CHAPTER 4

LAWRENCE HARGRAVE—AVIATION PIONEER AN EVALUATION

W. Hudson Shaw

"There are epochs in the history of every great operation and in the course of every undertaking to which the co-operation of successive generations of men have contributed (especially such as have recorded their movements at various and remote periods of history), when it becomes desirable to pause for a while, and, as it were, to take stock, to review progress made and estimate the amount of work done; not so much for complacency, as for the purpose of forming a judgment of the efficiency of the methods resorted to, to do it, and to lead us to inquire how they may yet be improved, if such improvements be possible, to accelerate the furtherance of the object, or to ensure the ultimate perfection of its attainment."

—Sir John Herschel.

While the twentieth century saw the first controlled, powered flight of a heavier-than-air machine, it was in the nineteenth century that the main work was done by the many individuals who progressively solved the problems confronting man in his conquest of the air. Lawrence Hargrave was one of these.

We are inclined to take for granted the provision by Governments and corporations of facilities and finance for research and development; but this phenomenon is of comparatively recent growth. In the nineteenth century, facilities and finance for research were still largely the responsibility of the individual. The foundation of the Royal Society was, in itself, an expression of the realization by individuals working alone of their inadequacy.

In the year that Joseph Paxton, who might be called the father of standardization and mass production, was commissioned to build the great Crystal Palace, Lawrence Hargrave was born. He left England at the age of fifteen and arrived in Sydney with his brother Ralph in 1865, a year before the birth of the Royal Society in this country. The two youths lived with their father, the Puisne Judge of the Supreme Court, who had come out to New South Wales in 1857.

The judge's home, Bay House, a large wooden structure in Rushcutter's Bay, had an extensive garden ending at a beach. The house, garden and beach have long since disappeared. It was intended that Lawrence would be trained for the legal profession, but on his failure to matriculate, his father realized that his future career lay elsewhere. It is not known whether it was his father's or Lawrence's judgment that saw the future prospects in engineering. Lawrence

Lawrence Hargrave with his family, maid and governess at Stanwell Park, 1894.
Left to right: Susan Shephard (dec'd.) (with Hargrave family from 12 to 65 years of age, maid originally); Geoffrey Lewis (dec'd.); Mrs. Hargrave; Margaret (Hudson), Queensland; Helen (Nellie Gray), (dec'd.); Lawrence Hargrave; Governess (dec'd.); Brenda Olive (Blackman), United Kingdom; Hilda (Waller), (dec'd.).
Taken on day of kite lift experiment.

spent the next four years in the workshops and drawing office of the Australian Steam Navigation Company, where he laid the firm foundations for what was to be his future career.

New Guinea Adventures

Young Lawrence found New South Wales to be a well-established community and Sydney a picturesque and thriving town. Australians were already beginning to look elsewhere for opportunities for development and adventure. New Guinea, then a mysterious and unknown land, beckoned.

A New Guinea Company was formed in 1867, but the British Government did not encourage their proposals. Another attempt was made in 1871 with the formation of the New Guinea Prospecting Association and Lawrence Hargrave was one of the committee of management. The Association was devised on co-operative lines with the objectives of prospecting for gold, trading and opening up the country for settlement. The *Maria,* an old and unseaworthy brig, was purchased. The expedition, consisting of seventy-five men, sailed from Sydney on January 25, 1872. Twenty-eight days later, the *Maria* was wrecked on the Bramble Reef off the Queensland coast near Cardwell. Thirty-five members of the expedition lost their lives.

The spirit of adventure had now laid her hand on Lawrence. After a period in Sydney, he was in New Guinea waters once more in 1874 and again, the following year, with the Macleay expedition in the *Chevert.* Back in Somerset four months later, he joined Octavius Stone's expedition of exploration in the Port Moresby area. Sydney saw him briefly at the beginning of 1876 before sailing for New Guinea once more with the unhappy D'Albertis Fly River expedition. Hargrave operated the engine and navigated the launch *Neva* up the Fly River for a distance of 450 miles against almost unbelievable obstacles. He also produced an accurate navigation chart of the River. D'Albertis, a very temperamental man, gave no credit whatever to Hargrave in his journal of the expedition.

His last visit to New Guinea waters was made in 1877 when he was commissioned by Parbury Lamb to investigate their pearl shelling activities in the Torres Straits. His report and recommendations showed considerable acumen and sound judgment.

Sydney Observatory

Towards the end of 1878 we find Hargrave engaged in exploration of a different kind. H. C. Russell, the Government Astronomer, had appointed him extra astronomical observer at the Sydney Observatory. During the five years he spent there, probably his most important task was the observation of the transit of Mercury from a station set up in the Blue Mountains.

Hargrave postulated at the time of the Krakatoa eruption that the extraordinary sunsets, which became a regular feature of the evening skies for many months, were caused by the volcanic dust in the upper strata of the atmosphere. The Royal Society in Great Britain formed a special committee to investigate and report on the Krakatoa eruption and Lawrence must have read with great satisfaction that of the countless theories advanced for the sunsets seen in many parts of the world, his had been adopted.

Trochoidal Theory

During his New Guinea explorations, Hargrave had had many opportunities of observing the movement and power of the ocean waves. He began to give the subject close attention in 1877 and on June 30, 1882, put his ideas down in a complete statement. He conducted many experiments in the following two years and on May 22, 1884, wrote to the Royal Society of New South Wales and offered to demonstrate his ideas to the members. A demonstration was arranged at a reception to be held on June 17. On August 6, 1884, Lawrence Hargrave read the first of the twenty-three papers he was to give to the Society, titled "The Trochoided Plane". The paper proposed the use of a plane revolving normal to a trochoid, to generate reaction in a contrary direction to that of the propagation of the waves and the use of that reaction for propelling boats, ships or flying machines.

Aeronautics

This was an important milestone in Lawrence Hargrave's career. Although he had joined the Royal Society of New South Wales in 1877, this was, in effect, his introduction, and from then onwards he became a member of increasing prominence. It also marked the beginning of his long career in aeronautics. He had decided at the end of 1883 to leave the Observatory, and Mr. Russell, not understanding the reason for his decision, had asked him to reconsider. Hargrave had, at this time, achieved financial independence and he had decided to apply this independence to the full-time quest of human flight.

While his initial work on wave motion was concerned with ships and the sea, his theories applied equally to the air, with his trochoided blade or plane becoming a flapping wing. Hargrave developed the theory and practice of flapping flight to a much greater extent than probably all other experimenters put together and to a high level of efficiency. However, the limitation of its development meant that the majority of this work was wasted effort. The same single-mindedness applied to the development of air-screw propulsion would undoubtedly have produced far greater dividends.

In 1884, when Hargrave began his serious work in aeronautics, experimentation overseas was in the doldrums, so he strode on to an almost empty stage. The brilliant work of early pioneers had been almost forgotten and the momentum engendered in the previous generation had dissipated.

About this time, however, a generous and kindly man, an American, who was also an eminent engineer, had begun to collect information on the work of these early experimenters. This collection was commenced as a hobby with the expectation of its eventual use in his own experimentation. In October, 1891, he decided to give this information to the world, which he did in a series of twenty-seven articles published monthly in the *American Railroad & Engineering Journal.* The series concluded in December, 1893. The author, Octave Chanute, published them in book form in July, 1894. This book, "Progress in Flying Machines", is now one of the aviation classics.

Lawrence Hargrave, in far off Australia in 1884, knew nothing of the work of this host of early experimenters. He was obliged to start from scratch, as it were, and often duplicated work which had already been done by others. All this, too, in a country deficient in modern materials and the skills and know-how of Europe, the then centre of the technical world. That he did so well and became respected, admired and emulated by his contemporaries overseas is a measure of his competence and endeavour.

Some indication of Hargrave's stature on the world's stage is given by a well-informed article which appeared in the *Westminster Budget* published in London on September 18, 1896. This article reviewed the aviation experiments from the beginning of the century and the contributions of the leading pioneers from Sir George Caley onwards. ". . . Hargrave stands alone as one who had developed simultaneously the best form of aeroplane (wings) and motor before attempting to combine them in a flying machine. . . . The great advance made by Hargrave is in having constructed what has been experimentally found to be a perfectly stable aeroplane."

Flight Proven

We must now examine the highlights of Lawrence Hargrave's thirty years' work in aeronautics, the significance of which the writer considers was only bettered by Caley, Lilienthal and the Wrights. While Hargrave commenced full-time work on aeronautics in 1884, he undoubtedly spent much of his spare time before that on flying experiments with models flown tethered. All these models, fifty in number, were subsequently destroyed, as they had served their purpose.

His first free flight with a model flying machine was made on December 31, 1884, and this machine was presented to the Royal Society of New South Wales, but, unfortunately, cannot be located. It was operated by flappers powered by two rubber bands in tension. In the following four years he built nineteen india-rubber-powered machines, the most successful incorporating twenty-four and forty-eight rubber bands. Hargrave developed an ingenious and unique method of obtaining power from india rubber in tension. The last five of these machines were driven by air screws and the remainder by flappers. Machines Nos. 10 and 12, powered by 48 rubber bands with flapper propulsion, flew 300 feet in level flight. While Hargrave was able to obtain much more power from rubber bands than any other experimenter, he realized its limitation had been reached with his 48-band machines and another power source would have to be found. He decided to use compressed air.

First Engines

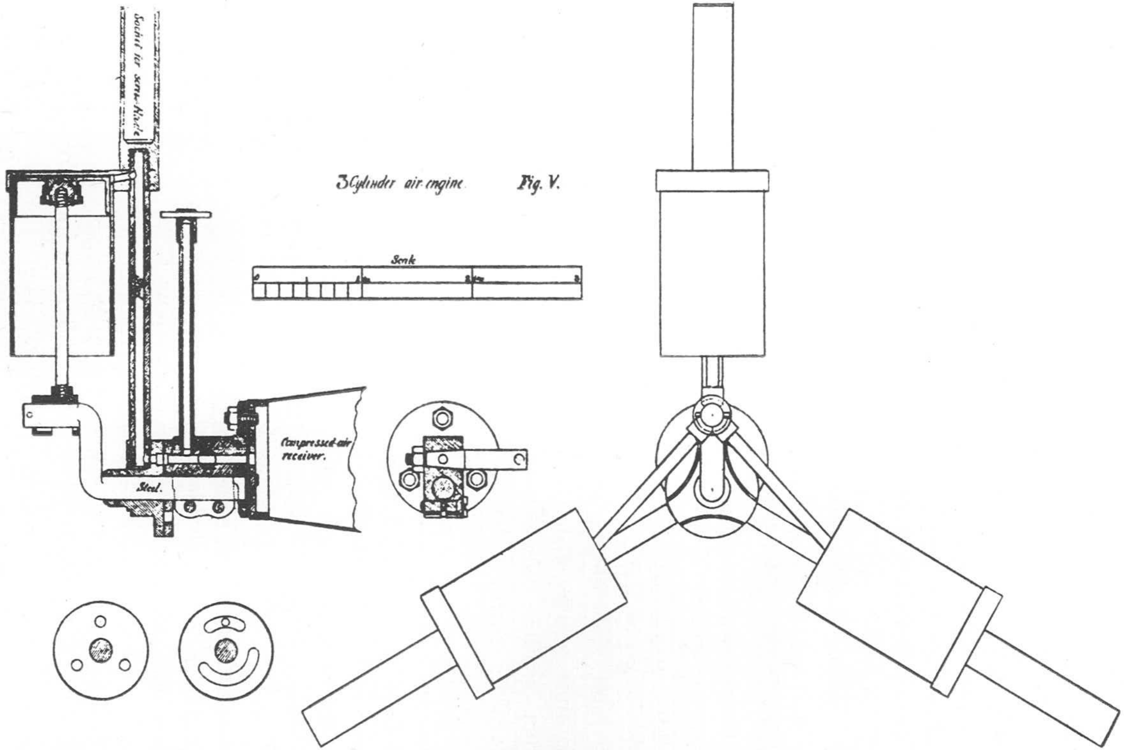
His experiments with compressed air motors occupied three years when he built fourteen engines. Ten of these were used to power flying machines, but only five of them performed to his satisfaction. The most successful was flapper-operated and flew 368 feet in free flight. The machine was six feet four inches long, with a total weight of only two and a half pounds. Its speed was thirteen miles per hour. The engine in this machine was an ingenious single cylinder vibrating motor made of sheet tin for lightness. It had a bore of one and a half inches and a stroke of one and a quarter inches and a weight of only six and a half ounces.

All Hargrave's earlier india-rubber-powered flappers were operated by cranks designed to provide the flapper with its thrust by a figure-of-eight motion. The body plane trochoided on a compensating wave so that the machine maintained level flight. Hargrave's later compressed-air motors, however, moved the flapper at a faster rate but in the same plane. The necessary thrust was obtained from the flappers equally on the up and down stroke, by the torsion of the flapper arms. The compressed air was contained in a long cylinder of sheet tin which also formed the body of the machine.

The Radial Rotary

Hargrave obtained his best results from flapper propelled machines. His repeated return to the propellor or air screw showed that he realized, despite previous failures, that the potential for future development lay with the air screw. On February 20, 1889, he developed what was one of his most significant achievements, the radial rotary air-screw engine. While the idea for this engine came from the Brotherhood engine which powered the Whitehead torpedo, the revolving cylinders, stationary crank shaft and valve gear were quite original.

Hargrave's work was well known overseas, thanks in no small measure to the wide distribution of the Transactions of the Royal Society. In 1889, thirty-three copies of these Transactions were sent



Drawing showing detail of design of the three-cylinder radial rotary engine invented by Hargrave in 1889.

to France and, it is reasonable to suppose, were read by a number of Frenchmen. This volume contained Hargrave's paper and line drawings of his radial rotary engine. The famous French radial rotary internal combustion engines which powered many of the first generation of European aeroplanes did not appear until 1909.

It is often impossible to say where an idea originated and therefore sometimes credit due to another is not given.

While the French radial rotary engine may have been developed quite independently of Hargrave's work, he should be given the credit for originating an idea for an engine which was to be a major factor in European aircraft design for nearly twenty years.

The First Six Years

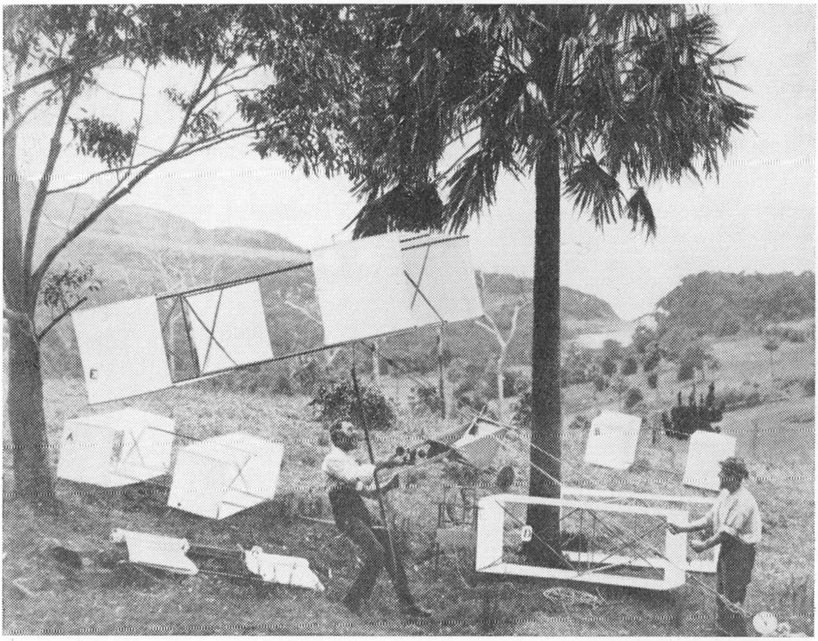
At the end of the eighties, Lawrence Hargrave could look back with some satisfaction on what had been accomplished in his first six years in his new vocation. He had built some seventy-five flying machines, many of them successful, had developed power units of many types of great originality and had read seven Papers to the Royal Society. So far he had made little contact with other workers overseas and could obtain little information on what they were doing. By this time a new group of experimenters were in the field. The Lilienthal brothers in Germany, Maxim and Phillips in England, Mouillard in Cairo, Ader in France and Langley and Chanute in the U.S.A.

On the other hand, Hargrave's work was becoming known, largely through the circulation of the Royal Society's Transactions, to some 364 bodies and institutions throughout the world. By this time he had an ever-growing mailing list to which he sent copies of his Royal Society Papers as soon as they were available and photographs of his work. Hargrave now knew that the two major problems remaining to be solved were the development of a stable supporting surface and a light, reliable power unit. This, he calculated, would be required to deliver at least three horsepower.

Supporting Surfaces

In 1885 he had built three terrace houses which are still standing in Roslyn Gardens, Rushcutter's Bay. The land was a leasehold acquired from his father and then forming part of the Bay House garden. He lived and worked in No. 40. At the begining of 1893, he began his important work on supporting surfaces. His famous box kite was evolved by experiment at the beginning of this period. Hargrave found, however, that wind conditions, now so important in his new work, were quite unsuitable and public interest was also restricting his operations. He decided to move to Stanwell Park, where a large house had been left to him by his brother, Ralph. Wind conditions on the ocean beach would be constant and privacy assured. He had married in 1878 and by now had a family of four daughters and a son, Geoffrey, who was born in the previous year. A governess and a maid accompanied them.

Hargrave constructed more than fifty kites of various kinds, the majority of them of a cellular (box) type. Our mental image of a box kite, a child's toy, is a very different object from the efficient flyer Hargrave developed after four years of experiment.



Posed photograph showing Lawrence Hargrave and assistant, Swain, on hillside at Stanwell Park with cellular (box) kites and gear used in kite lift experiment, November 12, 1894. Actual experiment carried out on beach in background.

While we are fortunate in having a fairly representative collection of Hargrave's work at the Museum of Applied Arts & Sciences in Sydney, they do not have any of his original box kites. One of these kites is in the Smithsonian and two in the Science Museum in London. The rest have been lost or destroyed.

The largest cellular kite Hargrave constructed was ten feet in length with a cell span of eleven and a half feet and five feet in height. This kite weighed only twenty-five pounds and had a surface-to-weight ratio of six to one. Altogether, a remarkable achievement. On November 12, 1894, Hargrave succeeded in raising himself 16 feet off the ground supported by four of his kites. The importance of this feat was that it provided evidence of the amount of surface area required to support a given weight at a known speed, a safe method of experimenting and proof of the stability of his supporting surfaces.

Curved Surfaces

The majority of his kites had flat surfaces, but Hargrave knew from his experiments and from reports on the work of others, particularly Phillips and Lilienthal, that greater lift could be obtained from surfaces that were curved. In 1897 he began a series of experiments on curved surfaces and built for this purpose a number of single and two-surface soaring machines. These models were quite small and their longitudinal equilibrium was obtained by an adjustable weight. The supporting surfaces had a high aspect ratio (the length of the wing was several times greater than its width), and its profile was a deep parabolic curve.

Full Size Machines

Hargrave designed six full size man-carrying aeroplanes. One of these was built, a glider. He also built the trimaran hull or float section of his 1903 machine. This was an advanced and beautifully streamlined design, twenty-five feet long and constructed of tin plate. The wings, which were to consist of three main planes and three smaller tail planes with a total surface area of 470 square feet, were not built because, as with his other designs, he had been unable to produce a satisfactory motor. In a letter to Chanute describing his 1903 machine, which was to be powered by a 14-horsepower steam engine, he said: "My new apparatus is merely a steamer if it does not lift out of the water and a flying machine if it does."

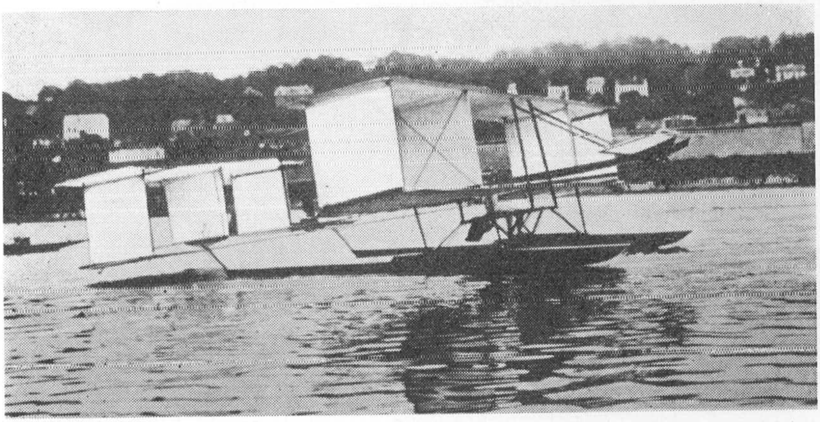
England Visited

In 1899, Hargrave decided to take his family to England where he felt there would be greater opportunities for completing his work by obtaining the engineering and financial assistance he badly needed. He found, to his disappointment, there was little interest being taken in aeronautics and returned to Sydney after a stay of only a few months. Soon after his departure, Percy Pilcher, the only active aviation worker in England, was killed in a gliding accident. All initiative in aeronautics then passed to the United States.

Box Kite Vindicated

Apart from the inspiration that Hargrave's work, particularly on supporting surfaces, gave to other experimenters, there were two significant sequels. The most important of these was the major role played by his box kite in the design of the early European biplanes.

The United States of America is characteristically publicity conscious. One of the strange facts of modern history is that one of mankind's greatest achievements, the first controlled flight in a powered heavier-than-air machine on December 17, 1903, passed almost unnoticed. Rumours of the Wrights' success eventually reached



Archdeacon-Voisin glider with Hargrave box kite wings on the River Seine, Paris, 1905.

the French experimenters, then active with gliders. While they disbelieved them, they were, nevertheless, spurred on to greater efforts. They had learned from Chanute, on his visit early in 1903, of the success of the Wrights' and his own gliding experiments. Typical of French comments made at that time was that of Captain Ferber, the leading experimenter in gliding flight: "The aeroplane must not be allowed to be achieved in America."

Several attempts had been made by the French to copy the Wright glider without success. The French then turned to Hargrave's work on supporting surfaces and in 1905 his cellular supporting surfaces were incorporated in the Archdeacon-Voisin float glider. This machine, a huge Hargrave box kite, flew successfully when towed behind a launch on the River Seine. Charles Gibbs-Smith states in *The Aeroplane* that the Archdeacon-Voisin became the prototype of the "classic" European biplane.

The Wrights' Wing

The other interesting development was an experiment by A. A. Merrill, a member of the Boston Aeronautical Society. After reading an illustrated report on Hargrave's work with soaring machines, he devised some equipment for testing the relative resistance to forward motion of curved surfaces. He made an exact copy of the aerocurve (soaring machine wing) recommended by Hargrave as much better than the Lilienthal curve. He also constructed four other curves of his own design. Each of Merrill's curves was identical with the Hargrave curve on the underside of the wing but varied in the shape of the leading edge. Merrill found that one of his aerocurves, with quite a unique profile, was 14% more efficient than the Hargrave curve.

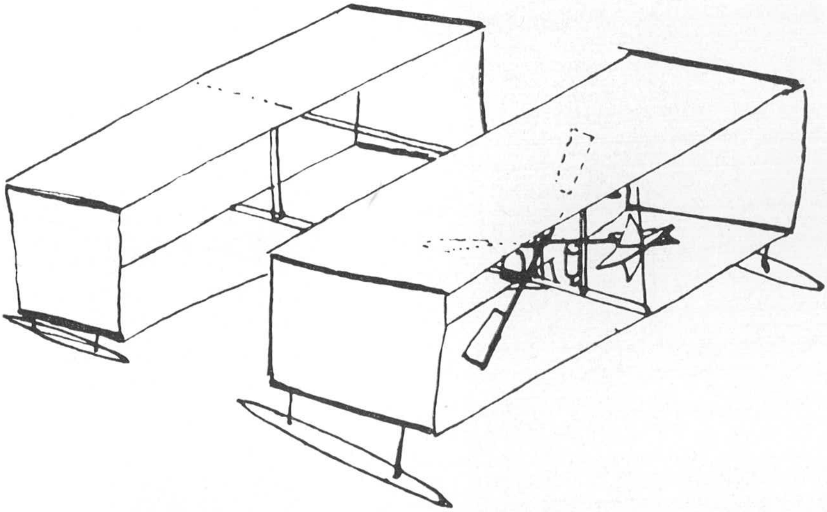
Details of these tests made in 1898 were set out in an article by Merrill in the *Aeronautical Journal* of July, 1899. As this was the only authoritative and regular publication in the English language at that time, it was sought after and read by most of the workers in aviation. While there is no definite evidence that the Wrights read Merrill's article, it is not unreasonable to assume that they did so for the following reasons. They wrote to the Smithsonian in 1899 and Chanute in 1900 for a list of books on aeronautics with a view of finding out what others had done. Chanute, in his reply on May 17, 1900, said: "Hargrave experimented with aspiration (soaring) kites suspended from a rope stretched between two masts, and it would be most interesting to endeavour to repeat the performance with a full-sized machine. You will find accounts in the *Aeronautical Journals* for April, 98" (Hargrave's Royal Society Paper "Soaring in a Horizontal Wind") "and July, 99" (Merrill's tests on Hargrave's aerocurve). "I send you the issue for April, 99, which you can keep." It is not unreasonable to assume that the Wrights would not have taken the advice given to them, particularly after going to some trouble to obtain it and in view of Chanute's strong recommendation.

Wilbur Wright, in a letter to Chanute of July 1, 1901, refers to a wing as an aerocurve, an uncommon term and, strangely enough, the same as that used by Merrill in describing his experiments on the wing of Hargrave's soaring machine.

The Wrights' first glider of 1899 was a large model and was flown as a kite. The wing profile of this machine was a segment of circle—a uniform curve. However, when they built their first full size glider the following year, the wing profile was changed dramatically from a uniform to a parabolic curve. This curve appeared to be identical with the strange shape found by Merrill to be more efficient than the Hargrave aerocurve. The Wrights apparently maintained this distinctive wing profile in their 1901 machine and in their very successful 1902 glider.

Orville Wright stated in a letter to Cecil Salier dated March 13, 1928, that while they knew of Hargrave's work they owed nothing to him. It is perhaps understandable that an old man some twenty-five years after the Wright brothers' pioneering work, would find it difficult to remember exactly where their indebtedness lay to the experimenters who preceded them.

However, Wilbur Wright, in a letter to Charles C. Stobel of January 27, 1911, said: "Six very remarkable men in the last decade of the nineteenth century raised studies relating to flying to a point never before attained. Lilienthal, Chanute, Maxim, Ader and Hargrave formed by far the strongest group of workers in the field that the world has seen."

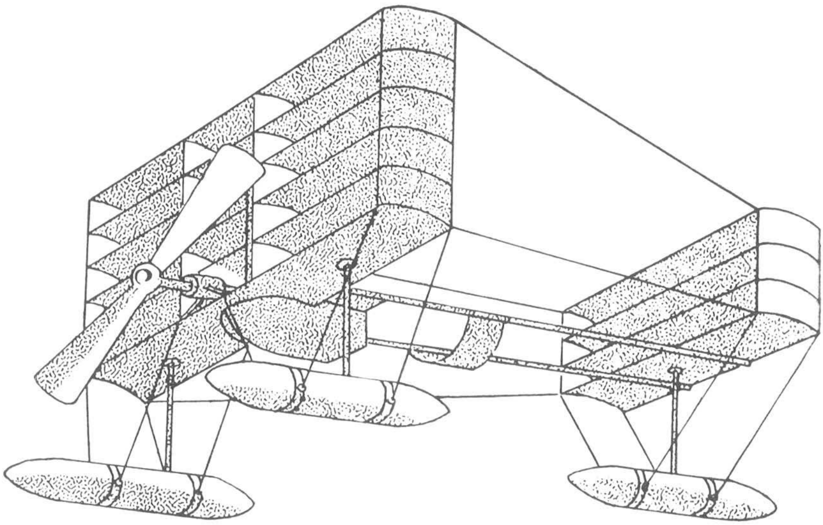


Sketch of Hargrave's third design for a full-size power-operated flying machine. Unique concept as machine designed for water take-off. No. 24 engine built to power this machine was a failure, so the machine was not built. Note combined control surfaces and flappers operating inside the wing.

This statement by Wilbur would suggest that the Wrights did indeed owe something to Hargrave and if this was as has been postulated the efficiency of the wing design of their gliders, this could be Lawrence Hargrave's greatest achievement.

Power for Manned Flight

Hargrave, in all his aviation work, was extremely conscious of weight. While this seems a very obvious consideration to-day, it is remarkable how many of the earlier experimenters paid scant attention to it. Sir Hiram Maxim's huge machine of 1894, for instance, had an all-up weight of three and a half tons. When Hargrave commenced work on an engine to power a full size flying machine, he realized that steam engines were the only ones that had behind them a long period of development and therefore some reliability. The pumps, fuel, furnace, boiler and water supply, however, imposed a severe weight penalty that Hargrave was loath to accept. He therefore experimented with fuels of many different types, including petrol vapour, gun powder, steam, carbonic acid, kerosene and petrol. He designed a wide variety of engines such as turbines, pure jet, jet propellor, rotary and semi-rotary, spring recoil, single cylinder crosshead and horizontally

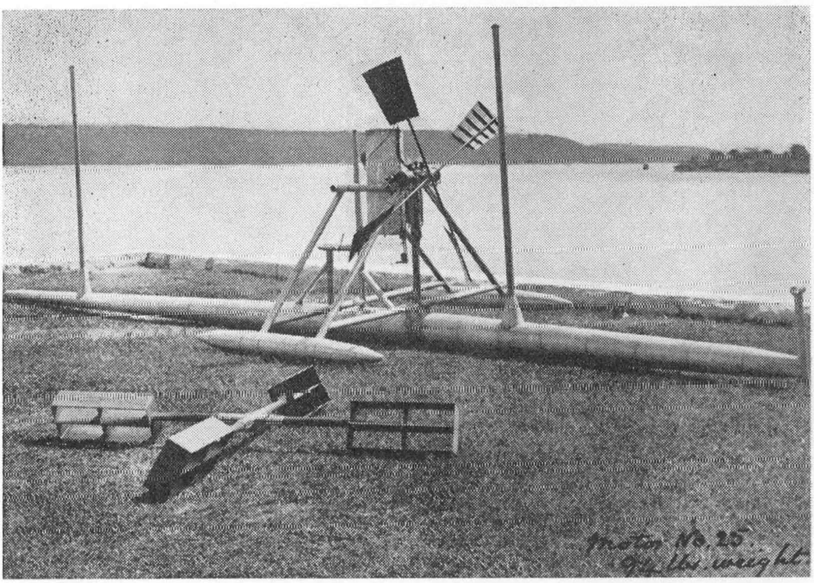


A sketch of Hargrave's original proposal for his 1902/03 flying machine. The fuselage of this machine was built in 1903 with a considerably modified and improved float design but wings were not constructed as Hargrave was unable to obtain satisfactory performance from the steam engine, No. 29, built to power it.

opposed types. Fifty-two engines in all, of which an amazing total of thirty-three were built. Fourteen were operated by compressed air, nine by steam and three were internal combustion petrol engines.

The very diversification of his work on engines might be considered the reason for his failure to produce a satisfactory motor for a full size flying machine. However, there were extenuating circumstances. A flywheel was essential for engines known at that time in order to smooth out the intermittent motion and to ensure that cranks were pulled past the end of the stroke of the piston. But a flywheel imposed a heavy weight penalty. Prior to this time, weight had not been a consideration in engine design. Chanute reported in the early nineties that the lightest steam engines were made for launches and they weighed some 60 pounds per horsepower; gas and petroleum engines 280 to 1,000 pounds, while electric motors and batteries 130 pounds per horsepower. Such weights were, of course, prohibitive for flight.

Aviation experimenters were accordingly obliged to develop their own power plants. The first successful aero engines were the Wright motor which powered their "flyer" of 1903 and the engine built by Manley in 1903, Professor Langley's engineer, and fitted in the unsuccessful Langley Aerodrome. Both of these were petrol engines.



Sixth full-size machine designed. Built in 1903, consisting of trimaran floats, engine cradle, steam engine No. 29, boiler and propellor. Note alternative propellor of unique design in foreground. Photo taken on terrace at rear of Hargrave's home on Woollahra Point.

Hargrave built his first petrol motor in 1900 but this was a failure due to his lack of knowledge of the heat problems with this new type of engine. Prior to this he had built eight steam engines, two of which were large (three horsepower), but he had been unable to obtain the necessary power output from either of them. Instead of redesigning his petrol engine, he turned again to steam, where he felt he was on more familiar ground. This was his twenty-ninth engine and his fourth motor for a full size aeroplane. It was designed in 1902 for his trimaran float plane of 1903, but once again he was unable to obtain the necessary power. He built two more engines for this machine, both for petrol operation and designed for flappers. These, too, were failures.

Air Screws

Had Hargrave been able to design an efficient propellor, he may have obtained the necessary performance from his two steam engines built in 1897 and 1902. The best of the two propellors made for the 1902 motor had an efficiency of only 17%. A 70% propellor efficiency was being achieved by others about this time.

Weaknesses

The main reason for Lawrence Hargrave's failure to achieve his aim of powered flight was a weakness in engineering theory which his undoubted technical skill was unable to make good. He was well aware of this as was clearly indicated by his efforts to purchase a suitable motor, his abortive trip to England and his appeals in correspondence to Chanute and others for information on internal combustion engines.

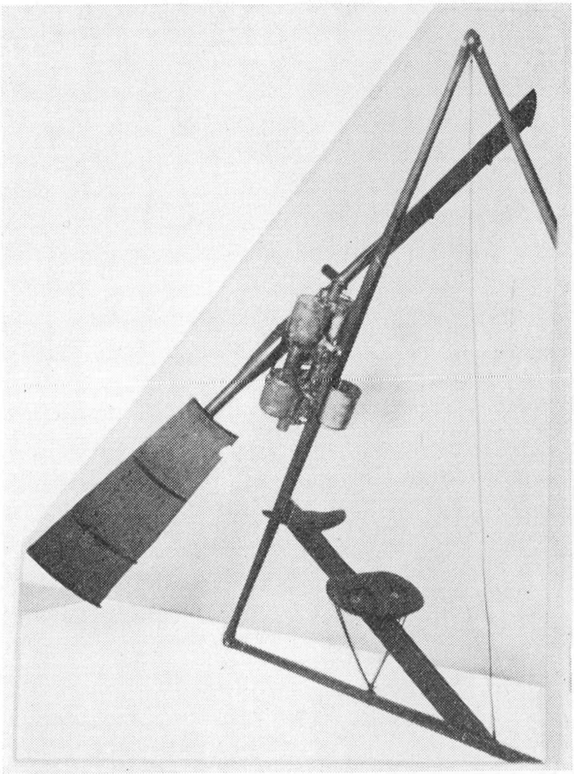
The isolation of Stanwell Park, while it assisted his practical work on supporting surfaces, was an effective barrier to discussion and advice which he had been able to obtain with his earlier work when living at Rushcutter's Bay. What he needed most of all was a collaborator, a like mind similarly dedicated, with whom he could hammer out the problems with which he was confronted. But how to find such an individual in New South Wales who had, in addition to the technical knowledge required, the necessary leisure?

While the quest of human flight became Hargrave's life's work, it was only in the late nineties that he realized that the possibility was within his grasp. Initially he saw his role as one of the many helpers along the road. While it must have been a disappointment to learn of the Wrights' success, he wrote at once a letter of congratulation. Lesser men would then have stopped work or moderated their own pace, but not Lawrence Hargrave. He carried on with his work as before and justified this by the comment that there could be many types of aeroplanes.

Retirement

In 1906 he was reluctantly obliged to give up full-time work on aeronautics, but he still continued with his experiments up to the time of his death from acute peritonitis on July 6, 1915. His only son, Geoffrey, was killed in action at Gallipoli two months before. Father and son had worked together in the large space underneath the house he built at the end of Woollahra Point in 1902. At least two more petrol engines were built by them as joint ventures and these are preserved in the Museum of Applied Arts & Sciences, Sydney. Unfortunately, no records exist of their testing or performance.

After his retirement from active work in aviation, Lawrence Hargrave read five more Papers to the Royal Society of New South Wales. These were on very diverse subjects, indicating the breadth of his interests and his mind's aptitude for enquiry. The first of these

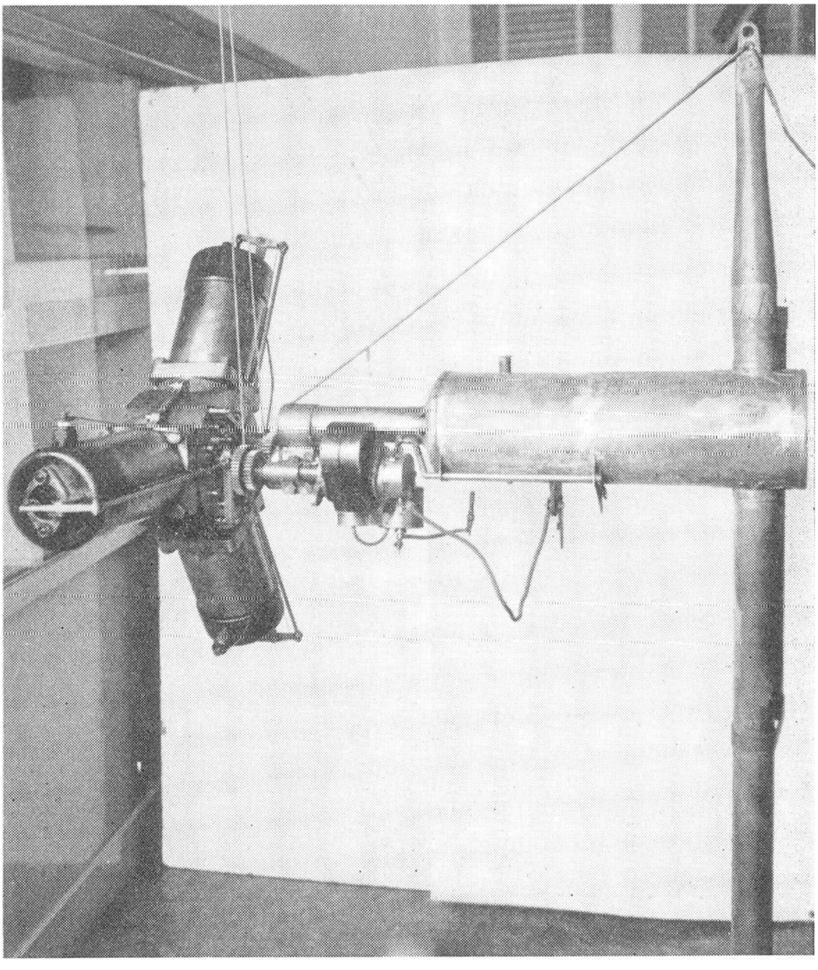


Engine No. 27, four-cylinder petrol motor built in 1900. The engine, which was a failure, is shown on its test rig. Note seat and hand grips for the operator. (At the Museum of Arts and Sciences, Sydney.)

Papers dealt with the design for deep-water berths in the Sydney Harbour on the Sow & Pigs Shoal off Watson's Bay with a connecting railway, a proposal for a one-wheel gyroscopic car to carry four people, two carefully documented Papers on the discovery of the East Coast of Australia by the Spaniards in 1595, and in 1909 a final Paper on aeroplanes dealing with a novel method of obtaining stability.

In Retrospect

Octave Chanute, in "Progress in Flying Machines", describes in some detail the work of some one hundred and seventy experimenters. It is not by chance that the work of Lawrence Hargrave occupies fourteen of the book's three hundred and eight pages, but a just tribute by a well-informed and remarkable man. Just before the close of the nineteenth century, Chanute also said: "If any man deserves to fly, that man is Lawrence Hargrave of Sydney, N.S.W."



Three-cylinder radial rotary petrol engine considered to have been designed and built as a joint venture by father and son about 1912. Showing petrol tank and supporting frame work. Propellor not fitted. (At the Museum of Arts and Sciences, Sydney.)

While the fruits of ultimate success eluded him, Lawrence Hargrave obtained his real reward in seeing powered flight in a heavier-than-air machine realized when, right up to its actual happening, he was one of a mere handful of men who believed it possible. The magnitude and extent of his work, his great skill as a draughtsman, designer and craftsman, his imagination, infinite capacity for taking pains and unselfish sharing of his ideas and achievements provided a much-needed inspiration to others, without whose efforts human flight would not have been accomplished.

To Lawrence Hargrave, to use his own words, "the act of invention was a sort of inspiration and a pleasure that the individual does not seek to be rewarded for undergoing".

This contribution has been compiled from Lawrence Hargrave's records in the Museum of Applied Arts & Sciences, Sydney.

Further works by the author on this subject:

Article—*Shell Aviation News,* Number 289, 1962—"Aeronautical Work of Lawrence Hargrave".

Article in *Qantas Airways Flight Staff Journal,* September/October, 1962, "The Aeronautical Work of Lawrence Hargrave".

An address delivered to the Royal Society of New South Wales, December 5, 1962, "Lawrence Hargrave—An Appreciation".

An address delivered to the Royal Aeronautical Society, November 27, 1963, "Lawrence Hargrave—Aviation Pioneer".

Article on above in *Aircraft,* January, 1964, "Lawrence Hargrave—Aviation Pioneer".