of new ideas, and a bigger staff. Perhaps the most helpful sign, however, was the establishment in 1946 of a Division of Fire Research in the Station's table of organization, with Gisborne at the head. His program had at last attained administrative equality with other research ventures.[103]

But perhaps the happiest event of 1946 for Gisborne was the addition to his staff of Jack S. Barrows, who was destined to carry fire research into new realms made possible by the technological developments of wartime. The two had become close friends during the 1930's, when Barrows was responsible for many of the fire control programs of the National Park Service. While still in the military service at the end of the war, Barrows had written to Gisborne about possibly joining his staff when he received his discharge. There was no question about his acceptance. He reported for duty on July 1, his salary coming from both Fire Research and Fire Control funds. Gisborne saw Barrows as the right man to continue Hornby's work. Barrows regarded Gisborne from the start as "certainly a man that I wanted to know and be associated with because he was obviously way ahead of his time. His concepts, his thinking, his vigorous approach to problems was absolutely infectious to people. He inspired me to do things."[104]

Barrows had scarcely started to work on a huge backlog of fire reports when he was ordered to assume, under Gisborne's cautious oversight, direction of the Aerial Bombing Project, a joint venture of the Forest Service and the Army Air Force to develop a new method of fighting forest fires.[105] The Forest Service hoped that advances in aviation and bombing technology made during the war would at last make aerial bombing of fires accurate and effective.

The 1946 season was devoted chiefly to preparing a test fire site on a ridge about 20 miles from Missoula, modifying aircraft, and preparing bombs. The latter were fashioned from 165-gallon and 310-gallon surplus aluminum wing tanks fitted with guiding fins. Some would erupt along the fireline on impact while others carried bursting charges to open them at 30 to 50 feet above ground. In the latter case, it was reasoned that the concussion might offer enough wind pressure to extinguish some flame, but everything was speculative at that point. A B-17 Flying Fortress airplane stood by in Montana, but no bombing runs were launched in 1946.[106]

The 1947 season, however, was an exciting one. A B-29 Superfortress and two P-47 Thunderbolts made many practice runs, first at level ground, later at mountainous burned areas and timber stands. The B-29 made precision bombing runs from several hundred feet above fires burning in mountainous terrain. The fighters executed glide bombing runs on fires in remote and inaccessible places. Several paired test fires were set, with the planes attacking one fire while the other fire provided a control. From the start, the objective was not to douse the fires but to retard their spread and give ground crews time to take over. The bombings drew wide publicity and large crowds of observers, and were generally regarded by fire control officers as successful demonstra-

Figure 38.--Jack S. Barrows of the Northern Rocky Mountain Station Fire Research Staff, speaking at ceremonies inaugurating the experimental "fire bombing" project with the US Army Air Force at Great Falls, Montana, in the summer of 1947. Water was used in large containers which burst on or above the ground. The goal was to halt fire spread until ground crews arrived. The B-29 Superfortress here was named the "Rocky Mountain Ranger."

(Gisborne collection)

tions of a possible new firefighting technique. But although the experiments were supposed to continue to the following year, they did not. Aerial firefighting did not become a regular part of the Forest Service arsenal until after the initiation of Operation Firestop in 1954.[107]

Gisborne left the project almost entirely in Barrows' hands, offering only occasional advice. Such massive ventures were not really his preferred kind of research, and although he supported the experiments enthusiastically, he remained skeptical at their conclusion. Even casual discussion of the economics of bombings, he cautioned, was "mere speculation until after the feasibility has been thoroughly tested. Such care is essential to the scientific method."[108]

Figure 39.--Jack S. Barrows directing the aerial forest fire bombing project at Lolo Hot Springs Lookout, Montana, in 1947. Both B-29 World War II bombers and P-47 Thunderbolt fighter planes were used. It was found highly effective in checking fire spread under some conditions, but high costs postponed its regular use by the Forest Service. Tests with chemicals scheduled for 1948 were not made. The next major trials were held in California by the Forest Service in 1954.

(Gisborne collection)

Barrows Takes on Planning

When Barrows was not occupied with the Aerial Bombing Project, he turned his attention to fire control planning. During his first winter at the Station, he began the machine compilation of about 23,000 punchcarded fire reports. Barrows' objectives matched those of Hornby before him: to determine the principles, methods, and techniques of planning adequate fire control at least possible cost. But some conditions had changed much since Hornby's time. Accelerated timber harvesting had left large areas of inflammable slash, even in areas previously regarded as inaccessible or of low value. Expanded road systems, airborne delivery of smokejumpers and supplies, aerial fire patrols, the promise of aerial fire bombing, and a wealth of wartime equipment had all entered the fire control scene, but the CCC had left. More fundamentally, according to Gisborne, an old problem remained. Administrators continued to base fire control decisions "on judgment, estimates, and even guesses without benefit of research analysis. The program is too big, the expenditures too large, and the stakes too high to be safeguarded by such tactics."[109]

By 1947, Gisborne could report that his division had started to regain ground in fire control planning that had been lost during the slack years of the war. Within another 2 years, Barrows' fire analysis had formed the basis for a complete revision of fuel-type classification methods. But in a reflection of the changing bureaucratic atmosphere of the times, the planning work was retitled "Fire Control Engineering Research" in 1948.[110]

Also during this period, Gisborne was able to resume and considerably enlarge studies of the relation between fire and watershed values, a subject he had investigated earlier. He cooperated in an Army Corps of Engineers study of snowmelt and runoff. In research following the 1948 floods on the Columbia River, he addressed the relative rate of snowmelt and runoff on burned and unburned areas. But in 1948, the work passed to a new division of Flood Control Surveys.[111]

For the most part, Gisborne spent the postwar years trying to perfect the significant advances he had made in earlier periods, even as the environment around him was being transformed by new Forest Service people and attitudes and wondrous new technology. Fire-danger rating, he believed, remained the heart of any effective fire control program. He was never satisfied that his system was as good as it could be. "Testing the accuracy and dependability of any fire danger meter," he wrote in 1946, "is as difficult as the development of such a device."[112] He had great hopes that Barrows' fire analysis work would improve calculations of danger classes and manpower availability, and he continued to promote the use of fire-danger measurement for presuppression decisions and the preparation of a fire dispatcher's guide. His persistent agitation for better fuel-type classification and maps significantly affected the design of fire control systems. Gisborne also developed better ways to use results of the large-log study in determining average fire danger and completed an analysis of weather conditions from 1903 through 1946 for the same purpose.[113]

A persistent spokesman for a rational, as opposed to a dogmatic, approach to fire control, Gisborne kept up his attacks against the 10 a.m. policy. "Apparently," he gibed at the end of 1947, "the objective of control by 10 a.m. can be sought so vigorously that costs will be skyrocketed beyond balance with the small additional reduction in acreage burned."[114]

Cloud Seeding Trials

Gisborne did not remain impervious to the scientific and technological advances all around him, however. He had formed an acquaintanceship with Irving Langmuir and Vincent J. Schaefer of the General Electric Company in the early 1930's, and they had engaged in some cooperative studies of lightning detection methods. When the two made the chance discovery of the principles behind cloud seeding with dry ice in 1947, Gisborne immediately seized upon it as another possible tool for fire control--in particular, the emasculation of dangerous storms. In 1948, he visited the two scientists at Schenectady, New York, and enlisted them in an informal cooperative project to test the applicability of cloud seeding to forest fire control. Schaefer visited with Gisborne and Barrows that summer to discuss the project. A C-47 was readied for a trial seeding run, but weather conditions forced cancellation. The next year, however, although Schaefer could not attend, Gisborne and Barrows organized a test using a leased C-47 to carry dry ice and a sizable contingent of Forest Service officials. Although the group broke their oxygen hose at 26,000 feet and nearly asphyxiated themselves, report of a snowfall after their flight raised their hopes. In 1949, Barrows used his connections to get an Air Force B-29 assigned to the experiment, but favorable cloud conditions never occurred.[115]

Gisborne was optimistic about the possibilities of cloud seeding but remained characteristically scientific and cautious. Under pressure to do something, to ice any cloud and see what would happen, he said in 1949, "I am not going to do that. I am not going to try to plug the gap by pulling a stunt instead of conducting an experiment, as much as I would like to go up and see what we can do." He planned to continue the tests in following years.[116]

In the course of his crusade for better fire-weather forecasting, Harry Gisborne entered into bitter relations with Weather Bureau personnel. Gisborne was aging, his health was worrying him, and his impatience turned to irascibility in his later years. But even his colleagues in the Forest Service were taken aback by his abusive dealings with his sister agency. Crocker berated him in 1948: "You advocate (and practice) needling, aggravating, fighting, and antagonizing the Bureau. That approach over the years has brought us nothing that could not have been realized through other more ethical means."[117] But to his dying day, Gisborne never ceased to demand from others, in the severest terms, the same standards of perfection that he required of himself.

In 1947, at ceremonies in Washington, D.C., Gisborne received the Department of Agriculture's Superior Service Award for "pioneering work and superior accomplishments in research leading to the development of techniques, equipment, and practices widely used in forest fire control."[118] But such testimonies to his achievements were not what he sought. He wanted to continue expanding the frontiers of forest fire research. In 1948, he criticized the Service's $350,000-per-year nationwide program as "grossly inadequate." In its place, he proposed a comprehensive effort with a much larger budget to determine safe and effective conditions for all kinds of prescribed burning; to produce a fire dispatcher's guide; to improve the quality of presuppression planning and practices uniformly in all Regions; to improve the fire-danger rating system in every Region and develop a national system; and to begin wide-ranging fire damage studies in all Regions.[119] He was not about to rest on his laurels.

End of an Era
1949

If what I have contributed so far has been good, it is well to consider where and how I obtained the background information and attitudes. I got it by living in the field in daily contact with field conditions....[120]

In August 1949, a serious fire erupted on the Helena National Forest in Montana. Forest Service smokejumpers and other firefighters rushed to the scene, but the conflagration was soon beyond human control. On August 3, the Mann Gulch fire swept over a crew of 16 firefighters (all but one were smokejumpers) and killed 13 of them.[121]

Gisborne was not present at the scene of the fire, but he soon became involved in the Service's attempts to discover why the disaster happened. By

Figure 40.--In this 1949 photo with Gisborne, at left, are Charles L. Tebbe and Arthur A. Brown. Tebbe was Station Director from 1946 to 1950 and soon after became Northern Regional Forester. Brown was Fire Control Chief at the Denver Regional Office before going to Washington, D.C. (headquarters), where he became Fire Control Chief in 1947 and Fire Research Chief in 1950.
(Gisborne collection)

mid-fall, he had reviewed all available reports on the fire and was trying to develop a theory of how the blowup could have occurred. On the recommendation of a special board that studied the tragedy, Gisborne was directed to study the matter and report his findings. He believed, as he had throughout his career, that he must examine the scene directly before coming to any valid conclusion. But the Station Director, Charles L. Tebbe, was more concerned for Gisborne's health. "Harry was not a young man," he later recalled. "Moreover, he had a heart condition and knew it.... Reluctantly I approved the trip but on condition that he make it and the inspection of the area and the fireline by jeep."[122]

On November 9, 1949, accompanied by a Forest Ranger, Gisborne left Helena in a jeep, planning to drive to the pass at the head of Mann Gulch and walk generally on a contour through the upper fire area. A slick, wet surface prevented that, so they drove to an adjacent gulch, from which point Gisborne insisted, over the Ranger's worried objections, on walking through the burned area. He promised to stop and rest every 100 yards, and did so. But late in the day, while starting to leave a resting place, Gisborne collapsed and died.[123]

When word reached the Station, according to Tebbe, "We were all stunned. I proceeded to do what he had asked me to do if anything of the kind ever happened. He had given me a key to a desk drawer he had always kept locked.... [R]ight on top was a large photograph of the south end of the Mission Range. It had been taken from the west side of the valley and showed a realistic profile of a reclining person. There were notes and pen lines all over the picture which gave the viewer specific instructions respecting just where he wanted his ashes to be cast--'right in the old man's eye.'"[124]

A year later, the mountain on the Priest River Experimental Forest where Gisborne's remains rested officially became Gisborne Mountain. It was dedicated in 1951 with a bronze plaque bearing the inscription:[125]

HARRY T. GISBORNE

(1893 - 1949)

Inspiring, Enthusiastic, Far-Seeing

Pioneer in Forest Fire Research

Gisborne was the last of the pioneers of forest fire research, and one of the greatest. An era ended with his passing, and times have continued to change. Gisborne worked in a period when the Forest Service was almost overwhelmed by its fire control responsibilities, a time of nearly ceaseless emergency. He made it possible for the Service to reduce that emergency to its own capabilities and bring it under control. To Gisborne and his colleagues, fire research was forestry, and he remained a Forester throughout his career, taking his work outdoors and facing the problem on the ground. But the mass of manpower that came on the scene in the 1930's, followed by the great variety of power equipment a decade later, made the economics of fire control no longer as pressing as they had been in Gisborne's heyday, before the 10 a.m. policy made economics officially irrelevant. Fire research was no longer purely forestry after Gisborne's era. It involved physics, higher mathematics, and later, biology. The research eventually moved indoors, to laboratories and universities, where Gisborne's successors now examine fire as a phenomenon in its own right, without the economic and administrative demands that had burdened the pioneers. These changes would not have been alien to Gisborne--he had, after all, done much of the groundwork that made them possible.[126]

Figure 41.--Harry T. Gisborne in August 1949, a few months before his death. (Gisborne collection)

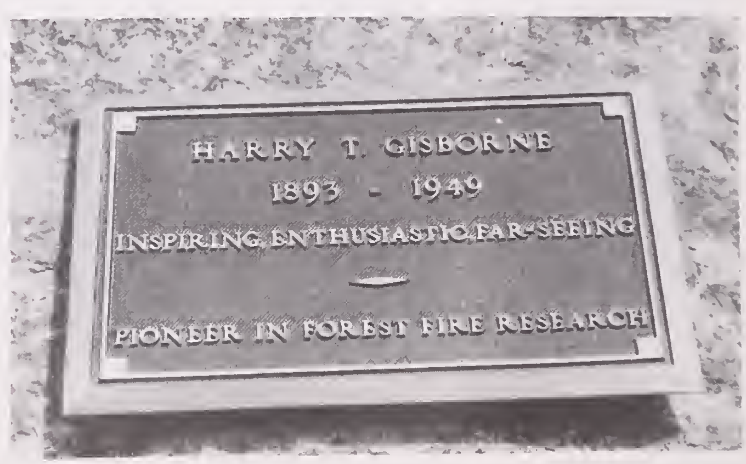

Figure 42.--Brass memorial plaque on Gisborne Mountain, formerly Looking Glass Mountain, 15 miles north of Priest River, Idaho, renamed in 1950 for the pioneer in forest fire research. (Gisborne collection)

Reference Notes

1. I have made occasional minor changes in quotations from interviews and written materials for reasons of brevity, simplicity, and relevance.

2. Letter, Gisborne to the Editor, Michigan Alumni, March 9, 1940, in the collection of Gisborne's personal and professional papers gathered by and until recently in the custody of Charles A. Wellner, USDA Forest Service, Forestry Sciences Laboratory, Moscow, Idaho (hereafter cited as "Gisborne Papers"). This collection, together with research data files related to Gisborne held at the Northern Forest Fire Laboratory in Missoula, Montana, have been transferred to the University of Montana Library Archives for permanent retention.

3. The foregoing summary of Gisborne's early life and career is based on his own personnel records, including a draft autobiographical form (1935) and an Application for Senior Silviculturist Position (1928), dating between 1919 and 1949, in Gisborne Papers.

4. When founded in 1911, the Priest River Experiment Station, on the Kaniksu National Forest in the Idaho Panhandle, was the third such field research establishment of the Forest Service. When research programs and their budgets expanded after World War I, a number of changes occurred. In 1921, the headquarters of the Priest River Experiment Station was moved to Missoula, Montana, and Weidman was appointed Director. By 1925, the name had been changed to "Northern Rocky Mountain Forest Experiment Station," and in 1931, it became the "Northern Rocky Mountain Forest and Range Experiment Station." In the meantime, the acreage and programs at the original location became the "Priest River Experimental Forest," in effect a substation of the Missoula headquarters. See Julius A. Larsen, "Beginnings of Forest Research at the Priest River Forest Experiment Station," an illustrated summary prepared for the 65th anniversary observance at the Priest River Experimental Forest, August 11, 1976, unpublished; "Forty Years of Forest Research in the Northern Rocky Mountain Region," the 40th Annual Report of the Northern Rocky Mountain Forest and Range Experiment Station (Missoula, Mont., 1950), and Charles A. Wellner, Frontiers of Forestry Research: Priest River Experimental Forest, 1911-1976 (Ogden, Utah, 1976). Although the research organization was originally intended to be a supporting element of the Forest Service's administration of the National Forest System, it has been a parallel entity almost from the start. The geographic area of the Northern Rocky Mountain Station's activities followed that of the Northern Region, and its projects were concentrated in the National Forests. But although both the Station and the Regional Office were based in Missoula, they had distinct programs with separate budgets and reported to separate Deputy Chiefs in Washington, D.C. The two organizations worked cooperatively, however, especially during the 1930's. In 1954, the Northern Station was merged with the Intermountain Station, which is headquartered in Ogden, Utah.

The administration of the National Forest System was first divided into three, and then six, "Inspection Districts." That district based in Missoula became District One in 1908. In 1919, the Districts were also given geographic designations; therefore, District One was also called Northern District. In 1929, the term District was changed to Region. The alternative numerical designations have continued to the present.

Since it has been called the Northern Region for a half-century, for convenience's sake, the term "Region" is used throughout this history. The person in charge of a Region is the Regional (previously District) Forester.

5. Memorandum, Clapp to District Forester at Portland, Oregon, January 21, 1922; and Memorandum, Gisborne to District Forester at Portland, Oregon, February 3, 1922; both in Gisborne Papers.

6. USDA Personnel Action, March 13, 1922, Gisborne personnel records, Gisborne Papers.

7. Gisborne, "The Trend of Forest Fire Research in Northern Idaho," Idaho Forester 9 (1926): 16-18, 38.

8. Jack S. Barrows, interview with the author, February 26, 1976. In another interview on April 28, 1976, Charles L. Tebbe said that Gisborne "didn't tip the scales very much, but in matters of the mind, he was a real heavyweight." Tapes, notes, and transcripts of all interviews cited here have been placed in the University of Montana Library Archives with the Gisborne Papers.

9. Brown, interview with the author, May 14, 1976. When, in later years, Gisborne's energy taxed his failing heart, Brown said that he "would not listen to any [admonishment] because he said there were bigger things ahead than he'd ever done before and he was not going to be stopped." George M. Jemison, interviewed on February 14, 1976, emphasized the same point: "He couldn't do anything without practically killing himself doing it. He had to be in action every minute. He couldn't relax and take things easy.... I'm sure that may have led to his heart condition."

10. Brown interview.

11. Jemison interview.

12. Virtually all the people interviewed for this research emphasized that Gisborne was "application oriented." They stressed equally his salesmanship and his rapport with field men. Brown said that "he was the best salesman for forest research in general, and fire research in particular, that we had for many years." Clayton S. Crocker, interviewed on April 27, 1976, said that Gisborne "sold his research on the spot. He could simplify highly technical matters so field men could grasp the crux of the ideas without them feeling talked down to." G. Lloyd Hayes, interviewed on February 27, 1976, recalled that Gisborne directed his employees to establish the same degree of familiarity with people and conditions in the forests in order to appreciate better the purposes of their research. And Barrows believed that "everything 'Gis' did he did rather aggressively, and there was never much misunderstanding on what his position would be on almost any subject that came up. He thought things out clearly and carefully and was a good communicator; he could get his points across to people."

13. Brown interview.

14. Act of March 1, 1911 (36 Stat. 961), the "Weeks Law." The most comprehensive history of the Forest Service is Harold K. Steen, The U.S. Forest Service: A History (Seattle, Wash., 1976); unless otherwise attributed, data on the general history of the Service in this history are derived from that source. The most comprehensive study of the entire subject of wildfires in the history and culture of the United States is the monumental manuscript by Stephen J. Pyne, completed in 1980 under a cooperative agreement between the Forest Service and Pyne. It was published by Princeton University Press in 1982 and entitled Fire in America:

A Cultural History of Wildland and Rural Fire. Especially pertinent are chapter 5, "The Heroic Age," a history of Forest Service fire policies; and chapter 8, "Fields of Fire," which includes a history of forest fire research. Hereafter cited as "Pyne, Fire History."

15. Joint Experiment Station-Region One Investigative Council Annual Report, 1916 (including attached study plan) and 1922. (The title of this annual series changed in 1936 to Northern Rocky Mountain Forest and Range Experiment Station Annual Report; either is cited hereafter as "Annual Report.") See also J. A. Larsen and C. C. Delavan, "Climate and Forest Fires in Montana and Northern Idaho, 1909-19," Monthly Weather Review 50 (No. 2, 1922): 55-68.

16. Donald R. Whitnah, A History of the United States Weather Bureau (Urbana, Ill., 1965), 151 p. The service resumed sporadically after the war, but did not become regular, or receive appropriations, until 1926. See below.

17. Pyne, Fire History, chapter 8. Edward N. Munns was also working before 1921 on the relationship among vapor pressure, evaporation, and fire danger. Brown interview.

18. Memorandum, Clapp to Experiment Station Directors, 1916, discussed in Annual Report, 1916.

19. Annual Report, 1920. See note 15.

20. Annual Report, 1919; District One Bulletin, February 1920 and April 1922; Northern District Bulletin, October 1922 and February 1923. The District One Bulletin (the Region's newsletter) became the Northern District Bulletin in October 1922, the Northern District News in October 1929, and since October 1931 has been called the Northern Region News--all reflections of changing administrative terminology in the Forest Service.

21. As reflected in the Annual Reports during the 1920's, the staff of the Station remained fixed at five, with a budget of about $14,000 per year, including salaries. Gisborne occasionally had a Field Assistant during the middle years of the decade, but his expense allotment was fixed at about $400 per year. Since his work was considered part of Silvical Investigations, Gisborne's titles were, successively, Forest Examiner, Assistant Silviculturist, Associate Silviculturist, and Silviculturist. Throughout the 1920's, he was the only person at the Station working on fire research; and after Larsen left in 1924, he was, until the end of the decade, the only professional at the Station engaged full time in research. Despite the increase in research programs after World War I, they remained comparatively small until the 1930's.

22. Annual Reports, 1922 and 1924.

23. Annual Report, 1922. The Forest Products Laboratory at Madison, Wisconsin, assisted Gisborne by making laboratory determinations of the equilibrium moisture content of duff, twigs, and downed logs in relation to temperature and relative humidity.

24. Annual Report, 1923.

25. Annual Reports, 1923, 1924, 1925, and 1926; Gisborne, "Importance of Duff Moisture Content in the Forest Fire Problem," Journal of Forestry 21 (1923): 807-809. Jemison and Hayes used the duff hygrometer throughout the 1930's. They found it difficult to maintain calibration. Although they were used in conjunction with fire-danger rating, according to Jemison, duff hygrometer measurements never became a factor in the fire-danger system. The device's use was discontinued about 1940. Jemison interview.

26. Letter, Larsen to Regional Forester, Northern Region, February 1, 1976, Re-

gional files (copy in Gisborne Papers).

27. Letter, Gisborne to L. H. Nichols, July 10, 1929; letter, Gisborne to Station Director, December 3, 1945; both in Gisborne Papers. Although Gisborne was dealing with dowels in substantial numbers by 1929, sets of three or four dowels as "hazard sticks" in support of fire-danger meters were not produced until the 1930's. See below.

28. Gisborne, "Measuring Forest Fire Danger in Northern Idaho," USDA Miscellaneous Publication 29 (Washington, D.C., 1928). The text was actually prepared in 1926.

29. Memorandum, Gisborne to Paul W. Stickel, April 3, 1926, Gisborne Papers.

30. Letter, Gisborne to H. B. Rowland, May 16, 1927, Gisborne Papers.

31. Annual Reports, 1926, 1927, and 1928. Lacking laboratory facilities of his own, Gisborne promoted research at the University of Montana and of Idaho on fuel moisture content, which he still regarded as the key to perceiving inflammability. The universities' scientists and others worked on various problems related to combustion of forest fuels such as an electrical method of determining the distribution of moisture in wood (an effort fruitless for Gisborne's needs, but which led to a lumber moisture meter), and the inflammability and heat retention of various species at different moisture contents.

32. Annual Report, 1922, and attached study status report and working plans.

33. Annual Report, 1923; Fire Manual, District One, Forest Service files, Missoula, Montana.

34. Gisborne, "An Investigation of Lightning Storms in the Northern Rocky Mountain Region," Northwest Science 1 (No. 4, 1927): 72-73, and "Lightning and Forest Fires in the Northern Rocky Mountain Region," Monthly Weather Review 54 (No. 7, 1926): 281-286. In 1926-27, the Station used a specially constructed "quadrant electrometer" provided by the University of Idaho Physics Department. It indicated, in some cases, a relationship between atmospheric electricity and the weather, precipitation, lightning, and possibly relative humidity. Little came of the work, however, because the head of the Physics Department left. Annual Report, 1927. Beginning in 1929, Howard R. Flint began part-time inquiries into the possibility that certain geological formations attract lightning. No formal results emerged from his studies, however. Annual Report, 1929.

35. Annual Report, 1929; Gisborne, "A Five-Year Record of Lightning Storms and Forest Fires," Monthly Weather Review 59 (No. 4, 1931): 139-150, and "Your Lookouts Have Information for You," Northern District Bulletin, July 1927. In 1929, Gisborne estimated that 3,000 to 4,000 reports would come in each year. Annual Report, 1929. Jemison gave an example of Gisborne's propensity to grasp every possible lead and follow up on it. He persuaded the Service's telephone engineers to develop some way of measuring static electricity in order to predict the advent of lightning storms. They "rigged up some kind of aerial and spark gap in the upstairs at the old fire lab. He would sit there during oncoming lightning storms and try to adjust the spark gap to measure the distance it would spark as the electricity built up in the air. But this never led to much." Jemison interview.

36. Annual Report, 1923; Wellner, personal communication, 1976.

37. See comments in Northern District Bulletin, November 1923 and February 1928.

38. Annual Report, 1924; Gisborne, "Cyclic Fluctuations of Rainfall in the Northern Rocky Mountains," American Meteorological Society Bulletin (August-

September 1925): 131-132, a paper first presented at the meeting of the American Association for the Advancement of Science in Portland, Oregon, 1925.

39. Whitnah, Weather Bureau, 151-152; Annual Reports, 1927 and 1929; Northern District Bulletin, January and February 1928. In 1927, a number of commercial radio stations in the Northwest began to carry daily fire-weather broadcasts. Northern District Bulletin, July 1927.

40. Howard R. Flint, "Fire Resistance of Northern Rocky Mountain Conifers," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 61 (Missoula, Mont., 1925) and "Characteristics Influencing Fire Resistance of Northern Rocky Mountain Conifers," Forest Worker (September 1925): 22-23; Annual Report, 1928. Flint's method was eventually reduced to a simple, one-page table. Pyne, Fire History, chapter 5, points out that economics determined fire control policy until the availability of massive manpower in the 1930's. That is, to oversimplify a complex matter, decisions to expend limited resources in fighting a given fire were to be based on a finding that the potential economic damage caused by the fire would significantly exceed the cost of controlling it, since all fires burn themselves out eventually, or are doused by rain or snow. See below for Gisborne's economic interpretation of fire control.

41. These activities are detailed throughout the decade in the Annual Reports and the Northern District Bulletin. Flint was also involved throughout the period in technological research, encouraging experiments with machinery, explosives, and radio for fire control work.

42. Annual Report, 1929. The Director and District Forester's proposals to Washington included requests for further research into improving methods of weather forecasting, measuring prevailing inflammability, intensively accounting for lightning storms and strikes, distributing and efficiently using the fire protection force, reducing elapsed time for discovery and attack, intensive fire prevention, tactics and tools of suppression, and many others. Gisborne's dream of a means for predicting fire danger remained at the core of the entire program.

43. Gisborne, "Mileposts of Progress in Fire Control and Fire Research," Journal of Forestry 40 (No. 8, 1942): 597-606.

44. Act of May 22, 1928 (45 Stat. 699).

45. Budgets are presented in the Annual Reports for the entire period.

46. Laboratory construction and Gisborne's arguments for it are detailed in the Annual Reports. Brown, in the 1976 interview, provided an extensive account of Gisborne's preoccupation with facility construction, which he regarded as "a waste of an awful lot of energy on the part of a top-notch researcher. Even so, it faithfully reflected Harry Gisborne. Without him, it just wasn't the Priest River Station anymore." In his 1931 Annual Report, Gisborne listed the major recognized factors influencing fire behavior as "...temperature, atmospheric humidity, wind, topography, and amount of inflammability of fuels." He continued, "In a problem rendered complex by so many natural variables it is often least costly and quickest to take the problem into the laboratory where each factor can be controlled and the results checked by repeated trials with several factors held constant. This method is applicable to fire problems dealing with rate of spread and similar items, and a wind tunnel in which fires can be created, using particular fuels arranged on simple topographic models with air temperature, humidity, and wind velocity and direction controlled, will permit the determination of fire behavior principles which can be intelligently checked on going fires." The report becomes more specific on the wind tunnel, stating that "This labo-

ratory should consist of a wind tunnel at least 10 to 12 feet in diameter to accommodate fuels of definite moisture content, at any desired slope, wind velocity, as desired, and the air held at any selected temperature and humidity. The effect of ridges and canyons on local winds could be determined so that forecasts can be made more accurately. This need should be given high priority; nationwide significance may place this project at the Madison Laboratory." The small portable wind tunnel actually built under Gisborne's direction was about 10 or 12 feet long, 2-1/2 feet wide in the test section, bell-shaped at both ends, accessible at the center for instrument placement, and had a two-bladed, hand-carved propeller driven by a variable-controlled electric motor. The tunnel was housed in a large extra-deep basement room (B-17) of the Federal Building in Missoula, which contained a large permanently mounted electric d.c. motor complete with d.c. convertor and controls and a separate chimney to dispel smoke from experimental fires, though it was never used for that purpose. George Weyerman, in a 1976 letter to the author, described the small tunnel and its long use. Ben Meier, superintendent of the Missoula Federal Building, provided details on the design and use of laboratory rooms in the building. Other developments, such as the meteorological tower and weather instrumentation, are discussed below.

47. Jemison interview.

48. Personnel in Gisborne's program are listed in the Annual Reports throughout the period.

49. Crocker interview; Charles A. Wellner, interview with the author, February 4, 1976. Not all victims of Gisborne's tongue were so understanding. In 1941, he permitted his employees to rate him in confidence even as he rated them. He received comments like these: "He is inclined to be a little quick-tempered and overly hasty in reprimanding some of his employees, particularly in view of his failing to give adequate supervision and inspection." "I refer to his caustic nature, being extremely critical of his own work as well as that of others. He is impatient when others fail to meet the high standards he has set up." "His sarcasm may be a stimulating barb to those who are his equals or superiors in rank, but he should be careful how he uses it on his subordinates." "In my case, sarcasm does not lead to a mental state conducive to effective work." Gisborne Papers.

50. Hayes interview.

51. Hayes interview.

52. Barrows, Jemison, and Hayes interviews.

53. Tebbe interview.

54. Note in Gisborne's handwriting dated June 2, 1941, Gisborne Papers.

55. Note dated March 8, 1945, Gisborne Papers. Gisborne maintained his severe attitude throughout his days. In a letter to Senator Mike Mansfield, December 27, 1943, Gisborne Papers, he protested the trend toward granting 30 days' vacation with pay for Federal employees, as well as the establishment of Federal employee unions. In a memorandum to his employees, March 3, 1949, Gisborne Papers, he objected to their joining in the regular coffee breaks established at the Station.

56. Jemison interview. Should it seem curious that an irascible boss could also impel his employees to excellence and earn their undying affection, one might recall the more famous example of Admiral Hiram Rickover, who drove his nuclear researchers unmercifully in the years after World War II, only to gain their intense devotion.

57. Jemison interview. Jemison said that sticks were laid on the ground and

elevated on wire brackets to simulate branchwood fuels in various positions. The first measurements did not allow for weight loss due to weather; subsequently, the sticks were dried and recalibrated each winter. Although data from the 1- and 2-inch sticks were never published, they were used in other research. Measurement of them ceased about 1936, and only the 1/2-inch sticks were used to represent branchwood in Gisborne's fire-danger rating system.

58. Jemison interview. William G. Morris, interview with the author, February 13, 1976; Richard E. McArdle, letter (commenting on the draft of this history) to the Forest Service History Section, May 29, 1979. McArdle and his associates had begun experimenting with natural branchwood as early as 1929, then turned to square sticks. By 1932 or 1933, they had conceived the idea of multiple sticks pinned together--an idea that Gisborne adopted, although he was critical of the square sticks, which he did not believe suitably represented natural branchwood. The Pacific Northwest Station had 100-gram triplets in use in the field by 1933, and 400-gram triplets of 2-inch sticks in the field by 1935. They, too, decided that 1/2-inch cylinders were more successful and dropped the larger sizes. The 1942 100-gram quadruplet was the product of agreement based on the combined experience of the Northern Rocky Mountain and Pacific Northwest Stations.

59. Variously attributed. Unless otherwise indicated, the following account of the origins of the meter is based on the Jemison interview. However, there is some discrepancy in dates. Jemison and the Annual Reports place the origins of the meter in 1931, and the issue of the first ones to the field in 1932 (the latter is verified by other documentary sources). However, Gisborne's hand-lettered first Model 1 meter, Gisborne Papers, has the date "1930" written on it in his handwriting. He may actually have begun working on the idea privately before 1931, or erroneous dating may have been added late in his life. The preponderance of the evidence suggests late 1931 or early 1932 as the birthdate of the meter, however, and I follow that in the text.

60. Annual Report, 1931. Gisborne had provided the first summary of this information in "Measuring Forest Fire Danger," 1928 (see note 28). The 5-year accumulation of records collected after those used in that report provided more information that could be used to help standardize expansion of the forest protective organization.

61. In the first meter, according to Jemison, the effects of wind and slope, although the most important, were the weakest factors because the data available were meager and came mostly from studies of large-fire behavior.

62. Northern Region News, July 6, 1932. The parks were Glacier and Yellowstone.

63. The descriptions, and those following, are taken from the original meters in the Gisborne Papers.

64. Annual Report, 1934.

65. Crocker interview.

66. Jemison interview.

67. Jemison and Crocker interviews. Pyne, Fire History, chapter 5, details the debates and revisions of fire control policies after the Selway fire. The success of the fire-danger rating meter was integral to both new policies.

68. See quotation at the beginning of this chapter, and discussion below. Among Gisborne's many excoriations of the 10 a.m. policy was a memorandum to the Station Director, dated March 11, 1936, Gisborne Papers, in which he stated that the policy made it impossible for Hornby to develop a system of

planning based on "least cost plus damage." Pyne, Fire History, chapter 5, points out that the availability of large crews and budgets during the 1930's may have been the determining reason why a wilderness "let burn" policy for rugged or low-value areas was not adopted. The 10 a.m. policy (also called the "Forester's policy") prevailed because available money and manpower made it possible. Although strongly imbedded, the Service's fire-fighting ethic became increasingly anachronistic over the years--because of budget limitations, advances in ecological science, and the growth of the wilderness systems--but was not abandoned by the Forest Service until the 1970's, some 40 years after it was adopted.

69. Briefly, the meter evolved as follows: Model 4, used from 1935 through 1937, eliminated "number of people in the woods" as a factor, refined the calculation of danger according to date and recent occurrence of lightning, and specified a higher wind class if fuel moisture was less than 5 percent; Model 5, 1938-41 [described in detail in Gisborne, "The Northern Rocky Mountain Fire-Danger Meter No. 5," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 85 (Missoula, Mont., 1938)], returned land clearing as a factor, amended visibility distances for different parts of the Region, scaled fire danger from 1.0 to 7.4 instead of by whole numbers, made technical changes in wind and fuel moisture factors, and listed "action commensurate with fire-danger class"; Model 6, 1942-53, consisted of two meters, a Burning Index (BI) Meter and a Fire-Danger (FD) Meter. The BI Meter, calibrated from 1 to 100, rated the combined effect of calendar date (according to hours of sunshine), relative humidity, 1/2-inch stick fuel moisture, and wind. The FD Meter weighted BI with visibility and lightning. BI was set to the nearest 5 mark; dark-ridge visibility distance replaced small-smoke visibility, and lightning in the recent period was extended to 3 days. Land clearing was again eliminated as a factor. Instead of describing action to take, a paragraph gave an interpretation for practical purposes, emphasizing that BI and FD are relative ratings and that the use of ratings is an administrative matter. Besides the meters, Gisborne began in 1934 to describe relative severity between seasons in terms of "percent of worst possible." "Worst possible" would occur if every day in July and August rated halfway between class 5 and class 6 danger, or 100 percent for average class 5.5. He determined that the 1934 season rated 86 percent of worst possible for the western forests of the Region, and for verification, pointed to the severity of the 1934 fire season. Northern Region News, November 21, 1934.

70. Jemison and Morris interviews.

71. Northern Region News, May 21, 1935, and April 22, 1940. See also Gisborne, "Measuring Fire Weather and Forest Inflammability," USDA Circular 398 (Washington, D.C., 1936).

72. Jemison, "The Significance of the Effect of Stand Density upon the Weather Beneath the Canopy," Journal of Forestry 32 (No. 4, 1934): 446-451; Jemison interview.

73. Jemison, "The Effect of Low Vegetation on the Rate of Spread of Fire in the Northern Rocky Mountain Region," unpublished Master's thesis, Yale University, 1936, and "The Effect of Vegetation on Rate of Spread of Fire," Northern Region News, July 16, 1936; Leon W. Richards, "Effects of Certain Chemical Attributes of Vegetation on Forest Inflammability," Journal of Agricultural Research 60 (No. 12, 1940): 835-838; Jemison interview. Gisborne, "Northern Rocky Mountain Fire-Danger Meter No. 5," said that he had hoped to substitute vegetative readiness for calendar date in his Model 4 meter to make it more sensitive to

seasonal shifts, but did not because the factor could not yet be measured as exactly as others.

74. Jemison, "Climatological Summary for the Priest River Forest Experiment Station, 1912-1931, Inclusive," Northern Rocky Mountain Forest and Range Experiment Station Publication 7 (Missoula, Mont., 1932), and "Beaufort Scale of Wind Force as Adapted for Use on Forested Areas of the Northern Rocky Mountains," Journal of Agricultural Research 49 (1934): 77-82. Jemison, interview, also recounted a story of Gisborne's instrumented observation of the burning of a 10- to 15-acre plot covered by about 15 feet of dead slash and timber near Priest River in 1932 or 1933, during which the heat became so intense that Gisborne was driven from the area. The instruments recorded temperatures passing 1,000° C before they were destroyed, and little was gained from the experiment but the removal of a fire hazard.

75. Jemison interview; letter from Jemison to Frank Harmon, History Section, FS, May 23, 1981.

76. Hayes and Jemison interviews; Annual Report, 1936.

77. Gisborne, "How the Wind Blows in the Forest of Northern Idaho," Northern Rocky Mountain Forest and Range Experiment Station Progress Report (Missoula, Mont., 1941).

78. Annual Reports, 1933 and 1934; Charles F. Marvin, "Air Drainage Explained," Monthly Weather Review 42 (1914); J. A. Larsen, "The Forest Fire Season at Different Elevations in Idaho," Idaho Forester 6 (1924): 19-23, and "Weather Records at Lookout Stations in Northern Idaho," Journal of Forestry 20 (1922): 215-219; Hayes interview.

79. Hayes interview; Hayes, "Variations of Some Fire-Danger Factors with Altitude, Aspect, and Time of Day," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 80 (Missoula, Mont., 1937), "Influence of Altitude and Aspect on Daily Variations in Factors of Forest Fire Danger," USDA Circular 591 (Washington, D.C., 1941), and "Differences in Fire Danger with Altitude, Aspect, and Time of Day," Journal of Forestry 40 (No. 4, 1942): 318-323. The quotation is from the Journal of Forestry article.

80. Hayes interview; Hayes, "The Moisture Content of Large Size Fuels as an Index of Intraseasonal Fire Danger Severity," unpublished Master's thesis, Yale University, 1940; A. P. Brackebusch, "Gain and Loss of Moisture in Large Forest Fuels," Intermountain Forest and Range Experiment Station Publication 173 (Ogden, Utah, 1975).

81. Gisborne, "A Five-Year Record of Lightning Storms and Forest Fires," Monthly Weather Review 59 (No. 4, 1931): 139-150.

82. Jemison and Hayes interviews; Gisborne, untitled essay, Northern Region News, May 14, 1933.

83. Developments in the fire-weather system were a continual subject of discussion in the Annual Reports and the Northern Region News throughout the period, the latter of which carried several commentaries by Gisborne. See also Jemison, Hayes, and Morris interviews, and Whitnah, Weather Bureau, 151-153.

84. Jemison interview. Gisborne's predictions, which he termed "guesstimates," appeared in the Northern Region News during March every year from 1933 through 1948. A number of other people in the Missoula offices entered the prediction sweepstakes, using the same or their own systems, shortly thereafter. The annual predictions were usually greeted with humorous rejoinders and ceased during the wetter years of the 1940's and 1950's.

85. Annual Report, 1932.

86. Annual Report, 1938. Gisborne renewed his call for economic research in the 1939 Annual Report: "This is no longer an academic relation adequately handled by publication of a few technical articles. It is a hard-pressing practical problem of dollars and cents, or rather, thousands and tens of thousands of dollars."

87. Gisborne, "Hornby's Principles of Fire Control Planning," Journal of Forestry 37 (No. 4, 1939): 292-296.

88. Gisborne, "Mileposts of Progress."

89. Annual Reports, 1930 and 1931; Northern Region News, April 30, 1931. Their work was part of a servicewide effort, planned along lines suggested by Show and Kotok in California, to develop a means of comparing the financial needs of the different Regions.

90. Annual Report, 1931, includes a lengthy discussion of all this. The completed analysis was distributed in mimeographed form to the field in 1932. Thereafter, it guided the direction of fire control planning for several years.

91. Annual Report, 1932, outlines all of this work in some detail.

92. Hornby, "Fire Control Planning in the Northern Rocky Mountain Region," Northern Rocky Mountain Forest and Range Experiment Station Progress Report 1 (Missoula, Mont., 1936). Silcox's memorandum is quoted in Northern Region News, January 21, 1937. The planning had not gone as either Hornby or Gisborne had wished, however, for they ran up against the strict 10 a.m. policy. As Gisborne complained in a memorandum to the Station Director, March 11, 1936, Gisborne Papers, "When Hornby developed his methods of systematic fire-control planning, he was blocked or impeded time after time by existing procedures and attitudes, or by lack of certain procedures. He was forced, against his beliefs, to plan his transportation system for fire needs alone.... Hornby started his planning on the basis of least 'cost plus damage,' but he was then forced to change all of his objectives to make them fit 'control by 10 a.m.' which was and is an uneconomic expression impossible to justify in low value or 'little injury' types of vegetation." Hornby's system was refined by the development by Clarence Sutliff between 1935 and 1938 of "Table X-1-c," which maintained a standard relationship between current fire danger (Hornby's was established on average fire danger) and the percentage of manpower on duty. Annual Report, 1935, and Gisborne, "Mileposts of Progress."

93. Gisborne, "Hornby's Principles."

94. In other fire research work during the period, it is worth noting that Gisborne experimented with aerial bombardment of fires by dropping extinguishing foam in heavy Kraft paper bags from the meteorological tower, and Flint tested dropping various containers and streams of water from airplanes. Neither was successful. Both were small scale and were not followed up. Flint, "Rain from Heaven--At Will," Northern Region News, March 21, 1935; Hayes interview.

95. Memorandum, Gisborne to Clayton S. Crocker, February 24, 1944, Gisborne Papers.

96. During the boom period, Gisborne had a staff of six to eight assistants and joined in the planning work of Hornby and his crew of 20 to 30 assistants. He assumed Hornby's planning work in 1938, without assistants. By the start of the war, he was left with Hayes and two assistants for his regular research work. But in 1942, Hayes transferred to another Station and the assistants went to war. These changes are reported in the Annual Reports and reviewed in a 1945 Gisborne note in the Gisborne Papers. From 1942

to 1945, Gisborne directed Silvics Research as well as Fire Research because of an absence of personnel from the Station. He relied on the Kaniksu National Forest staff to continue taking measurements from instruments at Priest River.

97. The research program is documented in the Annual Reports for the period; unless otherwise indicated, the discussion that follows is based on that source.

98. Annual Report, 1940. This area of research is still being pursued. At the expense of a silvicultural research position, Paul W. Stickel came to the Station in 1940 to continue Lyman's work. But short funds tied him to a desk: he studied only six fires in 1941. In response to a query from the History Section on August 19, 1980, C. Bentley Lyon, in charge of fire control technology, Forest Fire and Atmospheric Science Research Staff, Washington Office, stated that after Lyman's and Stickel's analyses, "mathematical models were developed as a basis for appraising fire spread and intensity in the National Fire-Danger Rating System, for application over broad geographical areas. Current work is aimed at developing cost-effective technology for predicting behavior on specific sites. Fire research has become much more refined since Gisborne's day, and much progress has been made."

99. Annual Reports, 1944 and 1945 (both projects); Lyman, "Principles of Fuel Reduction for the Northern Rocky Mountain Region," Northwest Science 18 (No. 2, 1945): 44-48.

100. Besides the Annual Reports, the conferences are described in the Northern Region News, April 6, 1940, and December 21, 1941. Gisborne had set forth his ideas on an expanded fire research program in a mimeographed "Analysis of the Forest Fire Problem in Regions I, II, III, and IV," issued May 30, 1941, in which he reiterated his economic philosophy of fire control and took another swipe at the 10 a.m. policy.

101. The program and its justification are set forth in the Annual Report, 1944.

102. Memorandum, Gisborne to Arthur A. Brown, May 13, 1941, Gisborne Papers.

103. The Station was organized into divisions in 1937. Then Gisborne's program became part of Gisborne's Division of Forest Protection Research, which eventually included Insect and Disease Control Research. Forest Protection Research merged with Silvicultural Research in 1942 and became the Division of Forest Management, again with Gisborne in charge. In 1949, his new division was renamed Forest Fire Research. These events are reflected in the Annual Reports. Gisborne personally benefited from the growing status of his program through promotions and employment classification changes. He had become a Senior Silviculturist during the 1930's. He was reclassified a Forester in 1947, and Forester (Fire Research) in 1949. Gisborne personnel records, Gisborne Papers. In addition to his other responsibilities, incidentally, Gisborne served as Acting Director of the Station for the last 6 months of 1946, between the death of Melvin S. Bradner and the appointment of Charles L. Tebbe.

104. Barrows interview.

105. The project originated in the wartime association of General Henry H. ("Hap") Arnold, Commander of the Air Force, and the Forest Service's postwar Director of Fire Control, David P. Godwin. Pyne, Fire History, chapter 5, describes the rapid postwar evolution of fire control technology, which was sparked by fascination with wartime advances and the availability of surplus military equipment. See also Barrows interview. Barrows had been a

lieutenant colonel in the 20th Air Force during the war.

106. Northern Region News, July 26, 1946, carried an article describing the program at length. See also Barrows interview. The Air Force planes and personnel were based at Eglin Air Force Base, Florida, and remained in Montana only during the test seasons. The Eglin base was formerly the Choctawhatchee National Forest.

107. Annual Report, 1947; Northern Region News, July 25, 1947; numerous Forest Service and Air Force reports, documents, publicity materials, and press clippings, Gisborne Papers and Forest Service files, Missoula, Montana. Northern Region News reported on the tests and associated public ceremonies throughout the summer. See also Barrows interview. Crocker, in the 1976 interview, blamed conservatives in the Forest Service for killing the project. Brown, in the 1976 interview, however, related a meeting at the Pentagon where the message was delivered that "orders from above," presumably from the Secretary, ended it.

108. Memorandum, Gisborne to the Station Director, August 12, 1947, Gisborne Papers.

109. Annual Report, 1946. The entire program is recounted in the Annual Reports for 1946 through the early 1950's.

110. Annual Reports, 1947, 1948, 1949, and 1951. By 1951, as a result of Barrow's work (supported ultimately by additional personnel detailed by the Regional Office to work on it), rate of spread was redefined. It was presented in key form for seven cover types, and included a "flash" fuel rating for grass. As modified by time of day and position on a slope (from Hayes' altitude and aspect study) and Burning Index, these data offered a prediction of fire behavior through a process that became known as "calculating the probabilities," one of Gisborne's lifelong goals.

111. Annual Report, 1947 and 1948; memorandum, Gisborne to Chief of Watershed Management, September 25, 1947, Gisborne Papers. Gisborne's division also gave some minor assistance to equipment and technique development research, including direction of a student, A. L. Haines, who studied tactical principles for aerial operations for a Master's thesis. Annual Report, 1949.

112. Annual Report, 1946.

113. Annual Reports during the period; Gisborne, "Calculating Precipitation Probabilities," The Timberman 49 (No. 10, 1948): 58. Gisborne also synthesized the knowledge he had gained during his career in a lecture for a 1947 fire-boss school, published as "Fundamentals of Fire Behavior," Fire Control Notes 9 (1948): 13-24. It was used in training for many years.

114. Annual Report, 1947.

115. Barrows and Brown interviews; Vincent J. Schaefer, interview with the author, summer 1976; Robert R. Johnson, interview with the author, April 28, 1976. Johnson was the owner and pilot of the C-47 used in 1948, and a long-time aviation contractor for the Forest Service.

116. Holograph memorandum, Gisborne to the files, August 21, 1949, Gisborne Papers. Schaefer, giving considerable credit to Gisborne and Barrows, reported on the project in "The Possibilities of Modifying Lightning Storms in the Northern Rockies," Northern Rocky Mountain Forest and Range Experiment Station Paper 19 (Missoula, Mont., 1949). The work continued into the 1950's and was formally established as Project Skyfire in 1953.

117. Memorandum, Crocker to Gisborne, May 25, 1948, Gisborne Papers. The

Gisborne Papers and other records provide a mass of documentation on Gisborne's caustic criticisms of the Weather Bureau. See his memoranda to the files, October 14, 1947; to Crocker, May 15, 1948, and to the Station Director and Regional Forester, August 17, 1948, as typical examples. On the other hand, he could be objective, as in his memorandum offering a "Statement of Policy and Practice," October 29, 1946, and an article on "Opportunities for Improving the Fire Weather Forecasts in the Northern Region," Northern Region News, March 4, 1948. Beginning in 1946, Gisborne began a campaign to have a surplus weather search radar erected on Mt. Spokane. The equipment was finally delivered and dedicated at a point in the Missoula area in 1961.

118. It was one of a number of professional honors that he received during his career. Among others were his elections as Fellow by the Society of American Foresters and the American Association for the Advancement of Science. Gisborne was also a member and officer of a number of professional and scientific organizations. Gisborne Papers.

119. Memorandum, Gisborne to Tebbe, March 3, 1948, Gisborne Papers.

120. Gisborne, longhand note dated June 3, 1941, Gisborne Papers.

121. The Mann Gulch tragedy was documented in a Board of Review report dated September 29, 1949, and an extensive number of other reports and memoranda, many of them to or from Gisborne, in the Gisborne Papers and Forest Service files, Missoula, Montana. The events also received a great deal of attention from the local and national press. The complete records of the incident are deposited at the Washington National Records Center and are well represented in Forest Service office files in Missoula, Montana, and Washington, D.C. Although the matter is tangential to this history, the deaths of the men were due partly to the behavior of the fire and partly to their inexperience: they panicked and ran from the relative safety of a burned-over spot against a verbal order from their crew leader.

122. Tebbe interview. Nearly everyone interviewed for this history expressed awareness of Gisborne's heart condition beginning in the 1930's and its increasing severity. Hayes, in the 1976 interview, recalled chastising Gisborne about his incessant cigarette smoking, but without effect. Tebbe said that he once ordered Gisborne not to climb the meteorological tower, but he refrained only when Tebbe was present.

123. J. Robert Jansson, who was the Ranger accompanying Gisborne, reported the circumstances of his death in a memorandum to Tebbe, November 10, 1949, and in a statement for insurance purposes, November 18, 1949, Gisborne Papers. Gisborne had planned to retire 4 years later, when he was 60, after writing a roundup of data on fire behavior and fire control (memo to Tebbe dated March 24, 1948, Gisborne Papers).

124. Tebbe interview. Tebbe, Crocker, and a Forest Service pilot performed the rites on May 26, 1950. Also at Gisborne's request, his personal and professional papers passed into the custody of Wellner, with a view to their ultimate preservation. Wellner interview. They are now part of the Gisborne Papers in the University of Montana Library Archives.

125. Northern Region News, June 9, 1950, and July 13, 1951. The mountain previously had no official name but was commonly called Looking Glass Mountain after the lookout at its peak. The name Gisborne Mountain was ordained by the US Board on Geographic Names.

126. This interpretation partly follows that of Pyne, Fire History, chapter 8.

Appendix I: Chronological List of the Works of Harry T. Gisborne

"Weather Records Applied to the Fire Problem," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 34 (Missoula, Mont., 1922).

"Preliminary Results of the Study of Lightning in Relation to Forest Fires," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 42 (Missoula, Mont., 1923).

"Objectives and Results of Fire Studies in Northern Idaho," unpublished (1923).

"Moisture Content of Fuels as an Index of Fire Danger," Lumber World Review 45 (1923): 44.

"A Million Dollars a Year for Smoke," The Timberman 24 (No. 7, 1923): 33-34.

"Lightning Storms in Relation to Forest Fires in District One--Results of Study in 1922," unpublished (1923).

"Importance of Duff Moisture Content in the Forest Fire Problem," Journal of Forestry 21 (1923): 807-809.

"Use of Moisture Content of Duff as a Measure of Fire Danger," The Timberman 25 (1924).

"Regarding Limit of Visibility," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 51 (Missoula, Mont., 1924).

"Moisture Content of Fuels as an Index of Fire Danger," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 46 (Missoula, Mont., 1924).

"Lightning in Relation to Forest Fires in the Inland Empire," unpublished (1924).

"Lightning Fires and Storms in the Northern Rocky Mountains," The Timberman 25 (1924).

"Using Weather Forecasts for Predicting Forest Fire Danger," Monthly Weather Review 53 (1925): 58-60.

"Some Rainfall Cycles for the Western Slope of the Northern Rocky Mountains," unpublished (1925).

"Forest Service Inventions Becoming Numerous," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 59 (Missoula, Mont., 1925).

"The Effect of Weather on the Inflammability of Forest Fire Fuels," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 58 (Missoula, Mont., 1925).

"Cyclic Fluctuations of Rainfall in the Northern Rocky Mountains," American Meteorological Society Bulletin (August-September 1925): 131-132.

"Another Effect of High Relative Humidity on Forest Fires," USDA Forest Service, Service Bulletin 9 (No. 27, 1925): 2-3.

"The Trend of Forest Fire Research in Northern Idaho," Idaho Forestry 8 (1926): 16-18, 38.

"More Forest Inventions," American Forests and Forest Life 32 (No. 390, 1926): 345.

"Meteorology and Forest Fire Protection," Forestry Kaimin (1926): 29.

"Lightning and Forest Fires in the Northern Rocky Mountain Region," Monthly Weather Review 54 (No. 7, 1926): 281-286.

"Forest Fire--A Mother of Invention," American Forests and Forest Life 32 (No. 389, 1926): 265.

"Progress Report on Behavior of Fires," unpublished (1927).

"The Objectives of Forest Fire-Weather Research," Journal of Forestry 25 (No. 4, 1927): 452-456.

"Meteorological Factors in the Quartz Creek Forest Fire," Monthly Weather Review 55 (No. 2, 1927): 1-4.

"An Investigation of Lightning Storms in the Northern Rocky Mountain Region," Northwest Science 1 (No. 4, 1927): 72-73.

"The Importance of Lightning as a Cause of Forest Fires," unpublished (1927).

"The Field of Forest Fire Research," unpublished (1927).

"Protection Costs and Damages Affected by Brush Disposal Method," unpublished (1928).

"Measuring Forest Fire Danger in Northern Idaho," USDA Miscellaneous Publication 29 (Washington, D.C., 1928).

"Lightning From a Clear Sky," Monthly Weather Review 56 (No. 3, 1928): 108.

"Forest Gas," Journal of Forestry 26 (1928): 1063-1064.

"Forest Forces Study Lightning as Fire Menace." New York Herald Tribune, June 24, 1928.

"Early and Modern American Fire Studies," Journal of Forestry 26 (1928): 128-129.

"Lightning in Relation to Forest Fires in the Inland Empire," unpublished (1929).

"The Industrial Revolution and Forestry," Journal of Forestry 27 (1929): 347-351.

"A Forest Fire Explosion," Frontier Magazine 10 (No. 1, 1929): 13-16 (University of Montana).

"The Complicated Controls of Fire Danger," Journal of Forestry 27 (No. 3, 1929): 311-312.

"Brush Disposal," The Timberman 30 (No. 3, 1929): 194.

"Atmospheric Indices of Forest Inflammability," unpublished (ca. 1929).

"How Dangerous Are Dry Lightning Storms?" Northwest Science 4 (No. 1, 1930): 20-22.

"Forest-Fire Research," Science Monthly 31 (1930): 76-80.

"Fire Damage and Degree of Protection," USDA Forest Service, Service Bulletin 14 (No. 30, 1930): 4.

"The Scheme of Forest Fire Control," Journal of Forestry 29 (No. 7, 1931): 1077-1079.

"Phases of the Fire Problem," American Lumberman (1931).

"Periodic Fluctuations in Rainfall in the Inland Empire," unpublished (1931).

"Not To Be Overlooked," West Coast Lumberman 58 (No. 3, 1931): 70.

"Lightning on the Lookouts," American Forests 37 (No. 9, 1931): 515-518, 574-575.

"A Five-Year Record of Lightning Storms and Forest Fires," Monthly Weather Review 59 (No. 4, 1931): 139-150.

"The Character of the 1931 Fire Season in the Northern Rocky Mountain Region," mimeographed (1931).

"Forest Fire Control Objectives and Practices in the Northern Rocky Mountain Region, Based on Forest Fire Reports for the National Forests, 1921-1930, Inclusive," (with Lloyd G. Hornby), unpublished (1931).

"The Wood Cylinder Method of Measuring Forest Inflammability," Journal of Forestry 31 (No. 6, 1933): 673-679.

"Progress in Forest Fire Research," Northwest Science 7 (No. 3, 1933): 71-76.

"Lightning and Forest Fires," Pulp and Paper of Canada 34 (No. 6, 1933): 327-329.

"Inexpensive Wind Gauge," USDA Forest Service, Service Bulletin 17 (No. 25, 1933): 3-4.

"Deadwood Lying on Duff Drier Than in Air," Journal of Forestry 31 (No. 8, 1933): 979-980.

"Woodlands Cut by the 'Selection Method' Less Liable to Fire Damage," Yearbook of Agriculture, 1934 (Washington, D.C., 1934), 376-378.

"Paired Minimum Temperatures as Indices of Fair or Foul Weather," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 65 (Missoula, Mont., 1934).

"Memorandum Concerning Spot Fires," unpublished (1934).

"Measuring Forest Fire Danger," Quarterly of the National Forest Protective Association (April 1934).

"Where is the Forest Meteorologist?" Michigan Forests 16 (1935).

"Shaded Fire Breaks," Journal of Forestry 33 (1935): 86-87.

"The Rating of Forest Fire Danger," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 67 (Missoula, Mont., 1935).

"The Character of the 1935 Fire Season in Region One," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 73 (Missoula, Mont., 1935).

"Recent Progress in Forest Fire Research," unpublished (1936).

"The Principles of Measuring Forest Fire Danger," Journal of Forestry 34 (No. 8, 1936): 786-793.

"Measuring Fire Weather and Forest Inflammability," USDA Circular 398 (Washington, D.C., 1936).

"Techniques of Duff Hygrometer Calibration," Journal of Forestry 35 (No. 8, 1937): 736.

"Some General Principles of Rating Fire Danger," Fire Control Notes 1 (No. 2, January 1937): 53-56.

"Fire Research at the Priest River Branch Experiment Station," unpublished (1937).

"The Northern Rocky Mountain Fire Danger Meter No. 5," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 85 (Missoula, Mont., 1938).

"A Lesson for Fire Control," USDA Forest Service, Service Bulletin 22 (No. 4, 1938): 3.

"Determination of Normal Fire Danger," American Forests 29 (1938): 27-31.

"The Character of the 1937 Fire Season in Region One," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 82 (Missoula, Mont., 1938).

"The Character of the 1938 Fire Season in Region One," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 87 (Missoula, Mont., 1938).

"Short-Term Forest Workers," Fire Control Notes 3 (No. 3, July 1939): 27-30.

"Hornby's Principles of Fire Control Planning," Journal of Forestry 37 (No. 4, 1939): 292-296.

"Forest Pyrology," Science Monthly 49 (1939): 21-30.

"Fire-Danger Meter Design," Utah Juniper (1939): 5-11.

"Determination of Small-Smoke Visibility Distance with a Dark-Ridge Visibility Meter, Objective Type," unpublished (1939).

"The Character of the 1939 Fire Season in Region One," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 93 (Missoula, Mont., 1939).

"Comparison of Intensive Versus Limited Forest Fire Control Action," Northern Rocky Mountain Forest and Range Experiment Station Research Note 10 (Missoula, Mont., 1940).

"Wood for Fuel," unpublished (1941).

"Results and Trends at the Northern Rocky Mountain Forest and Range Experiment Station," delivered to the Northwest Scientific Association Meeting, December 30, 1941, unpublished (1941).

"The New Trend in Fire Control," Michigan Forests (1941): 16-18, 57.

"How the Wind Blows in the Forest of Northern Idaho," Northern Rocky Mountain Forest and Range Experiment Station Progress Report (Missoula, Mont., 1941).

"Character of the 1940 Fire Season in Region One," Northern Rocky Mountain Forest and Range Experiment Station Research Note 13 (Missoula, Mont., 1941).

"An Analysis of the Forest Fire Problem in Regions I, II, III, and IV, May 30, 1941," mimeographed (1941).

"New Facts on Lightning," Northern Rocky Mountain Forest and Range Experiment Station Research Note 24 (Missoula, Mont., 1942).

"Mileposts of Progress in Fire Control and Fire Research," Journal of Forestry 40 (No. 8, 1942): 597-606.

"From Lumbering to Woodalurgy," unpublished (1942 or 1943).

"Fire Control and Fire Research," Pulp and Paper Magazine of Canada 44 (1942): 749-752.

"Certain Persons," unpublished (1942).

"Burn Wood, But Choose the Right Kind, If You Can," unpublished (1942).

"Sociological Shackles on Forestry," Ames Forester (1943): 23-28.

"Chemical Fireproofing of Cured Grass," Northern Rocky Mountain Forest and Range Experiment Station Research Note 28 (Missoula, Mont., 1943).

"The Challenge to the Society of American Foresters," Journal of Forestry 41 (No. 11, 1943): 803-897.

"Slash Burns Well at B.I. 10 to 20," Northern Rocky Mountain Forest and Range Experiment Station Research Note 35 (Missoula, Mont., 1944).

"An American Forestry for the Americas," unpublished (1944).

"Critical Fire Season Indicated for 1945 in the Northern Rocky Mountain Region," Northern Rocky Mountain Forest and Range Experiment Station Research Note 36 (Missoula, Mont., 1945).

"Forest Research--An Opportunity Grasped or Neglected?" unpublished (1946).

"The Business, Science, and Financing of Forest Fire Control," unpublished (1946).

"A Forest Fire Research Program for the Western States," unpublished (1947).

"Wood for Fuel," unpublished (1948).

"Fundamentals of Fire Behavior," Fire Control Notes 9 (No. 1, January 1948): 13-24.

"Dry Ice to Make Rain and Stop Lightning," Proceedings of the Thirty-Ninth Annual Meeting of the Western Forestry and Conservation Association (Victoria, B.C., 1948).

"Calculating Precipitation Probabilities," The Timberman 49 (No. 10, 1948): 58.

"Minimum Rate Fire Insurance," Northern Rocky Mountain Forest and Range Experiment Station Research Note 72 (Missoula, Mont., 1949).

"The Fire in the Fireplace," unpublished (194[?]).

"Tests Show Cigar and Cigarette Stubs Come Down Hot," Fire Control Notes 11 (No. 2, April 1950): 28-29.

"Forest Protection," chapter 2 of Fifty Years of Forestry in the U.S.A. (Washington, D.C.: Society of American Foresters, 1950).

Appendix II: Works of Others During the Gisborne Era

Anonymous. "Origins of Historic Fires," Pulp and Paper Magazine of Canada 49 (No. 9, 1947): 127-128.

Barrows, Jack S. "The Aerial Bombing Project," paper delivered at the 39th annual meeting of the Western Forestry and Conservation Association, Victoria, B.C. (1948).

Barrows, Jack S. "Forest Fires in the Northern Rocky Mountains," Northern Rocky Mountain Forest and Range Experiment Station Paper 28 (Missoula, Mont., 1951).

Barrows, Jack S. "Fire Behavior in Northern Rocky Mountain Forests," Northern Rocky Mountain Forest and Range Experiment Station Paper 29 (Missoula, Mont., 1951).

Beals, E. A. "The Value of Weather Forecasts in the Problem of Protecting Forests from Fire," Monthly Weather Review 42 (No. 2, 1914): 111-119.

Brackebusch, A. P. "Gain and Loss of Moisture in Large Forest Fuels," USDA Forest Service Research Paper INT-173 (Ogden, Utah, 1975).

Buck, C. C., and Hughes, J. E. "Solvent Distillation Method for Determining the Moisture Content of Forest Litter," Journal of Forestry 37 (1939): 645-651.

Burrill, M. F. "Weather and Fires From the Standpoint of the Meteorologists," Journal of Forestry 25 (1927): 467-472.

Byram, George M. "A Plains Haze Meter," Journal of Forestry 38 (1940): 401-403.

Byram, George M. and Jemison, George M. "Some Principles of Visibility and Their Application to Forest Fire Detection," USDA Forest Service Technical Bulletin 954 (Washington, D.C., 1948).

Ceast, P. R., and Stickel, Paul W. "Solar Radiation and Relative Humidity in Relation to Duff Moisture and Forest Fire Hazard," Monthly Weather Review 57 (1929): 466-468.

Clapp, Earle. "A National Program of Forest Research," processed (Washington, D.C., 1926).

Crocker, Clayton S. "What Rated Fire Danger Means in Region 1," Fire Control Notes 1 (No. 2, January 1937): 57-60.

Crocker, Clayton S. "Dividends from Fire Control Planning," The Timberman 42 (No. 2, 1940): 20, 22, 26.

Dieterich, J. H. "Selected and Annotated Bibliography on Fire Behavior, Fire Effects, and Fire Weather, 1940-51," unpublished Master's thesis, University of Washington, (1952).

DuBois, Coert. "Systematic Fire Protection in the California Forests" (Washington, D.C., 1914).

Fahnestock, G. R. "Correction of Burning Index for the Effects of Altitude, Aspect, and Time of Day," Northern Rocky Mountain Forest and Range Experiment Station Research Note 100 (Missoula, Mont., 1951).

Flint, Howard R. "Various Aspects of the Insect Problem in the Lodgepole Pine Region," Northern Rocky Mountain Forest and Range Experiment Station Research Note 54 (Missoula, Mont., 1951).

Flint, Howard R. "Fire Resistance of Northern Rocky Mountain Conifers," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 61 (Missoula, Mont., 1925).

Flint, Howard R. "Characteristics Influencing Fire Resistance of Northern Rocky Mountain Conifers," Forest Worker (September 1925): 22-23.

Flint, Howard R. "Fire as a Factor in the Management of North Idaho National Forests," Northwest Science 4 (No. 1, 1930): 12-15.

Forbes, R. D. "Science in Fire Control," Journal of Forestry 36 (1938): 841-843.

Guthrie, John D. "Historic Forest Fires of America," American Forestry 49 (1943): 290-294, 316-317.

Haig, I. T. "Fire in Modern Forest Management," Journal of Forestry 36 (1938): 1045-1049.

Haines, A. L. "A List of Annotated References for Use in Fire Behavior Research," processed, University of Montana (1949).

Hall, A. G. "Radar and Fire Weather," American Forests 53 (1947): 357.

Hanson, P. D., and Tebbe, Charles L. "Aerial Bombing--A New Approach to Forest Fire Control," mimeographed (1947).

Hawley, R. C., and Stickel, Paul W. Fire Protection. 2nd ed. New York, 1948.

Hayes, G. Lloyd. "Don't Let a 'Normal' Deceive You," USDA Forest Service, Service Bulletin 19 (No. 17, 1935): 4.

Hayes, G. Lloyd. "Variations of Some Fire Danger Factors with Altitude, Aspect, and Time of Day," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 80 (Missoula, Mont., 1937).

Hayes, G. Lloyd. "The Moisture Content of Large Size Fuels as an Index of Intraseasonal Fire Danger," unpublished Master's thesis, Yale University (1940).

Hayes, G. Lloyd. "Influence of Altitude and Aspect on Daily Variations in Factors of Forest Fire Danger," USDA Circular 591 (Washington, D.C., 1941).

Hayes, G. Lloyd. "Reliability of the Forest Service Type Rain Gauge," Monthly Weather Review 70 (1942): 267-268.

Hayes, G. Lloyd. "A Discussion of Hygrographs," Northern Rocky Mountain Forest and Range Experiment Station Research Note 25 (Missoula, Mont., 1942).

Hayes, G. Lloyd. "Differences in Fire Danger with Altitude, Aspect, and Time of Day," Journal of Forestry 40 (No. 4, 1942): 318-323.

Hayes, G. Lloyd. "Where and When to Measure Forest Fire Danger," Journal of Forestry 42 (No. 10, 1944): 744-751.

Hayes, G. Lloyd. "A Method of Measuring Rainfall on Windy Slopes," Monthly Weather Review 72 (No. 5, 1944): 111-114.

Hayes, G. Lloyd. "Fire Danger and Forest Fires," Southern Lumberman 172 (No. 2154, 1946): 52-43.

Hayes, G. Lloyd. "Forest Fires and Sea Breezes," Fire Control Notes 8 (Nos. 2 and 3, April and July 1947): 30-33.

Hayes, G. Lloyd. "Forest Fire Danger,"

Yearbook of Agriculture, 1949 (Washington, D.C., 1949): 493-498.

Hoffman, J. V. "How Fires Destroy Our Forests," American Forests 26 (No. 318, 1920): 329-336.

Hoffman, J. V. and Osborne, W.B., Jr. "Relative Humidity and Forest Fires," pamphlet issued by Western Forestry and Conservation Association (Portland, Oreg., July 1923), 16 pp.

Hornby, Lloyd G. "Fuel Type Mapping in Region One," Journal of Forestry 33 (No. 1, 1935): 67-72.

Hornby, Lloyd G. "Fuel Type Mapping: Its Relation to Forest Fire Control Planning," Northwest Science 10 (No. 3, 1936): 3-7.

Hornby, Lloyd G. "Fire Control Planning in the Northern Rocky Mountain Region," Northern Rocky Mountain Forest and Range Experiment Station Progress Report (Missoula, Mont., 1936).

Jemison, George M. "Meteorological Conditions Affecting the Freeman Lake (Idaho) Fire," Monthly Weather Review 60 (No. 1, 1932): 1-2.

Jemison, George M. "Manpower Placement and Facilities for Fire Control," Journal of Forestry 30 (1932): 626-627.

Jemison, George M. "Drought Not Yet Broken," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 62 (Missoula, Mont., 1932).

Jemison, George M. "Climatological Summary for the Priest River Forest Experiment Station, 1912-1931, Inclusive," Northern Rocky Mountain Forest and Range Experiment Station Publication (Missoula, Mont., 1932).

Jemison, George M. "A Comparison of the Duff Hygrometer and the 1/2-inch Wood Cylinder Methods of Measuring Fuel Moisture," unpublished (1933).

Jemison, George M. "The Significance of the Effect of Stand Density upon the Weather Beneath the Canopy," Journal of Forestry 32 (No. 4, 1934): 446-451.

Jemison, George M. "Beaufort Scale of Wind Force as Adapted for Use on Forested Areas of the Northern Rocky Mountains," Journal of Agricultural Research 49 (1934): 77-82.

Jemison, George M. "Influence of Weather Factors on Moisture Content of Light Fuels in Forests of the Northern Rocky Mountains," Journal of Agricultural Research 51 (No. 10, 1935): 885-906.

Jemison, George M. "The Character of the 1936 Fire Season in Region One," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 77 (Missoula, Mont., 1936).

Jemison, George M. "The Effect of Low Vegetation on the Rate of Spread of Fire in the Northern Rocky Mountain Region," unpublished Master's thesis, Yale University (1936).

Jemison, George M. "Loss of Weight of Wood Due to Weathering," Journal of Forestry 35 (No. 5, 1937): 460-462.

Jemison, George M. "Bolts From the Blue," American Meteorological Society Bulletin 21 (No. 9, 1940): 345-350.

Jemison, George M. "The Measurement of Forest Fire Danger in the Eastern United States and Its Application in Fire Prevention and Control," Appalachian Forest Experiment Station Technical Note 50 (Philadelphia, Pa., 1942).

Jemison, George M. "Forest Fire Danger

Indexes," Journal of Forestry 42 (1944): 261-263.

Kotok, E. I. "Fire: A Problem in American Forestry," Science Monthly 31 (1930): 450-452.

Larsen, J. A. "Wind and Its Relation to Forest Fires," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 7 (Missoula, Mont., 1921).

Larsen, J. A. "Sunshine and Air Temperature in Relation to Forest Fires," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 9 (Missoula, Mont., 1921).

Larsen, J. A. "Relative Humidity of the Atmosphere and Its Relation to the Fire Problem," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 6 (Missoula, Mont., 1921).

Larsen, J. A. "Precipitation in Relation to Forest Fires," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 15 (Missoula, Mont., 1921).

Larsen, J. A. "Weather Records at Lookout Stations in Northern Idaho," Journal of Forestry 20 (1922): 215-219.

Larsen, J. A. "The Smokey Trail," American Forests 29 (1923): 394.

Larsen, J. A. "Natural Reproduction on Single and Double Burns in Northern Idaho," Northern Rocky Mountain Forest and Range Experiment Station Applied Forestry Note 52 (Missoula, Mont., 1924).

Larsen, J. A. "Dust Storms of Northern Idaho and Western Montana," Journal of Forestry 22 (No. 5, 1924): 576-577.

Larsen, J. A. "The Forest Fire Season at Different Elevations in Idaho," Monthly Weather Review, 53 (No. 2, 1925): 60-63, reprinted from Idaho Forester 6 (1924): 19-23.

Larsen, J. A. "Natural Reproduction After Forest Fires in Northern Idaho," Journal of Agricultural Research 31 (No. 12, 1925): 1177-1197.

Larsen, J. A. "The Study of Natural Reproduction on Burned Forest Areas," Journal of Forestry 26 (1928): 332-337.

Larsen, J. A. "Fires and Forest Succession in the Bitterroot Mountains of Northern Idaho," Ecology 10 (No. 1, 1929): 67-76.

Larsen, J. A. "Forest Types of the Northern Rocky Mountains and Their Climatic Controls," Ecology 11 (No. 4, 1930): 631-672.

Larsen, J. A. "Early Researches in the Relations of Forest Fires and Unusual Weather Conditions, Humidity, Duff Moisture, and Inflammability," Iowa State University Journal of Science 22 (No. 4, 1948).

Larsen, J. A. and Delavan, C. C. "Climate and Forest Fires in Montana and Northern Idaho, 1909-1919," Monthly Weather Review 50 (No. 2, 1922): 55-68.

Loveridge, E. W. "Countrywide Forest Fire Weather Hazard Index," Journal of Forestry 33 (1935): 379-384.

Lyman, C. K. "Principles of Fuel Reduction for the Northern Rocky Mountain Region," Northwest Science 18 (No. 2, 1945): 44-48.

Lyman, C. K. "Slash Disposal as Related to Fire Control on the National Forests of Western Montana and Northern

Idaho," Journal of Forestry 45 (1947): 259-262.

McArdle, Richard E., Matthews, Donald N. "Fire Research Issue: New Instruments for Measuring Fire Danger; Fire Detection Studies; Fuel Inflammability Studies; Lightning Fire Studies; Fire Damage Studies," Pacific Northwest Forest Experiment Station Research Note 15 (Portland, Oreg., November 15, 1934).

Marvin, Charles F. "Air Drainage Explained," Monthly Weather Review 42 (No. 10, 1914).

Morris, William G. "What is 'Average Bad'?" Fire Control Notes 3 (No. 3, July 1939): 25-26.

Morris, William G. "Comparison of Wind Velocity Measurements," Fire Control Notes 6 (No. 1, January 1942): 25-27.

Morris, William G. "Effect of Weathering on Accuracy of Fuel Moisture Indicator Sticks in the Pacific Northwest," Pacific Northwest Forest and Range Experiment Station Research Note 171 (Portland, Oreg., 1950).

Peiffer, A. W. "Evolution of the Fire Danger Meter," American Forests 56 (No. 4, 1950): 12-13.

Redington, P. G. "What Is the Truth? Forest Service and Stuart Edward White Agree to Study Forest Fire Damage," Sunset Magazine 44 (No. 6, 1920): 56-58.

Richards, L. W. "Effects of Certain Chemical Attributes of Vegetation on Forest Inflammability," Journal of Agricultural Research 60 (No. 12, 1940): 833-838.

Schaefer, Vincent J. "The Possibilities of Modifying Lightning Storms in the Northern Rockies," Northern Rocky Mountain Forest and Range Experiment Station Paper 19 (Missoula, Mont., 1949).

Shallenberger, G. D., and Little, Edward. "Visibility through Haze and Smoke, and a Visibility Meter," Journal of the Optical Society (April 1940).

Shames, Leo. "Measurements of Forest Fire Danger," Science 88 (No. 2287, 1938): 401-402.

Shank, H. M. "Measure of Forest Fire Danger in Central Idaho," Journal of Forestry 33 (1935): 389-391.

Shoemaker, Theodore. "Held Line Production," Fire Control Notes 1 (No. 4, April 1937): 210-212.

Tilley, W. B. "Fire Danger Rating," West Coast Lumberman 66 (No. 8, 1939): 40-47.

US Air Force, Air Proving Ground Command. "Tactical Evaluation of Aerial Bombing of Fires, Prepared Jointly by Air Proving Ground Command and USDA Forest Service, Northern Rocky Mountain Forest and Range Experiment Station," processed (unpublished, 1947; since declassified).

USDA Forest Service, Aerial Bombing Evaluation Board. "The Aerial Bombing Project," mimeographed (unpublished, 1947).

Weidman, R. H. "Relation of Weather Forecasts to the Prediction of Dangerous Forest Fire Conditions," Monthly Weather Review 51 (No. 11, 1923): 563-564.

Western Forestry and Conservation Association. Western Firefighters Manual 6th ed. Seattle, Wash., 1934.

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