The Aircraft and Its Use in Fire Control

by

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CONTENT

I INTRODUCTION

In any enterprise in which the capital involved is exposed to a force that would destroy it or so render it incapable of yielding an acceptable return, the first step in the management of that capital is to provide a degree of protection for it that will give reasonable assurance of an acceptable rate of return.

Forestry is such an enterprise and fire is the outstanding destructive force.

The question arises, however, as to how intense the control should be. What should be the extent of the fire prevention program? How many men should be required in the regular fire presuppression organization? How much equipment should be required by the regular presuppression organization? What should be the extent of the operational use of this equipment in presuppression work? How many part-time men should normally be employed in fire suppression work? How much equipment should normally be on hand for fire suppression? What should be the extent of the normal operational use of this equipment in fire suppression?

Approaching this problem from the economical standpoint, it may be said that the fire control organization should be of such intensity as to make its cost plus the fire loss equal to the minimum. Then, if fire control is meant to include prevention, presuppression, and suppression, it may be said that the fire control should be of such intensity as to make the costs of prevention, presuppression, and suppression plus the fire loss equal to the minimum.

Therefore, in determining the correct intensity of the fire control, as approached from the economic standpoint, the following four variables must be considered: (1) Prevention cost, (2) presuppression cost, (3) suppression cost, and (4) fire loss.

These variables are all interrelated and interdependent. The extent of each depends upon the respecive intensities that are required of the prevention program, the presuppression program, and the suppression program, as integral parts of the whole, in rendering the objective--cost of control plus the fire loss equal to the minimum. These required intensities vary as different conditions are encountered on different protection areas.

In the final analysis, on each protection area, these required intensities depend upon two determinants. They are: (1) The degree of effectiveness per unit cost of the prevention program, the presuppression program, and the suppression program, assuming that the degree of effectiveness of these programs remains constant; and (2) the overall value per acre of the protection area.

By knowing the degree of effectiveness per unit cost of the above programs and by knowing the overall value per acre of the protection area, the correct intensity of the fire control may be calculated. It must be remembered in these calculations that, in the case of each of the programs, there is a point of diminishing returns beyond which furthur expenditures are not justified by the lessened fire loss.

Therefore, assuming that the degree of effectiveness of the prevention program, the presuppression program, and the suppression program remains constant, on each protection area there are certain definite monetary amounts that may be expended on these programs in order to render the objective--costs of fire control plus fire loss equal to the minimum.

These amounts remain constant as long as the status of the protection area remain constant. There are three ways, however, in which they may be made to change. They are: (1) A change in the physical status of the area, (2) a change in the overall value per acre of the protection area, and (3) a change in the effectiveness with which protection money is used. With reference to the third condition, one way of getting greater effectiveness is through the use of more efficient fire fighting equipment.

It is about this point that this paper is concerned. It is believed that the helicopter and the airplane, as used in both presuppression and suppression, would so increase the effectiveness per unit cost of these programs as to result in a greatly decreased fire loss and, consequently, a very appreciably lessened minimum figure as given in the objective--cost of control plus the fire loss equal to the minimum. It is recognized, however, that aerial transportation becomes economically practicable only where total costs, damages, or both are relatively high.

II THE AIRCRAFT

The Airplane

The first successful airplane was constructed by the Wright Brothers. The first successful flight was made in the year 1903 at Kitty Hawk, North Carolina. It was World War I which witnessed the first great advancement in the improvement in the airplane. World War II rendered further improvement. Today, the airplane represents the acme of mechanical perfection. The jet-propelled machines can fly at supersonic speeds. The large transports can carry cargo measured in tons. The smaller personal aircraft can be operated with the ease of an automobile.

The Helicopter

History - The helicopter emerged from World War II in much the same manner that the airplane emerged from World War I--engineering and development greatly accelerated and performance greatly stepped up.

But the principle of the helicopter is not a recent discovery. Leonardo da Vinci designed a helicopter in the 15th century, but the attempts of Leonardo, like the many others that followed, failed because of the lack of a force powerful enough to lift and propel the machine.

In 1922, Dr. George de Bothezat, a Russian exile, under contract with the United States Army, built a helicopter which made several short but successful flights. The machine did not live up to expectations, however, and the Army abandoned it (1).

Thereafter, for several years, attention in the United States was devoted almost wholly to the autogiro. And, while aeronautical technicians in this country were learning about this machine in various tests, news of vital importance broke in Europe. Unannounced and behind a veil of secrecy, the Germans have flown a helicopter with a success that astounded the aeronautical world (1).

The machine was built by the Focke-Wulf Company. It was flown for the first time in the Spring of 1937 by Ewald Rohlff, a German pilot. It broke all previous records for the vertical flight machine. Later, a woman, Hanna Rasch, flew this machine from Bremen to Berlin at the high speed of sixty-eight miles per hour. This was the first cross country flight of the helicopter (1).

In the United States the first entirely successful helicopter was built by Igor Sikorsky, a Russian-born engineer. In the Spring of 1940 this machine made its first short but highly successful flight in Stratford, Connecticut, with Igor Sikorsky at the controls (2).

The first successful cross country flight by a helicopter in the United States was made in the Spring of 1942 by a Sikorsky-built helicopter, the XR-4. The pilot was C. L. Morris, and the flight was from Stratford, Connecticut to Wright Field, Ohio, with intermediate stops. The average ground speed was 50 miles per hour with strong adverse winds (3).

The helicopter had left the conjectural stage and had become an actuality. And, as stated before, the late war marked great improvement in the helicopter. Currently, there are about 15 companies in the United States who are making helicopters.

Operational Principles - The helicopter has a suitable engine geared directly to a vertical shaft, or shafts, which drives lifting blades rotating in a horizontal plane. These blades and accessorial parts are called the rotor. Movement up and down is determined by the speed of rotation of the rotor and by the degree of pitch of the blades. Movement forward is obtained by tilting the rotor forward. Movement backward is obtained by tilting the rotor backward. Movements to the right or left is obtained by tilting the rotor to the right or left. This does not result in the turning of the helicopter itself, however. The helicopter merely slides sidewise. The operation undertaken in the turning of the helicopter depends upon the rotor system used. In the case of the helicopter using a single main rotor configuration, the pitch of the small tail rotor, which is needed to overcome the torque, is either increased or decreased beyond or below that degree of pitch which is needed to equalize torque reaction, with the turning of the helicopter being the resultant action. In the case of the helicopter using two rotors, either intermeshing or non-intermeshing, in which went the counter-torque tail rotor is not needed, turning is obtained by increasing the degree of pitch of one rotor beyond that of the other rotor. For instance, to turn left the pitch of the right rotor is increased beyond that of the left rotor. There are many variations of this principle. In some cases, the helicopter is turned either partly or entirely by means of rudders as in the airplane.

A forced landing in the event of engine failure is almost as simple in a helicopter as coasting to a stop in an automobile. In case of engine failure, landing is made by autorotation which is the power-off operation of a helicopter in which the helicopter becomes an autogiro. By means of a free wheeling unit the rotor is disengaged from the engine and lift is obtained through the windmilling of the blades (4).

The helicopter smooths out rough air. The whirling canopy of blades sustains? it bites off the worst of the up-and-down movements of air. Gusts striking the helicopter from the side cause a slight swaying, or they may send the nose skittering off course. If the pilot will be content to give the ship its head, usually it will come back on course.(2).

Except in extreme emergency, no aerial pick-up by hoist of personnel should be attempted over mountainous terrain in which the helicopter cannot land. It is probable, under critical conditions that the added weight might be sufficient to pull the aircraft into the brush or undergrowth and cause serious damage (4). As future improvements are made in the helicopter, this situation will doubtlessly change.

Hovering is probably the most important operation of the helicopter. A helicopter is capable of climbing vertically to its hovering ceiling (without ground effect). This is not practical, however, as it places undue strain on ship and engine. Pilots find it easier to climb with forward speed. Hovering between 30 and 300 feet above the ground is considered hazardous, since in the case of engine failure, a successful autorotation landing may not be made. The hovering ceiling (without ground effect) is the maximum density altitude[1] at which the helicopter can maintain altitude with zero air speed (4).

When hovering close to the ground, an air cushion is built up between the rotor and the ground. Usually the main rotor must be within one-half of the rotor diameter of the ground to produce a ground cushion. This cushion provides additional lift and the operation is called hovering with ground effect. Vertical Descents are not normally made except within the ground cushion (4).

Landing Field Requirements - Normal landing and take-off paths for the helicopter are similiar to those for a light airplane, except no run on the ground is required for the helicopter, and the helicopter climbs and descends more steeply. With maximum gross weights, the helicopter travels on take-off from 75 to 100 feet on the ground cushion before it gains sufficient speed to leave the cushion, and climb with translational lift. Upon normal approach for landing, the helicopter's speed is checked and a ground cushion picked up as it comes within 200 to 300 feet of the landing spot. The helicopter is then eased over the spot and let down from hovering to the ground (4).

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[1]Density altitude is that altitude under N. A. C. A. standard air conditions. True altitudes under field air conditions may be converted to the "density altitude" having the same air density. Conversions of true altitudes to density altitudes are based upon the field air conditions, namely, barometric pressure and air temperature. Conversion of pressure altitude to density altitude is based on temperature alone.

In mountainous country spot landing areas located on knolls or ridge tops are most desirable. Open canyon bottom locations are a good second best, while mountain side locations are usually a poor third choice. Since landing approaches and takeoffs should be into the wind, location of spot should be such that the terrain or obstacles in takeoff and landing paths will be suitable without excessive clearing. Cross wind landings and takeoffs can be made, but they become difficult and sometimes hazardous when the wind is gusty and the landing spot is small. If the maximum density altitude of the landing spot is above the hovering ceiling (without ground effect), terrain must slope gently away from the landing spot along the final approach and takeoff paths for a distance of 300 to 500 feet from the center of the spot. This is also desirable, when possible, at all landing spots (4).

Generally, the landing spot should be level and cleared from 150 to 200 feet in diameter. However, for ridge or knoll top landing spots where the terrain drops sharply from the edge and below the level of the spot, and where the density altitude at the spot will never exceed the hovering ceiling without ground effect, the spot should be at least 125 feet long in the direction of landing and takeoff paths, and 75 feet wide. It should be level and cleared to the ground for its full length. No obstruction should be permitted above the level of the spot along the takeoff on landing paths (4).

<u>Delivery of Men and Cargo</u> - Delivery of men to points having density altitude too high to permit landing or hovering close to

the ground can not be made. However, when landing or takeoff can not be made, delivery of cargo suitably packaged can be accomplished by dropping free fall close to the ground or vegetative cover and at very slow speeds. The minimum air speed can be nearly zero when the density altitude is below the hovering ceiling without ground effect, and it will increase about 10 miles per hour per 1000 feet above that ceiling (4).

Leading Helicopters in the United States - Helicopters of different manufacturers of the United States are of widely varying designs. Sikorsky, Firestone, and Bell each use a single main rotor configuration with a torque compensating, yet Bell uses a 2-blade, tilting rotor system, whereas, Sikorsky and Firestone use 3-bladed, articulated blade rotor systems. Platt Le Page and McDonnell use twin 3-bladed rotor systems, with articulated non-intermeshing rotors mounted outboard on either side of the fuselage. Kellet uses a 3-bladed rotor with twin rotors intermeshing near the blade roots. Piasechi uses an articulated 3-bladed twin rotor system, with rotors fore and aft. Hiller and Bendix use 2-or 3-bladed rotors, rigid or articulated, with twin rotors mounted on a single shaft (5).

Many additional design configurations show promise and accordingly are being developed at the present time. But none of these designs show outstanding promise of lowering the average manufacturing cost, or average operating cost, of any class of helicopter. Since single-rotor designs are about 10 percent less expensive than twin-rotor types for equal power, it can be assumed that the most satisfactory avenue for cost reduction will be some revolutionary simplification of design, followed by mass production manufacturing methods. Thus, considering prices of the two helicopters presently certificated by the C. A. A., and now being manufactured for commercial use, Bell's 2-place Model 47 may be considerably reduced from its initial $25,000 figure, and Sikorsky's 4-place S-51 from its $48,500 figure (5).

Cost Factors of the Aircraft

Any individual or organization who owns an aircraft, either airplane or helicopter, is interested in its operating costs. Different operating costs may be catalogued as being: (1) ownership costs, (2) current operating costs, or (3) labor costs.

Ownership Costs - Ownership costs are fixed costs and are based on calender time and continue even when the aircraft is idle. In most cases these expenses will be stated on a yearly basis. Ownership costs include: (1) depreciation, (2) interest on the investment, (3) hangar rental, and (4) insurance.

Depreciation - An aircraft owner buys an aircraft, flies it for a period of time, and then sells it for a price less than that which he originally paid for it. The difference between the initial purchase price and the selling price represents a definite loss of money to the owner and must be considered as a part of his operating expense. It is this expense that is known as depreciation.

The first step that must be taken in determining the depreciation rate of an aircraft is that of deciding upon the period of time that the aircraft is to be utilized before it is to be sold. Then the probable value of the aircraft at the end of this period of time must be estimated. This value is then subtracted from the original selling price. The annual depreciation rate is determined by dividing the resultant by the number of years in the period of time that the aircraft is to be used.

Interest on the Investment - Interest on the investment is a fixed cost item that is often neglected. When an individual,or an organization, purchases an aircraft, he makes an investment. If he does not purchase an aircraft, he will have the money, which could be drawing interest or perhaps could be invested in some profitable enterprise. For example, an individual has $3,000 to buy an airplane. If he does not buy it, he may invest this amount and realize $60 annually, assuming a simple interest rate of 2 per cent. If he uses the money to buy the airplane, he is depriving himself of a possible income of $60 per year. This should be considered as a part of his annual cost of operation. It is important that the owner realize that his loss, therefore his cost, is the interest that he might realize on the amount of the initial investment, and not on the depreciated value of the aircraft (6).

Hangar Rental - Estimation of hangar rental is extremely difficult. The two main factors that determine rental rates are the space occupied by the aircraft and the expense involved in moving it in and out of the hangar (6). In the case of a governmental agency such as the Forest Service, the cost of hangar rental is negligible.

Insurance - The two main types of aviation insurance are aircraft hull insurance, which indemnifies the owner against damage to the aircraft, and liability insurance, which protects him against liability for injuries to passengers or third persons outside the aircraft or for damage to property caused by the aircraft (6).

There are various opinions on the relative importance of these two types of insurance. It appears that liability insurance is the most important to the average aircraft owner because it protects him from possible losses of relatively large sums, whereas, hull insurance protects him only from the loss of that amount which he has invested in his aircraft (6).

It is important that the aircraft owner realize that the costs of insurance are not fixed, but are quite likely to be different for each aircraft and each owner. It is because of this that insurance companies generally state that all forms of aviation insurance may be written only after submission of full particulars. In occupational flying, each risk is individually rated. In especially hazardous types of flying, coverage must be obtained from Lloyd's of London (6).

Current Operating Costs - Current operating costs are variable costs and are based on flight time and, therefore, have a total that varies with the number of hours flown. The costs include: (1) fuel and oil costs, and (2) maintenance and overhaul costs.

<u>Fuel</u> <u>and</u> <u>Oil</u> - Fuel and oil costs are the easiest costs to determine. Both of these costs are closely dependent upon the cruising horsepower of the aircraft. The larger the engine, the more fuel and oil will be used. It is important that cruising horsepower, not rated horsepower, be the basis for fuel and oil cost determination. Cruising horsepower is the power used in normal straight and level flight. It is approximately 60 per cent of rated horsepower (6).

<u>Maintenance</u> <u>and</u> <u>Overhaul</u> - The maintenance and overhaul costs of an aircraft is extremely difficult to predict as they depend upon so many factors.

These costs depend, primarily, upon labor costs. Since labor costs vary from place to place, consequently, maintenance and overhaul costs vary from place to place. In some parts of the country labor is at a premium, and in other parts there is little difficulty involved in locating a licensed mechanic who will inspect or repair an aircraft for reasonable wages (6).

In addition to the variation in wages, there is also a variation in the cost of replacement parts, depending upon the aircraft's location and upon the production status of the aircraft (6). In the case of helicopters, because of the limited production, the cost of replacement parts will be high.

Finally, the cost of maintenance and overhaul depends upon the cruising horsepower of the aircraft and on it weight. The larger, heavier, and more powerful the aircraft, the longer it will take for an inspection. Also, replacement parts are more expensive for larger aircrafts and the time involved in repairs is increased (6).

<u>Labor Costs</u> - Labor costs in the case of the aircraft includes only one item--the wages of the pilot. This cost depends upon the availability of a licensed pilot and the type of work involved. The greater the danger in flying, the greater the pilot's wages, and, consequently, the greater the labor costs.

III THE AIRCRAFT IN FIRE CONTROL

The history of the aircraft in fire control has been the history of a struggle between an idea and its practical application. There was a period, shortly after World War I when fire patrols were flown over the forests of California, that it looked as though the aircraft might become a regular piece of fire control equipment. But the idea soon lost its appeal and was abandoned because of the inadequacy of communication between the ground and the air and the general independability of the aircraft of that day. But later technical improvements in the field of communications and aeronautics made practical the use of the aircraft in fire control activities. During the late thirties, the aircraft was again adopted. Knowledge resulting from World War II has accelerated this movement. Today, the aircraft, both the airplane and the helicopter, is an established price of fire control equipment. "It has won its wings."

There are four separate but definitely related functions for the aircraft to perform in fire control. They are: (1) detection, (2) scouting, (3) transportation of men and cargo, and (4) water and chemical bombing.

<u>Detection</u> - In order to determine the most economical combination of ground and aerial detection, based on per cent of coverage and frequency of observation, Region One in 1945 embarked on an aerial fire control experiment involving some two million acres of

inaccessible forest land. Region One was selected not because it is especially adapted to the practical use of aerial detection, but merely as a basis for illustration. Airplanes were used in this experiment, but the same principles apply for the helicopter, although the figures would differ (7).

In this study, comparisons between aerial and fixed detection were made. The Coeur d'Alene Forest was used as a basis for comparison of the two systems. It is recognized that, as different physiographic conditions are encountered on other forest areas, results would vary from the ones given here for the Coeur d'Alene Forest.

At 40 dollars per hour for flying time (present contracted rate), aerial detection becomes cheaper than fixed detection after ground coverage becomes in access of 73 per cent. In other words, when the required ground coverage is less than 73 per cent, then it is cheaper to use fixed detection. However, when the required ground coverage is more than 73 per cent, then it is cheaper to use aerial detection. At 20 dollars per hour for flying time (a more reasonable cost), the corresponding figure is 39 per cent (7).

This comparison indicates what might be expected if air detection was substituted for the fixed lookout system. However, the most economical method would be a combination of the two. The cost relationship can be determined by observing the point where the cost of fixed detection begins to increase at a faster rate per percent of ground coverage than does the aerial detection.

Using the 40 dollars per hour figure, the fixed detectors should be placed in sufficient intensity to give about 55 per cent coverage, which requires (on the Coeur d'Alene Forest) 37 lookouts per million acres. The required coverage beyond 55 per cent can be more cheaply attained by aerial detection (7).

These comparisons are made upon the assumption that the flying times of the planes are so arranged that all the seen areas, in accord with the ground coverage requirement, are observed with the same frequency that areas are observed from fixed lookouts. In this study, this frequency was considered to be once each hour. Such rates would not always be necessary, particularly in areas of low fire occurrence and low hazard. Even on the more critical units, there is a chance for great savings over and above those shown by the direct comparisons. The cost of a ground lookout system in isolated areas goes on continually even during those times when the danger has been temporarily relieved and detectors are not necessary. In the air detection plan only the few fixed lookouts are a fixed charge. On safe days planes may be grounded or used for other purposes. On many other days of low danger the frequency of observation can be drastically reduced. Also, it is evident that greater flexibility will allow danger spots and critical situations to be covered with far greater intensity with aerial patrol than with the conventional ground detection system (7).

In aerial detection there is another great source of savings that should not be overlooked. Even a moderately intensive ground detection system necessitates a large investment in improvements and servicing facilities. The cost of maintenance and repair of the living quarters, the lookout towers, and the transportation and communication systems that are needed simply to service a moderately large lookout system amounts to a considerable figure. To this should be added the operating and upkeep costs of pack stock, trucks, and warehouse space, together with the servicing personnel and the additional overhead required to recruit, train, and supervise a lookout force (7).

The conventional airplane can be used to supplement fixed ground lookouts, but they can not substitute for them entirely. One great fault with the airplane in aerial detection is that they move across the forest at an average speed of 100 miles per hour, and observation of any given spot is limited to a fraction of a minute. Should smoke or a fire be lying below the tree tops at that particular moment, it may go undetected and could spring to life at a later time (8).

When visibility is greater than three miles, fire detection patrol can be more economically accomplished by the conventional aircraft. However, the excellent maneuverability and slow flying speed make the helicopter the most suitable aircraft for fire detection patrol when visibility is from one-half mile to three miles (4).

The helicopter permits prolonged observation of any questionable spot by the air observer. It will provide better intelligence in that the observer while suspended at treetop level may evaluate and study conditions intensively (8).

The manufacturers of helicopters expect to increase the hovering ceiling without ground effect of helicopters to the extent that hovering may be possible at all elevations at which fire protection is necessary (8). Currently, the hovering ceiling without ground effect for the two Sikorsky helicopters, R-5A and R-5D, is 6200 feet, density altitude (4). That is high enough for most fire protection work. And, even though the density altitude may be too high to allow hovering without ground effect, the service ceiling for most of the current leading helicopters is high enough to allow slow circling at all practical altitudes.

Scouting - Scouting on any large fire is a vital factor in attaining the best use of manpower. The lack of detailed scouting information has long been one of the stumbling blocks in the quick organization of suppression forces.

This situation can be greatly relieved through the use of aircraft in scouting. Circling above the fire, the observer in the aircraft can quickly determine the intensity, location, extent, rate, and direction of the burning. He can also determine the character of the material that is burning and the character of the material in the path of the burning. He can spot the natural barriers, and he can ascertain the most advantageous routes of travel.

Developments in air-to-ground communication, using ultra-high frequencies, are making it possible for the observer in the aircraft to relate his information to the fire chief without delay.

Photography is becoming an important phase of aerial scouting, It is now possible for the observer in the aircraft to make oblique or vertical shots of recognizable areas, develop and place key marks on the picture, and drop them to the fire chief on the ground. From the snap of the camera shutter until the time that the finished photograph is dropped in camp takes just 11 minutes. The dark room is a small box, with a red glass top through which the photographer views his work. His hands enter the box, gloved in black velvet. The gloves are sewed into the velvet sides of the box (9).

The use of photographs eliminates the discrepancies that occur when one person tries to visualize conditions through the eyes of another person.

The helicopter has been proven by demonstration to be superior to the airplane in making reconnaissance of burning forest fires. By flying at slow speeds near the ground and the edge of the fire, it is possible to obtain information more accurately and in more detail than by any other method. Since the helicopter can land nearer the fire, often at the fire camp, the observer is able to make his report directly to the fire boss, thereby, effecting a minimum of error (4). Or the fire boss can be taken around the fire and view for himself the progress of his fire.

Transportation of Men and Cargo - When prevention fails, and after the fires are detected, the key to successful fire fighting is to get men and equipment there--and fast. Almost every fire is a one-man job providing the one man can get there fast enough. The best answer in lessening the elapsed time between detection and arrival of the first men is the aircraft.

Because of the absence of airplane landing fields in the western forests, and the almost impossibility of constructing them, the smoke jumping idea was conceived and developed by the United States Forest Service.

The idea was first conceived in the early 1930's by a few air minded Forest Service men who thought that it might be possible to drop fire fighters by plane and parachute directly on the scene of fires. These men argued that all forest fires have tiny beginning, and if it were possible to put them out speedily after detection, many dangerous, large fires would be prevented, and vast savings in timber, manpower, and money would result (10).

By 1939 sufficient interest had been generated, and the first experiments were undertaken in the feasibility of smoke jumping. The site of the experiments was the Chelan National Forest in Region Six. Fire Control officers of this region were successful in contracting a professional parachute jumper who agreed to make 60 test jumps under varying conditions. The purpose of the test jumps was to determine the best type of parachute to employ and to develop gear that would give maximum protection to the jumpers, recognizing the extra hazard involved in getting tangled up in trees or being deposited on the top of rock pinnacles (10).

The Chelan experiment proved very satisfactory. At the end of the sixtieth jump, several Forest Service employees were allowed to jump into both open field and timbered areas. No injuries of consequence occurred (10).

In 1940, as a result of the experiments of the previous year, Regions One and Six each decided to organize a small squad of smoke jumpers for the 1940 fire season. Region Six started out with five jumpers but lost one through an injury which, however, was not connected with parachute jumping. Due to a light fire season, the remaining four had little action during the summer, although a few fires were handled by this squad. Region One, on the other hand, started with eight men. One was lost through physical default and another because of unfavorable nervous reactions. The remaining six handled nine "selected" fires during the season. An analysis of the nine fires indicated very large savings in suppression costs on three, substantial savings on three more, small losses on two, and no gain or loss on one. The indicated net over-all saving was approximately $30,000, or three times the cost of the project (11).

In 1941 the smoke jumping project was transferred wholly to Region One and centered at Missoula for the coming season. Success of the previous year's activity only partially accounted for this decision. Region One contains about eight million acres of roadless or relatively roadless area of which the regional headquarters at Missoula is the geographic center and logical hub. Furthermore, the Johnson Flying Service at Missoula could provide the ships, pilots and mechanic service which was extremely difficult, if not impossible, to obtain elsewhere at that time. In taking over the project, Region One agreed to provide jumpers on call for Regions Four and Six, to the limits of availability. (11).

In the year, 1941, increased funds allowed an expansion to a three-squad outfit totaling 26 men. As in 1940, nine fires were handled by the smoke jumpers at an estimated saving in excess of $30,000 (11).

Continuing in 1942 as a Region One project, a further expansion led to a four-squad unit. During this year, smoke jumpers controlled 31 fires alone, and four more were controlled with the aid of ground forces. The estimated savings in suppression costs was $66,000 (11).

In 1943, smoke jumping continued as a Region One project, but with small detachments in Regions Four and Six. A total of 70 smoke jumpers were used in 1943. In Region One, 47 fires were handled at an estimated savings in suppression costs of $75,000 (11).

In 1944, about 160 smoke jumpers were used. Region One was continued as the base of operations, but detachments were again sent to Regions Four and Six. In Region One, more than a hundred fires were handled by smoke jumpers (11).

The following year, 1945, will have an important place in the history of smoke jumping. The total number of smoke jumpers was increased to about 235 men. The base of operations again was Region One, with detachments in Regions Four and Six (11).

The record for 1945 shows that in the three regions smoke jumpers were used on 269 fires, with a total of 1,236 individual jumps. A far from complete cost analysis, covering only two of the three regions, indicates a net saving of $346,780 for the season. But in numerous cases it was apparent that the savings on a single fire might conceivably have equaled the entire figure (11).

Up to 1945 smoke jumpers were used predominantly on small spot fires. In 1945 they were used in larger groups to spearhead control action on the larger and more threatening fire--often with complete success (11).

In the years, 1946 and 1947, the project was carried on. In Region One in 1946, 647 individual jumps were made on 211 fires. In 1947, 576 individual jumps were made on 123 fires. In 1947 the smoke jumpers expanded to the extent that a crew of smoke jumpers were sent to Region Three at Deming, New Mexico. They proved successful, and the operation will be repeated in 1948.

Air freighting or cargo dropping is an essential phase of aerial fire control. In 1945, three-quarters of a million pounds of tools, equipment, and supplies were dropped to camps by parachutes or put on back-country landing strips by air delivery. Crews going in to fires have been able to "travel light" and find food and tools on the spot. This lessens the fatigue factor which is an important factor in fire control. Tossing out a 35 to 50 pound pack to a one or two man crew at the scene of action can effect great savings in the use of highly trained personnel (12).

Even before the war, the forest fire fighting agencies were dropping hot meals and light equipment to fire fighters. As early as 1939, over 10,000 pounds of water, food, and supplies were dropped by parachutes to fire fighters on the Los Padres National Forest in California. The plane delivered 1500 pounds every two hours, while the best that a pack mule could do was 300 pounds in six and one-half hours (9).

The future limits of aerial transportation of men and cargo are, with the exception of the helicopter, dependent upon economics rather than mechanical and technical development. The point of diminishing returns must be determined. It has not as yet been ascertained. However, it is not unreasonable to expect that this point will not fall short of a plan which provides adequate attack forces on any fire within one-half hour following its detection (8).

In the past years, the airplane has been used almost exclusively in the transportation of men and cargo. However, the helicopter is causing an innovation in this field. In 1947, on a fire in the Big Tujanga Canyon area of the Los Angeles National Forest, two Armstrong-Flint helicopters performed the following feats: (1) Transported 80 men to a mountain peak, (2) brought 60 men back to the fire fighting base, (3) took four minutes for each round trip instead of several hours on foot, the only other alternative, (4) made landings and take-offs with full load at altitudes as high as 6500 feet, (5) easily placed fire-fighting crews at working points in the fire lines, inaccessible except by helicopter, and (6) supplied these crews with food, water, tools, and bedding (13).

One major reason for using the helicopter as an adjunct to the airplane in the transportation of men and cargo is because of its ability to pick up cargo in the wilderness without development of expensive airfields. Conventional planes can distribute cargo in the forests, but a vast system of trails, mules, roads, and trucks is required to retrieve men and equipment. Maintenance expense for these developments is large and will be eliminated through use of the helicopter. Those ground facilities essential to other purposes will of course be retained (8).

Water and Chemical Bombing - Prewar experience in bombing of fires was very discouraging. Best available equipment and planes were used in exhaustive experiments. Effective accuracy could not be accomplished. Anything short of a direct hit on the fire's edge is without desired effect, and with prewar equipment that degree of accuracy could not be attained. (8).

However, with advancements made during the war in precision bombing, there appears reason to believe that bombing of forest fires may play an important part in future suppression work.

Experiments are presently underway on the Lola National Forest in northern Montana for the purpose of testing the feasibility and efficiency of new equipment in the bombing of fires. A B-29 bomber was used for tests of level bombing and two P-47 thunderbolts for dive and glide bombing. Bombs used to date have been 165-gallon water bombs. The B-29 carries eight of these bombs, and the P-47 carries two. The bombs carried by the B-29 were equipped with radio proximity fuses which causes the bombs to burst at a desired height above the ground. In the case of bombs carried by the P-47s, burster charges were not necessary because the light tanks burst easily upon contact with the ground (14).

During the summer of 1947, 35 bombing missions were made, and nearly 150 bombs were dropped. On these missions each fighter plane carried two bombs which were released simultaneously. The B-29 carried eight bombs which were released singly or in a train. At the end of the summer the following conclusions were made:

First, Aerial bombing can reduce the potential danger of fires under the following situations: (1) Large numbers of fires burning at the same time in a given area; (2) Hot burning fires against which present suppression work by ground forces is not effective; and (3) Fires in inaccessible areas where present methods of control are too costly, too dangerous to personnel, or too slow considering fuel and weather conditions.

Second, Minimum altitude glide bombing attacks by fighters using unstabilized tanks are most effective against small hot fires. This technique gives good accuracy and will effectively check the spread of small hot fires. Two bombs released simultaneously will cover an area averaging 139 feet long by 118 feet wide. The dirt and mud thrown by the force of the impact are important and unexpected benefits of this type of attack.

Third, Aerial burst bombs dropped from a B-29 show great promise in forest fire control work. The explosion creates a water cloud directly over the fire. B-29s may be able to check the spread of large fires. A six-ship formation might lay down 8,000 gallons of water on a strip 1,800 feet long by 400 feet wide.

Fourth, Operational procedures require careful briefing of the air crews, and full coordination with ground forces to insure that the target area is clear of men who might be injured by bomb case fragments. Air to ground radio communication is essential (15).

Plans for future tests include the use of foam instead of water, which should give a better extinguishing blanket and a better indicationof the pattern. Other sizes of bombs will also be used. They include a 4,000-pound light-case bomb that holds 260 gallons of foam, and a 500-pound light-case bomb holding 23 gallons of foam. Both of these bombs will have proximity fuses. In addition, tests are to be made with the 100-pound chemical bomb case, with a capacity of 8 gallons of fire extinguishing liquid. This bomb will be fused for impact burst. At the present time a solution of monoam-monian phosphate appears to be the most suitable for chemical-filled bombs (14).

The cost of aerial bombing presents somewhat of an enigma. If the Forest Service had to stand the entire cost, aerial bombing would be out of the question. Fortunately, the United States Air Force officers who have worked on this project are very enthusiastic about it. The air proving ground command at Elgin Field has recommended that a group of 75 fighters and 30 bombers be assigned to practical field attacks against live fires in 1948 in the Missoula area. How long the Air Force retains this attitude is a matter of conjecture (15).

To a large extent the common use of chemical sprays or bombs in fire fighting depends upon the helicopter. When it becomes possible to apply large quantities of retarding substances from carriers suspended motionless at treetop level, then forest fire control will have reached its climax in transportation (8).

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