Water Bombers

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Abstract - Water bombers, also known as scoopers, are an emerging class of aircraft designed specifically to fight fires. Having been used and experimented with for more than fifty years, water bombers are only now beginning to be designed from the ground up. These firefighting tools have already saved countless lives and homes; their further development represents one of the cheapest and most effective ways to give firefighters an edge in combating large, destructive fires.

1
The Importance of Aerial Firefighting

Wildfires under the right conditions can grow to be large, angry furnaces incinerating everything they touch while quickly spreading over hundreds or thousands of acres, causing millions of dollars in damages. Perhaps that's why insurance companies are so quick to label them as "acts of god." Such fires wreak havoc all over the globe from the Mediterranean to Canada to the American West. In California alone, 172,000 acres get scorched every year [5]. Although the vast majority of fires are small, a few large ones every year are responsible for the vast majority of damage [10]. One of the best tools in stopping a fire before its gets too large is the use of aircraft to dump large amounts of water or fire retardant on the area. Air tankers, the name firefighters use for such aircraft, first began appearing in the 1950s as old military and crop spraying planes retrofitted to carry water and retardant tanks in place of bombs or fertilizer. Since then, air tankers have become permanent staples of firefighting services around the world, and their design has evolved with them, moving from retrofitted aircraft to purpose-built.

1.1
What are water bombers?

Asked to visualize a firefighting aircraft, most people's minds jump to a dramatic image of a plane or helicopter dropping a large plume of white or red onto a dark background of smoke and fire like the image shown in Fig. 1. Fire services call these vehicles "air attack" or air tankers when discussing fixed-wing [5]. As the development of aerial firefighting has progressed, two camps have emerged surrounding air tankers; supporters of aircraft carrying water or water-based foams and gels, and supporters of aircraft carrying chemical fire retardant. While the retardant-carriers got no special name, water carrying air tankers got the nicknames water bombers and scoopers, reflecting the use of these planes to "scoop" up water from a nearby source with which to "bomb" the target area. While there's reason and room to use both kinds of air tanker, water bombers far out-perform their air tanker brethren in ability to get as much volume of fire-stopping-stuff on scene in the least time possible. Whereas land-based tankers need to return to an airbase and refill with a pump, water bombers need only find a medium-to-largish body of water at which they can throttle down and scoop up water in their tanks, not unlike a how child uses a pail at the beach.

Fig. 1: A Spanish Air Force Bombardier 415 executing a drop

For perspective, a RAND corporation paper estimated that two thirds of historical fires in the U.S. occurred within ten miles of a suitable body of water, which at 100 knots equals about 5 minutes travel time [10]. Meanwhile, California's state firefighting service, maintains 13 air attack and 9 heliattack bases and estimates that it can reach most fires in 20 minutes [5]. That gives water bombers about a fourfold advantage in time-to-arrival in a profession where minutes and seconds can mean the difference between the loss or rescue of people's homes and livelihoods.

2
Principles of Operation

The principles of water bomber operation are relatively simple, though at first surprising. Water bombers don't actually put out fires; ground crews do that. Instead, water bombers are used to "knock down" the hottest spots in a fire, which means they're employed in reducing the heat or flame on a fire edge, thus making it safer for ground crews to do their job [8].

In making a run on the fire, there are three strategies of attack that air tankers generally use; Indirect attack, parallel attack, and direct attack [8]. These strategy names mean roughly: dropping away from the fire in order to help contain a fire's growth beyond a prescribed control line, dropping close to the fire to guide its burn along a control line, and dropping right on the fire edge to reduce the fire's intensity, respectively. Because of water bombers' advantage over retardant-bearing tankers in transporting large volumes of suppressant quicker, they are most often used in direct attack.

To accomplish this mission, water bombers must locate the closest large, open, source of water to the fire. After establishing where the water is, water bomber pilots land, load tanks, and climb back out to the fire. Observation aircraft, known as "air tactical", relay coordinates prescribed for a bombing run while the water bomber is en route. The pilot then lines up and executes the drop. Repeat as necessary.

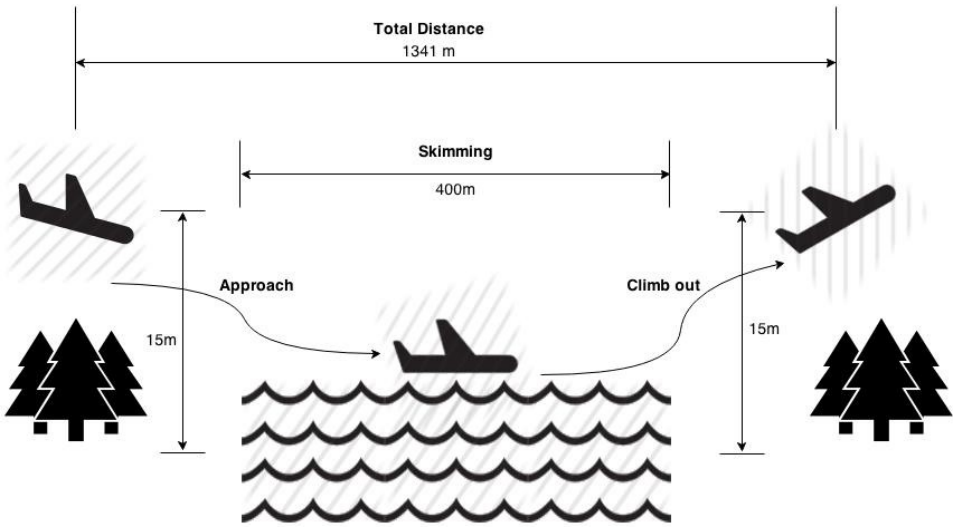

Fig. 2: Typical approach, scoop, and climb profile of the Bombardier 415

2.1
The Approach

To find a suitable body of water, a pilot has to know their aircraft well. Landing and takeoff distances provided by aircraft manufacturers include the ground distance needed to clear a 15m obstacle – a standard chosen to reflect conditions on an airport runway. Since amphibious landings don't always have the same managed conditions as encountered on airbases, the pilot has to estimate how a plane's maneuverability, sink, and climb rates will affect its ability to clear nearby obstacles. Even when a pilot is confident that there's enough space to land and takeoff, the sea state – roughness of the water – also needs to be taken into account to ensure safe operation. Additionally, tank capacity and rate of water uptake by the scoops affect skimming distance required in between touching down and taking off. Knowing these numbers allows a pilot to estimate how much volume can be taken from any body of water. With all of these criteria satisfied, it's time for the pilot to line up and make the decent approach as they would with any land-based airplane.

2.2
Loading Up

Once the plane touches down on the water surface, the pilot keeps it "on the step," which means taxiing nearly as fast as possible without becoming airborne. A water bomber on the step usually has a speed of around 70 knots [9]. At this point, the scoops are lowered, and the plane begins to take on water.

Scoops are an essential component of water bombers, and one of the reasons behind the name "scooper". As seen in Fig. 3, scoops are relatively simple devices which direct water flow up and into the tanks. Keeping a plane on the step while lowering scoops creates a huge ram pressure, and this pressure is what drives water into the water bomber's tanks so that no pumps are needed. Uptake speed can vary from plane to plane, with the largest flying boat ever to be converted into a water bomber, the Martin Mars, averaging about 1100 L/s, or a ton of water every second [9].

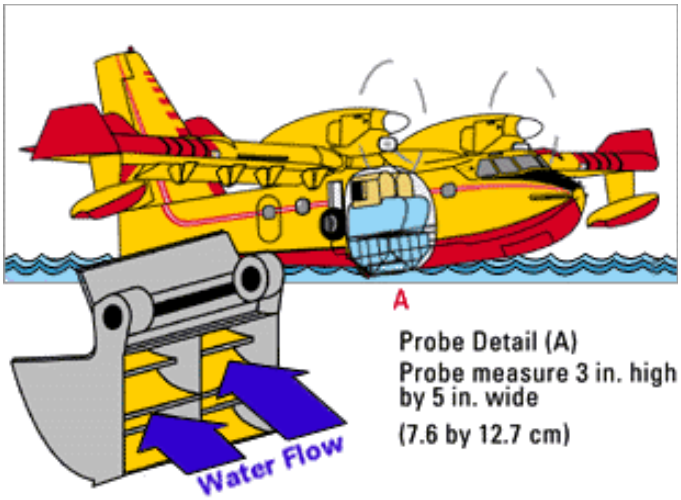

Fig. 3: Illustration of a Bombardier 415 with scoop detail [3]

The marked increase in weight associated with scooping means that all water bomber pilots need to continually increase the throttle while skimming to keep the plane on the step. If there isn't a long enough stretch of water surface to load a full tank, it is possible to load partial tanks on some aircraft and even turn while scooping in order to avoid hazards or follow the water [2].

To ensure the water gets to destination, a check valve keeps water in the tanks, while vents on top guarantee that no pressurization occurs. Accidentally capturing the ram pressure could explode the tanks, ripping the whole plane apart. In cases where water-based gel is being used in the drop, water bomber crews take advantage of the turbulence during scooping and add gel concentrate to the tanks as scooping takes place in order to ensure proper mixing. With full tanks, the pilot hits full throttle and climbs out. It's time to return to the fire.

2.3
Return and Attack

Back in the air and en route, water bomber pilots are again in communication with air tactical, who've remained on site the whole time. Updated attack coordinates are given to the water bomber, and the crew readies to make the next pass. If foam is going to be used, concentrate is injected into the tanks before arriving at the new attack coordinates; the tumbling motion during the drop will mix the foam which expands and smothers almost all surfaces it comes into contact with.

The second trickiest part of the whole operation, after loading tanks, is the drop. In order to make an accurate drop a pilot has to fly low and slow. At low altitudes and speeds, airplanes become vulnerable to relatively small gusts and turbulent effects stirred up by interaction with surface objects. If there is a sudden down or up draft, the plane can wind up either in the ground or in a spin. If a plane is flying too slowly, it will stall, literally falling out of the sky. For water bomber pilots and planes, however, these conditions are routine. When flying over large fires, extreme temperature differences can stir up massive turbulence.

Combined with a blanket of smoke, flying in these conditions is undeniably rough on both personnel and equipment.

The design of the Bombardier 415, which is the only purpose designed-and-built scooper in production today, takes these harsh conditions into account. It has a typical drop height of only 10-13 stories and speed of 110 knots [2]. To make it safe to operate in rough conditions, it was engineered to have a power-to-weight ratio of 0.29 *after scooping* and is able to pull +3.25 G's (most humans black out around 5-6 G's without pressure suits), making it highly maneuverable[2]. It also has an very low stall speed of 68 knots, which is only about 10 mph faster than the speed limit on California highways [1].

When a water bomber reaches its designated attack coordinates, the pilot opens the water doors and executes the drop, completing a circuit.

All in all, each of these circuits from fire to water and back take only about 5-15 min depending on the distance from the water source to the fire. With water bombers having regular endurance figures of 2-3 hours, they prove highly effective tools at knocking down fires before they get too large, saving firefighter's lives and helping prevent the destruction of homes and property wherever they operate.

3
The Future of Water Bombers

The future of water bombers is blazing bright. Bombardier's purpose-designed plane seems to have made a big impression in the global market; it's firefighting planes are currently in service with 21 operators in 11 countries [3]. Domestically, the U.S. Forest Service (USFS) has been looking to reevaluate their aircraft holdings as their inventory of older aircraft that were retrofitted to be air tankers are starting to retire. A study the USFS solicited from RAND indicates that the corporation, too, believes the future lies in increasing the number of water bombers used by U.S. fire services in order to provide faster, cheaper, effective fire relief to regions across the country [10].

To be sure, water bombers are not the sole technology around which firefighting inventories should be built – in order have any amount of effectiveness, they must work in tandem with a team of aerial observation aircraft and ground crews. Air tankers carrying chemical retardant will still be needed for parallel and especially indirect attack strategies when fires have spiraled out of control and it is no longer safe to fly any aircraft right over the flame edge. Heliattack still has an advantage in being able to take water from bodies with even less surface area than those water bombers can scoop from. However, as the largest, most direct and blunt hammer to the face of destructive fires too large for ground crews alone, water bombers display the greatest operational versatility, and ultimately, cost effectiveness.

Water bombers are a proven tool for combating wild fires, and as high fire season approaches in Southern California, it may be worth our while not only to welcome these planes back into our skies, but to look toward a future of engineering more purpose-built water bombers so that our kids and grand kids can live secure from the threat of wildfires.

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