# Design and Development of an amphibious ethereal firefighting aircraft capable to carry both water and fire stifling fluid synthetic compounds

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ISSN No:-2456-2165

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# ABSTRACT

**Today woodland fires are a significant issue from one side of the planet to the other. Step by step there is exhaustion of timberland cover because of wood fires. This putting off this fire ground firefighting is illogical. Somewhat recently the appalling frequencies of metropolitan fire (tall structures both private and business), modern fire and additionally timberland fire have been recorded in the country, a large portion of them were exceptional that brought about colossal misfortune. Traditional fire tenders need capacity to control this fire because of a few impediments like clogged metropolitan streets, tall structures, inadequate sources like water, fire stifling fluid synthetic compounds. Water Scooping land and/or water capable planes for putting out fires can assume a significant correlative part in taking care of these eccentric catastrophes. So ethereal firefighting is awesome and the simplest technique for the present circumstance. There are many existing airplanes for firefighting, some are land and/or water capable. So here we will talk about the land and/or water capable airplane plan which can convey 5000 kg of water or 4500 kg of synthetic compounds for firefighting. We further examine its novel plan and how it battles fire. Later the estimation which gives numerical confirmation for our plan. Then, at that point, other investigation reports give confirmations to our plan portrayal.**

ISSN No:-2456-2165

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ISSN No:-2456-2165

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# CHAPTER 1

# INTRODUCTION

An airplane is a vehicle or machine that can fly by acquiring support from the air. It counters the power of gravity by utilizing either static lift or by utilizing the unique lift of an airfoil, or in a couple of cases the descending push from stream motors. Normal instances of airplanes incorporate planes, helicopters, aircrafts (counting zeppelins), lightweight flyers, paramotors, and tourist balloons. [9]

There are various sorts of airplanes ordered upon the utilization. It might very well be a respectful traveler, contender, float plane, flying boat, land and/or water capable and so forth. Floatplanes are a particular sort of seaplane that highlight boats, all the more normally called floats, mounted to the plane's fuselage rather than wheels. Flying boats are one more sort of seaplane and are not quite the same as floatplanes in more ways than one. So consolidating essential plans of over two Amphibious airplanes is planned. [8]

A land and/or water capable airplane or land and water proficient is an airplane that can take off and land on both strong ground and water. Land and/or water capable planes offer a half and half choice between land-based and water-based flight tasks. By including either wheels connected to the floats, on account of float planes, or retractable wheels, on account of flying boats, a plane can be arrived on one or the other land or water.

Land and/or water capable airplanes are heavier and more slow, more complicated and more costly to buy and work than equivalent landplanes but on the other hand are more adaptable. Regardless of whether they can't drift or land upward, for certain positions they contend well with helicopters and do as such at an altogether lower cost. Land and/or water capable airplane can be a lot quicker and have longer reach than equivalent helicopters, and can accomplish almost the scope of land based aircraft,as a plane's wing is more productive than a helicopter's lifting rotor.useful for long-range air-ocean salvage tasks.It Mainly helps in Fire battling which is very crucial.This capacity to be so multifunctional is frequently preferred by shrubbery pilots and other people who regularly travel to more tough and less created regions. [1]

*A. History*

Firefighting is the demonstration of endeavoring to forestall the spread of and smother huge undesirable flames in structures, vehicles, and forests. A fireman smothers flames to ensure lives, property and the climate. We utilize various modes to effectively do this help. It very well might be a land vehicle, elevated vehicle and so forth.

The primary fruitful fueled seaplane flight happened in 1910 in Marseilles, France. Henri Fabre steered a development he called the Hydravion (French for seaplane/floatplane). Fabre's airplane was furnished with pressed wood drifts that empowered the lightweight plane to take off from water, fly around a large portion of a kilometer, and land securely on water.[12]

By the last part of the 1930s, seaplanes were among the biggest and quickest airplanes on the planet. The capacity to stop at seaside stations to refuel made flying boats a moderately protected and trustworthy method for significant distance transportation.

Later the advancement of land and/or water capable airplanes occurred for Aerial firefighting. Airborne firefighting is the utilization of airplanes and other flying assets to battle out of control fires. The kinds of airplanes utilized incorporate fixed-wing airplanes and helicopters. Smokejumpers and rappellers are likewise named elevated firemen, conveyed to the fire by parachute from an assortment of fixed-wing airplanes, or rappelling from helicopters. Synthetic compounds used to battle flames might incorporate water, water enhancers like froths and gels, and exceptionally defined fire retardants like Phos-Chek. [1]

ISSN No:-2456-2165

A portion of the aeronautical firefighting occurrences as per reports, On July 22, 1960 A North American B-25 Mitchell, N3446G, SN 44-31466, working as Tanker 66, affected the earth during a water bombarding run in Mill Canyon in the San Gabriel Mountains on the Magic Mountain Fire. The three group individuals were killed. This was the main elevated firefighting episode. Later numerous airplanes, for example, Lockheed C-130A, Douglas C-54G, Bell 212. Air Tractor 802, Canadair CL-215, Canadair CL-415 and so on were utilized for various tasks.

Fig. 1: From left to right: B-25 Mitchell, N3446G, SN 44-31466 (Source: Google)

*B. Background and Importance*

Later at the end of World War II, progresses made in military airplane innovation during the conflict were immediately squeezed into peacetime administration to battle one of the most seasoned and most dreaded regular peculiarities—out of control fires. Until the 1950s, when a fierce blaze had spread across completely dry backwoods or dried meadows, there wasn't a lot that firemen could do with the exception of watching it consume and attempt to get control over its area of annihilation. That unequal battleground was fairly evened out with the presentation of the air tanker.Ingenious (in any case unrealistic) early examinations in California zeroed in on unloading water or fire-retardants onto backwoods fires from wooden lager barrels mounted in single motor planes, or in any event, utilizing a typical nursery hose to splash water from above into the fiery blaze. In the mid 1950s, public security authorities in California perceived the potential for elevated firefighting and collaborated with the U.S. Woods Service to foster a useful air big hauler to battle backwoods fires. [14]

Water isn't typically dropped straightforwardly on flares since its impact is brief. Fire retardants are not ordinarily used to douse the fire, however rather are utilized to contain the fire, or dial it back to permit ground groups to contain it. Along these lines, retardants are normally dropped before or around a moving fire, rather than straightforwardly on it, making a firebreak.

Land and/or water capable airplanes with frames can likewise profit from hydrofoils correspondingly by arriving at their departure speeds all the more rapidly, lessening the distance and time in the water-departure stage. The examination on hydrofoils for land and/or water capable airplane configuration is scanty; the quantity of planned hydrofoil profiles is far lesser contrasted with that of airfoils, and the quantity of examinations concerning hydrofoil shape enhancement with the significant limitations is a lot lesser, too. [5]

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Fig. 2: Fire suppression aircraft of 1950s (Source: Google)

### C. *Current Market*

Aerial Firefighting Market Size and forecast:

According to Verified Market Research, the Global Aerial Firefighting Market was valued at USD 8,450.10 Million in 2019 and is projected to reach USD 12,553.18 Million by 2027, growing at a CAGR of 5.18% from 2020 to 2027. [15]

There has been an escalation in the number of forest fire incidents worldwide, and this has led to the growth in the usage of helicopters and aircraft for fire fighting. Moreover, the increased number of wildfires in the last few years has made the various countries think of procuring aerial firefighting amphibious aircraft.

Another factor that is driving the growth of the market is the rising application of Unmanned Aerial Firefighter Vehicles. The aerial firefighting organizations are now leveraging the benefits of unmanned aircraft or drones to perform aerial reconnaissance. The conditions for manned aircraft become challenging, difficult, and dangerous in wildfires due to the heat and smoke.


Fig. 3: The Global Aerial Firefighting Market is segmented on the basis of Type, Service Provider Aircraft, and geography. [15]

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Fire fighting Aircraft Market 2021, and analysis till 2024:

The fire-fighting aircraft market is anticipated to grow at a CAGR of above 3% during the forecast period. Many countries like the United Kingdom, Germany, Greece, Sweden, Norway, Portugal, Spain, Finland, and Latvia among others have better aerial firefighting capabilities compared to other regions. However, most aircraft are aged and need heavy maintenance. Also, the increased number of wildfires in the last couple of years have made the countries think of procuring aerial firefighting amphibious aircraft. Collective procurement of aircraft by a group of countries on a usage basis is expected to be an economical choice, which may drive the market demand in the region, during the forecast period. [16]


Fig. 4: Global Amphibious Aircraft Market Share, By Application, 2020 [16]

Amphibious Aircraft Market Size, Covid19 Impact and forecast:

The global amphibious aircraft market size was USD 159.2 million in 2020. The global impact of COVID-19 has been unmatched and staggering, with amphibious aircraft witnessing a negative impact on demand across all the globe amid the pandemic. Based on our analysis, the global market exhibited a lower growth of -41.06% in 2020 compared to the average year-on-year growth during 2017-2019. The market is projected to grow from USD 159.2 million in 2020 to USD 358.1 million in 2028 at a CAGR of 11.71% during the 2021-2028 period.

Owing to the lockdown imposed in major countries globally, halted production and delayed deliveries of amphibious aircraft have majorly impacted the aviation industry. According to the International Civil Aviation Organization (ICAO), there was a 60% decline in passenger traffic in 2020 than in 2019. In addition to that, approximately USD 371 billion loss of gross passenger operating revenues for airlines. Moreover, significant disruption in the supply chain, a slowdown in the economy, slow production rate, and others are expected to impact the market growth.

According to the General Aviation Manufacturers Association (GAMA) report 2020, the deliveries of ICON A5 aircraft were 41 in 2019, whereas in 2020, it stood at 26. Additionally, DAHER delivered 20 Kodiak 100 models in 2019, while in 2020, it could only deliver 8. Thus, reduced aircraft deliveries due to COVID-19 has impacted the growth of the market in 2020.

The increasing defense expenditure, military modernization programs, and procurement of advanced seaplanes for special operations are expected to drive the global amphibious aircraft market growth. According to the Stockholm International Peace Research Institute (SIPRI), the U.S. had the highest defense budget of USD 732 billion in 2020. China, India, Russia, and Saudi Arabia's defense budget was USD 261 billion, USD 71.1 billion, USD 65.1 billion, USD 61.9 billion, respectively. Thus, the increasing procurement of seaplanes for military and special operations is propelling the market's growth. [7]

The increasing number of seaplane accidents across the world is likely to hamper the growth of the market. The aircraft requires trained pilots, but the lack of special training simulators hampers the functioning during critical operations. Accidents are caused mainly by pilot error, maintenance, survivability, and product failure. Critical climatic conditions such as challenging waves, changing wind,

ISSN No:-2456-2165

water currents, water, shore obstructions, and boat traffic further involve high flight operations risks. For instance, in October 2020, the Cessna 182 seaplane crashed in Queens, New York, and the mishap led to a passenger's death and left two other people severely injured. Therefore, the increasing incidence of mishaps is expected to hinder the growth of the market during the forecast period. [6]

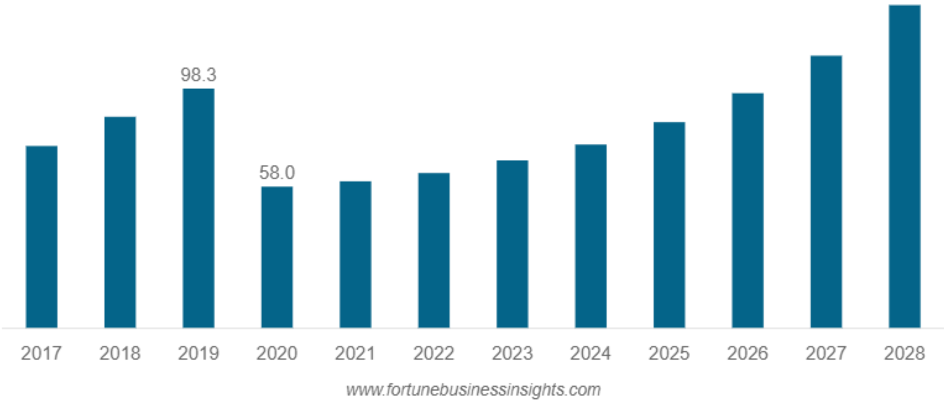


Fig. 5: North America Amphibious Aircraft Market Size, 2017-2028 (USD Million) [6]

*D. Scope of Study*

Since amphibious aircraft are capable of performing both air and water-based activities, their design needs to be carefully considered. Some of the issues that need to be considered are the aerodynamic design of the fuselage and the cruise speed of the aircraft. Aircraft make noise impact more important in the design than traditional aircraft. This means that noise shielding or mitigation techniques should be considered in the design. Due to the harsh conditions of the environment, aircraft components are more prone to damage. For instance, they require special protection and maintenance to prevent corrosion.

This requires a solid and durable structure and as an outcome, a land and/or water capable airplane is ordinarily heavier than an ordinary airplane for similar mission necessities. As an option in contrast to the frame plan, some land and/or water capable airplanes use hydrofoils, e.g., LISA Akoya. [17]

Fig. 6: LISA Akoya: An airplane able to land on either land, water or snow [17]

The hydrofoils can assist with decreasing drag, and subsequently considers higher pace-of-climb and journey speed.

Likewise, there are some essential necessities of land and/or water capable airplanes that don't exist in ordinary airplanes. The airplane should be watertight, particularly for entryways, windows, and any boards that give admittance to dry parts. The lower streamlined proficiency may require extra highlights to control the airplane when there are insufficient streamlined powers. The airplane dependability should be guaranteed both during flight and when it is on water, and the airplane should be controllable in water at all paces. [5]

# CHAPTER 2

# LITERATURE SURVEY

*A. Aircraft Models referred*

a) Canadair CL-215

The Canadair CL-215 (Scooper) is the first model in a series of flying boat amphibious aircraft designed and built by Canadian aircraft manufacturer Canadair, and later produced by bombardier. It is one of only a handful of large amphibious aircraft to have been produced in large numbers during the post-war era, and the first to be developed from the onset as a water bomber. The CL-215 is a twin-engine, high-wing aircraft that was designed during the 1960s. From an early stage, it was developed to perform aerial firefighting operations as a water bomber; to operate well in such a capacity, it can be flown at relatively low speeds and in high gust-loading environments, as are typically found over forest-fires.[18]

Fig. 7: Canadair CL-215 (Source: Wikipedia)

b) Canadair CL- 415(Super Scooper)

The Canadair CL-415 (Superscooper, later Bombardier 415) is an amphibious aircraft built originally by Canadair and subsequently by Bombardier and Viking Aircraft. It is based on the Canadair CL-215 and is designed specifically for aerial firefighting; it can perform various other roles, such as the search and rescue and utility transport. Development of the CL-415 commenced in the early 1990s, shortly after the success of the CL-215T retrofit programme had proven a viable demand for a turboprop-powered model of the original CL-215. Entering production in 2003, in addition to its new engines, the aircraft featured numerous modernisation efforts and advances over the CL-215. [19]

Fig. 8: Canadair CL - 415 (Source: Wikipedia)

c) Air Tractor AT-802
The Air Tractor AT-802 is an agricultural aircraft that may also be adapted into fire-fighting or armed versions. It first flew in the United States in October 1990 and is manufactured by Air Tractor Inc. The AT-802 carries a chemical hopper between the engine firewall and the cockpit. In the U.S, it is considered a Type III SEAT, or Single Engine Air Tanker. [20]

Fig. 9: Air Tractor AT-802 (Source: Wikipedia)

d) Beriev Be-12
The Beriev Be-12 was a successor to the Beriev Be-6 flying boat, whose primary roles were as an anti-submarine and maritime patrol bomber aircraft. Though tracing its origins to the Be-6, the Be-12 inherited little more than the gull wing and twin oval twifin configuration of the older aircraft. The Be-12 has turboprop engines, which gave it an improved speed and range over the Be-6. The Be-12 also had retractable landing gear, which enabled it to land on normal land runways, as well as water.


Fig. 10: Beriev Be-12 (Source: Wikipedia)

e) Beriev Be-200
The Beriev Be-200 *Altair* is a utility amphibious aircraft designed and built by the Beriev Aircraft Company. Marketed as being designed for fire fighting, search and rescue, maritime patrol, cargo, and passenger transportation, it has a capacity of 12,000 litres (3,200 US gal) of water, or up to 72 passengers.

Fig. 11: Beriev Be-200 (Source: Wikipedia)

f) Lockheed C-130 Hercules
The Lockheed C-130 Hercules is an American four-engine turboprop military transport aircraft designed and built originally by Lockheed (now Lockheed Martin). Capable of using unprepared runways for takeoffs and landings, the C-130 was originally designed as a troop, medevac, and cargo transport aircraft. The versatile airframe has found uses in a variety of other roles, including as a gunship (AC-130), for airborne assault, search and rescue, scientific research support, weather reconnaissance, aerial refueling, maritime patrol, and aerial firefighting.


Fig. 12: Lockheed C-130 Hercules

## *B. Critical evaluation of Technology*

An amphibious aircraft is an aircraft that can takeoff and land on water and on land. It typically features a hull-type fuselage that can assist in the water operation and retractable landing gear to enable landing on land. Some of the earlier generations of amphibious aircraft from the 1950's and 1960's include de Havilland Canada DHC-3 Otter, Viking Air DHC-6 Series 400, and Viking Air DHC-6 Series 400S Seaplane. The Dornier Seastar was introduced in 1984, which is a turboprop-powered amphibious aircraft. Composite materials form the bulk of its structures. There have been some recently developed amphibious aircraft designs in the market, such as the ICON A5, MVP Model 3, and LISA Akoya. All three of them are

ISSN No:-2456-2165

designed to carry two passengers. These three promising designs are shown in Figure 10. The design for each aircraft is described briefly below.

Fig. 13: From left to right, ICON A5, MVP Model 3, and LIS Akoya respectively (Source: Google Images)

- ICON A5 is a high-wing monoplane with its wing and fuselage made up of carbon-fibre material. It is powered by a single 100hp Rotax 912iS engine driving a three-bladed push propeller. Its Dornier-style sponsons provide hydrodynamic stability. One main advantage of ICON A5 is that its wings can be folded for ground transport and storage purposes. [17]
- MVP Model 3 looks very similar to ICON A5 but it is designed to operate on snow and ice, in addition to water. It has a high-wing structure with foldable wings, made up of carbon fibre and is powered by 115hp Rotax 914 engine driving three-bladed push propeller. One unique feature of the MVP Model 3 is that its floor panels can be rearranged to accommodate fishing or camping.[17]
- LISA Akoya looks different from the previous two designs. Its unique features include: the wing that can be folded almost 90o , the single engine (100hp Rotax 912 ULS) mounted high on the tail, and its carbon-fibre-reinforced polymer composite body and wing structures. It has a very high aspect ratio of 18, which is uncommon for a powered aircraft, and uses unique trailing edge extensions rather than the conventional hinged flaps. [17]

# CHAPTER 3

# CONCEPT INTRODUCTION

The aircraft flies at high speed (approximately 100 mph) just above the surface of a lake or reservoir, scooping up copious amounts of water into its belly. Based on the problem statement, In just 15 seconds, the plane should accumulate 5000 liters of water or. In 4 mins, the plane should scoop 4500 liters of chemical retardant, and be subsequently dropped onto nearby fires raging out of control. [13]

This scooping ability obviates the need to return to a water "refilling station" which could possibly be very far away. A pilot must be certified to operate a seaplane, to ensure water conditions are safe for scooping.

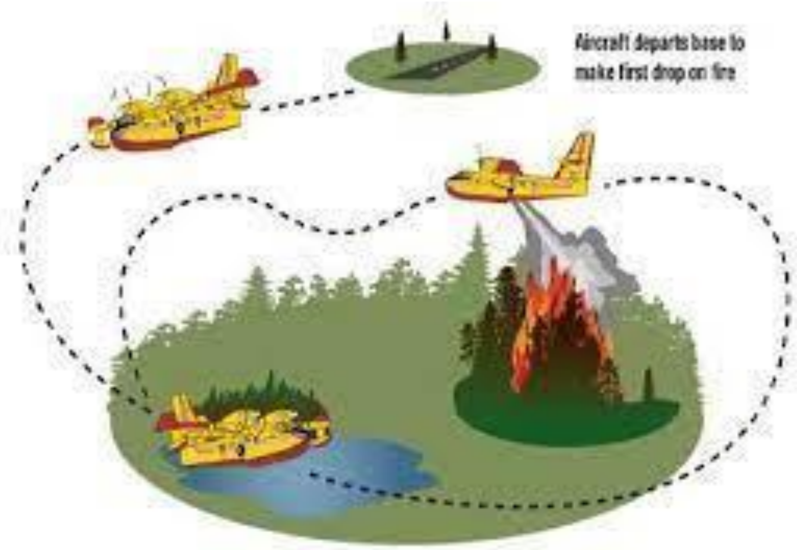


Fig. 14: Firefighting profile of the aircraft [16]

# CHAPTER 4

# CONCEPT PROPERTY ESTIMATIONS (ASSUMED DATA CALCULATION)

*A. Weight Estimation:*

$$\mathrm{W_O} = \mathrm{W_{Crew}} + \mathrm{W_{Payload}} + \mathrm{W_{Fuel}} + \mathrm{W_{Empty}} \quad \text{...Eq. 1}$$

$$\mathrm{W_O} = \text{Gross Weight}$$

$$\mathrm{W_{Crew}} = \text{Weight of Crew}$$

$$\mathrm{W_{Payload}} = \text{Weight of Payload}$$

$$\mathrm{W_{Fuel}} = \text{Weight of the Fuel}$$

$$\mathrm{W_{Empty}} = \text{Empty Weight}$$

$\mathrm{W_O} = \mathrm{W_{Crew}} + \mathrm{W_{Payload}} + \mathrm{W_{Fuel}} + \mathrm{W_{Empty}}$

Or, 35651.2 = 9500+160+25991.2

Or, $\mathrm{W_O}$= 35651.2 kg

*B. Equation of Initial Sizing:*

$$\mathrm{W_O} = \frac{\mathrm{W_{Crew}} + \mathrm{W_{Payload}}}{1 - \{\frac{\mathrm{W_{Fuel}}}{\mathrm{W_O}} + \frac{\mathrm{W_{Empty}}}{\mathrm{W_O}}\}} \quad \text{...Eq.2}$$

$$\mathrm{W_O} = \frac{\mathrm{W_{Crew}} + \mathrm{W_{Payload}}}{1 - \{\widehat{\mathrm{W_e}} + \widehat{\mathrm{W_f}}\}} \quad \text{...Eq. 3}$$

Here, $\widehat{W_e}$and $\widehat{W_f}$ are weight factorsof empty weight and fuel weight respectively compared to total weight.

*C. Estimation of empty weight fraction:*

$$\widehat{W_e} = A \times W_o^c \times k_{vs} \quad \text{...Eq. 4}$$

A & C = Constant [We use statistical curve fits]

$k_{vs}$= is a factor depending on aircraft sweep

Therefore,

$k_{vs}$= 1.00 [For fixed wing]

Now considering twin turboprop

A= 0.92

C= -0.05

Therefore,
Or, $\widehat{W_e}$ = 0.92×(35651.2)$^{-0.05}$×1 [using Eq.4]
Or, $\widehat{W_e}$ = 0.5447

$W_{Empty} = W_O \times \widehat{W_e}$ …Eq. 5

Or, $W_{Empty}$= 35651.2×0.5447

Or, $W_{Empty}$= 19,420.4 kg

*D. Estimation of mission fuel fraction ($\widehat{W_f}$):*

$$W_{Fuel} = W_{Mission\ Fuel} + W_{Reserve\ Fuel} \quad \text{…Eq.6}$$

$W_{fuel} = W_{Empty+fuel} - W_{Empty}$ …Eq.7
Or, $W_{fuel}$= 25991.2 – 19420.4
Or, $W_{fuel}$= 6570.8 kg

*E. Mission Profile:*
Conveys About:

- Purpose of Aircraft
- Range of corresponding Speed
- Types of Engine and SFC
- Combat Range
- $\frac{L}{D}$ ratio

- As the weight of the fuel gets consumed, as per the stages we cross, the fuel gets consumed and no fuel is left.

$$W_f = W_O + W_8 \quad \text{…Eq.6}$$

$$(or)\ \frac{W_f}{W_O} = 1 + \frac{W_8}{W_O} \quad \text{…Eq.7}$$

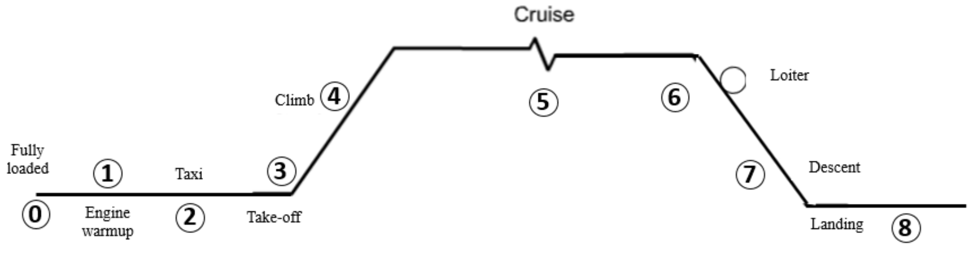


Fig. 15: Mission profile of general aircraft

*F. Fuel fraction of several mission stages*

| Sl . No | Mission | Engine warm up | Taxi | Take-off | Climb | Descent | Land |
|---|---|---|---|---|---|---|---|
| | Aircraft | | | | | | |
| 1 | Twin Engine | 0.992 | 0.996 | 0.996 | 0.99 | 0.992 | 0.992 |
| 2 | Amphibious | 0.992 | 0.99 | 0.996 | 0.985 | 0.99 | 0.99 |

Table 1: Estimated fuel fraction of several mission stages

At the end of the mission, the fuel tanks are not completely empty, typically 6% to 8% allowance is made for reserve and trapped.[4]

$$\frac{W_f}{W_0} = 1.06 - \left(1 - \frac{W_8}{W_0}\right) \quad \text{[using Eq.7]}$$

*G. Calculated fuel fraction for every mission stages*

| Stage | Description | Wi/Wi-1 | Turbojet | Amphibious |
|---|---|---|---|---|
| 1 | Engine Start and warmup | W1/Wo | 0.992 | 0.992 |
| 2 | Taxi | W2/W1 | 0.996 | 0.99 |
| 3 | Take off | W3/W2 | 0.996 | 0.996 |
| 4 | Climb | W4/W3 | 0.99 | 0.985 |
| 5 | Cruise to full range | W5/W4 | 0.965 | 0.870 |
| 6 | Loiter | W6/W5 | 0.981 | 0.927 |
| 7 | Descent | W7/W6 | 0.992 | 0.99 |
| 8 | Landing | W8/W7 | 0.992 | 0.99 |

Table 2: Calculated fuel fraction for every mission stages

*H. Breguet Range equation:*

| | Length (in m) | Wingspan (in m) | Height (in m) | Wing Area (in $m^2$) | Max. Take off weight (in Kg) (on Land) | Empty Weight + Fuel weight(in Kg) | Gross Weight (in Kg) |
|---|---|---|---|---|---|---|---|
| CL-415 | 20.4 | 28.38 | 9.01 | 100 | 19,890 | 13,608 | 21,319 |
| Beriev Be-200 | 32 | 32.8 | 8.9 | 117.4 | 48,000 | 27,600 | 31,750 |
| Lockheed C-130 Hercules | 29.79 | 40.41 | 11.66 | 162.1 | 70,307 | 34,382 | 59,000 |
| Beriev Be-12 | 30.11 | 29.84 | 7.94 | 99 | 36,000 | 24,500 | 29,500 |
| IFF Scooper | 29.78 | 29.51 | 7.854 | 97.93 | 35,611.2 | 25,991.2 | 29,181.4 |

Table 3: Dimensions of IFF Scooper and dimensional benchmarking with relevant aircrafts referred

*I. Breguet Range equation:*
The amount of fuel used during this part of the mission can be estimated from Breguet Range equation.

$$R_{cr} = \frac{V}{C_{i_{cr}}} \times \frac{L}{D}_{cr} \times \ln\left(\frac{W_4}{W_5}\right) \quad \text{...Eq.8}$$

$$or, \frac{W_5}{W_4} = exp\left[\frac{-R_{cr} \times C_{i_{cr}}}{V \times \frac{L}{D}_{cr}}\right] \quad \text{...Eq. 9}$$

Here $C_j$ is SFC

Here we assume,

Range$_{max}$= 200km [With full payload]

And according to the problem statement,

Velocity at cruise = 250km/hr

Therefore,

At cruise,

L=W

T=D

Usually from (L/D) estimation table, we have

| AIRCRAFT DRIVEN BY | CRUISE | LOITER |
|---|---|---|
| Jet | $0.866 \frac{L}{Dmax}$ | $\frac{L}{Dmax}$ |
| Prop | $\frac{L}{Dmax}$ | $0.866 \frac{L}{Dmax}$ |

Table 4: (L/D) estimation table for Jet and Propeller driven aircraft

At cruise flight condition, (assuming, L=W)

$$C_l = \frac{L}{\frac{1}{2} \times \rho \times v^2 \times s}$$

Or, $C_l = \frac{35651.2}{0.5 \times 0.6601 \times 69.44^2 \times 150}$

Or, $C_l = 1.5$

Now let us assume,

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$C_D$= 0.326

Therefore,

$\frac{L}{D} = \frac{C_l}{C_d} = 4.6$

Therefore,

At cruise of propeller driven aircraft, we have,

$\frac{W5}{W4} = \exp\left[\frac{-200\times0.8}{250\times4.6}\right]$ [using Eq.9]

=<u>0.870</u>

Similarly, for loiter at stage 6

The fuel fraction for this phase follows from Brequet endurance equation:-

$$E_{ltr}= \left(\frac{Vcr}{Cj}\right)\left(\frac{L}{D}\right)\ln\left(\frac{W5}{W6}\right) \qquad \text{…Eq.11}$$

$$\left(\frac{W6}{W5}\right) = \exp\left[\frac{-E.Cj}{(\frac{L}{D})}\right] \qquad \text{…Eq.12}$$

As per the problem statement, the value of endurance given =<u>30min</u>

=<u>0.5hr</u>

Therefore,

$\left(\frac{W6}{W5}\right)=\exp\left[\frac{-0.5\times0.6}{0.866\times4.6}\right]$ [using Eq.12]

$\left(\frac{W6}{W5}\right)=$ <u>0.927</u>

- From Table (a):

To find the mission phases,

$$\frac{W_8}{W_O} = \frac{W_8}{W_7}\times\frac{W_7}{W_6}\times\frac{W_6}{W_5}\times\frac{W_5}{W_4}\times\frac{W_4}{W_3}\times\frac{W_3}{W_2}\times\frac{W_2}{W_1}\times\frac{W_1}{W_O} \qquad \text{…Eq.13}$$

For twin engine,

$\frac{W_8}{W_O} = 0.992\times0.992\times0.927\times0.870\times0.990\times0.996\times0.996\times0.992$ [using Eq.13]

$$\frac{W_8}{W_O} = 0.7726$$

Now substituting $\frac{W_8}{W_O}$ = 0.90758

$\frac{W_8}{W_O} = 1.06(1 - \frac{W_8}{W_O})$ [using Eq.7]

=1.06(1-0.7726)

$$\frac{W_8}{W_O} = 0.241044$$

Now substituting in,

$W_O = \frac{W_{Crew}+W_{Payload}}{1-\{\frac{W_{Fuel}}{W_O}+\frac{W_{Empty}}{W_O}\}}$ [using Eq.2]

$$W_O = \frac{1667.7 + 49050}{1 - \{0.241044 + 0.098\}}$$

Here $W_{Crew}$= 1667.7 N if the member are of members are of 85 kg each.

$W_{Payload}$= 49050 N of Water

For LFR = 44145 N

Weight of fuel $W_f$= 0.098× $W_O$

= 0.098×71680.12

$W_f$= 7024.65 N

w.k.t, density of AVGAS = 768.08 $kgm^{-3}$

Volume of the fuel =$\frac{W_8}{\rho_{gasoline}}$

=$\frac{7024.65}{768.08}$

= 9.15$m^3$

Therefore, Tank Capacity = $\frac{Volume}{0.75}$

=$\frac{9.15}{0.75}$

= 12.2$m^3$

Here, 0.75 is the Packing Factor (Integral tank wing)

Wing Loading = $\frac{W}{S}$

=$\frac{71680.12}{21.79}$

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= 3289.57 $Nm^{-2}$

From Table, we have,

Wing area, S= 150$m^2$

Wingspan, b = 29.51 m

Fuselage length = 75% of wing span

= 0.75 × 29.51

= 22.1325 m

Aspect Ratio (AR) $=\frac{b^2}{S}$

$= \frac{29.51^2}{150}$

= 5.8056

# CHAPTER 5

# WATER SCOOPING PROCESS

*A. Introduction*

The Water Scooping process plays an important role in Fire fighter aircraft. Water Scooping mechanism is a catching and dropping mechanism where an floats just above the water/reservoir.

Here are some of the Diagrams that how an Amphibian Aircraft Scoop the Water from the near Lake/ River and drop it on fire:

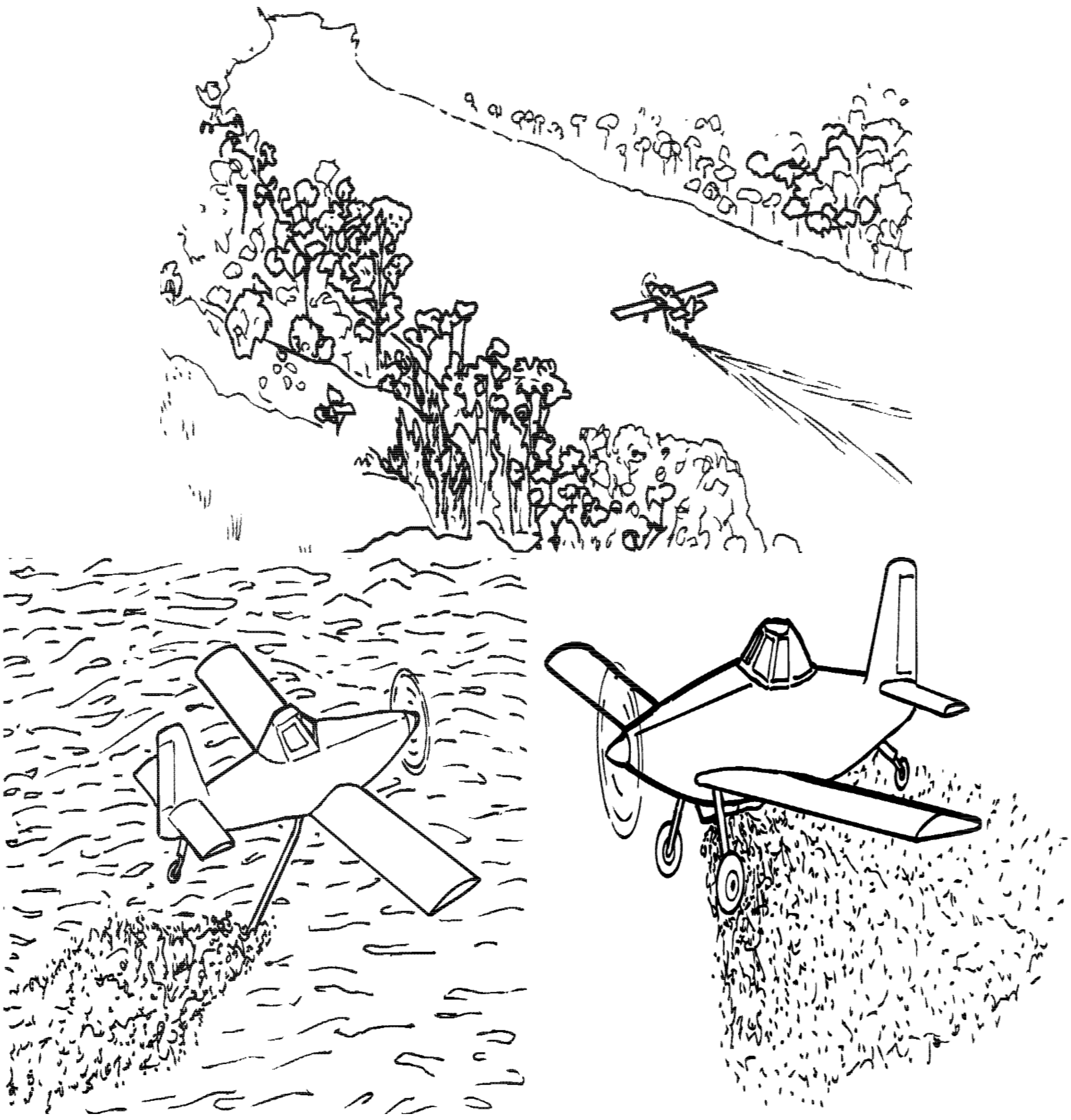

Fig. 16: Representation of general water scooping process (Source: Google)

*B. Mechanism*

In almost all aircraft scooping mechanisms are the same, like Aircraft flies just about the surface of water the probes catch the water into the belly where tanks are placed, when the aircraft is moving with a velocity to fill the tank at a given time.

To perform a better Scooping Mechanism in an aircraft there are some operations:

- **Placement** : To increase effectiveness, Scoopers should be geographically grouped in pairs.
- **Dispatch** : To increase effectiveness, Scoopers should be dispatched in pairs.
  Ex:Fire Boss aircraft are capable of being ground loaded before departure. CL-415s and CL-215Ts can be ground loaded if requested. In the absence of ground loading, flight crews should pickup water en-route to the incident.
- **Water Source Selection** : Upon receiving dispatch the flight crews will determine the closest suitable water source. Coordination between the aircraft manager, flight crews, and local dispatch will vary depending upon regional water source access protocol. Water source selection may occur en-route depending on the geographic area of operations.[11]
- **Winds** : Water scoopers typically pickup into the wind. Direction, velocity, gusts, and downdrafts are visible from above during the water source survey and while on the water. Surrounding terrain and vegetation will impact mechanical turbulence and should be considered for the approach, pickup, and climb out.
- **Length** : Distance needed for pickup is calculated per aircraft performance charts, and is impacted by aircraft weight, water conditions, winds, density altitude, and available engine power. Length of water source may be estimated by recording the time flown from one shore to another. For example, a 30 second run at 120 knots of ground speed on the GPS will be approximately one nautical mile. Water sources with higher density altitude will produce a longer scooping run due to reduced lift, propeller efficiency, and possibly lower power settings. Higher aircraft weights require a faster liftoff speed and will also increase takeoff distance.
- **Width** : Selection of a narrow water source should be made with consideration given to directional control that may be impacted by crosswinds, poor technique, or mechanical malfunction.
- **Terrain** – Ingress and egress will be dependent upon terrain and obstacles surrounding the water source. Terrain will also impact local wind conditions and may render a water source unusable in certain wind conditions.
- Natural hazards include but are not limited to daily tidal changes, shallow areas, rocks, debris, and birds. Examples of human-made hazards include towers, power lines, buoys, watercraft, bridges, surrounding structures, and proximity of airports. [2]

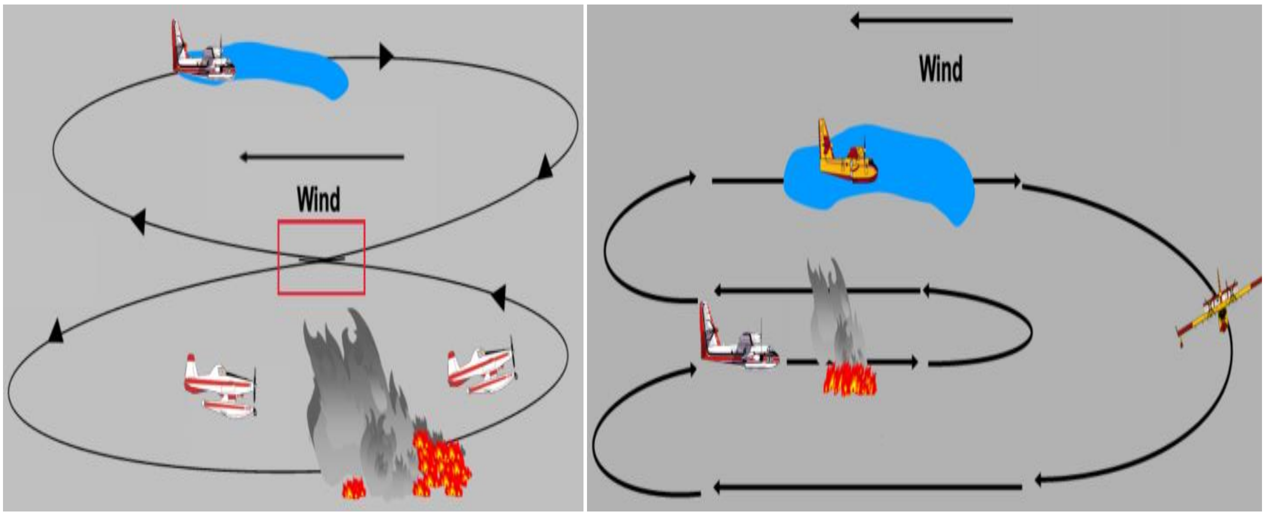


Fig. 17: (a) Pickup and drop into the wind. Note conflict area and increased maneuvering.
Fig. 17: (b) U Shaped: Pickup and drop into the wind. Note increased maneuvering.

### *C. Conditional Quantity Calculation*

Considering the water scooping condition, where we have a given scooping distance D (in m), for collecting a Volume V of 5 $m^3$ in a limited time period of t (in seconds). The aircraft is considered to be flying at a speed, V of 100 m/s. Calculating the Diameter, $d_p$ of the Probe duct for n no. of probes:

| Volume, V($m^3$) | Time, t(s) | Distance, D(m) | Volume flow rate, Q ($m^3$) | No. of Probes, n | Probe volume flow rate, Qp ($m^3$/sec) | Velocity of A/C, v (m/s) | Area, A of duct ($m^2$) | Diameter, dp of Probe duct (cm) |
|---|---|---|---|---|---|---|---|---|
| 5 | 12 | 500 | 0.4166666667 | 2 | 0.2083333333 | 100 | 0.002083333333 | 0.05151628687 |
| 5 | 12 | 500 | 0.4166666667 | 3 | 0.1388888889 | 100 | 0.001388888889 | 0.04206287209 |
| 5 | 12 | 500 | 0.4166666667 | 4 | 0.1041666667 | 100 | 0.001041666667 | 0.03642751579 |
| 5 | 10 | 500 | 0.5 | 2 | 0.25 | 100 | 0.0025 | 0.0564332648 |
| 5 | 10 | 500 | 0.5 | 3 | 0.1666666667 | 100 | 0.001666666667 | 0.04607756776 |
| 5 | 10 | 500 | 0.5 | 4 | 0.125 | 100 | 0.00125 | 0.03990434422 |
| 5 | 8 | 500 | 0.625 | 2 | 0.3125 | 100 | 0.003125 | 0.06309430814 |
| 5 | 8 | 500 | 0.625 | 3 | 0.2083333333 | 100 | 0.002083333333 | 0.05151628687 |
| 5 | 8 | 500 | 0.625 | 4 | 0.15625 | 100 | 0.0015625 | 0.04461441314 |
| 5 | 12 | 400 | 0.4166666667 | 2 | 0.2083333333 | 100 | 0.002083333333 | 0.05151628687 |
| 5 | 12 | 400 | 0.4166666667 | 3 | 0.1388888889 | 100 | 0.001388888889 | 0.04206287209 |
| 5 | 12 | 400 | 0.4166666667 | 4 | 0.1041666667 | 100 | 0.001041666667 | 0.03642751579 |
| 5 | 10 | 400 | 0.5 | 2 | 0.25 | 100 | 0.0025 | 0.0564332648 |
| 5 | 10 | 400 | 0.5 | 3 | 0.1666666667 | 100 | 0.001666666667 | 0.04607756776 |
| 5 | 10 | 400 | 0.5 | 4 | 0.125 | 100 | 0.00125 | 0.03990434422 |
| 5 | 8 | 400 | 0.625 | 2 | 0.3125 | 100 | 0.003125 | 0.06309430814 |
| 5 | 8 | 400 | 0.625 | 3 | 0.2083333333 | 100 | 0.002083333333 | 0.05151628687 |
| 5 | 8 | 400 | 0.625 | 4 | 0.15625 | 100 | 0.0015625 | 0.04461441314 |
| 5 | 12 | 300 | 0.4166666667 | 2 | 0.2083333333 | 100 | 0.002083333333 | 0.05151628687 |
| 5 | 12 | 300 | 0.416666666 | 3 | 0.1388888889 | 100 | 0.00138 | 0.0420628720 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | 7 | | | | 8888889 | 9 |
| 5 | 12 | 300 | 0.416666666 7 | 4 | 0.1041666667 | 100 | 0.00104 1666667 | 0.0364275157 9 |
| 5 | 10 | 300 | 0.5 | 2 | 0.25 | 100 | 0.0025 | 0.0564332648 |
| 5 | 10 | 300 | 0.5 | 3 | 0.1666666667 | 100 | 0.00166 6666667 | 0.0460775677 6 |
| 5 | 10 | 300 | 0.5 | 4 | 0.125 | 100 | 0.00125 | 0.0399043442 2 |
| 5 | 8 | 300 | 0.625 | 2 | 0.3125 | 100 | 0.00312 5 | 0.0630943081 4 |
| 5 | 8 | 300 | 0.625 | 3 | 0.2083333333 | 100 | 0.00208 3333333 | 0.0515162868 7 |
| 5 | 8 | 300 | 0.625 | 4 | 0.15625 | 100 | 0.00156 25 | 0.0446144131 4 |

Table 5: Calculation of Diameter of probe for water scooping mechanism

From the above table, we have considered 4 no. of probes of diameter 4.46cm each to collect 5000L of water in 8 seconds by covering a distance of 300m at 360kmph.

| A/C Length | Wing Length | Wing Area | Chord | Height | Gross weight | Density | Velocity | cL | MTOW | Empty Weight | Fuel Weight | Crew | Payload |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 29.78 | 29.51 | 97.93 | 3.28 | 7.854 | 35651.2 | 0.6601 | 69.44 | 0.2287490171 | 43506.549 | 19420.4 | 6570.79 | 160 | 9500 |
| 30 | 29.78 | 99 | 3.3 | 7.854 | 35651.2 | 0.6601 | 69.44 | 0.2262766792 | 43506.549 | 19420.4 | 6570.79 | 160 | 9500 |
| 32 | 29.84 | 120 | 3.75 | 8.21 | 35651.2 | 0.6601 | 69.44 | 0.1866782604 | 43506.549 | 19420.4 | 6570.79 | 160 | 9500 |
| 38.67 | 29.95 | 145 | 3.75 | 8.3 | 35651.2 | 0.6601 | 69.44 | 0.1544923534 | 43506.549 | 19420.4 | 6570.79 | 160 | 9500 |
| 40 | 30.11 | 150 | 3.75 | 8.35 | 35651.2 | 0.6601 | 69.44 | 0.1493426083 | 43506.549 | 19420.4 | 6570.79 | 160 | 9500 |

Table 6: Dimensional values with multiple iterations

ISSN No:-2456-2165

# CHAPTER 6

## DESIGN SCHEMATIC DIAGRAMS

Controlling ranger service fires through aeronautical besieging with water, or by water with fire retardant, has ended up being especially successful. It empowers the fire control workforce to begin managing another fire within an issue of a couple of hours from when it is first distinguished, despite the fact that the fire might be situated in a remote shrub country that is unavailable via land. Previously, water planes have typically been somewhat Small Seaplanes or huge land and/or water-capable airplanes. Such land and/or water capable airplanes ordinarily have a focal fuselage which is furnished with a profile or frame having a lower shape that is adjusted to arrive on the water and is outfitted with wingtip that floats to adjust the airplane when on the water. Little ocean planes in the past have been furnished with outer water besieging tanks fitted to the floats of the airplane, or with necessary tanks situated inside the floats.

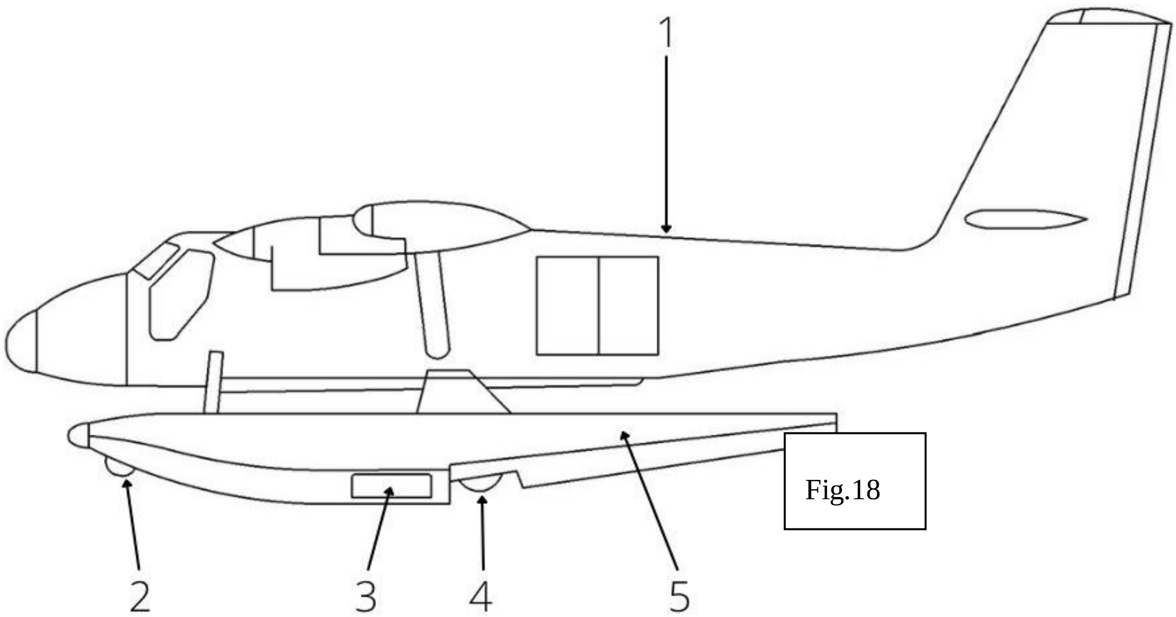


Fig. 18: Cross Sectional Side View of the Aircraft

In the **FIG 18.** the **1** indicates Chemical retardant storage tank with floats. And floats have front and rear wheels **2** and **4** which may be extended and retracted in a conventional manner. In order to contain water for dumping each of the floats is provided with a water collecting tank **5**.

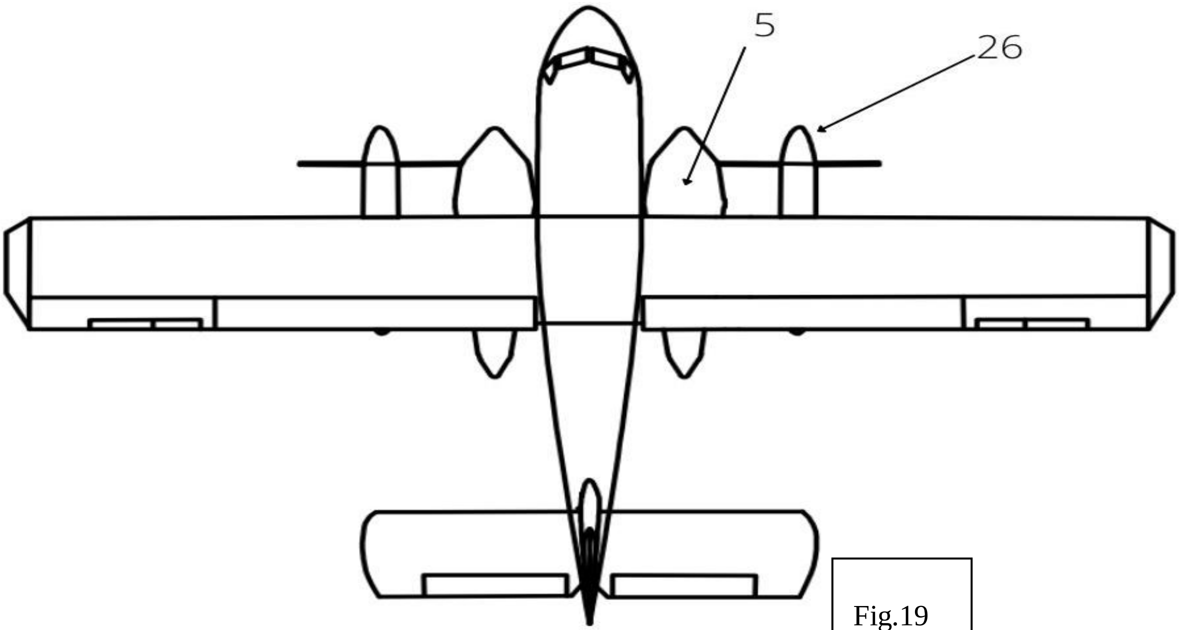


Fig.19

Fig. 19: Top View of the Aircraft

**FIG 19** is the top elevational view of aircraft where twin Turbo prop engine are placed below the wing. Wings want to bend upwards as lift increases, and to counteract this wing bending relief, fuel tanks are in the wings and engines are mounted under the wings.

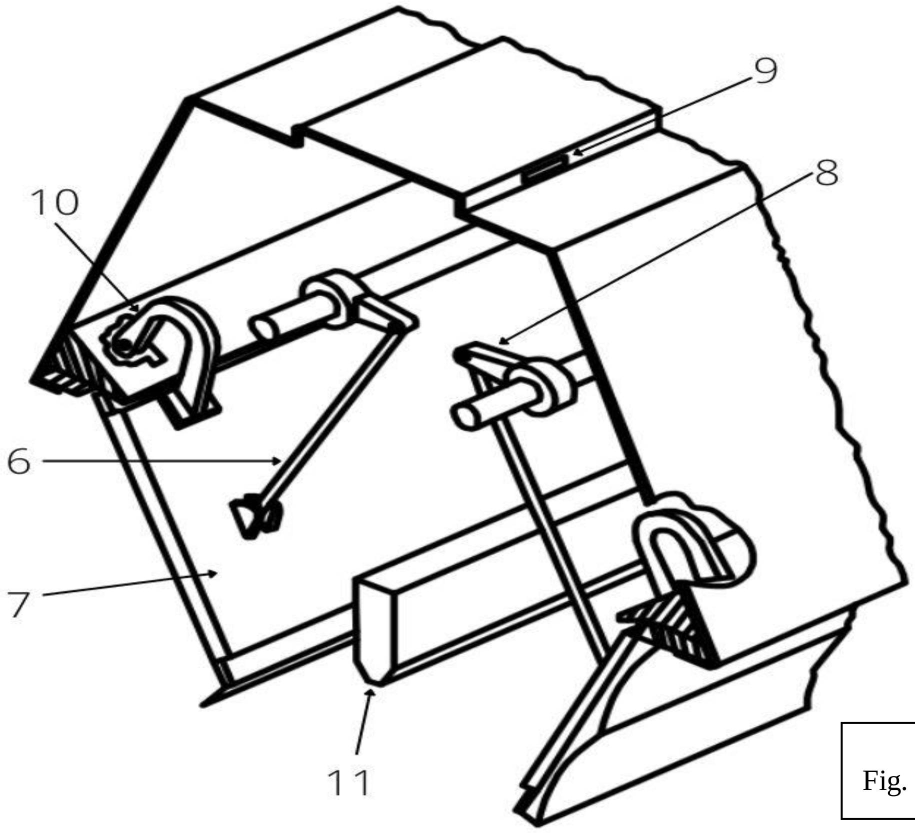


Fig. 20

Fig. 20: Is a cut away perspective view of the Door mechanism of each float/skid

In the **FIG 20. d**ump door(s)**7** are provided with right and left hand. The dump doors are pivotally mounted on opposite sides of each float at hinges **10** so that they swing downwardly and outwardly. In order to operate the dump doors in a rapid and uniform manner each of the doors is provided with rods**6**. The rods are connected to operating arms **8.**

Fig.21

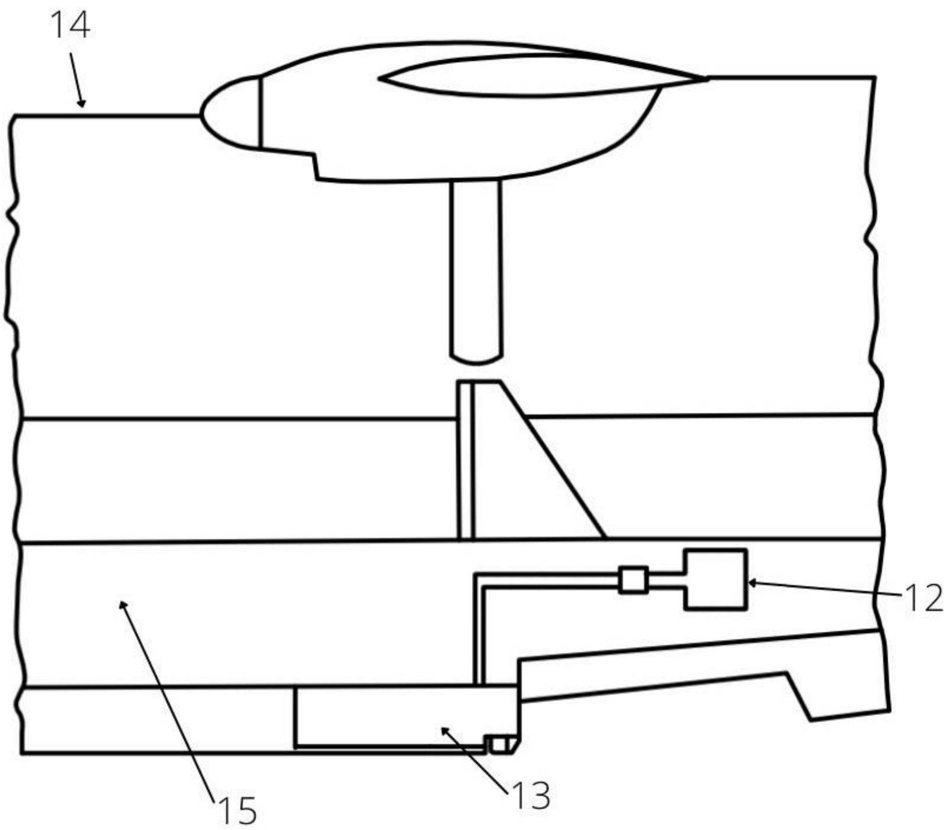


Fig. 21: Schematic illustration of a side view of a float showing the installation of a fire retardant chemical tank.

In **FIG 21**. fire retardant is carried in the fire retardant additive container **12**mounted in the rear position of the fuselage. Opening **13** is provided where required amount of retardant is pumped into the float(s).

In order to increase the effectiveness of the water on the fire, fire retardant chemicals or foaming agents is to be added to the water in the tanks.

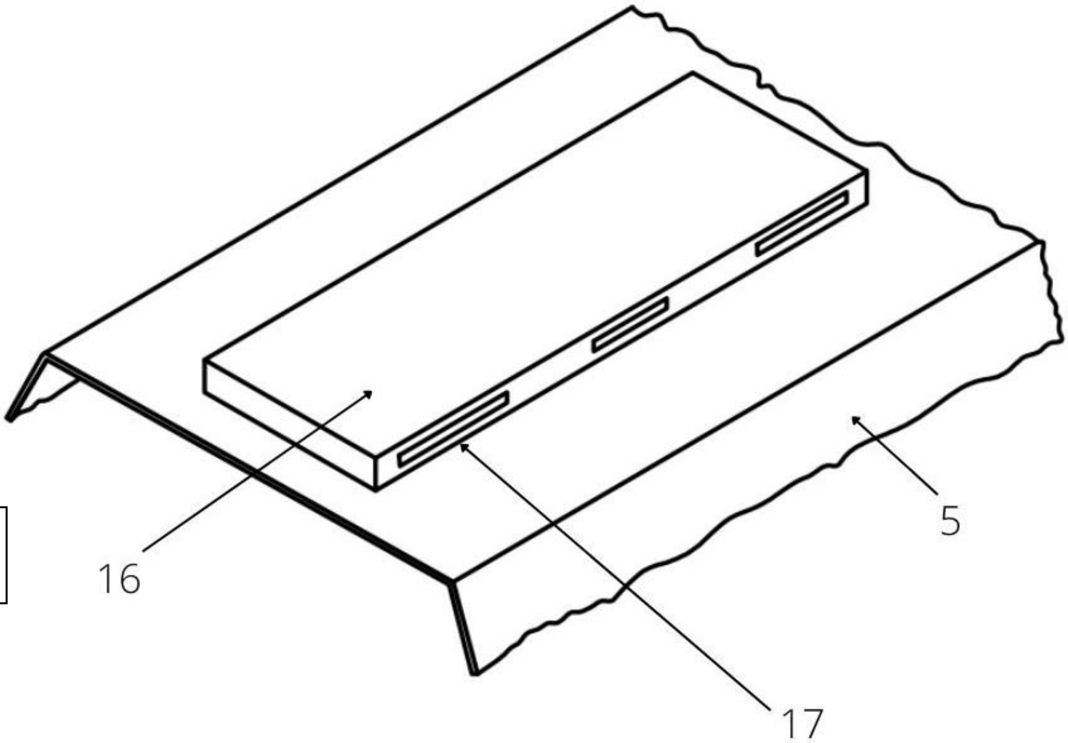


Fig.22

Fig. 22: Is a top perspective illustration of one float, showing the upper Surface of the float with upper openings for permitting outflow of excess water, and for permitting inflow and outflow of air

In practice the tanks is rapidly fill with water. In order to provide visual indication to the pilot that the tanks are full, In the **FIG 22. t**he floats are provided with a rectangular upward extension **16**.The upward extension has side openings **17**.

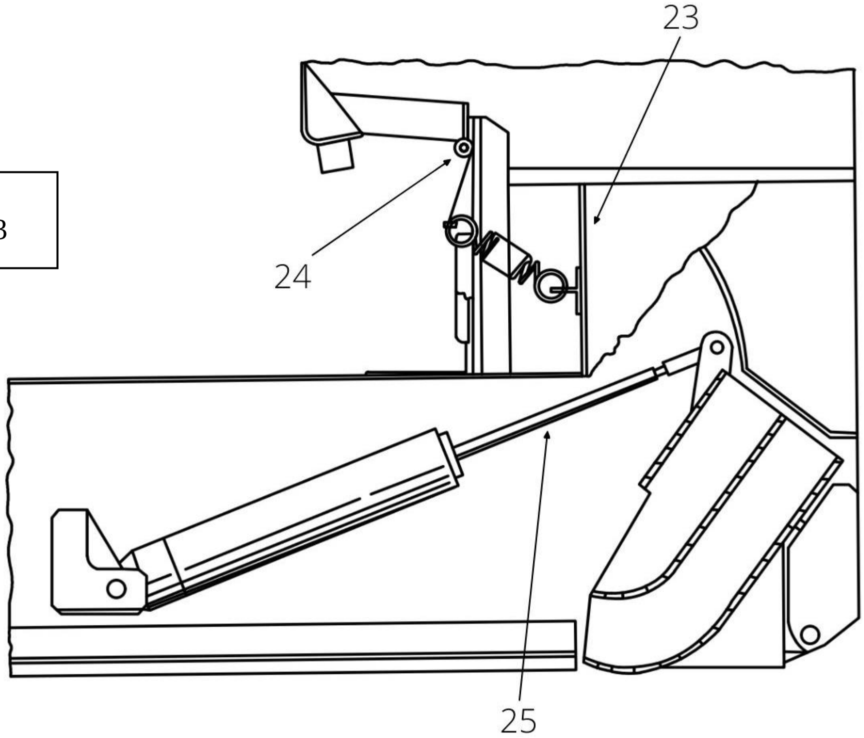


Fig.23

Fig. 23: Is an illustration of the water scooping mechanism

ISSN No:-2456-2165

In order to pick up water from the lake, a scoop assembly is provided on each float as shown in **FIG 23.** the scoop assembly comprises a scoop member which is mounted at pivot bracket on the underside of each float having an opening at the forward side.

Fig.22

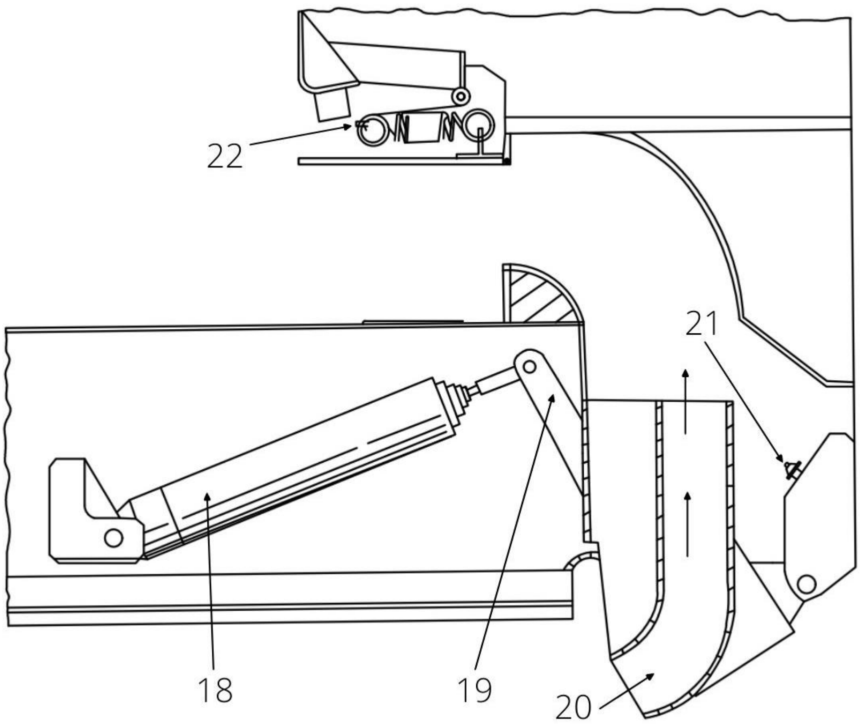


Fig. 24: Illustrating the water scoop lowered for collecting Water

The scoop assembly is normally in its upper position and can be swing downwardly into surface of the lake by piston rod as shown in **FIG 22.** by which the water is stored into the floats.

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# CHAPTER 7

## IFF (INDIAN FIRE FIGHTING) SCOOPER DRAFTING

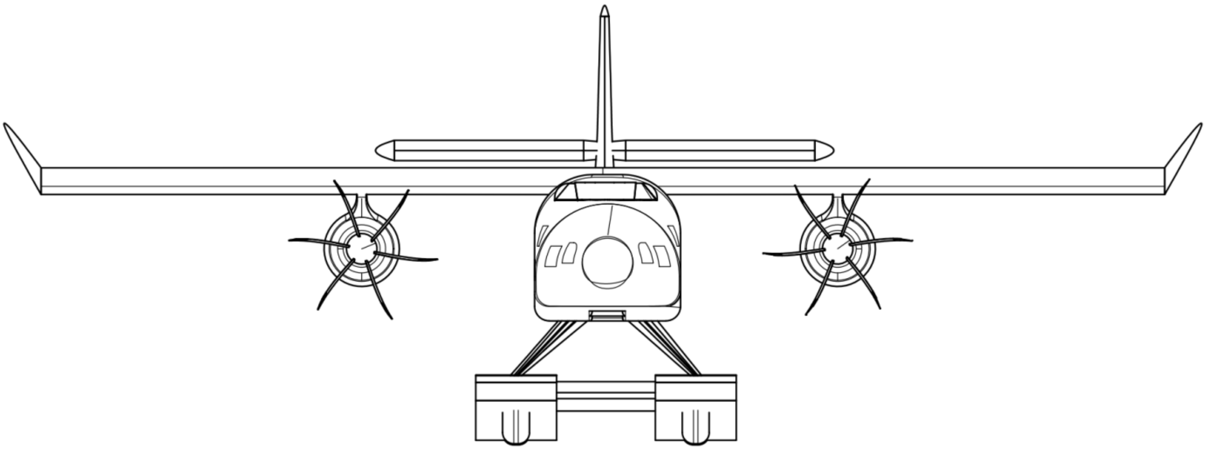

Fig. 25: Schematic front view of IFF Scooper

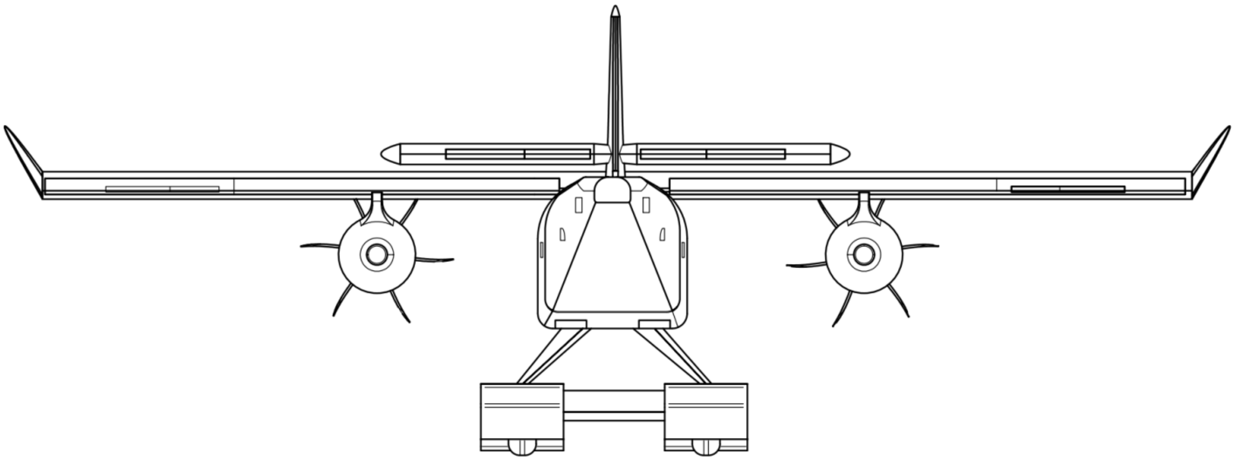

Fig. 26: Schematic back view of IFF Scooper

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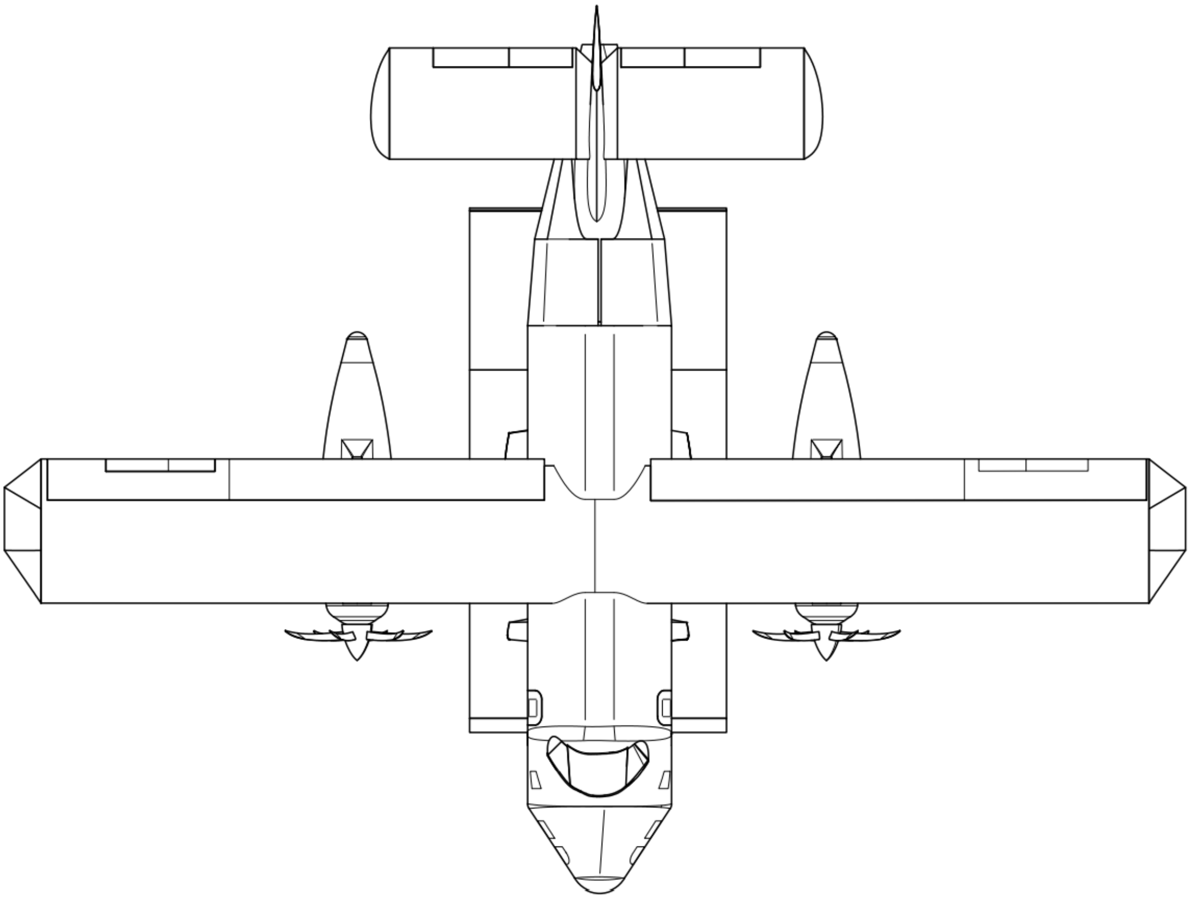


Fig. 27: Schematic top view of IFF Scooper

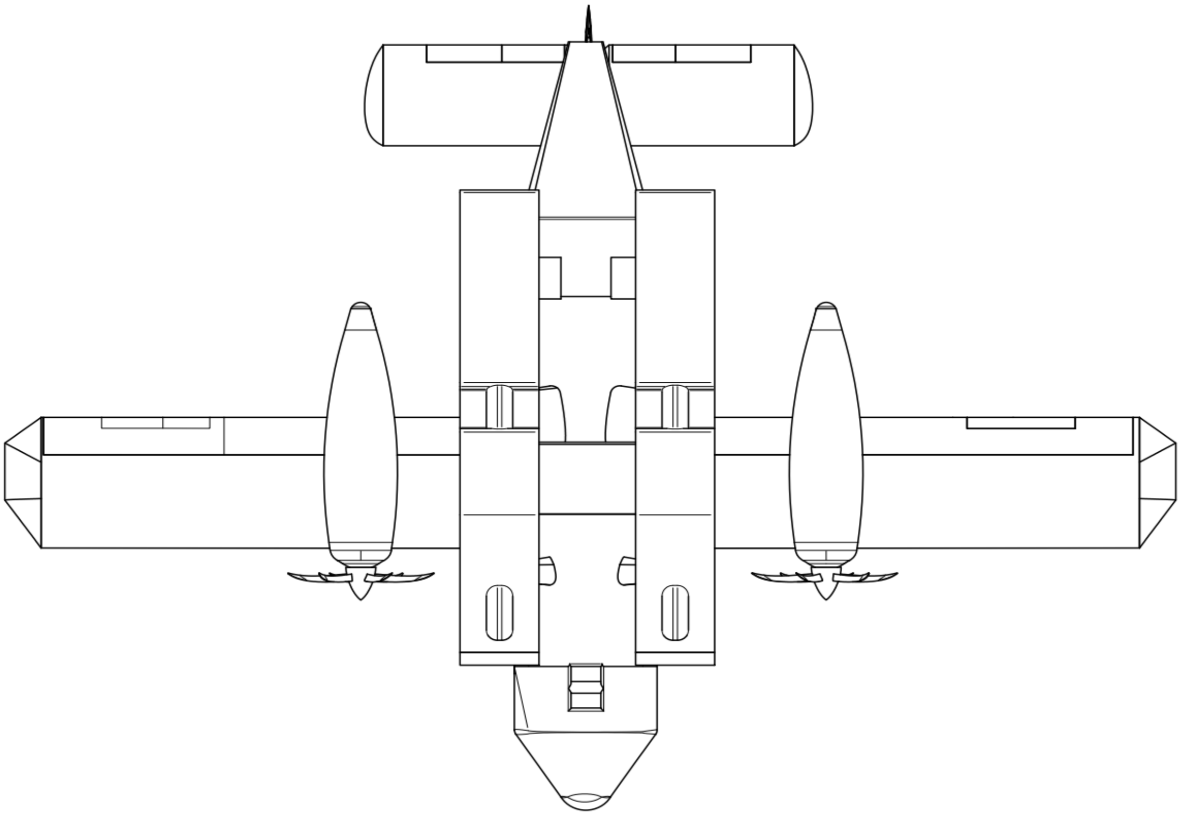


Fig. 28: Schematic bottom view of IFF Scooper

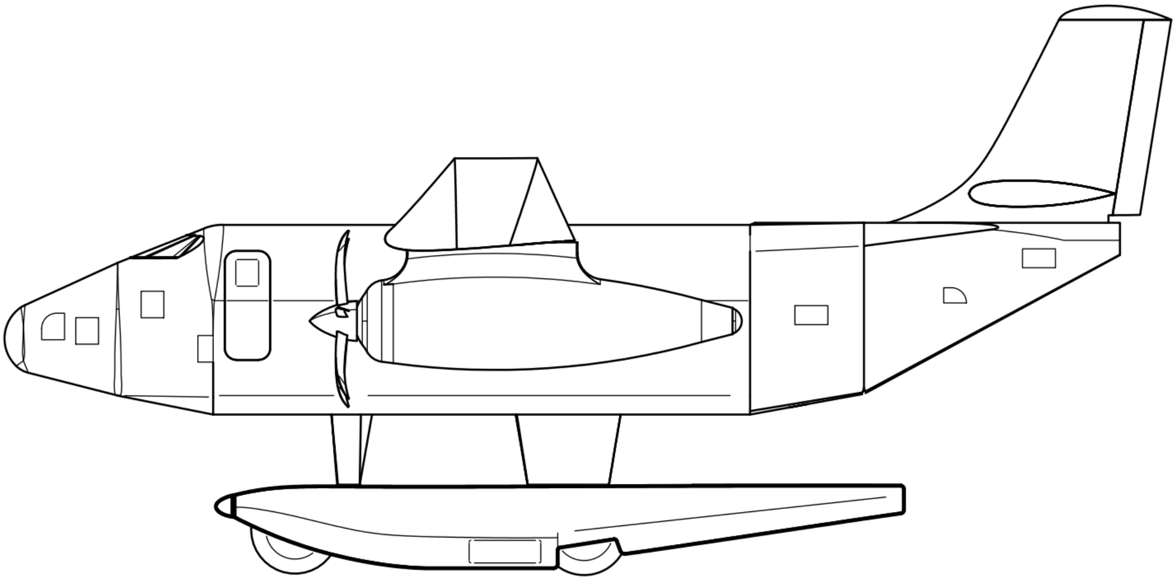
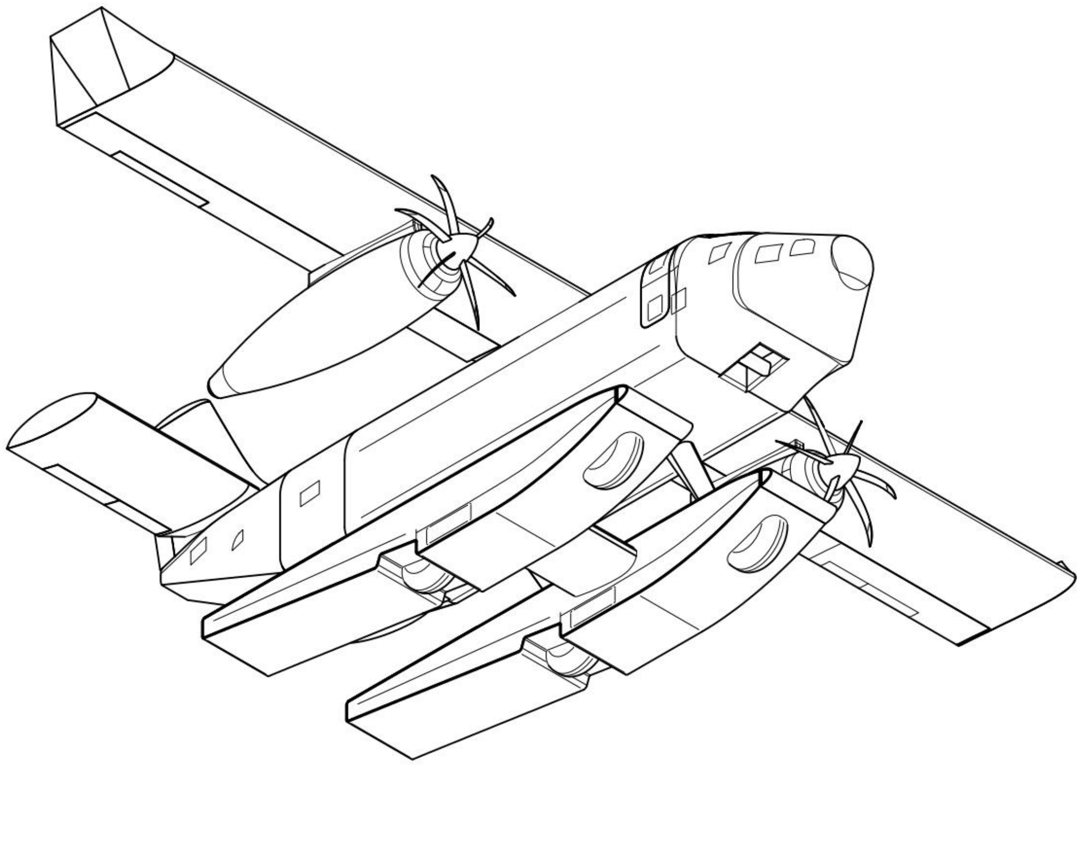


Fig. 29: Schematic side view of IFF Scooper



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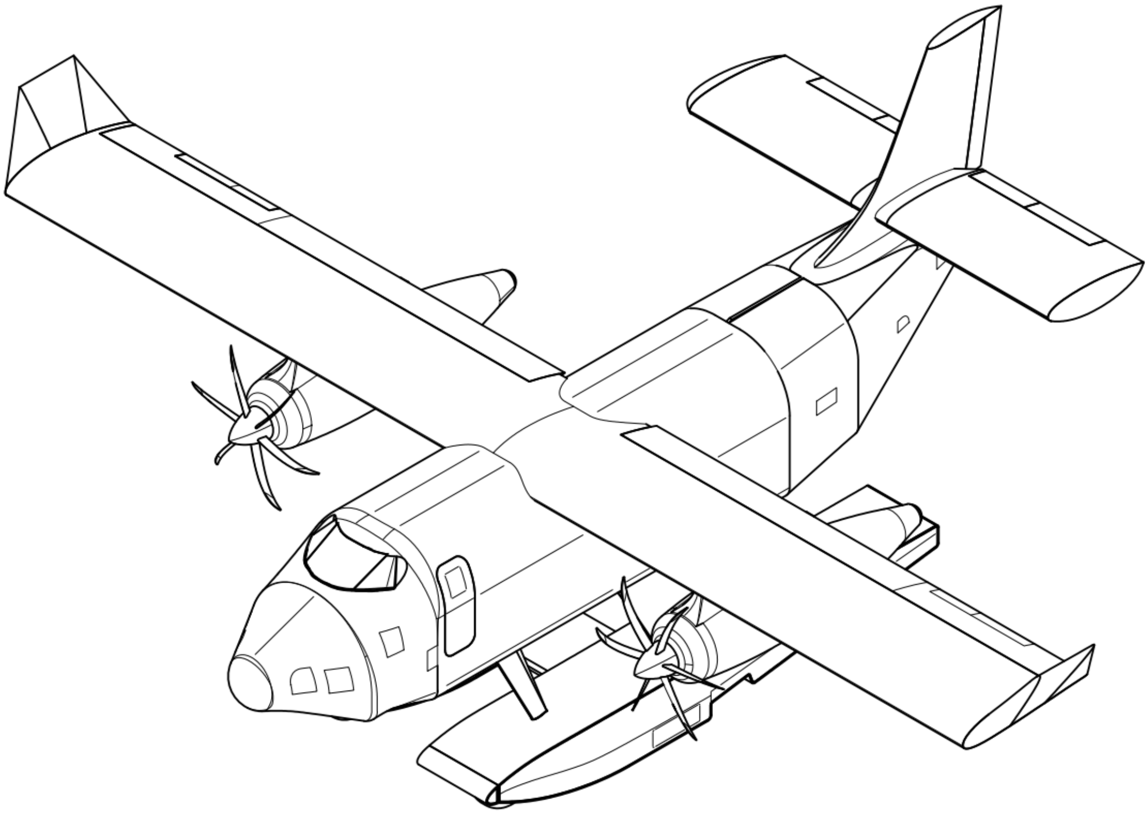

Fig. 30: (a), (b), Schematic isometric views of IFF Scooper

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Fig. 31: (a), (b), (c), (d), On land visualization of IFF Scooper

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Fig. 32: (a), (b), (c), (d), On water visualization of IFF Scooper

# CHAPTER

# CONCLUSION

In the recent decade, the country has seen a surge in the number of urban fires (both residential and commercial), industrial fires, and forest fires, with the majority of them resulting in massive losses.

Due to limits such as clogged urban roadways, tall buildings, and insufficient sources such as water and fire extinguisher liquid chemicals, conventional fire tenders are unable to manage this fire. Water scooping amphibious planes for firefighting can play an important additional role in dealing with these unanticipated calamities. Currently, India operates a small number of seaplanes for tourism and defense uses from a few seaports along the country's lengthy sea coast. Water-scooping amphibious aircraft can be very effective and affordable firefighting devices if used appropriately.

The water-scooping amphibian plane's current design, which serves the function of combating fires, has the following noteworthy features:

- Amphibious vehicles can take off and land on both land and water.
- Capable of collecting Fire Retardant Chemical from Airport-Services Bowsers.
- Inbuilt water scooping mechanism.
- CG management system during water scooping, flight maneuvers, and jettisoning water or liquid fire retardants while combating fires.
- Capable of jettisoning the water/fire-retardant in lesser quantities in multiple-drop mode, in numerous passes over the fire zone, or the entire quantity of stored liquid in one go, as the circumstance requires, in the prescribed mode, at the assigned aircraft speed/altitude.
- Designed to function in salty seawater or freshwater lakes, and capable of taking off and landing in calm conditions.
- Able to take-off and land in calm lake surfaces or moderate sea states.
- Takes into account the risk of exposure to high temperatures and smoke.
- Home to the Sea, Lake, or Airport to securely land. The firefighting scenario's mission objectives must be accomplished at least ten times.

# REFERENCES

[1.] Dr. Serkan Özgen, AIAA UNDERGRADUATE TEAM DESIGN COMPETITION PROPOSAL 2017 Conceptual Design of TADPOLE Multi-Mission Amphibian
[2.] Kevin Merrill, AWSA Program Specialist, Amphibious Water Scooper Aircraft Operations Plan 2016, United States Department of Agriculture
[3.] Colonel Kip P. Nygren, Major Robert R. Schulz, Breguet's Formulas for Aircraft Range & Endurance An Application of Integral Calculus, United States Military Academy, 1996 ASEE Annual Conference Proceedings
[4.] Jahnavi&Avinash, "Aircraft Design and Weight Estimation Nomenclature", Global Journals Inc. (USA), Vol.14 Issue 4 Version 1.0 Year 2014
[5.] FAA-H-8083-23, Seaplane, Skiplane, and Float/Ski Equipped Helicopter Operations Handbook, U.S. Department of Transportation, Federal Aviation Administration, Flight Standards Service, 2013 Elsevier, Inc.
[6.] EASA Type-Certificate Data Sheet, Pratt & Whitney Canada PW100 series, Number: IM.E.041, Issue: 03, Date: 04 June 2014
[7.] Raymer, Daniel P. Aircraft Design: A Conceptual Approach. Reston, VA: American Institute of Aeronautics and Astronautics, Second Edition
[8.] Andrew J. Keane, AndrásSóbester, James P. Scanlan, SMALL UNMANNED FIXED-WING AIRCRAFT DESIGN: A Practical Approach,5th Edition
[9.] Ajoy Kumar Kundu, Aircraft Design, Queen's University Belfast, First Edition
[10.] CAL FIRE Aircraft Contact Frequency 122.925, Firefighting Aircraft Recognition Guide, 1987, First Edition
[11.] Nelson, William, Seaplane Design, McGraw-Hill, 1934
[12.] Biran, Adrian, Ship Hydrostatics and Stability, Butterworth-Heinemann, 2003
[13.] "Air properties", 1976 Standard Atmosphere Calculator, https://www.digitaldutch.com/atmoscalc/
[14.] "Amphibious Aircrafts", Wikipedia, https://en.wikipedia.org/wiki/Amphibious_aircraft
[15.] "NWCG Gov NIAC Committee", NIAC, https://www.nwcg.gov/sites/default/files/committee-correspondence/niac-m-21-06a.pdf
[16.] "Water Scoopers Help Firefighters", USDA Gov, https://www.fs.usda.gov/Internet/FSE_DOCUMENTS/fseprd514790.pdf
[17.] "A new generation of private plane: AKOYA", LISA Airplanes, http://lisa-airplanes.com/en/
[18.] "Canadair CL-215", Wikipedia, https://en.wikipedia.org/wiki/Canadair_CL-215
[19.] "Canadair CL-415", Wikipedia, https://en.wikipedia.org/wiki/Canadair_CL-415
[20.] "Air Tractor AT-802". Wikipedia, https://en.wikipedia.org/wiki/Air_Tractor_AT-802