The world's largest flying boat, Martin JRM-3 Mars, dropping 7,000 gallons of water on a fire near Vancouver, B.C. This plane, CF-LYJ, was lost in a fatal accident on 23 June 1961. (Photo - British Columbia Forest Service 13143)

Forest Fire Air Attack System

By WILLIAM T. LARKINS

The current practice of fighting forest fires from the air is a rare and unique combination of private enterprise, government financing, military-type operation, hazardous flying and all the glamour and risk of man's fight against the titanic forces of nature. Certainly nothing that has happened in aviation since World War II has come so close to the feeling and aura of flying in the Late 1920s.

Although it is now in its eighth year of operation, the California-developed system of massive air drops of chemical fire retardants, popularly identified by the newspapers as "borate bombing", is still as fascinating as ever. Each year brings new knowledge and refinements of technique, but the hazard remains and many fine pilots have lost their lives. Ironically it has not always been the violence of low-level mountain flying in hot, turbulent air that has destroyed aircraft and men, for several have been killed in practice and demonstration flights.

The current system involves dozens of air tankers on a stand-by basis at permanent installations with living quarters, radio communication facilities and mixing tanks for chemical fire retardants. The primary purpose in the use of aircraft in fighting forest fires is the same as that of any fire department--to hit the fire fast while it is small and before it can develop into an uncontrollable inferno. Thus speed of delivery is of equal importance to total volume delivered in air attack. This theme lies behind the term "initial air attack" that is used continuously in all descriptions of air tanker operations. From the fire fighters viewpoint the airplane is simply another tool available for use and never a single solution to the problem.

Air operations are rigidly controlled by the Fire Boss, through the Line Boss on the ground to the Air Attack Boss. In addition, there is usually an Air Officer, Air Traffic Manager and Air Service Manager. Tankers are led to the fire line by the Air Attack Boss riding in a lead plane, usually a Forest Service Beech T-34,who marks the drop zone and informs the tanker pilots of any special hazards such as excessive turbulence, high tension lines, etc. He then circles the area and evaluates by radio the accuracy of each drop. These are made at an average altitude of 75 feet with the planes always flying downhill and into open canyons for greater safety in case of tank or engine failure. Several accidents during the formative years were caused by aircraft not being able to pull up over a mountain because of a full

load, or loss of power. There are hazards involved to the ground crews as well, from the impact of falling retardants. Serious damage to trees and vehicles, plus the death of at least one fire fighter, has led to the establishment of 50 feet above the terrain as the absolute minimum altitude for an air drop.

Chemical drops are not made directly on a fire, but slightly ahead of it, or on the flanks in an attempt to slow down its progress. In general, the final work is always done by ground crews, many of whom may be flown to the area in helicopters. The first chemical used in air attack work was sodium calcium borate, developed by the U. S. Borax Company in 1954 as "Firebrake". From four to five pounds of borate is mixed with one gallon of water to produce a heavy white, sticky, fire-resistant liquid which will pre-treat brush and wood, for eight to ten hours.

Bentonite swelling clay appeared in 19J9 and is now being widely used in the West. It is less than one-tenth the cost of borate, but only effective for two to three hours. Since an extensive retardant line may be put down as much as four hours ahead of the fire, borate may be necessary, but for immediate use they seem to be of equal value. While borate dries to a white crust, thus enabling the pilot to identify where the last drop has been made, bentonite is colorless. It was thus necessary to add Rhodamine B pink aniline dye to bentonite and this produces spectacular air drops.

Because it was found that high concentrations of borate temporarily sterilize the soil, other mixtures have been tried in the Southwest. Two of these are liquid fertilizers developed and laboratory tested in London in 1945; DAP (diammonium phosphate) and NAP (monoammonium phosphate). A third is Algin (sodium alginate) first used in Georgia in April 1960. Algin is a non-toxic water thickener derived from kelp harvested from the Pacific Ocean. Research continues in Forest Service laboratories around the world for effective, inexpensive and readily available fire retardants.

The historical use of aircraft in conjunction with forest fires is essentially that of a 30-year period of limiting their use to observation. In order to better understand the length of time that it has taken to develop the present system, a brief history of this background is important.

The earliest specific mention seems to be 1911. During a 1916 convention of the Western Forestry and Conservation Association, and while commenting on W.E. Boeing's proposal for an aeroplane patrol, its president stated, "This association was the first protective agency to consider seriously aeroplanes in fire work. In 1911 we went so far as to draw up a contract with the Curtiss people for a trial, but abandoned it because so many people thought we were visionary. Now we seem about to be vindicated. " (1)

Nothing further, other than sporadic individual attempts, was done until after World War I when both men and machines were suddenly available. Two key people stationed in San Francisco talked over the idea of aerial reconnaissance for forest fires; Coert du Bois, Regional Forester for the U. S. Forest Service, and Major Henry A. "Hap" Arnold, Air Service Officer for the U. S. Army Ninth Corps Area. As a result, on June 1, 1919 "the first organized and sustained airplane Forest Fire Patrol ever attempted in the United States was inaugurated in California." (2) Five Air Service Curtiss JN-4Ds, with military pilots, were put into operation. Within two months these had been replaced by de Havilland DH-4Bs and by the end of the year 12 planes were flying daily patrols. The Patrol discovered and reported 550 fires from Mt. Lassen to the Mexican border and flew a total of 235,000 miles. Because of the inability to use the 1919 radio equipment, particularly in the mountains, reports on fires were dropped by parachute or released with carrier pigeons.

The Air Service provided an increased patrol in 1920 even though the funds were approved for California only. DH-4Bs operated from Mather Field (Sacramento), Red Bluff, Fresno and March Field (Riverside).(3) The total number of aircraft used varies between 26 and 37. The higher figures, provided by Major Arnold to the Aircraft Year Book credit the Air Service with 1,301 patrols, 1,632 fires discovered and 467,000 miles flown in 1920. (4)

Unfortunately lack of funds, the single most important factor in the history of the use of aircraft in forestry, brought this valuable service to an end by 1923. Neither the U. S. Forest Service nor the Air Service would budget the money necessary and nowhere is this better illustrated than in this 1921 description:

> "It is very unfortunate that, owing to lack of appropriations during the period of greatest fire hazard, it was necessary to suspend the patrols for a period of three weeks due to shortage of gasoline, and for this reason, it can readily be seen that the aerial patrols were unable to make as good a showing as they should have that year. They were well equipped, had two years' experience in back of them and were all eager for the work. However, when the greatest number of fires were burning and the airplanes could have done the most good, for three weeks not a patrol was sent out." (5)

With the withdrawal of Air Service equipment, two private timber protective associations in Idaho contracted with Nick Marner of Spokane, Washington, for private aerial patrols. This shift to private enterprise was further emphasized by Secretary of War Davis in 1925, when he suggested that for forest fire patrol work in 1926, arrangements be made by the Department of Agriculture for the use of commercial aircraft so that the government would not be competing with private industry. This policy laid down in the early 1920s is still in effect today and all actual fire fighting done on federal forests in the United States is carried out by private contractors with civilian aircraft.

Unfortunately, because of this very individualistic and private approach, there are few documentary records of early pioneering and experiments by private operators in the U. S. Most references are vague and uncertain as to the type of aircraft, dates, etc.

At least three sources allude to a forest service fire fighter and an early bush pilot teaming up in 1930 to drop some kegs of water from a "tri-motor plane". Although these stories vary from one to six beer kegs, they probably all refer to Howard Flint, USFS Fire Chief for Region 6, "kicking a beer keg full of water out the door of an airplane flying over Felts Field, Spokane." (6, 13, 14) The airplane was most probably Ford 4-AT-E NC-9612 or NC-8403 flown by Nick Marner. And Russ Leadabrand adds a further story not found elsewhere: "But the pioneering pair did not give up. Next they took to the air with a length of hose hanging from the plane. Flying back and forth over a target fire, they sluiced water through the hose. It was another failure. The small stream of water vaporized before it hit the ground."(6)

One very interesting report credits C. J. "Red" Jensen of Sacramento, California with modifying a "World War I Hispano Suisa" with two water-tight hoppers on the outside of the fuselage near the cockpit. (7) Jensen claims to have made two drops on fires burning in Butte County, east of Oroville, in the summer of 1931.

Government reports being what they are, we have much more detailed accounts of two scientific experiments in the 1930s. The first was in Russia in 1934, and the second in California in 1937. An extensive "aviation chemical study" was carried out in July and August 1934 in the Egor'evsk Industrial Forest Unit of the Moscow district. The aircraft type is not mentioned, but it was an agricultural sprayer with a small 40-gallon tank. In an attempt to place as full a discharge as possible, the plane was flown so low that the propwash blew over the paper cups used to measure the effectiveness of the spray. As with other attempts at spraying, it was found that the liquid dissipates into a fine spray and was of

Getting fire retardant into aircraft is often a messy business as witness loading of this TBM. Loading areas and planes soon become pink or white. (Harry Gann)

The Lockheed PV-2 Ventura above shows the "D" letter assigned to Region 4 of the U. S. Forest Service. (Photo - L. S. Smalley, Seattle, Wash., 26 May 1962)

no practical value in extinguishing fires. It is interesting that as early as 1934 their conclusions were that the aircraft would need a tank capacity of 240 gallons to be effective. The report summarizes their work as follows:

> "During 1934 a number of experiments were also made aiming at clearing up conditions for extinguishing fire with water and chemical solutions released from a plane. The experiments were made above lines of fire with the plane flying at a height of only 35 meters. Only 6 experiments were made (16 flights). In 6 cases the liquid did not reach the fires at all; in one case only drops fell; in 6 cases it reached only part of the fire; and in 3 cases all fires were extinguished or put out temporarily, but they usually flared up again. No special difference was observed between the influence of water and chemicals, but the chemicals exercised a more lasting effect against a flare up. These experiments confirm the necessity of increasing the volume of the tank and the lifting power of the plane. As far as the actual extinguishing of large fires is concerned, this problem still remains unsolved because it is necessary to take into account the air currents created by the fire of varying intensity and direction, and the great quantity of smoke." (8)

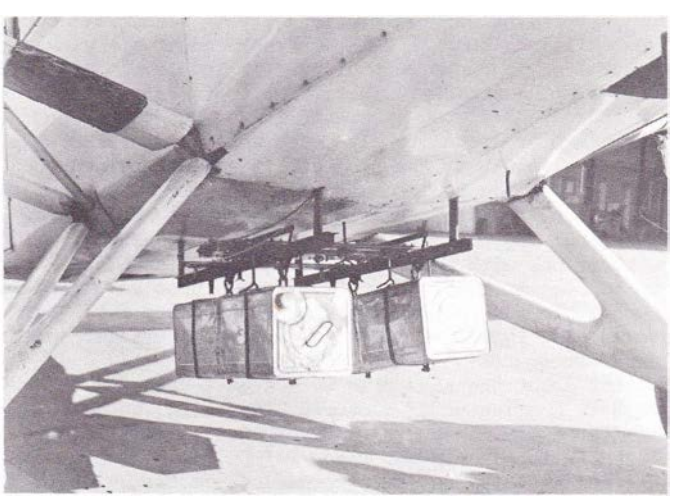
In a similar vein, the U. S. Forest Service saw little future in the use of aircraft to fight fires. With an annual appropriation of under $50,000 for the use of aircraft on all national forests (including the costs of constructing landing fields), the USFS limited the use of aircraft to detection and transportation. An interesting 1935 comment on aerial fire fighting points out the fire extinguisher philosophy of the time: "Such materials to be effective must be applied to a strip which ordinarily does not exceed 6 to 8 feet in width on the immediate front of the fire." (9) Imagine the consternation at a Forestry meeting in 1935 if someone had predicted the use within 25 years of a plane capable of dropping 7,000 gallons of water in a swath 175 feet wide and 700 feet long!

With the only experience involving small loads and/or spray nozzles, and the bulk drop concept not to be tried until many years later, it is understandable that the first extensive scientific tests made by the USFS in February 1937 would limit themselves to small chemical "bombs". Ironically however, it was the result of a theoretical study by the Physics Department of the University of California that prevented this experiment from trying uncontained, free water drops. This study had "proven" that the slip stream effect of a moving plane would so break up a falling column of water that none could effectively reach the ground. As a result, this pioneering study was limited to ten-gallon tin cans filled with a chemical extinguisher, the results of which were so ineffective that nothing further was to be done for ten years.

The Department of Commerce auxiliary landing field at Livermore, California, was lined off in a grid of ten foot squares 100 feet wide by 400 feet long. A special bomb rack was installed on the Travel Air S-6000-B (NC-9084, c/n 865) leased from Duck Air Services at Oakland Airport. Attached to this were two ten-gallon cans made by soldering two five-gallon cans together with a scored lead diaphragm which would break, mix the chemicals and thus produce a foam fire extinguisher. Various combinations of can sizes, and even Navy bombs with balloons attached were tried. Two sacks of cement, and two of lime, were dropped to measure the ground coverage of such an air drop. Sixteen flights were made, at an average altitude of 300 feet, and speed of 85 mph. The results conclusively showed the ineffectiveness of frothy mixtures for aerial bombing. (10)

No further activity took place in the U. S. until after World War II, but it is worth mentioning that the U. S. Forest Service took delivery of its first plane in 1939. This was a new Stinson Reliant SR-10FM (NC-2166, c/n 7-5845). It carried the USFS insignia and flew out of Oakland Airport for Region 5 at one time. Although it was used primarily as a staff transport, it was also instrumental in the early development of the Smokejumper program.

On September 9, 1946 the first use of a helicopter on a going fire took place during the Castaic fire in the Angeles National Forest of California. A Sikorsky R-5A from the 62nd AAF Base Unit at March Field was used on a scouting and mapping expedition during an 800-acre break over into rugged mountain areas. Because of the altitude the R-5A dropped its cargo loads without land-



Rare photo of the ten-gallon cans mounted on a bomb rack under a Travel Air S-6000-B for Livermore tests in February 1937. (Photo - U. S. Forest Service)

ing. (11)

The historic large scale tests of aerial bombing of forest fires carried out in 1947 were the end result of an idea proposed in 1936 by David Godwin, Chief of Fire Control for the USFS. Shortly after the end of the war, he was successful in effecting a cooperative agreement between the Army Air Forces and the Forestry Service. Unfortunately his death in an airplane crash in May 1947 prevented him from witnessing the tests and further development to the point of today's very successful air attack system.

Initial AAF experimentation was done at Eglin Field, Florida, in June 1947 to test various types of bombs and aircraft. As a result it was determined that with a slight modification of the bomb racks, the Boeing B-29 could carry eight modified 165-gallon tanks to be used as water bombs, and that the Republic P-47N could carry one under each wing for glide bombing. (12, 13)

In July the Air Proving Ground Detachment moved to the Great Falls Army Air Base, Montana, with one B-29, two P-47Ns and one B-25. Contrary to some published reports, the B-25 was not used to drop any water bombs but was flown as a liaison plane to provide radio communication not possible with the Forest Service Beech Bonanza. On July 22, 1947 the B-29 was christened "The Rocky Mountain Ranger" by officers of the AAF and USFS. It is undoubtedly the only B-29 to ever carry the official USFS insignia. The pilot of the B-29 was 1st Lt. Charles G. Mathison, and the P-47Ns were flown by Lieutenants Stewart and Lampart. (12) Unfortunately, none of the photos available show the serial number of the B-29 so that it cannot be identified and given credit for this little known project.

During the B-29 operations on test fires, forty-six 165-gallon stabilized fuel tanks fuzed for air burst were dropped on seven missions at an average altitude of 3,000 feet. The normal dispersal of one tank was 48 ft. wide by 108 ft. long. The purpose of the test was to evaluate the tactical use of aerial bombing using water and chemicals for retarding the spread of fires burning in rough, mountainous country. The planes were employed on missions against test fires in the Lolo National Forest, Montana. Measurements of bombing accuracy, fuel types (referring to timber, not aircraft fuel), weather conditions and rate of spread of fires were made in the target area. The final phase of the tests included operations against actual forest fires in three western Montana forests.

Modification of the standard B-29 by repositioning standard racks in the bomb bay midway between stations "B" and "C" allowed clearance for a load of eight tanks hung on B-10 shackles at stations three and eight. The B-29 tanks had proximity fuses so that they would burst 50 feet above the ground to give maximum dispersion.

The P-47Ns carried two tanks, both stabilized and unstabilized, hung on S-l bomb racks under the wings. A total of 56 tanks were dropped in low level glide and dive bombing attacks. These fighter tanks were not fused and depended upon the rupturing of the tanks upon striking the ground to give good water dispersion.

As a result of the project, it was determined that better ordnance design was needed for the B-29 type of operation, but that the fighter drops were effective. The final recommendation called for continued operational testing, with a proposal for 30 B-29s and 75 fighters to be used in 1948. However, the old problem of lack of funds, already felt in the grounding of the P-47s for seven days in August due to a gasoline shortage, ended any further tests of this nature. (12, 13, 14)

At about the same time (exact date unknown) the Forests Commission of Victoria, Australia, undertook similar experiments with a Royal Australian Air Force B-24H, Avro Lincoln and three P-51Ds. Ammonium phosphate and ammonium sulphate were added to the water in 50 and 65-gallon unfused bombs. Various drops were made at 100 to 200 feet altitude and for the first time a specific comparison was available between plain water and a chemical solution: "When sufficient water alone was applied to the fire to extinguish the flames, glowing coals were left which flamed again if the wind velocity was increased. On the other hand, the application of the chemical solutions resulted in glow extinction, so that further flaming could not be caused by increased wind velocity." (15) The final conclusion from the Australian tests was that "In Victoria, it is considered that fire suppression by aerial bombing has its principal application to small or spot fires not over one acre in extent in areas which are not readily accessible to ground crews." (16)

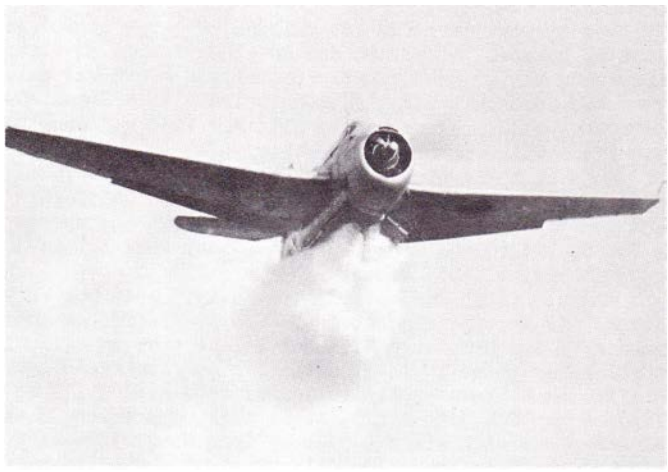
After reading of the AAF and RAAF trials, the Canadian Government decided that fuses and falling bombs were definitely not suitable in Canada. Because of the large amount of natural water available, they decided to experiment with water bombs. Collapsible paper bags, coated with asphalt, designed by the Canadian Defence Research Board, were made by the St. Regis Paper Company. Tests were carried out by the Ontario Department of Lands and Forests in 1949 at Sault St. Marie. (17) In an excellent article by Q. F. Hess (18) on the subject he states that water bombs were also tried in India and possibly Russia.

The first use of water bombs on an actual fire was on September 9, 1950 by de Havilland Beaver CF-OCJ. The crew dropped 2,800 pounds of water on a fire north of Sault St. Marie in Ontario, slowing the fire down enough that ground crews could extinguish it. This was quite an accomplishment as the system required landing on a lake and coming to a stop, climbing out on the float to scoop the water out of the lake into five-gallon bags, take off and drop the bags, and return to the lake again to repeat the process. Even so this crude, back breaking system was successful enough to lead to continued experimentation with the idea. Tests in June 1951 led to the belief that at least eight bombs should be dropped in one pass at 300 feet altitude.

The further development of this concept led to the construction of 3.5 gallon plasticized Kraft paper bags; 17 to 24 of these bombs could be carried in a Beaver to be dropped in salvos of eight. "The water bombing of small, inaccessible fires generally follows a set pattern. The aircraft lands on the nearest water, two smokechasers are dispatched to the fire, a third man is kept to assist the pilot in the water bombing operation. The water bombing equipment is installed, 17 to 24 bombs are filled with water, and the bombing begun." (19) The Beaver equipment consisted of a conveyor, camera hole fixture, water bombs and pail for filling the bombs. A standard 8-bag drop covered an area ten feet wide and 90 feet long.

The hazard of falling fuel tanks was certainly not the answer in the United States either, but it remained for a somewhat accidental occurrence to trigger the chain of events which have resulted in our present effective air tanker system. In late 1953, during a test flight of the prototype DC-7, the Douglas crew decided to jettison its 1,300 gallons of water ballast. This was done over the runway at Palm Springs airport and produced a strip of water 200 feet wide and almost a mile long--so impressive that the Douglas Aircraft Company saw the potential and offered the plane to the Los Angeles County Fire Department for a measured test. (20) The DC-7 (N-301AA) was equipped with six 400-gallon tanks, water pumps and three six-inch diameter holes in the bottom left hand side of the fuselage. A series of measured 800 foot long strips were set out on Rosamond Dry Lake, approximately eight miles northeast of Lancaster in Los Angeles County. At 11:00 AM on December 2, 1953 Douglas test pilot B. A. Foulds made the first drop of 415 gallons before representatives of the USFS, California Division of Forestry, Los Angeles City and County Fire Departments and Douglas Aircraft Company. Four drops were made at an average speed of 150 mph; the first of 415 gallons at 150 feet altitude, the second of 376 gallons at 300 feet, the third of 515 gallons at

The prototype Douglas DC-7 on its history-making drop at Rosamond Dry Lake, California on 2 December 1953. (Photo - Los Angeles County Fire Department 280-41)



Paul Mantz' General Motors TBM-1C (note air scoop on top of cowl only) making first fire drop in U. S. on 1 Sept. 1954. (Photo - L.A. Co. Fire Dept. 404-2)

400 feet, and the fourth of 310 gallons at 600 feet. (21)

Shortly thereafter, in early 1954, Major Warren Schroeder USMC designed a special 250-gallon napalm tank to he carried under the fuselage of a Douglas AD-2. This tank was fitted with glass plates on both ends of the tank, each with an electric detonator and filled with a chemical foaming agent. The plane made- a low-pass, detonated the glass panels, and dropped its load during a demonstration at MCAS El Toro. The water-foam solution was dropped from a height of about 35 feet at an airspeed of 160 mph and produced a swath 50 x 300 feet. (22)

Finally our modern system was devised by Paul Mantz during Operation Firestop in 1954. Firestop was a year-long accelerated program entered into by the USFS, California Division of Forestry, Los Angeles County Fire Department, the Federal Civil Defense Administration, the U. S. Marine Corps, the U. S. Weather Bureau and the University of California. The goal was to test every idea and piece of equipment that could be produced to fight grass and forest fires. Great progress was made in the helicopter field, but perhaps the most important was the program entered into with Paul Mantz Air Services to modify a TBM Avenger torpedo plane. The bomb bay of TBM-1C (N-9394H, USN 46122) was modified by Otto Timm by removing the bomb bay doors, lining the bomb bay with a plywood container divided into two tanks, and installing two plywood doors for each compartment. Wood was used on the prototype to cut engineering costs and time. "Total capacity of the tank was 600 gallons. To save the cost of making the units water-tight for the tests, a thin rubber lining was provided by placing a 750 kg weather balloon in each compartment. The doors of the two tanks were secured by four bomb rack shackles on each pair. The shackle release mechanisms were controlled by toggle switches in the cockpit. When the releases operated and the doors dropped open in flight, the balloon linings burst and released the water in free fall." (23) Eight drop tests were made at varying heights from 10 feet to 100 feet. The most effective was flown at 50 feet and produced a drenched area 90 x 270 feet. On September 1, 1954, two operational water drops were made on the Jamison fire making this the first bulk water drop on an actual fire to be made in the United States.

It is interesting to note that Group Captain W. C. Sheen of the Royal New Zealand Air Force modified an Avenger for dropping fertilizer by converting a spare fuel tank and placing it in the bomb bay. The initial trials took place at Ohakea Aerodrome in September 1948, and further demonstrations were made in late 1948 and early 1949. (24, 25, 26) The optimum height was found to be 400 feet, and the procedures and techniques were so similar to borate drops with the TBM that it is hard to understand why it was six years later before it was finally tried in this country.

A new word was created during the 1954 Operation Firestop. "Helitanker" was coined to describe a unit of two 50-gallon drums, a pump and 300 feet of lightweight hose. This unit, combining the advantages of a small ground tanker with the air delivery potential of the helicopter, was developed with the use of a Marine Corps Sikorsky HRS-2 of HMR-362 from El Toro. The 1,200 pound unit was carried on a sling beneath the fuselage. (27) With the advent of ten years of helicopter development, the word has become a description of helicopter air tankers rather than a small portable pumping unit.

The first crude experiments with direct attack by helicopter also took place at this time. A hose from a ground pumper was passed to a man in a hovering Bell 47 (N-933B) of La Mesa Flying Service. The copter then backed away from the pumper and the fire fighter attempted to water down an area with the hand held hose. Needless to say, this system proved to be completely impractical.

The next major step forward and credited by many references as the first, was the joint effort of Joseph Ely, Fire Control Office of the Mendocino National Forest, and Floyd and Vance Nolta, operators of the Willows Flying Service. The effectiveness of precision agricultural flying still impressed Joe Ely and so he persuaded Floyd Nolta to modify his standard 450 hp Stearman sprayer by installing a 7 x 18 inch gate in the bottom of the tank. Preliminary trials were conducted in August 1955 at

PT-17 N-75081 (numbers are transposed on plane) which made the 1955 test at Willows and became No. 1 on the California Register. (Photo - W. T. Larkins 6-18-64)

Willows Airport carrying 125 gallons of water or 100 gallons of lorate. At 80 mph and an elevation of 30 feet, the swath was 20 x 600 feet. Before the month was out, they had. an opportunity to drop 12 loads (l,470 gallons) on actual wildfires at Mendenhall, Mud Flat and John David Place with encouraging results. (28)

This historic airplane was Stearman PT-17, N-75081, c/n 75-3182. It Became Air Tanker No. 1 in California and is still flying at Willows, although it now sports a 600 hp R-1340 and wing tip plates that were not used on the original 1955 tests.

Another first was established in 1955 when the Wenatchee Air Service suggested to Fire Staff Officer Bob Beeman of the Wenatchee National Forest that an agricultural spray plane could be effective in fire fighting. Unlike the Willows experiment, this test used a 135 hp Piper Super Cub with a 100-gallon tank, and a wing mounted spray bar with six one-quarter inch nozzles on each side of the fuselage. "On July 23, 1955 a dry lightning storm set a fire on the slope of the Wenatchee River Canyon near Cashmere, Washington. The fuel type was cheatgrass with scattered sagebrush. The slope was steep. Here was the chance for a test.... Pilot Carey made two runs across the head of the fire, flying with one wingtip at the fire's edge, 10 to 15 feet above the ground. The water spread was approximately 33 feet, the air resistance breaking the water up into a fine spray. The runs Were made on the uphill side of the fire on the wind side. Water discharge was 1.5 gallons per second and the plane carried enough water for 60 seconds of application. One-quarter mile of fire front was covered at each run. This trial proved the effectiveness of the spray in checking the head of the fire and gave the ground crew time to control the flanks without difficulty. The fire was controlled at 55 acres." (29)

The first air tanker "squadron" was formed in August 1956. It was composed of four Stearman PT-17s and three Naval Aircraft Factory N3Ns, from agricultural operators in. the Willows-Red. Bluff area. The planes dropped 83,120 gallons of water on 21 of 25 fires fought, and 65,990 gallons of borate on 14 of them. The cost of delivery averaged A6 cents per gallon. Air attack was a deciding factor in assuring control of 20 out of the 25 fires on which the tankers were used. (30) Although these planes were normally based in Northern California, they were ferried 500 miles south to fight the Inaja fire in the Cleveland National Forest in November 1956. Over one thousand drops were made and this naturally led to the first full scale publicity that the air tankers received. In addition, it was the first wide scale use of borate and so naturally led the Los Angeles newspapers to coin the phrase "borate bombers."

A unique contribution was made between December 26th and 29th, 1956, when the Transland Aircraft Company loaned, without charge, its brand new prototype Ag-2 duster-sprayer (N-823OH, c/n 1) to the Los Angeles County Fire Department. The plane, flown by company test pilot Robert Masterson, made 31 flights from its operating base at Santa Monica Municipal Airport. "The majority of aerial drops were made into canyons covering areas in the path of the fire. The drops were made flying downhill into the canyon at 80-90 mph, with 20 degrees of flap, and at altitudes varying from 6 to 20 feet. The swath widths were about 35-40 feet wide and up- to 1/2 mile in length." (31) The borate load was limited to 161 gallons in the four wing tanks as the plane had been built for agricultural spraying only two months before and there was no time to design and build a drop gate for this fire. This was done four years later and two Ag-2s were leased to Sonora Flying Service arid used on state fires in California.

Meanwhile, on the other side of the world, a de Havilland DH-82 Tiger Moth was making initial test drops of 40 gallons of water at Rongotai, New Zealand in October 1955. This gave a strip 20 x 200 feet and was considered good enough to continue the tests in November 1956. At this time three de Havilland Beaver top-dressing aircraft had their tanks fitted with a water-tight lining to hold 200 gallons. These tests were continued in April 1957 at Rotorua on a test fire of one-half acre of 9-ft high manuka scrub. After six drops the fire was completely contained in six minutes. Further tests were made in September 1957 on tussock grasslands in the Rangitata Gorge using one Beaver and two Auster J5Bs (one was ZK-AZU) carrying 50 gallons of water each. (32, 33)

A great deal of experimental activity took place in 1957 and 1958, and by the end of the period of operational experience in 1959 the current practices and methods had been well established. In late 1956 the USFS purchased eight surplus TBM-3Us from the U. S. Navy, these becoming N.-102Z through N-109Z. Early in 1957 N-104Z was equipped with a 400-gallon tank designed by the California Division of Forestry and built in their shops at Davis, California. A modified triangular tank was fitted to N-105Z about the same time. The first bulk drop by a USFS TBM was made at Redding, California, on May 15, 1957 with the two compartment 400-gallon tank. Dropped from 100 feet altitude, at 115 mph, it formed a swath 50 x 300 feet.

On July 31st and August 1st tests were made with N-104Z, Mantz' N-9394H with a new tank and Jim Routh's PBY-6A on the runway at Orange County Airport, Santa Ana. (34, 35) N-104Z had two 200-gallon tanks that could be opened individually or simultaneously; N-9394H had a new 515-gallon metal tank divided into three compartments and using electric bomb shackles for locking and tripping the doors, necessitating manual closing on the ground each time they were opened; and the PBY-6A had two 750-gallon tanks, each tank with twin doors in the bottom of the hull. The PBY-6A showed the highest consistent concentrations in the drop pattern and the need for larger tanks was evident. The USFS immediately went ahead with the conversion of N-104Z to a 600-gallon tank and issued working shop plans from the Arcadia Equipment Development Center to all interested operators. (36) Impact forces on the ground from low drops, which were greater than expected, were first observed, and an instantaneous upward acceleration of 4 G's upon dropping the load was recorded.

At least two sources refer to the Fairchild C-82 Packet being used in California in 1957, but no photographs or further identity has been found. (6, 37) It is reported that one was used and that it had a tank capacity of 2,000 gallons.

The total number of air tankers used in California increased from eight in 1956 to 26 in 1957 and with this increase a system of aircraft identification was needed. This was formulated in March 1957 for the first time by Region 5 as follows:

> "13. Numbering aircraft for identification and reference. a) Numbers will be assigned by Forest Service (1-50 for northern California and 51-99 for central and southern California); b) Numbers will be in a contrasting color from base color; c) Numbers will be a minimum of two feet high with 4-inch stroke; d)Numbers will be painted on both sides of fuselage and on bottom of right wing." (38)

Since each USFS Region assigned their own numbers, duplications began to appear so that it was necessary in 1962 to add an identifying letter to designate the Region within which the aircraft was under contract. This was particularly necessary in northeastern Oregon where it was possible to have aircraft from Regions 1, 4 and 6 all flying on the same fire. The letters so far in use are: A - Region 1, Montana, Idaho, Washington; B - Region 2, Colorado, Wyoming, South Dakota, Nebraska, Kansas; C - Region 3, New Mexico and Arizona; D - Region A, Utah, Idaho, Nevada; E - Region 5, California; F - Region 6, Oregon, Washington.

In 1957 the Wenatchee National Forest conducted a pilot air tanker project financed by Region 6. A Stearman PT-17 (N-58501) duster-sprayer was converted to carry 100 gallons of borate, and the same operator converted his Piper Super Cub to drop 60 gallons of borate slurry.

Ford 4-AT-E, N-9612, with a 300-gallon capacity was used in Montana in August 1957- N-8407 was also used during the same year. (Photo - U. S. Forest Service)

Two Ford Tri-Motors were used to drop borate in 1957, but it is not known which plane was the first to be equipped with a tank. On August 8, 1957 the Northern Rocky Mountain Region contracted with a private operator at Missoula, Montana, who equipped 4-AT-E, N-9612, with three 100-gallon tanks, each with a separate dump valve and control. On August 9th test drops of water were made and following a training period, the plane was dispatched on eight fires. (40)

N-8407, a 4-AT-E at Boise, Idaho rigged for aerial spraying, was converted to an air tanker by the addition of 19 x 20 inch free-swinging gates to the bottom of the spray tanks. The aircraft carried two 275-gallon tanks in tandem. Cable releases permitted emptying one tank at a time or both at once. Five hundred gallons of water-suspended sodium calcium borate was normally carried in the two tanks. This water and chemical slurry weighed approximately 10 pounds per gallon, making the total cargo exceed 5,000 pounds. Calibration tests showed a drop pattern roughly 70 feet wide and 700 feet long when both tanks were emptied at an altitude of 50 feet. (41) The Ford was used on 24 drops on fires in the Boise National Forest with great success, much of this credited to the flying skill of operator-pilot Glenn Higby. Surely the following quote from USFS Ranger Jim Butler is a fitting tribute to the 28 year old Tin Goose still working away in August:

"The Ford was on this fire immediately and hit the head of the fire with a load of slurry that really flattened it. Without this help, considering the 30 mph wind which prevailed, we would have been unable to control it at the 2 or 3 acres it burned." (41)

Three techniques were developed in 1957, two for helicopters and one for seaplanes. The first was the development of a 35-gallon tank made of lightweight neophrene-coated nylon fabric. This was hung from a bomb shackle adapter assembly between the landing skids on a Bell 47. When ready to drop, the pilot electrically released the snout of the bag to drench a small fire on the ground. In addition the hose-lay tray was perfected for use on various models of helicopters. This idea was first used on an actual fire with an earlier model tray on July 5, 1956, when 1,000 feet of hose was laid on the fireline of the Sterling fire in the San Bernardino National Forest. (42) An undated photo has been found showing a U.S. Army H-21 laying hose at Fort Belvoir, Virginia, that may be from this same period.

The third development was the perfection of water-dropping from float planes. (43, 44, 45) The Air Service Division of the Ontario Department of Lands and Forests, after much experimentation with internal tanks, devised a system of dual rotating tanks mounted on the top of the floats and filled by two 2.5 inch diameter scoops. These tanks, having an operation capacity of 80 imperial gallons, were six feet long and 22 inches in diameter and were filled in 10 seconds at 40 mph while taxying on the step. Once airborne, the pilot cascaded the water by rotating the tanks upside down. The original flight tests were done with a de Havilland Otter CF-DOQ but it was soon found that by limiting the capacity to 50 gallons that the system could also be used by the de Havilland Beaver. CF-DOQ was used on actual fires in Canada in 1957 thus being the pioneer prototype for this system.

The first concept of gallons-per-hour, rather than measuring the effects of a single drop, can be credited to Canada. Because of the ready availability of water from numerous lakes, this method is particularly suitable for fires close to a water source. The Otter established a record of 2,900 gallons of water dropped in one hour, in 18 trips of one mile distance. With 35 Beaver and 8 Otter aircraft in the Dept. of Lands and Forests, in 1960, the potential of this system can be better understood.

Experiments along this line were also carried out in the U. S. by the USFS. A Noorduyn Norseman with an internal tank, was tried in 1957; with a Beaver using an internal tank in 1958; and finally with an external tank in 1961. All tests were carried out at Ely, Minn. (46)

A two year experimental initial air attack program was begun by the California Division of Forestry in 1958 to evaluate the entire concept under operational conditions. N3N-3s and PT-17s were still in wide use, but the General Motors TBM-3 Avenger was beginning to appear in

Bell 47 helicopter making a demonstration drop of 35 gallons of bentonite at Clark Tract, West Virginia, on 22 Oct 1959. (Photo - U. S. Forest Service 493131)

the hands of private contractors as a result of the demonstrations given by the USFS in N-104Z.

The first Canadian TBM-3 was converted by Skyway Air Services in 1958. They modified one of their TBMs, already e quipped for forest spraying, by installing four 18-inch square dump gates. Their experience was so successful that within three years they had purchased 12 more TBMs. (47)

During the same year, a helicopter bombed a fire in British Columbia using a 225-gallon tank slung under the belly. A trap door on the bottom of the tank released the water. Two tanks were used, one being loaded on the ground while the other was airborne. In this manner one helicopter was able to drop 6,000 gallons of water.on a fire at the mouth of the Ashlu and Squamish Rivers in two days and contain it until the rains came. (48)

The first experimentation with a Grumman F7F-3 Tigercat took place at Salem, Oregon in late 1958. Two externally mounted tanks, each holding 500 gallons were hung under the center section of the wing by Kreitzberg Aviation. (49) No further details are available on this predecessor of the "standard" belly-tank F7F-3.

The first use of borate in New Zealand took place during trials at Tara Hills in October 1958. Auster J5B, ZK-HDM, with a capacity of 40 gallons, made drops from 25 feet. These tests were continued in 1959 with the addition of six Fletcher FU-24s; 47 test flights were made on a controlled burn of 3,000 acres at Tihoi. (32)

1959 was a year of rapid operational development in the United States. (50, 51) During this year the trend toward surplus military aircraft began with the introduotion of one B-25 (1,000 gallons), one PB4Y-2 (2,000 gal.) and several F7Fs (750 gallons). The two thousand gallon capacity of the PB4Y-2 offered a new capability as yet untried in fire fighting. In addition, the four USFS TBMs that were "used to set standards, develop techniques, and provide leadership" (52) stimulated a wide interest on the part of private operators to switch from light aircraft to TBMs. Its 600 gallon capacity and rugged construction soon made it the aircraft type used in the greatest number for fire fighting.

An interesting experimental type was proposed in 1959 when an operator at Tulare, California hung an external tank (approximately 200 gallons) under his Interstate TDR-1 (NX-77900, USN 64-507). This twin-engine Navy version of the AAF XBQ-4 was built to carry a 2,000 pound bomb externally on its center section rack.

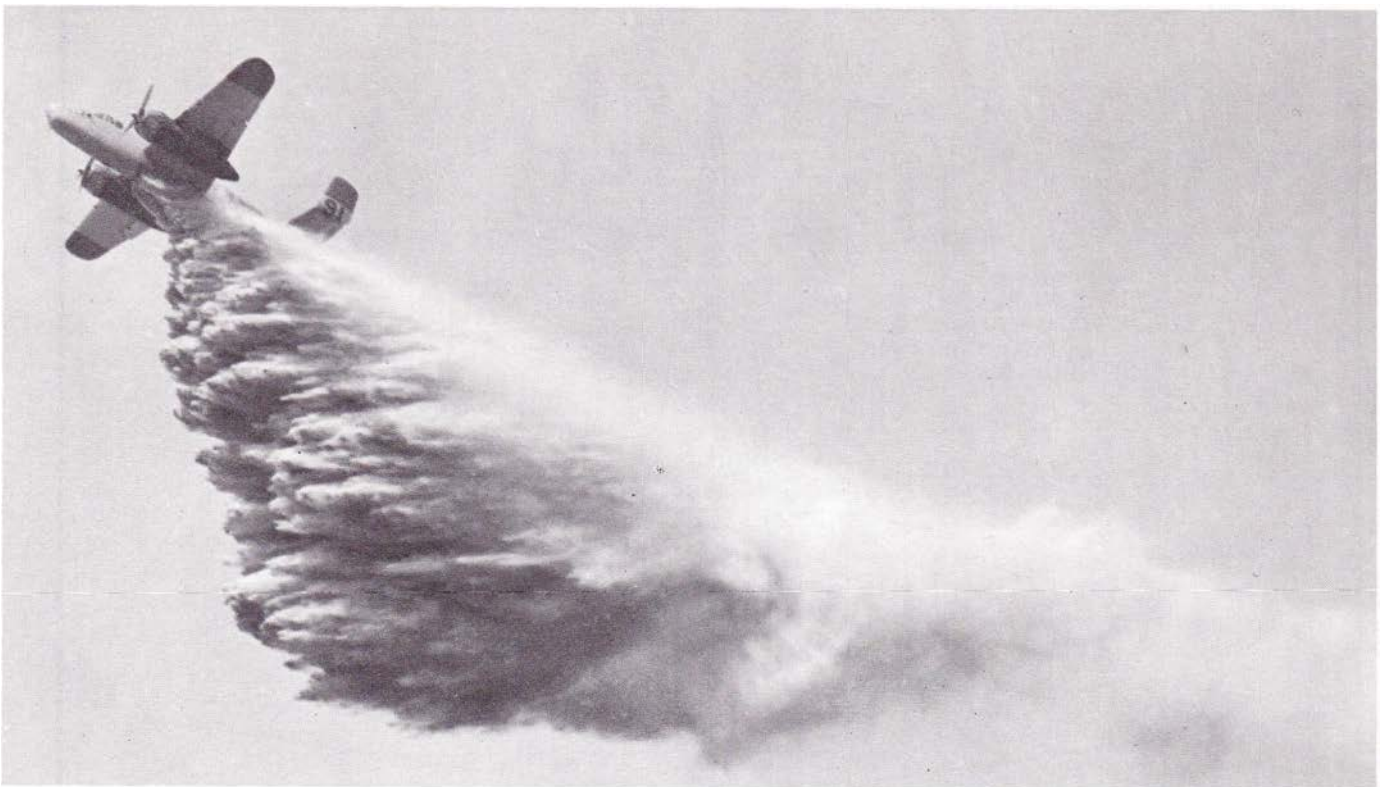
On March 3, 1960 Paul Mantz took off from Miami with two B-25s equipped for borate drops to help fight a huge fire that had ringed Caracas, Venezuela, for five days. (53) These planes flew fire drops for four days near Caracas and Paul Mantz writes that they are now on exhibit at his "Movieland of the Air" at Orange County Airport. It is interesting to note a reference in the New York Times (54) which states that the U. S. Air Force had previously sent three B-25s to Caracas to help fight this fire. It is not known whether this news story was confused with Mantz' B-25s or if the USAF actually had aircraft equipped for such work. It is, unfortunately, in the same vague but fascinating category as an earlier report in April 1958 to the effect that the Chinese Nationalist Air Force "dropped 200 fire extinguishing bombs" on a bad mountain fire in North Taiwan. (55)

Two extremely important developments took place in 1960 with the introduction of the converted Martin JRM-3 Mars flying boat, and the North American AJ-1 Savage.

In July 1959, six lumber companies in British Columbia joined to found Forest Industries Flying Tankers Ltd. and purchased the four remaining Mars from the U. S. Navy at Alameda, California. Navy serial number 76821, the "Marianas Mars" became CF-LYJ; 76820 "Philippine Mars" became CF-LYK; 76823 "Hawaii Mars" became CF-LYM. All were flown to Patricia Bay Airdrome near Victoria, B.C., and conversion to water scooper configuration began on CF-LYJ.

Fairey Aviation of Canada Ltd., installed four fibreglass, plywood stiffened tanks in the hull and two large scoops on the sides which enabled the Mars to load its 7,000 gallons of water in 15 seconds while skimming the surface of a lake. The load was dumped in three seconds

North American AJ-1, Number E 77, making a bentonite drop on a fire in Southern California. Intense smoke and lack of visibility are two of the major hazards in this type of flying. (Photo - L.A. Co. Fire Dept. 1867-19)



North American TB-25N, Number E 91, dropping borate in Southern California about 1959. This plane, N-10564, was later used, by the Forest Service for flight tests. (Photo - Los Angeles County Fire Dept. 983-I-10)

from 250 feet altitude and. produced, a swath 175 feet wide by 600 feet long. After its initial flight test on March 8, i960, CF-LYJ was put to work on about a dozen fires in September. Results were good, and at the Spius Creek Fire it knocked out 1,500 feet of fire line on the first three drops, and 1,200 feet on the next two drops. (56, 57, 58) Even at an operating cost of $1,600 per flying hour the Mars showed a tremendous new potential in water bombing. Unfortunately on the afternoon of June 23, 1961, the plane crashed and burned during a fire drop on Vancouver Island, killing the crew of four and setting the program back three years. The second. Mars (CF-LYK) is now, in the summer of 1964, completing conversion while the remaining two have been dropped from the Canadian Civil Register.

Three AJ-ls were purchased by the J. M. Jackson Company and flown from Litchfield Park, Arizona, to their base at Long Beach, California. (N-9144Z, USN 124164 crashed on the ferry flight; for serials of the other two see Table 1 at end of article.) The first was test flown as a tanker in June and the second in August 1960. (59) In addition to being able to carry 2,000 gallons of retardant, the AJ-ls have a speed of 230 knots which becomes of prime importance when the fires are a considerable distance from the nearest airport.

In addition to these two types, the Douglas B-26 (1,200 gallons), and the Lockheed PV-2 (1,000 gallons), were first used on fire fighting. A single Douglas SBD/A-24 (N-4488N, c/n 17421) with an external belly tank was first flown in 1960 by Aero Flight Inc. of Troutdale, Oregon. Two extensive publications were issued in 1960 (60,61), as well as flight test reports on the Bell 47G-3 (N-6783D), and Hiller 12E/61 (N-5331V). (62,63)

Two fatal accidents in July 1960 (see Table 7) involving an overload structural failure in the B-25J led to the grounding of this type as a fire fighter in California. A description of one of these is given by Elmont Waite in his graphic article "Fire Pilots":

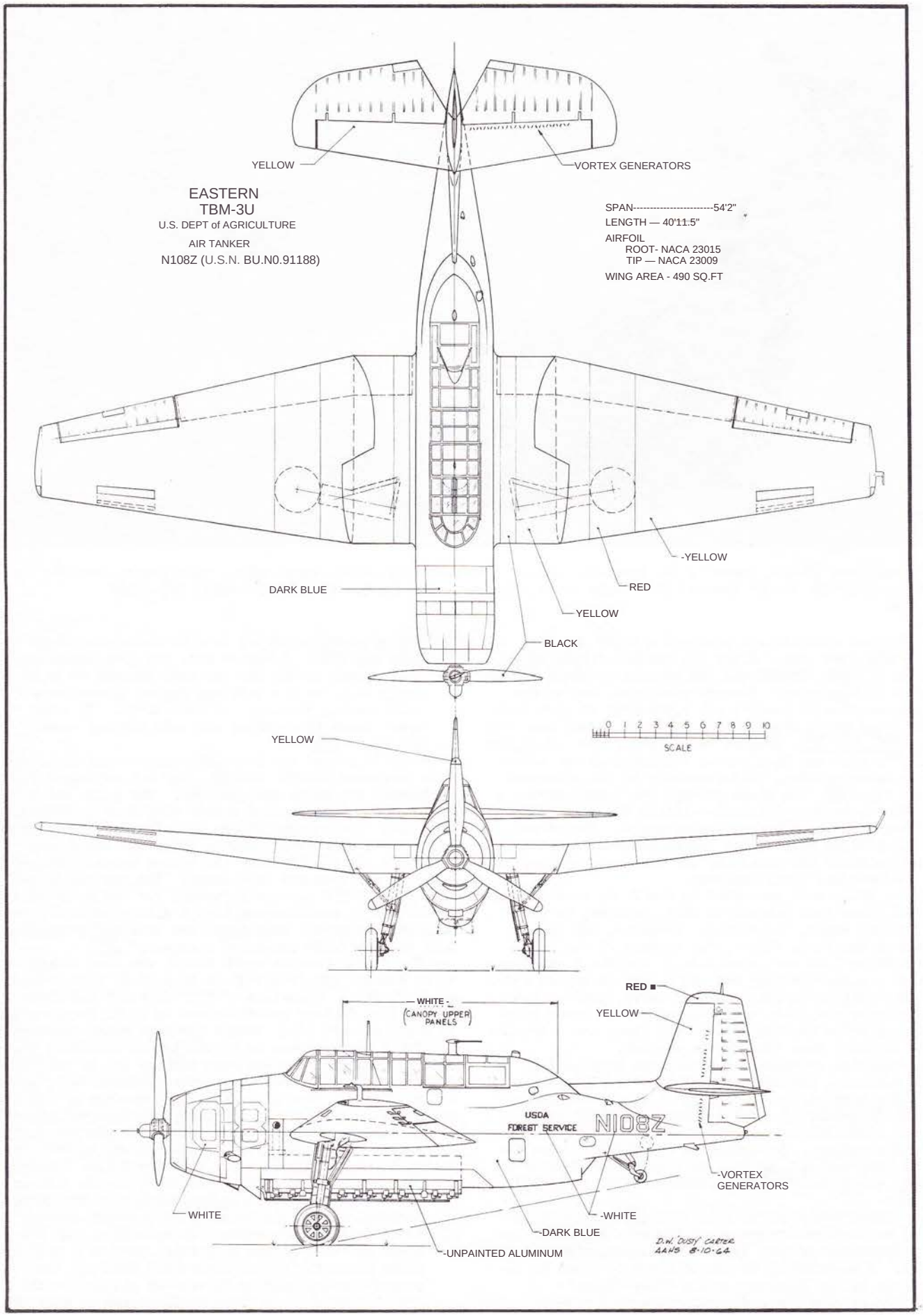
> "Pitch-up caused a spectacular crash of a B-25 tanker during a forest fire in Washington state on July 26, 1960. A tanker made its drop traveling beyond normal speed, and the nose snapped up so violently that the aircraft was thrown upside down still moving forward, but tail first. It broke apart under that stress and both crewmen were killed."

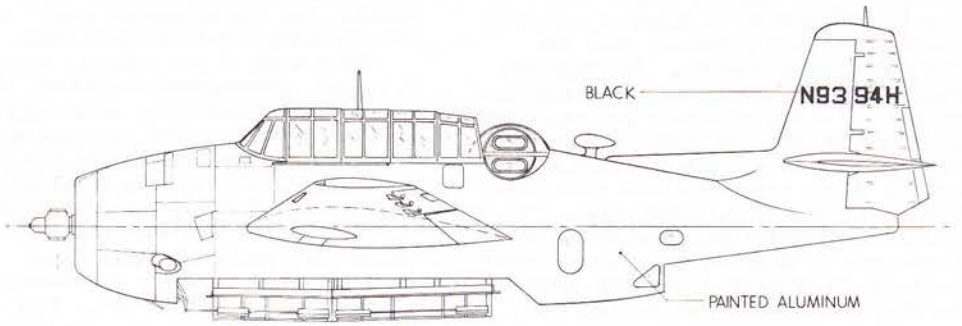
In order to gather the necessary engineering data, the USFS purchased TB-25N, N-10564, and ran extensive tests at Edwards Air Force Base in 1961. The plane had a 1,240 gallon capacity and a tank with four individual openings. The results showed that the B-25 demonstrated severe nose-up rotation during drops and had a wing structure not stressed for the severe G-loads imposed by the drop maneuver and turbulence. The conclusion was that "the TB-25N is unsatisfactory for use as an airtanker because it cannot accomplish a mission with any degree of safety if normal techniques are used while dropping a load of over 3,000 pounds of chemical." (65)

The Forest Service's TBM N-108Z was also flight tested at Edwards AFB from 7-20-61 to 9-16-61 with a total of 23 flights. (Drawings of this aircraft and five other TBM fire fighter modifications by D. W. Carter appear on pages 164 and 165.) Except for some minor deficiencies the TBM-3 was approved as an air tanker providing the air speed during the drop was kept between 105 to 120 knots. A series of vortex generators were experimentally installed on the left hand side of the fin and top of the left horizontal stabilizer in an attempt to improve lateral directional stability. The contrast between its designed mission in the Navy and its present use is best described in the following quote from the flight test report:

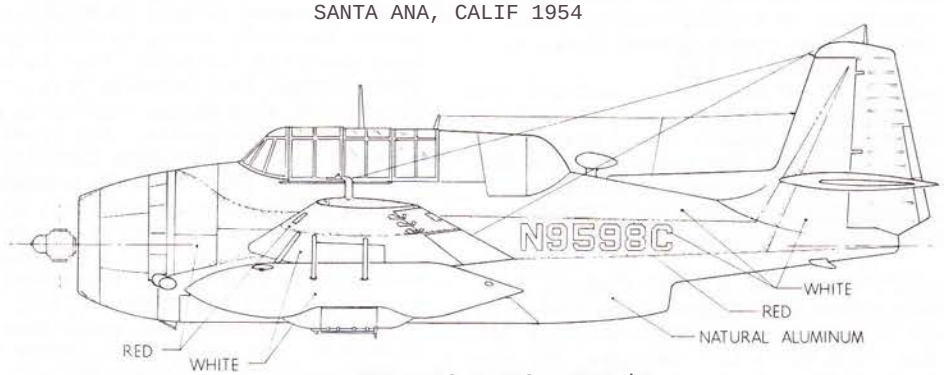
> "The mission, assigned to the TBM-3 in its role as an air tanker differs considerably from its design mission. As an air tanker, the aircraft mission is to take-off at the maximum gross weight, fly for a short distance to the drop zone, perform a drop in close proximity to the ground (75 feet off the ground) in mountainous terrain at rather low air

Continued on page 166


EASTERN
TBM-3U
U.S. DEPT of AGRICULTURE
AIR TANKER
N108Z (U.S.N. BU.N0.91188)
SPAN----------54'2"
LENGTH — 40'11:5"
AIRFOIL
ROOT- NACA 23015
TIP — NACA 23009
WING AREA - 490 SQ.FT
YELLOW
VORTEX GENERATORS
-YELLOW
RED
YELLOW
DARK BLUE
BLACK
YELLOW
0 1 2 3 4 5 6 7 8 9 10
SCALE
RED
YELLOW
WHITE
(CANOPY UPPER PANELS)
USDA
FOREST SERVICE
N108Z
-VORTEX GENERATORS
WHITE
-WHITE
-DARK BLUE
-UNPAINTED ALUMINUM
D.W. 'DUSTY' CARTER
AAHS 8-10-64

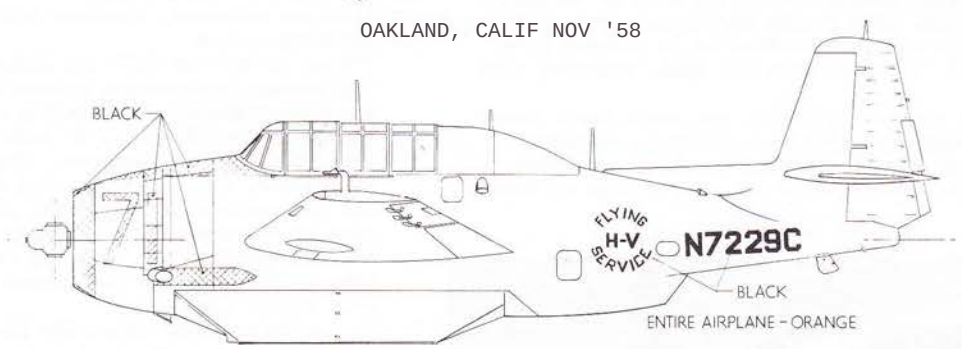


SANTA ANA, CALIF 1954

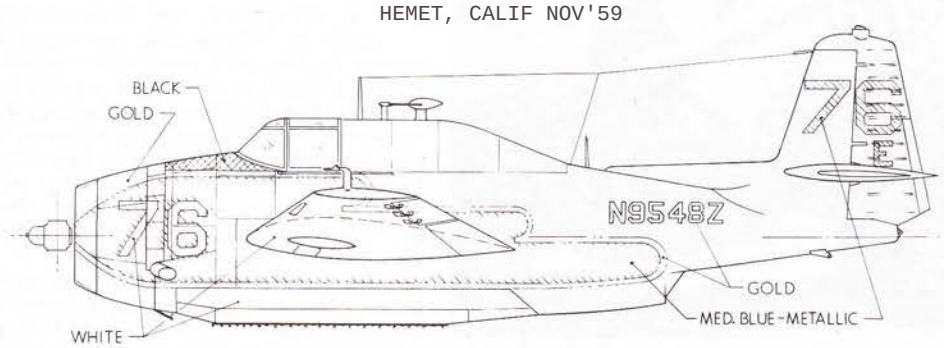


FAIRBANKS, ALASKA MAY '57

OAKLAND, CALIF NOV '58



HEMET, CALIF NOV'59



CHINO, CALIF AUG.'62

D.W. 'DUSTY' CARTER
AAHS 8-9-64

speeds, and return to its landing field. The sudden release of 6000 pounds of chemical solution (or liquid) is considerably different than the dropping of one 1500 pound torpedo. The airplane is also subject to the severe turbulence associated with the mountains on a hot afternoon and sometimes with that generated by the fire itself. Whenever possible, the bombing runs are planned with a downhill escape route in the event the tank doors malfunction and also to provide an added margin for error. On occasion, fighter-type maneuvering is necessary to get out of dangerous situations. Most of the missions are flown in temperatures corresponding to an Army Hot Day and even hotter. The low altitude mission of the TBM-3 air tanker, coupled with the dependence on a single engine, implies a need for a low altitude escape system (i.e., a zero altitude ejection seat)." (66)

The first extensive use of aircraft in Region 2 took place between July and September 1961 when a Consolidated PB4Y-2 of Avery Aviation operated out of Spearfish Airport in South Dakota. Except for two drops by a TBM of Aerial Applicators of Salt Lake City, while the PB4Y-2 was out of commission, the Privateer dropped 27,600 gallons of slurry in the Black Hills National Forest. (67)

Four demonstration drops with a civil Piasecki H-21 helicopter were made before fire fighting officials in southern California in July 1961. A bag containing 300 gallons of water was slung below the fuselage. The continuous experimentation with a Beaver water scooper (N-191Z) by the USFS at the Ely Service Center in Minnesota led from an internal fuselage tank to an external mounting beneath the fuselage of a 125-gallon tank. This F-87 wing tank was cut down to hold 125 gallons of water which was dumped from six gates in the bottom to form an effective swath pattern of 61 x 157 feet. (68)

The trend towards larger payloads continued in 1961 with the introduction of the Boeing YC-97 with a capacity of 4,500 gallons. Two of these planes had been used for spraying on the east coast since 1959, but a semi-external tank was installed on N-9538C for borate drops. The plane was assigned Region 5 Number 67 and operated on several fires although there was reluctance on the part of fire bosses to utilize such an expensive piece of equipment. The flight performance was satisfactory but would have been better if it had not been the service test "Y" model with the small vertical tail surfaces.

In contrast to the big YC-97, the small North American AT-6 was tanked in 1961 and as far as is known three such planes were modified. Two have been destroyed in crashes and the third is now up for sale at Bakersfield, California. With a small tank capacity of 220 gallons, and the hazard of single engine operation, they are now disapproved in California.

Tank modification is shown on Boeing B-17F-70-BA, N-17W, former AAF 42-29782, photographed at Fresno, California on 20 July 1962. (Photo - William T. Larkins)

Since most of the national forests in Region 5 are in rugged, mountainous territory, the USFS has adopted a policy of recommending multi-engined tankers for better flying safety. Not only are engines overworked and strained, but the superheated air rising from a large fire will, at times, stop an engine dead from lack of oxygen. As a result, the four-engine Boeing B-17G (1,800 gallons) came into wide use in 1962 and is currently very active in California.

A private contractor in Phoenix, Arizona, equipped a Curtiss C-46A with a borate tank in 1962, but the FAA would not certify the plane and it was never used. One PBY-5A appeared in 1962 (N-9752Z) at Columbia, California and as far as is known, is the only -5A that has ever been converted for borate work in the U. S. Two little-known Grumman AF-2 Guardian Navy attack planes have been tanked at Redding, California and one (N-3144G) has been used operationally. The first Snow S-2C air tanker was delivered to the North Carolina Forestry Service in the Spring of 1962, although company demonstrations had been held for forestry officials in November 1961. With an internal tank capacity of 300 gallons, the company estimates that as much as 6,000 gallons per hour can be delivered by flying from unprepared strips near the fire. As of July 1961 the State of North Carolina had purchased three S-2Cs and three additional planes had been sold elsewhere. The largest helicopter used so far has been a jet powered Marine Corps Sikorsky HR2S-1 from MCAS El Toro. A water drop demonstration was held on May 16, 1962 with a 450-gallon internal fuselage tank emptying through a hatch in the floor.

In August 1962 Accurate Electronics Corporation delivered the first of five "Firebird" gliders to the USFS for test. These rocket-powered, radio-controlled gliders were intended to carry 100 gallons of chemical retardant released in flight upon radio signal. The delivery of the first article was over a year after extensive newspaper publicity in the Los Angeles area had announced the development of a $350 guided missile for fighting forest fires. (69) Upon delivery, the glider was mounted below the fuselage of a USFS C-46A. On August 31st a test flight was made at Edwards AFB during which severe oscillations occurred, together with a 78% overload on the mounting system.

"These situations left the alternative of: 1) obtaining another bomber-type aircraft and re-developing the installation, or 2) making a feasibility drop from a helicopter-carry to determine if the glider would function as designed. The Army furnished the helicopter, the Forest Service arranged the target, and the contractor rigged the glider and associated hook-up equipment. On December 7, failure of the hook-up equipment on lift off caused rupture of the test glider tanks on the ground and no further tests were made." (70)

It was determined that extensive further engineering work was necessary, and because of the unsatisfactory performance of the glider, the contract was closed.

April 9, 1962 marked the first date of use of an air tanker in Region 8 when TBN-3 N-108Z made a drop of ammonium phosphate on a fire in the Nantahala National Forest. The Southern Appalachian Air Tanker Project dropped 6,600 gallons of phosphate retardant on nine fires between April 9th and May 1st. A propeller malfunction grounded the TBM on May 1st and a contract B-26 was called in as a replacement. The B-26 dropped 7,000 gallons on five fires between then and the end of the fire season on May 19th. (71)

This project was so successful that in 1963 it was extended to include Region 7 (Northeastern U. S.). The successful bidder for the contract for both Regions, to provide services from March 1 through May 15 was Rosenbalm Aviation of Medford, Oregon. They provided B-26s N-3428G and N-5544V to Region 8 at Knoxville, Tennessee;

and B-26s N-4819E and N-7954C to Region 7 at Dublin, Virginia. The fire danger was so great by April that their 2,400 gallon PB4Y-2 (N-3191G) was brought in as a replacement for N-4819E. (72) Earlier tests in the southeast (73, 74) had shown that sodium calcium borate, so widely used in the West, would kill vegetation and sterilize the ground--particularly when applied in large amounts. Because of this, it has never been used in Region 8, DAP and MAP having been used instead. The 1963 season used formula 11-37-0 manufactured by the Tennessee Valley Authority.

A completely new aircraft type entered the air tanker business in 1963 when Flying Fanners, Inc., of Fresno, California, put a 1,600 gallon tank on the Northrup P-61B Black Widow N-30020. Unfortunately it had just begun to operate when it was lost on a brush fire on the Tule Indian Reservation, 15 miles east of Porterville, California, on August 23, 1963, killing veteran pilot Robert Savaria.

Two other one-only types appeared in 1963. One was a Vultee BT-I3A (N-57282) with an AT-6 engine and 300-gallon tank modified by Nick Moller of Maxwell, California: and the other was a Columbia J2F-6 (N-67790) at Phoenix, Arizona. The latter was a water-scooper utilizing its amphibious hull for a 300-gallon capacity, and was operated as No. C-07 in Region 3.

Extensive tests were made with three new helicopter tanks at Bakersfield, California, in April 1963. (75) The first was a 105-gallon tank designed by the Los Angeles County Fire Department featuring electrically operated gates for controlling the flow during the drop maneuver. The second was the Meade tank, stressed for 800 pounds, Which was an open top tray hinged at the front and opened manually. The third was the Irvin Air Chute tank which consisted of a 100-gallon bag dumping through a long snout. Meanwhile Okanagan Helicopters in Canada developed its "Monsoon Bucket" which is essentially a 45-gallon oil drum with an electrically operated dump valve at the bottom. With this device, a helicopter pilot can lower the bucket into a lake, fill it with water, hover over a small fire and dump its contents, and return for another load.

Consolidated PB4Y-2, F 85, at Medford, Oregon in September 1962. Based in Oregon, it fought fires in Virginia in May 1963. (Photo - Clay Jansson)

By the end of 1963 the State of Georgia had purchased two TBMs, and Florida had replaced their previous Beech C-45 (N-64970) with a PBY-6A. The results of air attack in British Columbia shewed the average fire-suppressiOn Cost per fire down 17.6% from 1962. During the year 36 air tankers operated in B. C. for a total of 428 flying hours; these consisted of TBM, Beaver, Otter, Piper Super Cub, Bell helicopter and Hiller helicopter aircraft. (76)

Another one-only aircraft came into use in July 1964 when Northrop F-15A, N-9768Z (California E-35), started operations out of Fresno. This interesting photo-recon version of the P-61 was sold as surplus by the NACA Ames Laboratory in September 1955. It was trucked to San Jose,

Consolidated PBY-6A, flown by Mitch Marr, making a low altitude demonstration drop at Columbia, California on 19 October 1963. The tall-tail "6A" model is standard for use in the U. S., with the PBY-5A being used in. Canada. Most U. S. Catalinas have had their wing tip floats removed as with E 57 here. (Photo - William T. Larkins)

California, registered N-5093V, and put into flying condition. After operating with an aerial mapping firm in Los Angeles, it went to Mexico City, where it flew for Cia Mexicana Aerophoto S.A., as XB-FUJ. It was brought back to the U. S. in early 1964 by King Baker, overhauled in Los Angeles, and flown to Grass Valley for the installation of its 1,800-gallon tank by Cal-Nat Airways.

Perhaps the most important current development is the production of Field Aviation modified PBY water scoopers. The first of these was delivered in 1962 and 18 conversions are now flying as follows: 5 by the Province of Quebec; 1 by the Province of Newfoundland; 2 by Northland Airlines for the Province of Manitoba; 1 by Saskair for the Province of Saskatchewan; 4 by Renting Aviation for the Province of Ontario; and 2 by the Department of Civil Protection in France. A 960-gallon tank is filled in 14 seconds and forms a drop pattern 90 x 190 feet. The cost per gallon for water drop in this manner is about 7.5 cents, as compared with an average cost of 2 cents for Bentonite and 42cents for borate. But the most impressive figure of all, for those who happen to have lakes handy to their fires, is the June 1964 record of 112,320 gallons of water dropped in one day by one Field modified PBY-5A! (77)

A final 1964 development, with far-reaching implications, is the hew contract entered into by AJ Tankers, Inc. and Los Angeles County. For the first time an operator has been put under contract for a 24-hour-a-day basis for 365 days a year. The two AJ-ls are now based at Lockheed Air Terminalin Burbank. "One is loaded with water and the other with a commercial slurry, and depending on the type of fire and. the location, either one can be called out. In return for this guarantee the County agrees to pay the company $80,000.00 a year. For every hour that a plane is called out after the minimum hours have been exhausted, the County agrees to pay an additional $600." (78)

With the final acceptance of the utility of air tankers by all concerned, the air attack system is now settling down to a well-organized and stable business. The greatest problem facing this industry at the present time is the haunting spectre of aircraft replacement. The TBMs and B-17s cannot withstand the constant G-loads forever and will have to be replaced at some time in the near future. Since bitter experience has proven that only heavily stressed military typ.es, or a plane specifically designed for the purpose, have the tank capacity, performance and safety necessary, there is considerable uneasiness over possible piston-engine replacements. The present system was. built upon the availability of inexpensive, surplus piston-engine military aircraft, and these are vanishing. Two companies have made paper proposals for large aircraft: Lockheed for a C-130B modification; and Douglas for their D-828F VTOL design. Both would involve large initial expenditures that the small operator cannot afford.

Perhaps the growing need for year-round standby service providing adequate time for training and maintenance, together with the cost of future replacement aircraft, will result in a new "United States Forest Guard" Air Service, on the same basis as the U.S. Coast Guard which operates under the Treasury Department in peace time.. Certainly the new developments already being tried indicate the need for such an organization. Two such items are the use of Tiros satellites for spotting lightning storms to. give a priceless few hours warning to the fire fighter, and the use of heat seekers. A department of lands and Forests' Beaver in Ontario has already flown as an airborne platform for an infrared heat detector that can spot a match flame 30,000 feet away, and for a flame scanner which will detect a highway flare one-quarter mile away. (79)

For those of us interested in aircraft development this will certainly be a fascinating subject to watch in the forthcoming years.

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TABLE 1.

U.S. Forest Service Region 5 (California) Air Tanker Register for the 1963 fire season (July 1963 through June 1964). These R-5 numbers are recognized by both the USFS and the California Division of Forestry. Those marked with an asterisk (*) are planes that did not have a 1963 contract but had been prequalified so that in case of emergency they could be put to immediate use on a fire.

R-5#	Reg't'n.	Aircraft	Serial (1)	Operator and 1963 Base
E 1	N-75081	PT-17	75-3182	Willows Flying Service, Gravelly Valley
E4	N-45163	N3N-3	2885	Lee Sherwood, Gravelly Valley
E 5	N-45233	N3N-3	2634	Harold Hendrickson, Hobergs CDF (2)
E6	N-45032	N3N-3	1933	Gene Elian, Chester
E 8	N-45014	N3N-3	2740	Neal Wade, Hobergs CDF
E 9	N-45177	N3N-3	2733	L.C. McCurley, Ukiah CDF
E 10	N-7752C	N3N-3	4353	Hills Flying Service, Chester CDF
E 12	N-7753C	N3N-3	4405	Hills Flying Service, Placerville CDF
E 14	N-44972	N3N-3	2810	Frank Michaud Jr., Hobergs CDF
E15*	N-45089	N3N-3	2747	Lee Sherwood
E 17	N-9323Z	B-17G	44-83514	Aero Union Corp., Redding
E 18	N-9324Z	B-17G	44-83542	Aero Union Corp., Redding
E 19	N-9596C	TBM-3	69361	P & B Aviation, Oroville CDF
E 20	N-45057	N3N-3	2895	Ostaire Flying Service, Ukiah CDF
E 21	N-45228	N3N-3	1763	Ace Aerial Service, Ukiah CDF
E 23	N-6179C	F7F-3	80494	Sis-Q Flying Service, Siskiyou Co. Arpt.
E 27	N-45188	N3N-3	2815	Hills Flying Service, Placerville CDF
E29	N-9318Z	TBM-3	91113	P & B Aviation, Red Bluff CDF
E 30	N-3144G	AF-2S	123100	Aero Union Corp., Redding
E 31*	N-6177C	F7F-3	80397	Sis-Q Flying Service
E 32	N-7195C	F7F-3	80532	Sis-Q Flying Service, Siskiyou Co. Arpt.
E 33	N-6458C	PBY-6A	46644	Liston Aircraft, Devil's Garden

E 34	N 1340N	B-17F	42-6107	King Baker, Fresno
E36*	N 1369N	TBM-3	85715	IBM Inc.
E 37	N-6825C	TBM-3	85883	Cai-Nat Airways Inc., Ramona CDF
E 38	N-9926Z	TBM-3	91474	Aircraft Specialities, Beckwourth
E 39	N-9927Z	TBM-3	85869	Aircraft Specialities, Beckwourth
E41	N-7238C	F7F-3	80525	Cai-Nat Airways, Grass Valley
E 42	N-7626C	F7F-3	80404	Cai-Nat Airways, Grass Valley
E43	N-7619C	F7F-3	80400	Cai-Nat Airways, Porterville
E 44*	N 7226C	TBM-3	85938	Sierra Aviation
E 45	N-6823C	TBM-3	85636	Sierra Aviation, Porterville
E 46*	N-9711Z	TBM-3	53697	Sierra Aviation
E 48*	N-9752Z	PBY-5A	11040	B.B. Burson S Associates
E 52	N-9434Z	TBM-3	86090	F.H. Haradon, Goleta
E 53	N-30020	P-61B	938	Ranchers Inc., Fresno CDF
E 54	N-6453C	PBY 6A	64041	B.B. Burson & Associates,Columbia
E 57	N 9651C	TBM-3	91664	Cal-Nat Airways, Ramona CDF
E58*	N-6827C	TBM-3	91110	TBM Inc.
E59	N-7628C	F7F-3	80412	Cal-Nat Airways, Goleta
E60*	N-1366N	TBM-3	85594	TMB Inc.
E61	N-3702G	B-17G	43-38635	Fast-Way Air,Chino
E68	N-5168V	TBM-3	53592	Hemet Valley Flying Svc, RyanField CDF
E71	N-7229C	TBM-3	86195	Hemet Valley Flying Svc, RyanField CDF
E72	N-3357G	TBM-3	53858	Hemet Valley Flying Svc, RyanField CDF
E73	N 9082Z	TBM-3	53727	Hemet Valley Flying Svc, RyanField CDF
E74*	N-7833C	TBM-3	91289	Hemet Valley Flying Svc
E 75	N-3356G	TBM-3	85844	Hemet Valley Flying Svc, Ryan Field CDF
E 76	N-9548Z	TBM-3	91598	Rector Air Service, Chino
E77	N-9143Z	AJ-1	124167	AJ Air Tankers, Van Nuys
E78	N-3703G	B-17G	44-83546	Fast Way Air, Chino
E 79	N-9710Z	TBM-3	53804	Columbia Flying Svc, Hollister CDF
E 80*	N-9547Z	TBM-3	85957	Aero Crop Corporation
E85*	N-66573	B-17G	32226	Ewing Aviation
E88	N-9142Z	AJ-1	124158	AJ Air Tankers, Van Nuys
E89	N-9187Z	TBM-3	53818	Columbia Flying Svc, Hollister CDF
E 92*	N-7961C	TBM-3	69323	Daro Inc.
E93	N-2887D	PBY-6A	64098	B.B. Burson, Gravelly Valley
E 95	N-9860C	TBM-3	861 18	Routh Aircraft, Ramona
E 96	N-9679C	TBM-3	69293	Routh Aircraft, Paso RoblesCDF
E97	N-7161C	TBM-3	86064	Routh Aircraft, Paso RoblesCDF
E 98*	N-9708Z	TBM-3	53307	Daro Inc.

(1) The serial number given is that from the UNITED STATES CIVIL AIRCRAFT Register for June 1, 1963 and except for E-1 is either the AAF or Navy serial number.

(2) CDF indicates a California Division of Forestry facility.

TABLE 2

U.S.F.S. Region 5 Air Tanker Number Cancellations for 1963. If at any future date these planes are reactivated a new number would be assigned.

R-5#	Reg't'n.	Aircraft	Serial	Operator
E2	N-6591C	AT-11	42 36884	Willows Flying Service, Willows
E3	N-44959	N3N-3	4383	Varney Air Industries, Willows
E 7	N-45292	N3N-3	2728	C.T. Jensen, Sacramento
E11	N-45251	N3N-3	4450	Lee Sherwood, Willows
E 16	N-66666	AT-11	1010	Willows Flying Service, Willows
E22	N-6831C	TBM-3	86123	C.T. Jensen, Sacramento
E 23	N-45084	N3N-3	4497	C.T. Jensen, Sacramento
E 24	N-68Q	AT-11	5065	P & B Aviation, Red Bluff
E 25	N-79A (?)	AT-11		Aero Atlas, Red Bluff
E 26	N-6961C	AT-11		Aero Atlas, Red Bluff
E 28	N-6956C	AT-1 1	42-37217	P & B Aviation, Red Bluff
E 30	N-9865C	TB-25N	44-28834	Aero Union Corp., Redding
E 38	N-6456C	PBY-6A	63996	Sonora Flying Service, Columbia
E 47	N-45047	N3N-3	2641	Siskiyou Airways, Montague
E 49	N-6457C	PBY-6A	64071	Sonora Flying Service, Columbia
E 51	N-9429Z	TBM-3	91714	Sonora Flying Service, Columbia
E 56	N-9564Z	TBM-3	91388	Cisco Aircraft, Lancaster
E 63	N-9083Z	TBM-3	53492	Riverside Aircraft, Riverside
E 64	N-7239C	TBM-3		Riverside Aircraft, Riverside
E 65	N-5260V	TBM-3	91726	Riverside Aircraft, Riverside
E 67	N-9595C	TBM-3	53479	Cisco Aircraft, Lancaster
E 70	N-5170V	TBM-3	53886	Hemet Valley Flying Svc, Hemet
E 81	N-9590Z	TBM-3	91733	Cisco Aircraft, Lancaster
E 82	N 9307Z	TBM-3	86091	Cisco Aircraft, Lancaster
E 84	N-17W	B 17F	42-29782	Abe's Aerial Service, Stafford, Arizona
E 87	N-2846D	PBY-6A	64017	Jadon Enterprises, Riverside
E 94	N-7082C	PBY-6A	225	Routh Aircraft, Long Beach

TABLE 3

U.S. Forest Service Region 4 (Nevada, Utah, Idaho, Wyoming) Air Tanker Register for 1961. No regional numbers were used and all planes operated from Boise, Idaho

Reg't'n.	Aircraft	Serial	Operator
N-7030C	TBM-3	53454	Tom White, Boise, Idaho
N-3337G	B-25J	44-86891	Lee Roser, Phoenix, Arizona
N 66267	B-18B	38-593	Roberts Aircraft, Boise, Idaho
N-4171A	TBM-3	91521	Reeder Flying Svc, Twin Falls, Idaho
N-4169A	TBM-3	5653 (?)	Reeder Flying Svc, Twin Falls, Idaho
N-4168A	TBM-3	91565	Reeder Flying Svc, Twin Falls, Idaho
N-7086C	PV-2	1410	Larabee & Rabinette, Boise
N-9590C	TBM-3	53784	Idaho Aircraft, Boise
N-9856C	B-25J	43-28204	Idaho Aircraft, Boise
N-9116Z	B-25J	44-29287	Idaho Aircraft, Boise
N-9623C	B-25J	44-30692	O. Hine, Maricopa, Arizona
N-7157C	TBM-3	86020	D. Goodman, Missoula, Montana
N-9080Z	B-25J	44-30734	Donaire Inc., Phoenix, Arizona
N-9593C	TBM-3	69472	Clayton Curtis, Boise
N-6123C	B-25J	44-86893	Abe's Aerial Service, Safford, Arizona
N-9117Z	B-25J	44-29199	Abe's Aerial Service, Safford, Arizona

TABLE 4

U.S. Forest Service Region 4 Air Tanker Register for 1963.

R-4#	Reg't'n.	Aircraft	Serial	Operator and 1963 Base
D3	N-5635N	TBM-1C	A20260	Idaho Aircraft, Boise, Idaho
D 4	N-7026C	TBM-3	69294	Idaho Aircraft, Bruce Meadows, Idaho
D 5	N-9593C	TBM-3	69472	Clayton Curtis, Boise
D6	N-9010C	TBM-3	53200	Hillcrest Aviation, Boise
D 7	N-7028C	TBM-3	53775	Hillcrest Aviation, Boise
D8	N-4168A	TBM-3	91565	Reeder Flying Svc, BruceMeadows
D10	N-4170A	TBM-3	91453	Reeder Flying Svc, BruceMeadows
D11	N-4171A	TBM-3	91521	Reeder Flying Svc, Salmon, Idaho
D 12	N-9429Z	TBM-3	91714	Reeder Flying Svc, BruceMeadows
D13	N-7C30C	TBM-3	53454	Tom White, Salmon
D 15	N-7848C	TBM-3	91206	Aerial Applicators, Salt Lake City,Utah
D 19	N-9529C	TBM-3	53256	Aerial Applicators, Salt Lake City,Utah
D 23	N-73642(?)	TBM-3	69329	Reeder Flying Svc, Bruce Meadows

TABLE 5

U.S. Forest Service Region 6 (Oregon and Washington) Air Tanker Register for 1963

R-6#	Reg't'n.	Aircraft	Serial	Operator
F 11	N-6459C	PBY-6A	46653	Liston Aircraft, Klamath Falls, Oregon
F 12	N-5544V	B-26C	44-35552	Rosenbalm Aviation, Medford, Oregon
F15	N-5237V	PB-1W	77233	Butler Farm Air,Redmond, Oregon
F 16	N-6129C	F7F-3	80390	Butler Farm Air,Redmond
F17	N-7235C	F7F-3	80425	Butler Farm Air,Redmond
F18	N-7654C	F7F-3	80373	Butler Farm Air,Redmond
F 20	N-5457V	B-26B	44-34313	Hillcrest Aircraft, LaGrande, Oregon
F21	N-9681C	PB4Y-2	69810	Hillcrest Aircraft, LaGrande
F 23	N-9161Z	B-26C	43-22621	Hillcrest Aircraft, LaGrande
F 24	N-9159Z	B-26C	43-22673	Hillcrest Aircraft, LaGrande
F 29	N-3428G	B-26C	44-35523	Rosenbalm Aviation, Medford
F 30	N-7459C	PV-2	37230	Aero Ag., Medford
F 37	N-6657D	PV-2	1606	Wenairco, Wenatchee, Washington
F40	N-6651 D	PV-2	1503	Wenairco, Wenatchee
F42	N-6816D	PB4Y-2	59905	Wenairco, Wenatchee
F 46	N-6458C	PBY-6A	46644	Liston Aircraft, Klamath Falls, Oregon
F 47	N-6455C	PBY-6A	64069	Liston Aircraft, Klamath Falls
F56	N-86469	B-26C	43-22511	Aero Flight, Troutdale, Oregon
F 57	N-4819E	B-26B	44-34609	Rosenbalm Aviation, Medford
F62	N-7086C	PV-2	1410	B & B Flying Service
F71	N-5233V	PB-1W	77231	Aero Ag., Medford
F 74	N-74874	B-26B	44-34508	Kreitzberg Aviation, Salem, Oregon
F 76	N-9423Z	B-26B	44-34687	Central Oregon Aerial Co., Bend,Oregon
F 77	N-9425Z	B-26C	44-35721	C.O.A.C., Bend, Oregon (crashed)
F 83	N-7954C	B-26C	44-35724	Rosenbalm Aviation, Medford
F84	N-6884C	PB4Y-2	59701	Rosenbalm Aviation, Medford
F85	N-3191G	PB4Y-2	59754	Rosenbalm Aviation, Medford

TABLE 6

U.S. Forest Service Region 3 (Arizona and NewMexico) Air Tanker Register for 1963.

R-3#	Reg't'n.	Aircraft	Serial	Operator
C3	N-9927Z	TBM-3	85869	Aircraft Specialities, Willcox, Arizona
C11	N-9996Z	B-26C	44-35661	Donaire Inc., Deer Valley, Arizona
C 12	N-9301 R	B-26C	44-35872	Aircraft Specialities, Willcox
C 13	N-8037E	B-26C	44-35889	Moseley Aviation, Deer Valley
C 29	N-4820E	B-26C	44-35217	Flight Enterprises,Prescott, Arizona
C30	N-3739G	PB4Y-2	59819	Flight Enterprises,Prescott
C31	N-8629E	B-26B	41-39572	Flight Enterprises,Prescott
C33	N-9401Z	B-26C	44-35524	Donaire Inc., Deer Valley
C 34	N-9564Z	TBM-3	91388	Aircraft Specialities, Prescott
C 46	N-3968A	TBM-3	53692	Cochise County Airport, Willcox
C 47	N-6447C	TBM-3	53575	Sonora Aviation, Silver City, New Mexico
C 50	N-7219C	TBM-3	86280	Thurman Yates, Silver City, New Mexico
C 53	N-6826C	TBM-3	86244	Cochise County Airport, Marana, Arizona
C 55	N-6894C	TBM-3	53626	Sonora Aviation, Alamogordo, New Mexico
C 56	N-9433Z	TBM-3	91586	Sonora Aviation, Silver City, New Mexico
C84	N-17W	B-17F	42-29782	Aircraft Specialities, Willcox
C 96	N-9679C	TBM-3	69293	Routh Aircraft, Winslow, Arizona
C97	N-7161C	TBM-3	86064	Routh Aircraft, Winslow, Arizona

TABLE 7

Air Tankers Destroyed in Fire Control Activities 1959-1962.*

Reg't'n.	Aircraft	Date	Location	Cause
N-9830C	TBM-3	7-5-59	Near Yucaipa, California	Flew into mountain
N-9613C	B-25J	7-26-60	Near Twisp, Washington	Disintegrated in flight
N-109Z	TBM-3	8-18-60	Independence Lake, Cal.	Hit 115' tree in smoke
N-3503G	B-25J	7-22-60	LaGrande, Oregon	Failed to drop, stalled
N-6986C	PBY-6A	6-25-61	Winslow, Arizona	Engine failure
N-331SZ	TBM-3	6-15-61	Indian Garden, Arizona	Engine failure and fire
N-7032C	TBM-3	7-9-61	Idaho City, Idaho	Off runway on takeoff
N-188C	AT-6G	8-22-61	Frazier Park, Calif.	Loss of control in flight
N-3250G	TBM-3	9-16-61	McCall, Idaho	Engine failure, bailout
N-62701	AT-6B	9-3-61	Near Forbestown, Cal.	Stalled
N-9428Z	TBM-3	6-16-61	Nr. Glenwood, N. Mex.	Hit trees, sheared off wing
N-5170V	TBM-3	7-22-62	Near Beaumont, Calif.	Pilot had a heart attack"
N-7627C	F7F-3	8-31-62	Grass Valley, Calif.	Gear folded on landing
N-7625C	F7F-3	9-24-62	Near Callahan, Calif.	Hit trees
N-3578G	B-17G	10-11-62	Near Fallon, Nevada	Hit mountain

*Accidents in Fire Control, U.S. General Aviation, 1959, 1960, 1961, 1962, Civil Aeronautics Board, Washington, D.C., December 31, 1963.

Note: This table excludes non-tanker accidents, such as helicopter and lead planes, that are included in the above reports.

TABLE 8

Fixed-wing Air Tankers that have been used operationally on Fires.*

Beech AT-11, C-45	Grumman AF-2
Boeing B-17F, B-17G	Grumman F7F-3
Boeing YC-37	Lockheed PV-2/B-34
Columbia J2F-6	Martin JRM-3 "Mars"
Consolidated PBY-5A	Naval Aircraft Factory N3N-3
Consolidated PBY-6A	North American AT-6D, AT-6G
Consolidated PB4Y-2	North American AJ-1
DeHavilland DHC-2 "Beaver"	North American B-25J, TB-25N
DeHavilland DHC-3 "Otter"	Noorduyn "Norseman"
Douglas B-18B	Northrop P-61B
Douglas B-26B, B-26C	Northrop F-15A
Douglas SBD/A-24	Piper "Super Cub"
Fairchild C-82A	Snow S-2C
Ford 4-AT-E	Stearman PT-17/N2S-3
General Motors TBM-1C	Transland Ag-2
General Motors TBM-3	

*It is most probable that the Antonov An-2S has been used in Russia, and possibly the Commonwealth CA-28 "Ceres" in Australia.

AUTHOR'S NOTE: For those interested in further details extensive references are given because of the need to compress this article into available JOURNAL space. In many cases a passing reference merely indicates the existence of valuable resource material. No. 60, for example, does not begin to do justice to the 73-page illustrated Air Tanker Guide which is the official USFS manual for air operations; nor does No. 7 indicate that this 149-page document is done in this field.

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An example of the early methods of mixing borate is this scene at Chino in September 1959. (Photo - USFS 493297)