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Lawrence Hargrave—An Appreciation1

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Tonight we are concerned with the past, so I want you to step with me into the time machine and travel back into the middle of the last century to enable us to picture the background essential to our story and better understand the difficulties and so make a more reasonable judgment of the events.

Victorian England is in its heyday. The middle class has come into its own. Their splendidly equipped riders and carriages crowd the roads. The horse is still the chief medium of transport, but the railways are beginning to take over. The motor car is fifty years away. The candle is the main light source. On the Thames, some miles from London, lies Greenwich, made famous by Samuel Pepys and Christopher Wren, and our journey ends at a rather severe Georgian house on a grey day, the 29th of January in the year 1850. We arrive just in time to hear the cries of a new-born child. Lawrence Hargrave's career has begun.

He comes from a long line of Yorkshiremen who are thought to have come to England from Holland in the seventeenth century. His father is a London barrister. Shortly after Lawrence is born, the Hargraves move to nearby Otford. In 1856, doctors advise Lawrence's father to go to Australia for health reasons. That he decided to stay on after his recovery and became a prominent judge and one of the giants of the early political life of N.S.W. is another story.

Lawrence, at the age of 16, decided to follow his father and arrived in N.S.W. in 1866. The judge proposed a law course for his son, and after about a year's study and a failure to matriculate, it was decided that his future lay elsewhere. In 1868 we find him in the drawing office and later in the workshops of the Australian Steam Navigation Company, where, for the next four years, he learned much that was to be fundamental in his future career. He, in the company of 75 other young men of Sydney town, in 1872 chartered the unseaworthy brig *Maria* to search for fame and fortune in New Guinea. The wreck of this ship on the Barrier Reef and his part in two other New Guinea expeditions is yet another story.

1877 and 1878 were important years for young Hargrave as they saw him settling down in a steady job with the Sydney Observatory, become a member of the Royal Society of N.S.W. and his marriage to Margaret Preston Johnston. For many years Hargrave had been thinking deeply about the possibility of human flight. The thought was probably born by his observations of the albatross encountered in the "Roaring Forties" on his voyage out from England. It is known that he devoted a good deal of his spare time to watching bird flight and also the study of the movement of snakes, fishes and ocean waves. This study resulted, in 1882, in the production of his famous Trochoidal Theory of Serpentine propulsion.

A year later he made the important decision to devote his life's work to the conquest of the air, and as he then had sufficient income to be self-supporting, he resigned from the Observatory. His first paper on the Trochoidal Plane was read to the Royal Society of N.S.W. in 1884.

Judge Hargrave, Lawrence's father, passed away after a prolonged illness in 1885. In this year, Lawrence built his first home, a block of three terrace houses with four floors in Rushcutter's Bay Road. He occupied No. 40 and it was from this home that all his important work on model aeroplanes was carried out. The terrace is still standing, but the street has been renamed Roslyn Gardens. In 1892 his only son, Geoffrey, was born, and the following year the family, consisting of four daughters, son, nurse and governess, moved to Stanwell Park to a house left to him by his brother, Ralph. This move was made partly to reduce expenses, partly to obtain steady winds and permit experiments into supporting surfaces to be made without interruption from the public.

It was at Stanwell Park that the famous Box Kite was conceived and developed in 1893.

The whole family left for England in February, 1899. High costs, lack of opportunity and interest in his work caused them to return to Sydney after a stay of only six months. The family, now growing up, were no longer prepared to accept the isolation of Stanwell Park, so they occupied another of the terraces in Roslyn Gardens, this time No. 44. Hargrave's experiments were well into the third stage of engine development so that the decision to live in Sydney had some advantages as materials and foundries were close at hand. It meant, however, a most unfortunate rise in living costs.

Hargrave was still hopeful that he would soon be building a full-size aeroplane. As flight trials were to be made on water, the land at the end of Woollahra Point was acquired for this purpose and a house of three floors built and occupied in 1902. The house is still standing near the end of Wunulla Road, Point Piper, and apart from being converted into two flats is little changed.

The period which followed was undoubtedly the most frustrating of his whole life. His continuing efforts to produce a satisfactory engine were unsuccessful. His carefully considered and well supported theory that the Spaniards had discovered the east coast of Australia in

1 Address delivered before the Royal Society of New South Wales, 5 December, 1962. Opinions expressed are not necessarily those of Qantas Empire Airways, Ltd.

1595 was ridiculed. Unfortunately, time does not permit me to more than mention this fascinating subject tonight. His plan for the Port of Sydney appears to have been ignored. His only son, Geoffrey, was killed in action at Gallipoli on the 24th May, 1915. Lawrence Hargrave passed away two months later, on the 6th July, at Lister Hospital, as a result of acute peritonitis.

I hope that this brief background will assist in your understanding of the events I am about to relate, which have been arranged in the following order:

(1) A series of slides showing Hargrave's major inventions in chronological order.
(2) Some brief references to his work and association with your Society.
(3) Highlights of his aeronautical work.
(4) Background on personality.
(5) His attitude to his work and patents.
(6) Some inconsistencies.
(7) Clearing up some misunderstandings.
(8) Vision.
(9) His place in aeronautical history.

Major Inventions

The following slides have been made from Hargrave's records to provide some idea of his achievements :

Slide		
1.	Shoes for walking on water ..	1870
2.	One-wheel velocipede ..	1871
3.	Screw-driven airship	1872
4.	Mechanical snakes	1882
5.	Trochoided boats	1883
6.	Manpower operated flapper test unit	1887
7.	First propeller driven flying machine	1888
8.	Three cylinder radial engine ..	1889
9.	Wave-propelled vessel	1891
10.	Some early model flying machines	1893
11.	First box kite designs	1893
12.	First full size monoplane-glider ..	1894
13.	Design of steam turbine for an aeroplane	1895
14.	Jet propeller engine—steam ..	1895
15.	Second design for full size powered aeroplane—on floats	1896
16.	Third design for full size powered aeroplane—on floats	1902
17.	Compressed air motor contra rotating propellers quatre plane ..	1904
18.	18-foot steel hulled boat	1906
19.	Design for deep water port, Sydney	1906
20.	One wheel car	1907

Royal Society

Lawrence Hargrave became a member of the Royal Society of N.S.W. in 1877 and contributed the remarkable total of 24 papers. The papers were printed and sent to many parts of the world and were largely responsible for Hargrave's work being known in other countries.

It is indeed a pity that a contemporary account does not exist of members' reactions to a Hargrave lecture. Newspaper cuttings of the time do not do justice to these sometimes exciting occasions. Perhaps we can picture the scene in "The Society's House" with the small hall filled with serious, bewhiskered gentlemen. Hargrave's report of one such occasion concludes: "I will now wind up the machines and let them speak for themselves... if one of them threatens to strike any gentleman present, would he kindly hold up his hands—so—this will stop the flight and the machine will fall harmlessly to the ground."

Aeronautical Work—Model Period

I think it would be safe to say that this was the most productive and satisfying period of Hargrave's aeronautical experiments. Work commenced in earnest in 1883 and was spread over ten years. During the majority of this time, aviation experiments elsewhere were at a standstill. Even if it cannot be said with any certainty that the success of Hargrave's experiments triggered off the important work of Lilenthal, Pilcher and Chanute in the 90's, it is certain that they gained a great deal of encouragement from his work and his unselfish sharing of his discoveries.

The record is an impressive one. Hargrave demonstrated conclusively the practicability of flight by designing and building of some 50 model flying machines up to 10 feet in length. The majority of these machines were powered by india rubber on a most ingenious and original principle and obtained their thrust from flapping wings. The movement of the wings represented the mechanical reproduction of his conception of the action of a bird's wing in flight—the trochoical principle discovered in 1882.

He stated his case for flappers on the 1st June 1892, as follows:

1. Currents initiated by the up stroke increase the efficiency for the down stroke.
2. Only one cylinder needed for both flappers. (Referring, of course, to a compressed air motor.)
3. No tendency to veer.
4. Less liability to damage on landing.

His first steam engine was built in 1888, but this was not a success. Then followed a number of different types of compressed air engines of ingenious design. The hollow wooden spar which formed the body of the elastic powered machines gave way to a lightweight metal tube which also formed the container for the compressed air. Engine cylinders were made of tin and were of single and triple cylinder types. His famous three-cylinder radial rotary engine was invented in 1889.

The greatest distance flown by an elastic powered machine was 270 feet, and 368 feet by a compressed air model.

Difficulties in experimentation are indicated by the following extract from a letter dated 8th December, 1891: "No. 16 has just been tried and wrecked for the 5th time, there was a terrible smash; however, no real advance can

be made without flying the machine free so I plod on with renewed stubbornness."

At the conclusion of a paper to this Society on 1st July, 1891, Hargrave said: "It may be said that it is a waste of time to make machines of such small capacities and no practicable good can come of them. But we must not try too much at first, we must remember that all our inventions are but developments of crude ideas, that a commercially successful result in a practically unexplored field cannot possibly be got without an enormous amount of unre-munerative work."

One of the many interesting developments of this period was the chronograph designed and built by Hargrave to make simultaneous recordings on a chart, of time in seconds, flapper vibrations and air pressure. Many other devices were built for testing purposes.

A vital consideration in all Hargrave's aeronautical work was lightness. He expressed his philosophy on this subject to your Society in June, 1890, in these words: "It should be remembered that flying machines are only to battle with the air and not for knocking down fences or ploughing up the ground. It is not usual to proportion the plating of ships so that they will stand beating on the rocks, but only to safely resist the strains produced by the wind and the waves. Perhaps much of the writer's success has been due to the avoidance of this fault, although it is somewhat of a trial to see a month's work knocked out of all shape in a moment."

There was a sharp division of opinion amongst the earlier experimenters on the subject of weight which may seem strange to us today.

Aeronautical Work—Supporting Surfaces

I quote from paper to Royal Society, 7th June, 1893:

"Before beginning another motor, it was thought advisable to try whether a better disposition of supporting surfaces could be found and at the same time see if any foundation could be discovered for the assertion that birds utilised the wind in soaring. No amount of observation of birds will solve the soaring problem. It can only be done by making some form of soaring apparatus that will advance against the wind without losing its elevation."

He thought the expense of constructing a large whirling arm machine too great and it would not produce true conditions. He considered kites as best means towards the desired end. He knew that the experience of Wenham, Philips and others favoured superimposed planes for supporting surfaces.

The first box kite was produced on 15th February, 1893, and made of circular cells. The following day a square celled box kite was constructed. This was the true ancestor of the more sophisticated box kites, four of which lifted Hargrave 16 feet off the ground on 12th November, 1894. As a result of this experiment Hargrave stated that there is no limit to the weight that may be buoyed up in a breeze. The exhibits in the hall include models of the squared cell kite and the standard box kite eventually evolved from it.

When Hargrave received news of Lilenthal's successful gliding experiments, he constructed a full size monoplane glider with the same wing area as Lilenthal's but only half the weight. When testing this glider it was turned over by a cross wind and wrecked. Fortunately, Hargrave was not injured. This was the beginning and the end of his gliding experiments. He saw that safety was of paramount importance and that such an accident could cost him his life and put an end to his work. Both Lilenthal and Pilcher were to lose their lives in gliding accidents before the end of the century.

Hargrave's first full scale powered aeroplane was designed in 1895. This was to be doubly supported, firstly by a string of kites, and secondly, on its own wing surfaces when it got under way. This aircraft was not built, as the engine was a failure.

On the 20th April, 1896, the second full size power operated machine was designed. It was also to use box kite wings powered by a steam engine driving flappers. This machine was of particular interest as it incorporated a dual elevator rudder control and was to operate off water (a most original concept), supported by light wood or papier maché floats. The all-up weight was to be only 300 lb. Three engines, two steam and one petrol, built to power this machine were all failures.

His third full size powered machine was also to be a float plane. The proposed wing design was still on the box kite principle, but of curved section, showing evidence of his experimental work on soaring machines. The wings were further modified and improved in the final design for this machine developed in 1903. The arrangement of the floats was also improved and these were built, together with engine and wing supports. All the structure was made by Hargrave of tin sheet patiently soldered. A section of the main float was designed to carry water for the steam boiler. The design of this machine was in advance of the first generation aeroplanes built in Europe and U.S.A.

Hargrave calculated that 40 lb. of thrust was needed to drive this machine. The best he could obtain after several years of effort was only 17 lb.

In a letter to Octave Chanute on the 6th March, 1902, he said of this machine: "My new apparatus is merely a steamer if it does not lift out of the water and a flying machine if it does."

The Wright Bros.' aircraft made its first powered flight at the end of 1903. We cannot be certain that Hargrave's first and second machines of 1895 and 1896 would have flown had Hargrave been able to develop a suitable engine. There can be little doubt, however, that his 1903 machine would have been a success. It was indeed a tragedy that Hargrave could not afford to outlay the funds necessary to build the wings and control surfaces until he was sure of the engine.

Hargrave carried out important experimental work on curved surfaces. This work began in 1892. At the beginning of 1893, he discovered that the curved sails of a windmill when turned so that the blade was edge-on to the wind, rotation was maintained and the whole sail

assembly also moved forward on its axle. The full significance of this discovery was not realized until 1897 and valuable time was lost.

He then began a full series of experiments from which he deduced that wind striking a curved wing produced a reversal of air flow under the leading edge providing an aspirational effect on the wing. He designed simple wings balanced by a weight, which he called soaring machines. He found that these machines, when tethered, would advance beyond the zenith or perpendicular. It would appear that no further work has been done on this by others. If Hargrave's findings were correct, an important power source used by the soaring birds has been overlooked by later generations. This effect would be of vital importance in man-powered flight.

Aeronautical Work—Engines

Between 1896 and 1906, Lawrence Hargrave constructed five engines to power full size flying machines, and every one was a failure. It is interesting to speculate on the course of history should any one of these engines have been a success. Additionally, he constructed and exhaustively tested countless component parts, such as boilers, heat lamps, pumps, valves and propellors. It is almost unbelievably sad that such tremendous labour, originality and skill did not receive their due reward.

The two engines fitted with propellers, on display, are worth your inspection. The four cylinder motor in the test rig is petrol engine No. 24, built for the 1896 machine. The other is perhaps the most interesting. It was also built for the 1896 machine and its noteworthy features are light weight, compactness and the rotary movement. The tubular frame was designed to act as a container for water for the boiler and kerosene for firing. This engine was designed to produce five to six horsepower and must be one of the most unique steam engines ever built.

An extract from a letter to the Superintendent of the Railway Workshops, Sydney, written in March, 1900, indicates some of Hargrave's difficulties: "I am making a four cylinder oil (petrol) engine for my flying machine and on receiving the work that I had had done in a Sydney shop, I find the workmanship and material of sausage machine quality and on enquiry have not as yet found anyone who is likely to give me any more satisfaction."

On 29th October, 1900, he wrote: "Do you not see the crux of the whole matter is the engine. The motor car men are now helping by giving attention to light oil engines. I am driving at the same thing and although constantly failing, still see the certainty of success."

Two months later he wrote: "I have just had a bad knock in discovering some radical defects in my first attempt at a 4 cylinder oil engine, No. 24. This means 12 months work to do over again."

Hargrave was not to be beaten by his failures, for even when he was reluctantly obliged to give up full-time work on aviation in 1906, he designed and constructed yet another engine for his 1903 machine. A two-stroke petrol motor of two cylinders with recoil springs designed to operate flappers. This, too, was a failure.

Personal

Some very interesting material has recently been discovered, some of which I propose to quote in order to provide an insight into the range of Hargrave's interests and perhaps his character.

To his daughter in 1907: "I have been stuck over the drawing board for about two months and my twin two-stroke flapping flying machine motor looks as if it would work ; Mum has lost all faith in me as an engineer owing to my long list of failures ; she does not realise that a little success is only reached by climbing over piles of duffing jobs."

About the same time, and in reply to a letter which commented upon his brevity: "I understand your remarks about my short sentences, I find, the people who care to know do not misconstrue, those who want to carp have more scope if the writer is wordy."

One of his many letters to a newspaper: "Your leader in Saturday's issue traverses much ground but however good the idea of a universal language is, it is foredoomed from the jump because it is at variance with the fundamental truth that all living organisms are prone to vary. It is this law that always wrecks well-meaning socialistic efforts and makes an ideal universal religion a hopeless impossibility. But onward rolls the river of life, cutting away the bank on one shore and making a sand bar elsewhere, ever changing, ever forgetting, let us hope ever improving."

An advertisement contemplated for publication in *Aeronautics*, London, 1910: "Lawrence Hargrave—After almost 25 years of continuous effort in assisting to make flying practical: finds that his present income is inadequate to meet the calls made upon it. He is 60 years of age, and still has considerable technical con-structuve ability, his is weak on theory. He wants to know if his services are of value to any one and, if so, what is their value— Continental papers please copy."

A letter to his daughter, 1914: "I never seem to have any news to tell you, it is very curious that when I take up my pencil to write on your letter, and all around are deep in various books, there seems to be instantly a buzz of talk, and jangle on the piano, of course the disturbance is only accidental and my noticing it is a sign of old age creeping on me."

A letter to the Secretary of the Royal Aeronautical Society, London, is probably an unequalled summing up of British character: "I note with pleasure all English aeronautical news that dribbles to me. It is typical of the English character throughout. Ridicule and intolerance of independent thought. Slowness to grasp the impact of a new idea. Opposition if a vested interest is assailed, curiosity if things are done in a far country. Tardy appreciation of danger when a neighbour threatens. A rapid and thorough seizure of that situation and then supremacy—may it be so."

Hargrave's contribution to the Royal Society's Symposium on the feeding of man—" What Man should eat": "The nutriment that a reasoning man should eat and drink in order that death should not be hastened by

excess, can be regulated to any degree of accuracy. But our diet is rarely determined by reason, except in hospital or prison. We eat a pretty woman's cake and she smiles, we refuse and are dubbed bores, we drink a man's hard liquor and pretend we like it and henceforth rank as jolly good fellows, we reject his hospitality and lose a possible life-long friend. Strong indeed is he who adjusts his eating and drinking solely to work long and well—the intelligent man's eating and drinking are merely factors in the battle of life. The higher the intellect the greater the number of factors that enter the equation of the most trivial act."

A letter in 1915: "I wonder if the winners in this war will be any happier than the losers, one must exterminate the other or spend all their time in making or using arms. The other must do the work of providing the necessities of life or be shot down. Treaties are no use and if made no one can be trusted to keep them if there is any advantage in breaking them. I hope we shall know how it turns out, but the world is old enough to have seen all this before and left no traces in our geological strata."

Team Work and Patents

Throughout his life, Hargrave was a champion of free enterprise, especially free trade, and wrote many letters to the newspapers on these subjects. As would be expected, he fought against monopoly in every form. However, he obtained reports on four occasions on the possibility of patenting various inventions. This action was probably taken against his better judgment and as the only way open to him of supplementing his slender income in order to provide the funds needed to more adequately carry out his experiments.

In a letter to the Secretary of the Smithsonian Society of 8th December, 1891, Hargrave said: "Will you impress upon your co-workers the fallacy of secrecy—co-operation and the full interchange of ideas will hasten success in which all will share—there are so many forms of flying machine possible that it is hopeless to think any inventor will be able to monopolise the profits by a corner."

An extract of a letter in 1888: " But bear in mind I am not working with any idea of making money by my results, I simply have leisure, inclination and constructive ability and use them in a field where I am sure of success."

In a paper to your Society read in June, 1890, he said: "The writer thinks the act of invention to be a sort of inspiration and a pleasure that the individual does not seek to be rewarded for undergoing—it is followed by a greedy sensation or a wish to obtain money from others without giving an equivalent. Inventors will always invent—they cannot help it—you cannot stop them and a patentee is nothing but a legal robber."

Inconsistencies

There are several major inconsistencies in Hargrave's work which are difficult to understand, particularly in such a period when the tempo of life provided adequate time for reflection. The chief of these was his failure to capitalize on his discovery of the lifting power of the curved surface in 1892. In 1893 he found that a box kite with curved surface planes pulled twice as hard as one with flat surface planes. However, he came to the rather extraordinary conclusion that "a machine with curved surfaces would come to grief when flying against the wind if the wind fell calm unless surface area or driving power was increased, therefore he was on surer ground by making supporting surfaces as flat as possible ". About this time, too, Chanute advised Hargrave that Lilenthal experiments with curved surfaces showed added lift of from three to seven times that of flat wings.

Five vital years passed before he again took up experimentation with curved surfaces, but even then they were not incorporated in the design of a full size machine until 1902.

In 1890 he announced in a paper to the Royal Society he had discovered that more than 50% of the supporting surface of his model aircraft was not necessary and that two separate areas were equally satisfactory. Although he built several models after this, none incorporated this discovery, which meant, of course, reduced drag and increased range.

Notwithstanding advice from a consulting engineer, whom he paid to report on the possibility of patenting his Trochoidal Plane propulsion methods in 1882, Hargrave persisted in his endeavours to apply this theory to aircraft. Even his last engine, built after he had virtually given up aviation work, was designed to drive flappers. A portion of the consulting engineer's report referred to reads as follows: "Propelling principles adopted by animate nature need not necessarily be the best for artificial propulsion and the probabilities are the other way." Yet Hargrave persisted to the end.

Again, Octave Chanute advised that propeller efficiency could be expected to be between 50% to 70%. Hargrave's propellers were generally under 20 % efficiency. It is interesting to record, some thirty years later, the maximum efficiency obtained from fixed propellers was only 85%.

Misconceptions

Many people have not been able to understand why Hargrave gave 77 of his models to the Munich Museum in 1910. This caused much bitterness during the war years. The facts of the matter are that for eight years Hargrave endeavoured to interest the Sydney Technological Museum and the University in Sydney in them for permanent exhibition without suggestion of payment, even though some additional funds at that time were sorely needed.

They were also offered to the Melbourne Museum, Commonwealth Government, Royal Aeronautical Society in England, Science Museum, Liverpool Museum, Smithsonian Institute and others. The famous Technolo-gical Museum at Munich did not hear of this offer until 1910. Their immediate application by cable was accepted, after which, of course, both the Commonwealth

Government and the Sydney Technological Museum became interested, but it was too late.

The Munich Museum have now very generously returned all but four of the models, and several of them are on display tonight. Unfortunately, the major part of the collection was destroyed in the last war. This is perhaps a true measure of Hargrave's considered worth in this country when he could not even give away results of his work. Yet here was a man who, but for an unfortunate chain of adversity, would have been one of the truly great in history.

Since Hargrave's death, many references have been made, particularly in the press, to the Wrights' indebtedness to Hargrave for their success. There is no foundation for these statements. Hargrave wrote only two letters to the Wrights. One was of congratulation after he had learned of their first flight. Both were short and to the point.

Investigations lead me to believe, however, that there is a strong, indirect link through Octave Chanute. Records suggest that the significance of Hargrave's early work on curved surfaces, which was not missed by Chanute, influenced the design of his famous gliders. There is little doubt that the design of the Wright glider was based initially on the Chanute glider, which preceded it by several years. It is an interesting speculation.

Vision

Not by any means the least of Hargrave's contributions to aviation was his well-developed sense of history expressed in many ways, but particularly in preserving his models for the guidance of experimenters and the information of the public, and in the meticulous record of his work contained in his notebooks and the papers given to your Society.

Notwithstanding an almost unbelievable record of failures, Hargrave never wavered either in the course he had set himself or his conviction that man would fly in a heavier than air machine and that the aeroplane was the chosen instrument for transportation in the future. "Let no man be disheartened by the sneers of know-all acquaintances. Rely on it that the first man who paddled across a creek astride a log was thought a hare-brained fool by his contemporaries."

Two letters written in 1902 are of interest:

"We should have been flying long since had it not been for the unfortunate invention of the balloon."

"I can fully appreciate the splendid work of those engaged in driving balloons, but they must see as clearly as I do that such machines, however successful they may be, cannot be a type that will have any permanence."

In a letter to the Smithsonian Institute dated 1891, he said: "Very few have the slightest idea of the results of our work, but there are some here who can actually speak about flying machines without that pitying smile that is so galling to the recipient." The reply is equally interesting: "I congratulate you on your success. Work done by experimenters like yourself is to be regarded as most valuable and the success you have achieved gives renewed hope to all in the final solution of a problem which, when solved, will produce an effect upon civilisation greater than any since the invention of the steam engine."

A fitting conclusion to this part dealing with the vision of Hargrave is to be found in a letter to Chanute in 1892: "There is an opinion that the principal work of the flying machine will be to destroy life—this idea may predominate amongst men in the trade (referring to Maxium who was then building a huge machine at a cost of £20,000) but it is erroneous. The flying machine will tend to bring peace and goodwill to all, it will throw light on the few unexplored corners of the earth and will herald the downfall of all restrictions to the free intercourse of nations."

His Place in Aeronautical History

Some thought was given to the title of this paper, and it was considered that "An Appreciation" was adequate, although in modern usage the word "appreciation" tends to be regarded as "speaking in favour of". The dictionary, however, gives the meaning intended of "a just estimate ". History has not been just to Lawrence Hargrave. The aim of tonight's paper has been to attempt to redress the balance.

You will have noted that many quotations have been given from his records. This has been done partly to permit you to form your own opinion, but mainly because a number of the references have been taken from papers he gave to your Society 70 to 80 years ago.

Before concluding, I would like to attempt to draw together some of the threads of this broad canvas.

An important feature of Hargrave's work was his planned and logical approach. Firstly, he set out to prove his assumption that human flight in a heavier than air machine was possible. He decided that proof could best be demonstrated by the use of models. Concurrently with this work, he began experimenting with power plant design as he realized it was in this direction that the main difficulties lay.

He resisted the temptation to develop and improve his model aircraft and turned instead to the next step, stability and safety aloft. Hargrave realized that an accident could put an end to his work, so he made safety a major requirement. It was also clear to him that the first navigator of the skies in a heavier than air machine would have his hands very full indeed. He set out to minimize the problems with which he would have to contend and considered the achievement of stability was of paramount importance. His box kites were the brilliant realization of that aim.

Today, the box kite sounds a very simple affair—a child's toy. Hargrave had developed his box kites to become quite sophisticated flying machines. His three-deck box kite, for instance, had a surface area of 158 sq. ft., with 11 ft. 6 in. span, 10 ft. long and 2 ft. 6 in. high. There can be little doubt that Hargrave would have flown had he been able to obtain a satisfactory motor. We have the first generation of European aviators to bear witness,

as their wing design was purely the box kite invented by Hargrave some 15 years earlier.

There is one essential difference, however. The Europeans did not have Hargrave's knowledge of the subject. They snatched Hargrave's wing design in almost desperation and instead of developing and improving the wing as Hargrave would have done, persisted with it in its original form and for several years could not turn corners until the Wrights showed them how in 1909.

It is certain that once Hargrave had achieved flight and had learnt to control his machine, he would have progressively modified the stability factors he had designed for safety. In a paper to the Royal Society as far back as 1885, it was clear he could see the road ahead. Speaking of control, he said: "In larger machines this will have to be done by making the area of the tail variable for ascending or descending and tilting one corner up and down for turning to either side." He had anticipated aileron control which the Wrights reinvented 20 years later.

Perhaps the most significant of Hargrave's many contributions to man's final conquest of the air was his taking up the torch of experimentation when it had been dropped by the Europeans in the 80's and keeping it burning brightly for 25 vital years. His approach was a scientific one and it was made quite unique by his sharing of the results of his work and thinking with anyone who expressed a genuine interest. His dogged perseverance and unfailing optimism were an inspiration to many. Strangely enough, these virtues were to some extent a handicap, as they caused him to persist in unrewarding endeavour when his energies may have brought better results in other directions.

He was a superb draftsman, and his engines were all built firstly on the drawing board, often after weeks of work. Many of these drawings are in the library of the Royal Aeronautical Society, London. His skill as a draftsman was almost equalled by his skill as an engineer, as you may see by examination of the equipment in the hall, which has been very generously lent by the Trustees of the Museum of Arts and Sciences.

The originality of Hargrave's designs is quite remarkable, but originality was not enough when it came to engines and associated equipment. This problem could have been overcome had Hargrave had a larger income, been assisted financially in his work, or had had a fellow worker to help him, as Orville Wright had in Wilbur. His income was fixed at approximately £600 per annum. The combined effects of inflation and family growth meant that his surplus funds dwindled to extinction when they were needed most for full-scale work. In 1902, when he was so near to success, he sent a desperate appeal for funds to the *London Times*—without result.

This is a sad story with a tragic end, but it demonstrates, once again, the slender margin between success and failure. Hargrave had the attributes of character, skill, enterprise and hard work which deserved a better result. However, had he flown, it is certain he would not have claimed the success for himself. Due credit would have been generously given to the contributions made by many others, without whose work of dedicated endeavour, spread over 100 years, the brilliant achievement of the Wright brothers would not have been possible in December, 1903.

In conclusion, one final quotation from the American Octave Chanute, who was unquestionably the greatest aviation authority of this period. He said in a public gathering in 1894: "If there is a man more than another who deserves to fly through the air, that man is Lawrence Hargrave of Sydney, N.S.W."

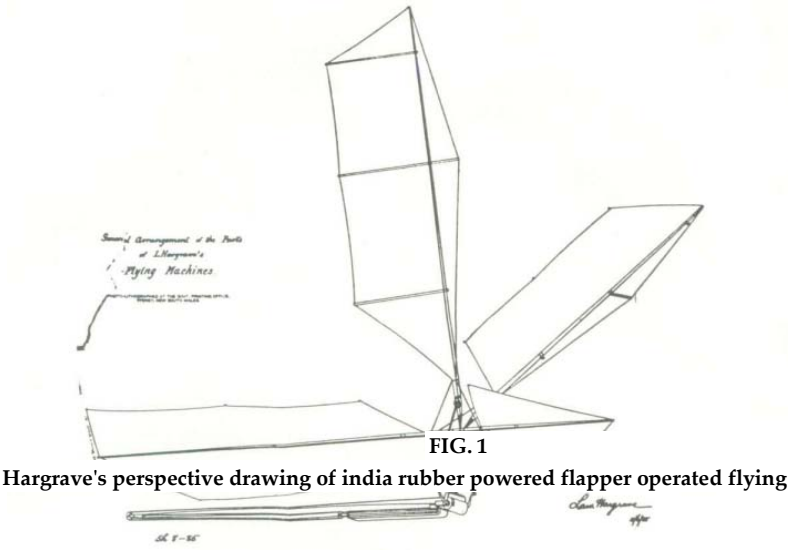


FIG. 1

Hargrave's perspective drawing of india rubber powered flapper operated flying machine of 1885

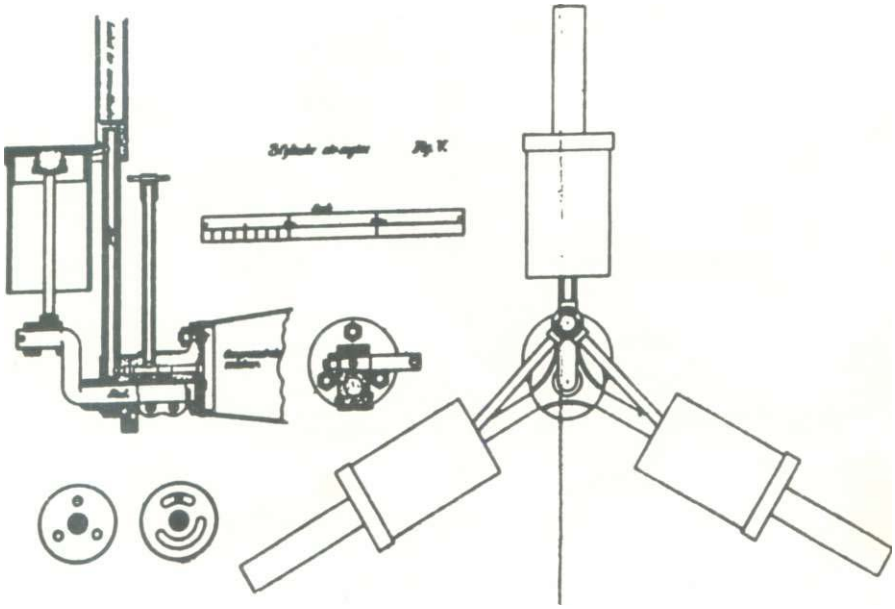
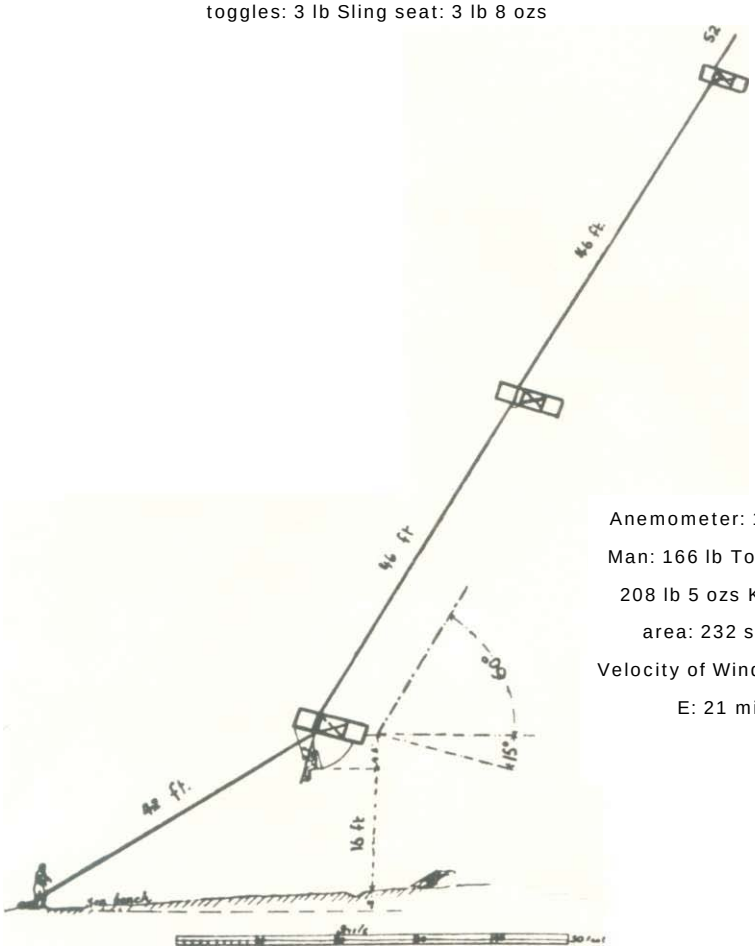


FIG. 2

Hargrave's drawing of the three cylinder radial rotary compressed air engine invented 1889

Side View of Kites. Weights aloft The 4 kites: 34 lb 13 ozs Lines & toggles: 3 lb Sling seat: 3 lb 8 ozs



Anemometer: 1 lb
Man: 166 lb Total: 208 lb 5 ozs Kite area: 232 sq ft
Velocity of Wind at E: 21 miles

FIG. 3

Drawing of the man lift by four box kites 1894

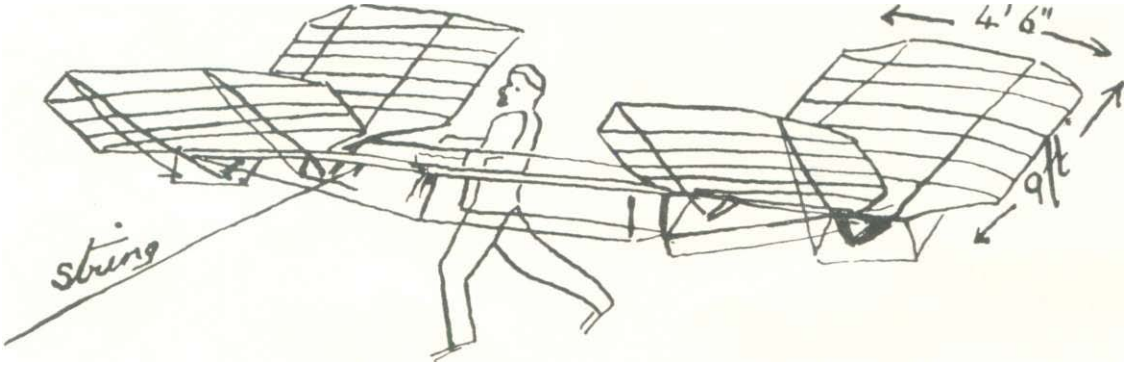


FIG. 4

Hargrave's sketch of the monoplane glider built 1894

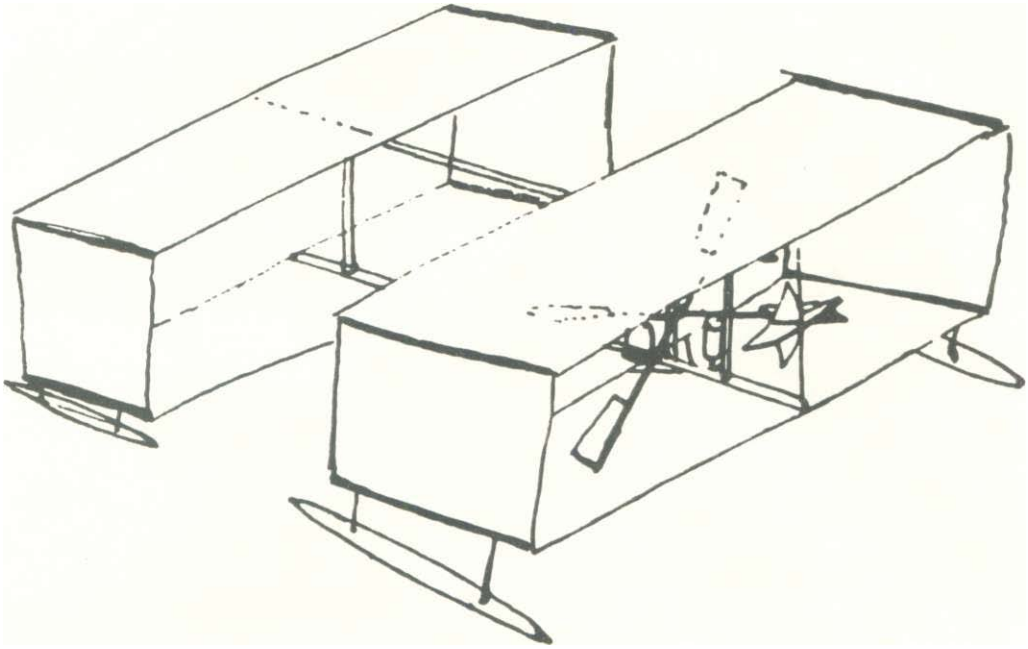


FIG. 5

Hargrave's sketch of his second design (1896) for a full-size power operated aeroplane for operation off the water. The machine was not built, as four engines designed to power it were all failures

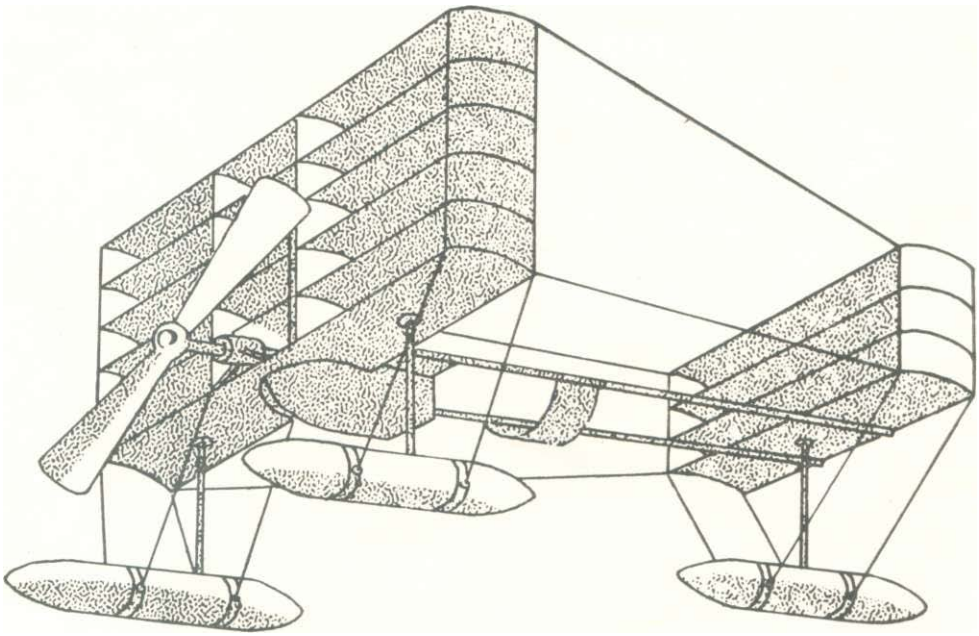


FIG. 6

Hargrave's drawing of his third design for a full-size powered aeroplane of 1902. The steam engine built to drive it was a failure. Note the sophisticated design and arrangement of the supporting surface which many years later was adopted by most aeroplane manufacturers. The floats were built in a much improved form in the 1903 machine

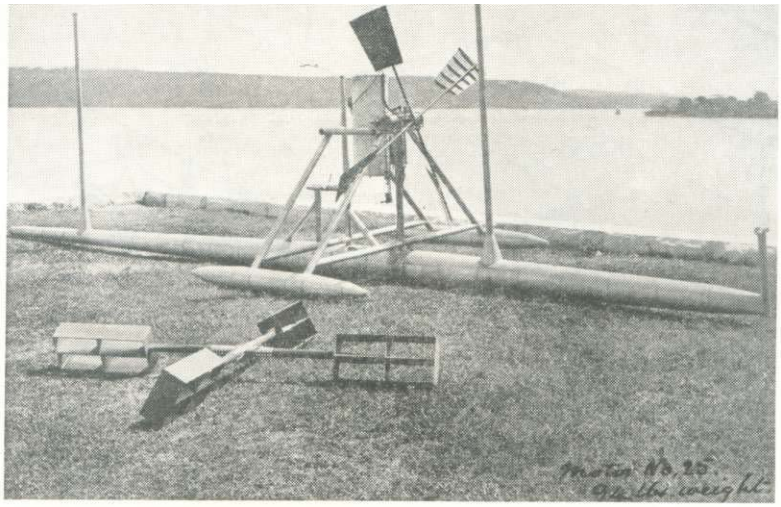


FIG. 7

Actual photograph of the modified design of the floats of the 1902 aeroplane. Main float 25' 7" long, weight 25 lb. also served as a container for water and fuel for the steam boiler. Designed all-up weight of this aeroplane, 471 lb. with a wing loading of 1 lb. per sq. ft. Photograph taken in 1905 at the rear of the Hargrave home on Woollahra Point. Note alternative propellor in foreground

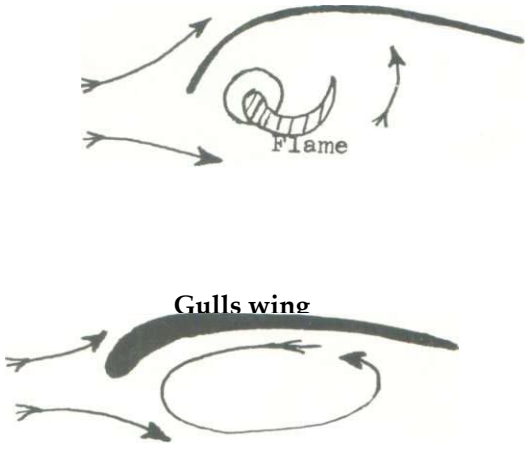


FIG. 8

Section of wing forms showing Hargrave's discovery of reverse air flow under the leading edge demonstrated by the movement of a candle flame and smoke. (Redrawn)

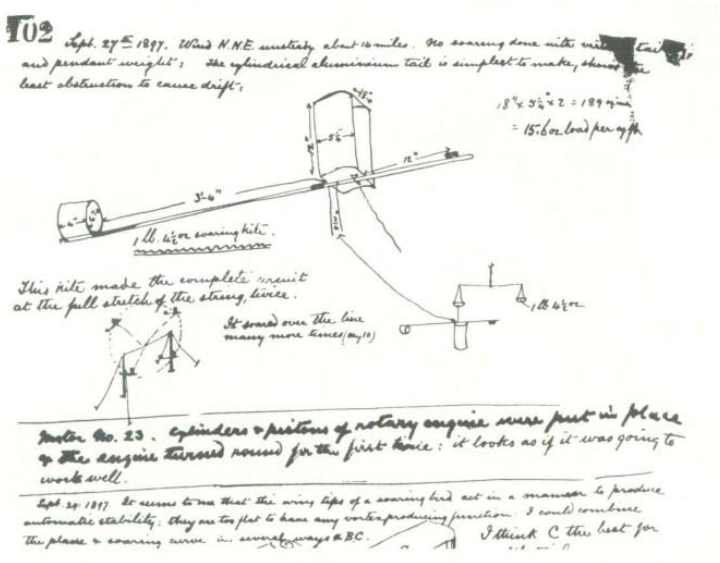


FIG.9
Portion of a page of a Hargrave notebook of 1897 showing ly types of soaring machines

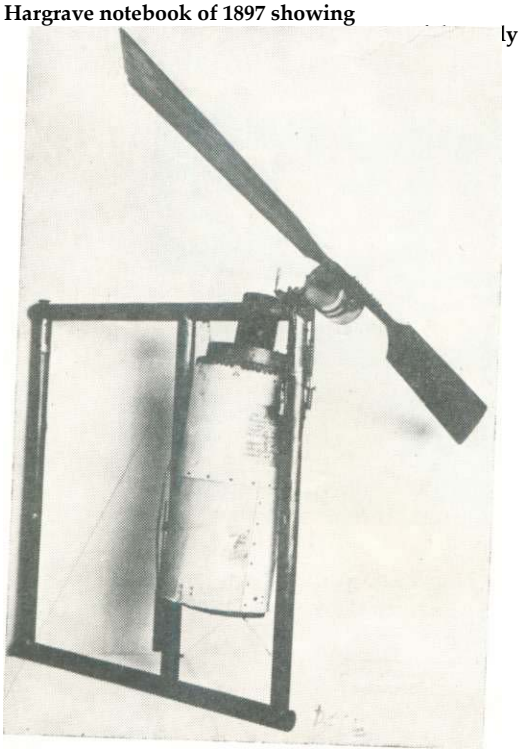


FIG. 10
No. 23 steam operated twin cylinder rotary engine built to power the 1896 aeroplane[7] showing steam boiler and tubular frame which also served as a container for water and kerosene for the operation of the boiler. Engine built in 1898

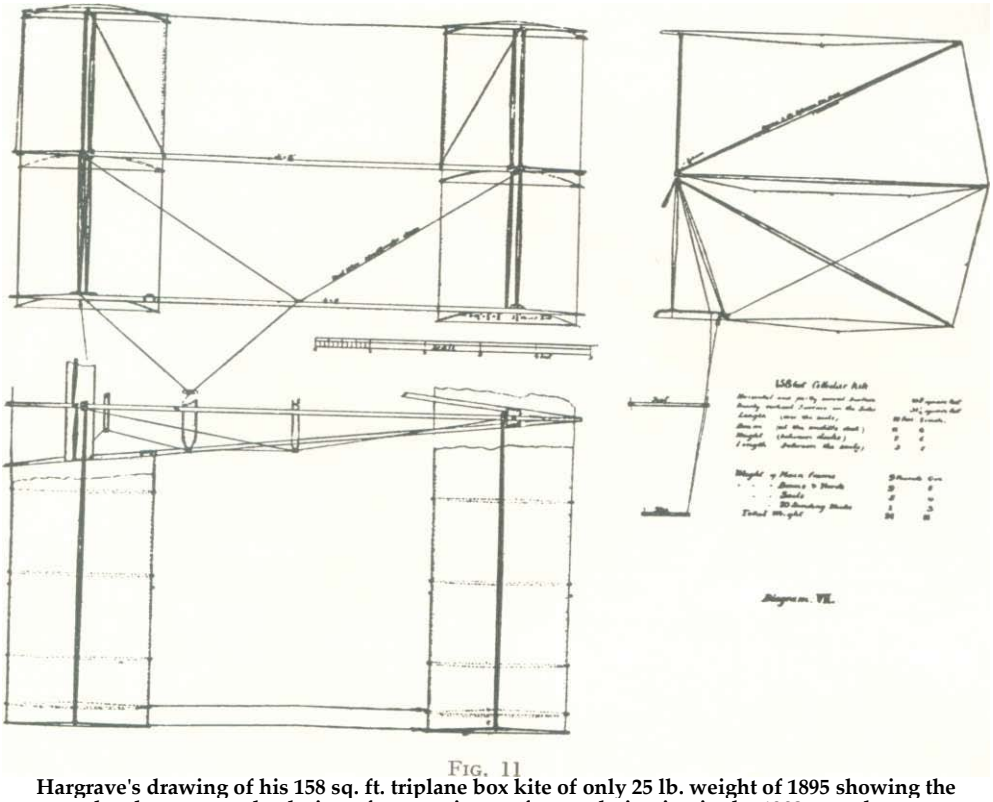


FIG. 11

Hargrave's drawing of his 158 sq. ft. triplane box kite of only 25 lb. weight of 1895 showing the development m the design of supporting surfaces culminating in the 1902 aeroplane

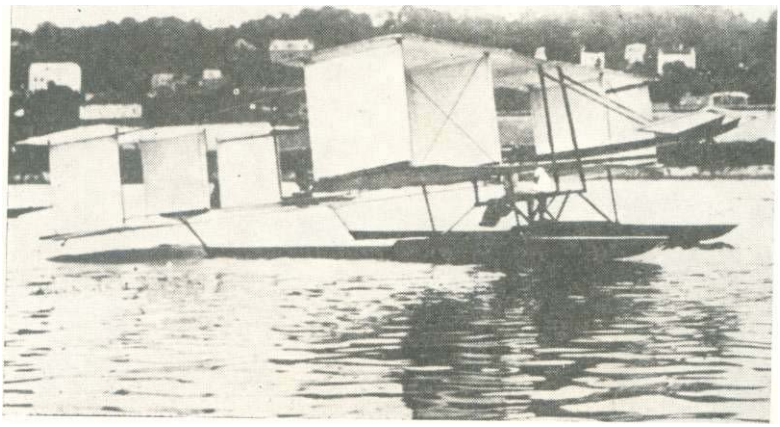


FIG. 12

The first aircraft to use the Hargrave box kite wing design was the Voisinj Archdeacon float glider built in Paris. It flew successfully when towed by a launch on the River Seine