Suppression of Forest Fire by Helicopter without Water

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Abstract

The natural occurrences of wildfires damage nature areas, produce the hundreds of millions of dollars in losses, and considerable pollution of environment. The author suggests a very efficient method of suppression of a forest fire without water. He offers a system of simple light plates or anchor suspended from any helicopter which directs the helicopter propeller airflow against the direction of a wildfire. After some minutes the natural fuel burns away in the front of fire and the fire cannot advance.

The author developed theory and methods computations and suggests some designs of the devices for so changing the helicopter airflow direction.

Key words: Wildfire, suppression of wildfire, suppression of forest fire by helicopter.

Introduction

A **wildfire** is any uncontrolled fire that occurs in the countryside or wildland (wilderness). Other names such as *brush fire, bushfire, forest fire, grass fire, hill fire, peat fire, vegetation fire, and wildland fire* may be used to describe the same phenomenon. A wildfire differs from other fires by its extensive size; the speed at which it can spread out from its original source; its ability to change direction unexpectedly; and to jump gaps, such as roads, rivers and fire breaks. Wildfires are characterized in terms of their physical properties such as speed of propagation; the combustible material present; the effect of weather on the fire; and the cause of ignition.

Fossil records and human history contain accounts of wildfires, and wildfires occur on every continent except Antarctica and can be cyclical events. Wildfires can cause extensive damage, both to property and human life (*e.g.* Black Saturday bushfires). Along with the damage caused, they also have various beneficial effects on wilderness areas, such as plant species that are dependent on the effects of fire for growth and reproduction. However, large wildfires may have negative ecological effects.

Wildfires have a rapid *forward rate of spread* (FROS) when fueled by dense uninterrupted vegetation, particularly in wooded areas with canopies. They can escalate as fast as 10.8 kilometers per hour (6.7 mph) in forests and 22 kilometers per hour (14 mph) in grasslands. The ability of a wildfire's burning front to change direction unexpectedly and jump across fire breaks is another identifying characteristic. Intense heat and smoke can lead to disorientation and loss of appreciation of the direction of the fire. These factors make fires particularly dangerous: in 1949 the Mann Gulch fire in Montana, USA, thirteen smokejumpers died when they lost their communication links and became disorientated; the fire consumed 18 km² (4500 acres). In the Australian February 2009 Victorian bushfires, at least 173 people died and over 2,029 homes and 3,500 structures were lost when they became engulfed by wildfire.

Overall, fire types can be generally characterized by their fuel as follows:

- **Ground** fires are fed by subterranean roots, duff and other buried organic matter. This fuel type is especially susceptible to ignition due to spotting. Ground fires typically burn by smoldering, and can burn slowly for days to months, such as peat fires in Kalimantan and East Sumatra, Indonesia, a result of a riceland creation project that unintentionally drained and dried the peat.
- **Crawling** or **surface** fires are fueled by low-lying vegetation such as leaf and timber litter, debris, grass, and low-lying shrubbery. Human-ignited ground-clearing fires can spread to the Amazon rain forest, damaging ecosystems not particularly suited for heat or arid conditions.
- **Ladder** fires consume material between low-level vegetation and tree canopies, such as small trees, downed logs, and vines. Invasive plants such as Kudzu and Old World climbing fern that scale trees may also encourage ladder fires.
- **Crown**, **canopy**, or **aerial** fires devour suspended material at the canopy level, such as tall trees, vines, and mosses. The ignition of a crown fire is dependent on the density of the suspended material, canopy height, canopy continuity, and sufficient surface and ladder fires in order to reach the tree crowns.

Fig.1. Typical wildfire.

The four major natural causes of wildfire ignitions are lightning, volcanic eruption, sparks from rockfalls, and spontaneous combustion. The thousands of coal seam fires that are burning around the world can also flare up and ignite nearby flammable material (*e.g.* Centrailia, Pennsylvania; Burning Mountain, Australia; and in China). However, many wildfires are attributed to human sources such as arson, discarded cigarettes, sparks from equipment, and power line arcs (detected by arc mapping).

Many ecosystems are suffering from too much fire, such as the chaparral in southern California and lower elevation deserts in the American Southwest.

Wildfire suppression may include a variety of tools and technologies, including throwing sand and beating fires with sticks and palm fronds in rural Thailand, using silver iodide to encourage snow fall in China, and full-scale aerial assaults by ALTUS II unmanned aerial vehicles, planes, and helicopters using drops of water and fire retardants. Complete fire suppression is no longer an expectation, but the majority of wildfires are often extinguished before they grow out of control. While more than 99% of the 10,000 new wildfires each year are contained, escaped wildfires can cause extensive damage.

Worldwide damage from wildfires is in the billions of euros annually. Wildfires in Canada and the US consume an average of 54,500 square kilometers (13,000,000 acres) per year.

Fig.2. A MAFFS-equipped Air National Guard C-130 Hercules drops fire retardant on wildfires in Southern California

On average, wildfires burn 4.3 million acres (17,000 km²) in the United States annually. In recent years the federal government has spent $1 billion a year on fire suppression. 2002 was a record year for fires with major fires in Arizona, California, Colorado, and Oregon.

These crews use heavier equipment to construct firebreaks, and are the mainstay of most firefighting efforts. Other personnel are organized into fast attack teams typically consisting of 5–8 people. These fast attack teams are helicoptered into smaller fires or hard to reach areas as a preemptive strike force. They use portable pumps to douse small fires and chainsaws to construct firebreaks or helicopter landing pads if more resources are required. Hand tools are commonly used to construct firebreaks and remove fuels around the perimeter of the fire to halt its spread, including shovels, rakes, and the pulaski, a tool unique to wildland firefighting. In the eastern United States, portable leaf blowers are sometimes used. In the western United States, large fires often become extended campaigns, and temporary fire camps are constructed to provide food, showers, and rest to fire crews. These large fires are often handled by 20 person hand crews, sometimes known as hotshot crews, specially organized to travel to large fires.

Fast attack teams, such as the Boise District BLM Helitack crew, are often considered the elite of firefighting forces, as they sometimes deploy in unusual ways. If the fire is on a particularly steep hill or in a densely wooded area, they may rappel or fast-rope down from helicopters. If the fire is extremely remote, firefighters known as smokejumpers may parachute into site from fixed-wing aircraft. In addition to the aircraft used for deploying ground personnel, firefighting outfits often possess helicopters and water bombers specially equipped for use in aerial firefighting. These aircraft can douse areas that are inaccessible to ground crews and deliver greater quantities of water and/or flame retardant chemicals. Managing all of these various resources over such a large area in often very rugged terrain is extremely challenging, and often the Incident Command System is used. As such, each fire will have a designated Incident Commander who oversees and coordinates all the operations on the fire. This Incident Commander is ultimately responsible for the safety of the firefighters and for the success of firefighting efforts.

Fig.3. Kern County (California) Fire Department Bell 205 dropping water on fire

1. **Statistics** (Wikipedia 2009)**.** Every year, the burnt surface represents about:

- France: 211 km², 52,140 acres, 0.04% of the territory.
- Portugal:
  - 2003 : 4,249 km², 1.05 million acres, i.e. 4.6% of the territory; 20 deaths ;
  - 2004 : 1,205 km², 297,836 acres, i.e. 1.3% of the territory ;
  - 2005 : 2,864 km², 707,668 acres, i.e. 3.1% of the territory; 17 deaths;
  - 2006 : 724 km², 178,904 acres, i.e. 0.8% of the territory; 10 deaths.
- United States: 17,400 km², 4.3 million acres i.e. 0.18% of the territory.
- Indonesia.
  - 1982 and 1983: 36,000 km² (8.9 million acres);
  - 1997 and 1998: 97,550 km² (24.1 million acres) - from ADB;
  - 1999: 440.90 km² (108,949 acres);
  - 2002: 366.91 km² (90,665 acres);
  - 2005: 133.28 km² (32,934 acres).

Wildfires can affect climate and weather and have major impacts on regional and global pollution. Wildfire emissions contain greenhouse gases and a number of criteria pollutants which can have a substantial impact on human health and welfare. Forest fires in Indonesia in 1997 were estimated to have released between 0.81 and 2.57 gigatonnes (0.89 and 2.83 billion short tones) of CO_2 into the atmosphere, which is between 13 - 40% of the annual carbon dioxide emissions from burning fossil fuels. Atmospheric models suggest that these concentrations of sooty particles could increase absorption of incoming solar radiation during winter months by as much as 15% (Bolonkin 2006).

2. Innovations and description.

Everyone has blown out the candles on their birthday cake by an air flow from their mouth. That is the simplest method to blow out a flame. The problem is supplying enough power.

Suppression of a forest fire by air flow at first was offered by Melchor Duran (Spain). He suggested delivering powerful fans (ventilators) to the locale of a forest fire, to install them at the fire front, turn on the ventilators (whence the energy?) and to stop the fire. That method is not practical for the following reasons:

1. The fire suppression ventilator (fan) is a big, heavy, power-hungry, expensive, immobile installation.
2. It is difficult to deliver to a forest fire front where good roads are absent.
3. The unpacking and setup takes a long time and a fire can rage over a large area faster than the fan can be moved. This could endanger crews.
4. It is difficult to move even a hypothetically effective installation from a given place to another place.
5. During fire seasons, many thousands of square kilometers or miles may need constant back and forth attention.

The author offers to use in place of this hypothetical movie-storm sized fan (ventilator) the conventional ***helicopter*** (Bolonkin 2009). Helicopter has the following advantages:

1. A helicopter is an already existing, paid for, ***ready-for-action*** power fan. Every major forest fire team has helicopters.
2. A helicopter has a big rotor (propeller), which produces a strong air flow (jet).
3. A helicopter has a high speed and it may be quickly delivered to fire areas and moved back and forth between ground crews preparing the cable stations at the fire fronts. This expensive asset can avoid waiting immobile while emplacements are made.
4 Any helicopter may be used as a fire helicopter by suspending of additional equipment.
5. The additional equipment is cheap (cables, anchor or plates).

For fire suppression we need a horizontal air jet flow against the wind direction. The helicopter produces a vertical air jet. The strong vertical jet can only increase the fire because the jet (near ground) sends the firebrands and sparks in all directions.

For producing the horizontal flow (changing the flow from vertical to horizontal direction at near of ground) the author suggest two methods. The first method is shown in fig.4, the second method is shown in fig. 5 – 6.

In the first method the helicopter has a ground anchor (hook). That joins the helicopter temporarily to the ground and gives a declination to the vertical axis of the helicopter rotor (fig.4). The ground surface helps to turn the flow in a horizontal direction. When the forest fire's fuel burns out (3 -10 minutes), the helicopter disconnects (from) the anchor (or the anchor from the ground surface) and moves to the next place the fire crews are setting up for this assistance.

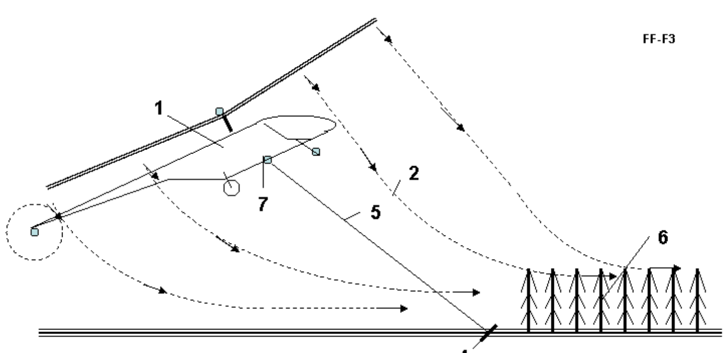

Fig. 4. Deflecting the helicopter air flow by anchoring. *Notations*: 1 – helicopter; 2 – air flow; 4 – anchor; 5 – connection cable; 6 – forest fire; 7 – emergency disconnection (anchor) device.

The second method is shown in fig.5. In this method the two plates (deflectors) are suspended under the helicopter.

The helicopter is relocated to the fire front, opens (declines) the directed plate (fig.6) and half of the rotor flow counteracts the movement of the fire and the other half of the rotor flow blows back the frangible material that is potential fuel (dry leafs, branches, grass) far from the fire front.

Different fire tactics are possible, depending on the winds on site. For example, if the wind is weak, the helicopter can slowly fly along the fire front and not allow progression of the fire front while the forest fuel loading on the forest floor will be consumed.

The helicopter can drive away the flame to places where new fuel is scarc e or absent.

If the helicopter uses the cable and the hook, it can reel the cable and drive away the flame more than on a spot basis. We can install a 'perimeter cable' along the fire front and the helicopter cable can slide along this fire front 'perimeter cable'.

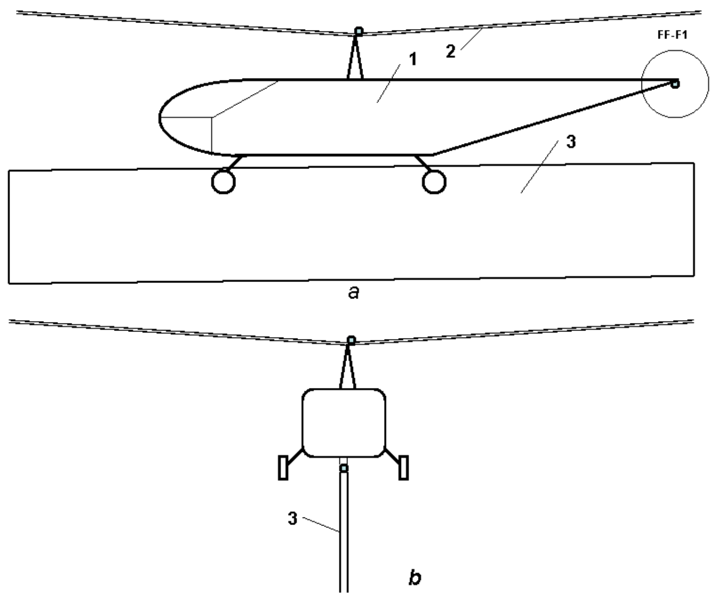

Fig.5. Fire helicopter with suspended plates. (***a***) – side view; (***b***) – front view. *Notations*: 1 – conventional helicopter; 2 – helicopter rotor (propeller); 3 – suspended plates. They are reeled up after take off of helicopter and deployed downward before landing of helicopter.

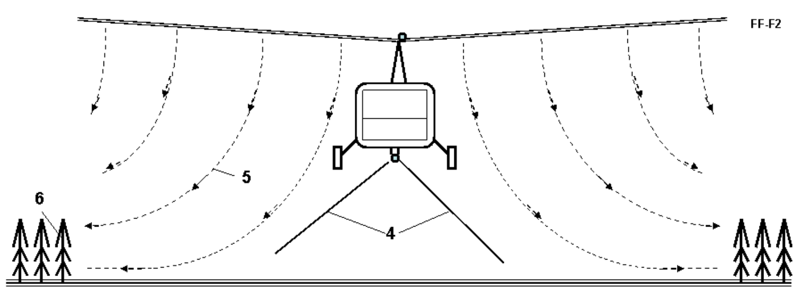

Fig.6. Suppression of fire. *Notations*: 4 – deflected plates; 5 – deflected air flow.

Advantages of offered method:

1. Cheapest; because it needs only anchors (hook) or simple plates (helicopters exist already in most major fire teams).
2. Quickly mobile. Helicopters will be immediately delivered to the fire.
3. Does not need water.

4. The helicopters can work continuously. It is not necessary to fly for water that may be located at the long distance and take much time.
5. One helicopter can suppress a fire in a large area.

3. **Theory of wildfire**.

Diffusing of fire. Diffusion of fire is shown in fig.7. Wildfires occur when the necessary elements of a fire triangle intersect: an ignition source is brought into contact with a combustible material such as vegetation, that is subjected to sufficient heat and has an adequate supply of oxygen from the ambient air. A high moisture content usually prevents ignition and slows propagation, because higher temperatures are required to evaporate any water within the material and heat the material to its fire point. Dense forests usually provide more shade, resulting in lower ambient temperatures and greater humidity. Less dense material such as grasses and leaves are easier to ignite because they contain less water than denser material such as branches and trunks. Plants continuously lose water by evapotranspiration, but water loss is usually balanced by water absorbed from the soil, humidity, or rain. When this balance is not maintained, plants dry out and are therefore more flammable, often a consequence of a long, hot, dry periods.

The fire moves in the direction of wind and fire speed depends on the wind speed. Strong wind increases the probable spread and speed of fire.

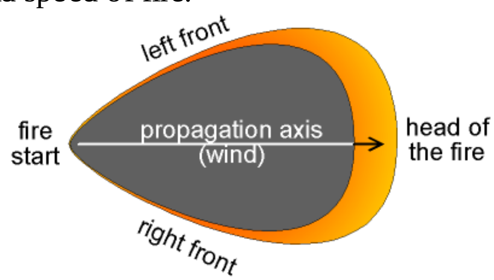

Fig.7. Diffusion of wildfire.

Computation

A typical fire speed is conventionally 0.5 – 5 km/hour (0.1 – 1.5 m/s) but fire can escalate as fast as 11 kilometers per hour (6.7 mph) in forests and 22 kilometers per hour (14 mph) in grasslands.

The air flow speed after leaving the helicopter rotor downwards can be computed by the equation:

$$P = mV, \quad m = \rho AV, \quad A = \pi R^2, \quad P = gM, \quad V = \frac{1}{R}\sqrt{\frac{gM}{\pi\rho}} \approx \frac{1.6\sqrt{M}}{R}, \qquad (1)$$

where P is thrust, N; m is second mass of air flow, kg/m^2; V is air flow speed, m/s; $\rho = 1.225$ is air density, kg/m^3; A is cross-section of air flow, m^2; R is radius of helicopter rotor, m; $g = 9.81$ is Earth's gravity, m/s^2; M is helicopter mass, kg; $\pi = 3.14$.

Result of computations regarding the different helicopter masses and different radii of the helicopter rotor are presented in fig.8.

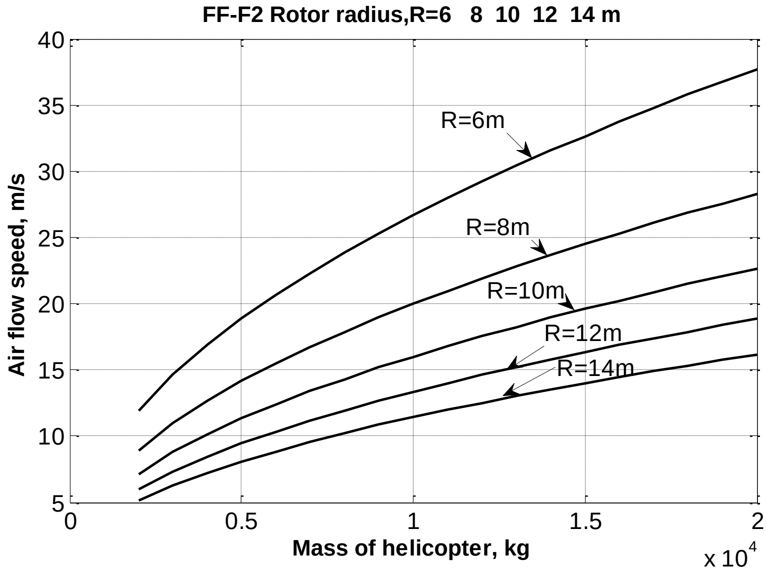

Fig.8. Air speed of wind generated under the helicopter rotor (propeller) vs. mass of helicopter and radius of the helicopter rotor.

If we use the notation $q = V/A$ – specific load on the helicopter rotor, kg/m^2, we get from Eq.(1) the simpler equation

$$V = 2.83\sqrt{q}\,, \qquad (2)$$

This equation may be more comfortable for purposes of comparison because the helicopter's q changes in a more narrow range than the helicopter mass or rotor radius of helicopter. The results of computation of equation (2) are presented in fig. 9.

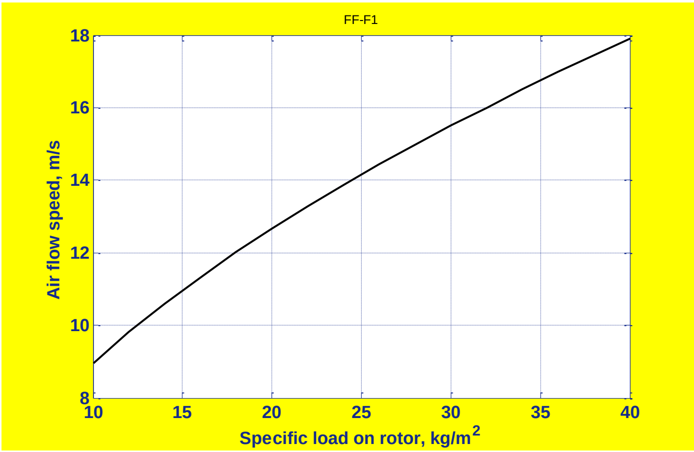

Fig.9. Air speed of a helicopter jet under the helicopter rotor (propeller) via specific load on helicopter rotor.

Typical data of helicopters:
1) *Helicopter Bell 204B*. Commonly used for fire teams.
Radius of rotor R = 7.3 m (24 ft).
Maximal mass M = 4310 kg (9500 lb).
Power of engine 820 kW.
Capacity 1360 kg (3000 lb) or 8-9 passengers (fire team).
Cruise speed 205 km/h = 135 mph.
You can compute the air flow under this model's hovering rotor to be V = 14.3 m/s = 51.7 km/h.

2) *Sikorsky S-76C++.*
Radius of rotor R = 6.7 m .
Maximal mass M = 5306 kg.
Capacity 12 passengers.
Speed 287 km/h .

3) *CH-47 (military, two rotors).*
Radius of rotor R = 9.15 m .
Maximal mass M = 12100 kg.
Capacity 33-55 troops.
Engine power 2×2796 kW .

If we use a conventional ventilator fan, the air flow speed after encountering the blade may be computed by equation (see Eqs. (1)):

$$\eta N = PV = \rho \pi R^2 V^3, \quad V = \sqrt[3]{\frac{\eta N}{\pi \rho R^2}}, \qquad (3)$$

where N is engine power, W; $\eta \approx 0.3 \div 0.7$ is the coefficient of fan (impeller, propeller) efficiency.

Discussion

Mr. Melchor Duran has shown the efficiency of fire suppression by air jet in some experiments. For example, he set fire to a small benzene (gas) puddle and drove away the flames to extinction very efficiently with a conventional room fan. He also demonstrated the fan's capability to suppress a fire in other materials.

The testing of the offered method should be possible in the near term. Most forest fire teams in the USA have helicopters and cables. They can improvise a rig under supervision of an engineer, connect the helicopter by a hook to any strongly rooted tree trunk and drive away the fire by the helicopter air flow. For safety's sake in extreme crosswinds worsened by local topography, as Richard Cathcart has pointed out, the helicopter must have an emergency detach option effective within moments for rapid egress in case of a rapid and uncontrollable change in fire direction.

The helicopter produces a strong and swift air jet. The helicopter jet in most cases is stronger than most bursts of wind speed. That means we can drive away the flame into a place where no new fuel exists and thus extinguish the fire (Bolonkin 2008).

Acknowledgement

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(The reader may find some of related articles at the author's web page http://Bolonkin.narod.ru/p65.htm and in the library of Cornel University http://arxiv.org, in http://www.sckribd.org, http://AIAA.org search "Bolonkin", in the books: "*Non-Rocket Space Launch and Flight*", Elsevier, London, 2006, 488 pages http://www.scribd.com/doc/24056182; "*New Concepts, Ideas, Innovations in Aerospace, Technology and Human Science*", NOVA, 2007, 502 pages http://www.scribd.com/doc/24057071: "*Macro-Projects: Environment and Technology*", NOVA 2008, 536 pages http://www.scribd.com/doc/24057930; and "*New Technologies and Revolutionary Projects*", Scjribd, 2010, 324 pgs http://www.scribd.com/doc/32744477).

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