THE CONTROLWING AIRCRAFT

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PART TWO — POSTWAR DEVELOPMENT

George G. Spratt, aeronautical engineer, has spent a good part of his life in the development of a totally different kind of aircraft . . . one originally conceived by his late father, Dr. George A. Spratt, around the turn of the century. Last month Mr. Spratt related the early history of the Controlwing and his father's association with aviation pioneer Octave Chanute and the Wright brothers. Various experimental machines built before World War II were pictured and described. This month the story is taken from the immediate postwar period to the present.

IN THE EARLY 1940's an article written by Wayne Morris came to the attention of Bill Stout who quickly saw the potential of the Controlwing as a roadable aircraft.

In 1944 the project was moved to the Stout Research Division of Consolidated Vultee (later to become Convair) at Dearborn. Designers came from all directions; they mathematically redesigned all the components — the wing was "improved" from 80 pounds to 250 pounds, a ratio that also held for most of the other parts.

As heavy as it was, it actually flew as you can see in Photo No. 7, much to the credit of Bob Townsend who flew it for many hours and wrote a very good report despite the poor weight-to-power ratio.

The next summer the Stout Research Division was moved to Nashville. Now with fewer engineers and Tony La Nave in the shop, we cut the aircraft in two at the pilot's seat. The front part was reworked, the aft part discarded and an entirely new structure built including the wing attachment. Now nearly 200 pounds lighter, performance was much better and the aircraft, after considerable flying at Nashville was taken to the home plant at San Diego where tests continued without incident. (Photo No. 8.)

After completion of the roadable, in 1947 I went back to my shop in Connecticut to concentrate on the flying boat. Two models were built, the first showed clearly what not to do. It was an all aluminum hull made from very thin metal in an effort to keep the weight down. On the first high speed water run the bottom was punctured, the engine drowned and the entire boat sank to the bottom of the Connecticut river where it still rests.

The second (Photo No. 9) had a much longer life, flying for over 12 years. It was made from a steel framework (Photo No. 10) with riveted plywood skin. A strong light structure but, we later found, subject to rusting between the steel and plywood surfaces.

At first the steering wheel was so connected that turning it rotated the wing about the forward and downward sloping axis. Moving it back and forth tilted the wing about an axis parallel with the spar. In turbulence the wing flies at a constant angle of attack but the angle of incidence varies with the turbulence, so the roughness is felt in the control wheel. To overcome this the pitch control was made a separate lever allowing the wheel to be fixed as in a car. This was an improvement but the feel was still not right, the inertia of the wing about the longitudinal axis was high and gave an uncomfortable feel to the control while responding to turbulence in roll.

While running at high speed over rough water there was also considerable feed back into the wheel. This was because the hull often rolls rapidly while the wing tends to be steady because of inertia and aerodynamic damping. Even at anchor in a chop there was a constant slatting in the control system because of wing inertia.

This single rigid, straight through wing was simple to build and required but three fittings. On the other hand with the larger boat it became heavy for one person to handle for trailering and storage.

These were some of the facts considered in the design of the present boat.

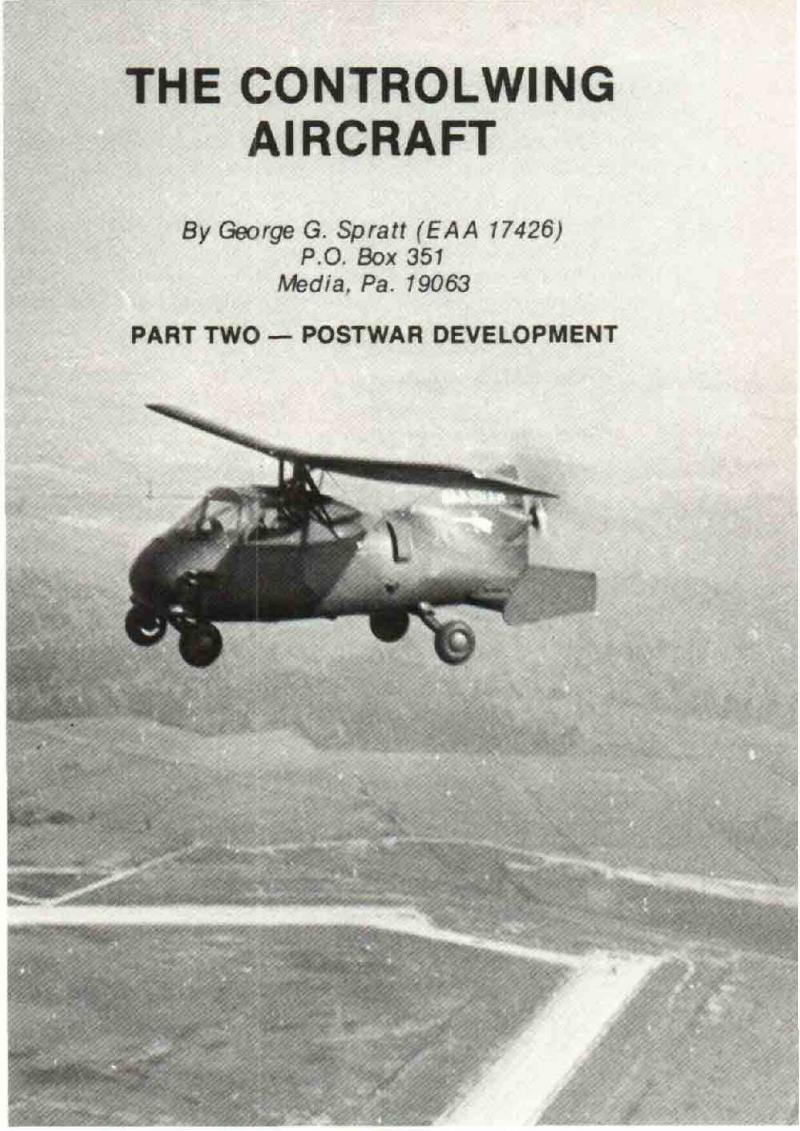


PHOTO NO. 7
First flight of the Convair roadable Controlwing at Elizabeth City, N.C. in 1945.

THE CONTROLWING FLYING BOAT

In 1962 my friend Elliot Daland joined with me to build the present boat. (Photo No. 11). This craft (Fig. II) has a hull not unlike a typical racing boat, the engine is mounted low just behind the passenger compartment. The shaft, however, goes up and rearward to an air propeller just over the transom, rather than downward to a water propeller under the transom as does a conventional boat.

The hull sides extend outward at about a 45° angle on either side of the propeller to prevent spray being drawn through the propeller disc and to provide weather cocking ability.

Two wings, a right and left, are mounted above the center of gravity high enough to clear the water surface when banking steeply in a turn and to adequately clear a small boat or docking float when coming along side. Each wing is independently hinged about an axis parallel with the span so that it is free to rock fore and aft. In other words the angle of incidence is not fixed. This hinge line is located about one quarter of the way back from the leading edge of the wing and just under the lower surface. Each wing is supported by struts at the center of lift to minimize the load at the center span attachment. The mechanism required for this control is quite simple as shown in Figure III.

The steering wheel is connected by cable to the water rudder and a quadrant pivoted concentrically with an arm having a "T" member pivoted at the far end. A link

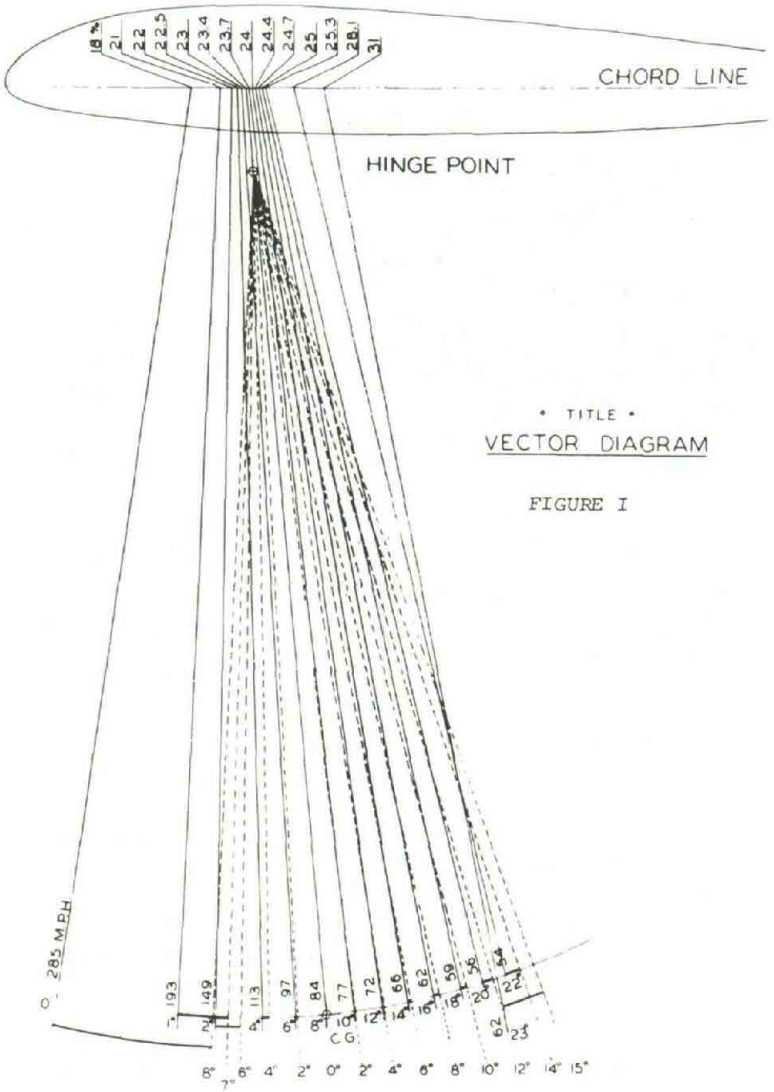
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CONTROLWING AIRCRAFT . . .

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connects the bottom of the "T" and the quadrant. The left side of the top of the "T" connects to the left wing and the right side to the right wing.

The speed control lever applies a torque equally to each wing without restricting the wings travel. The wings are thus allowed to move freely in pitch collectively while being controlled differentially by the wheel.



LONGITUDINAL CONTROL

In normal flight the resultant aerodyanamic force of the wing must pass through the hinge, thus holding the wing at the correct angle of attack. Any tendency for the wing to increase its angle is met with a rearward movement of this force vector and conversely a decrease in angle causes a forward movement of the vector. Regardless of any disturbance, the wing always tends to maintain the desired angle of attack. This action can be better understood by a careful look at the vector diagram, Figure 1, and airfoil characteristics, Figure IV.

This is a constant speed aircraft that can fly only at the speed for which it is set. Additional thrust cannot push it faster. The added thrust will instead make it climb. If less thrust is supplied by the propeller than required for level flight, the aircraft descends, taking only enough potential energy to maintain the set speed. In other words longitudinal or up and down control is the throttle.

Few people would want an airplane that takes off, flies and lands all at the same speed, so some provision must be made for changing this speed. This could be made infinitely variable over the flight range if desired. However, in the interest of simplicity we have tried a two position lever and found it adequate. One position for land and take off and one for cruise.

In order to change the speed the wing hinge must be moved to the desired flight vector, since as pointed out the flight vector must always pass through the hinge. There are three ways to do this: 1) Move the hinge in relation to the wing; 2) Deflect a trim tab on the trailing edge of the wing; 3) Apply a torque about the hinge with a spring.

Although method 3 is used in this flying boat, the following explanation will use the first method, that of actually moving the hinge. This is because it is the easiest to understand and possibly the best aerodynamically. The only disadvantage is that it is a little more complicated mechanically. The vector diagram, Figure 1, shows how sharply all vectors in the flight range focus above the wing and how symmetrically they spread out at the hinge line. This is plotted as a curve on Figure V with speed in miles per hour shown for reference.

Let us take some examples and see what all this has to do with longitudinal control and stability. First, suppose the hinge is on the 18° lift vector, the aircraft will be flying at 40 mph. The lift curve has so flattened at this point that little more speed reduction is possible, perhaps only 2 mph at 22°. Now suppose while flying at 18° a gust should increase the angle to 22°. There would be essentially no change in C_L but see what has happened to the center of pressure. At 18° it was 13 inches from the leading edge, now it is 14 inches. If the aircraft weighs 1000 pounds there is a 1000 inch pound moment tending to reduce the wing angle and prevent a stall. Beyond this point the curve is so steep that one additional degree gives an added moment of nearly 2000 inch pounds. Polar moments of the light wing are insignificant about this axis so recovery is almost instantaneous.

Now, let's look at the other end of the range and put the hinge on the 2° vector 10.5 inches from the leading edge, giving a speed of 104 mph. The curve is now sloping upward with increasing steepness so that a down gust or increase in speed will quickly be corrected and the aircraft continue to fly level with little speed change. Between these extremes the slope is nearly constant but sufficiently steep to overcome bearing friction and inertia so as to hold the speed within close limits.

DIRECTIONAL CONTROL

This aircraft is steered directionally by a control wheel, much like a car or boat. Moving this wheel tilts the wings differentially and moves a small water rudder. The ratios are such that the control feel on the water or in the air is almost the same. Because the wings are free to float this differential motion does not necessarily make the angle of one wing increase and the other decrease. If this were so it would be possible to stall one wing, as sometimes happens in the conventional system when both wings are flying at maximum lift. For example, with the aircraft flying at minimum speed, which is maximum angle of attack, if the control wheel is turned to the right the left wing does not increase its angle but the right wing takes full travel, decreasing its angle. Conversely, at high speed the exact opposite may occur, now in response to control the wing being given positive pitch will travel at a speed between these extremes, the tilting may be evenly divided between the wings. This is not a mechanical proportioning but an aerodynamic proportioning so the way the motion is divided between the wings depends on air flow at that particular instant. Another look at the center of pressure curve should make this clear.

Adverse yaw that so troubled the early experimenters with tilt wings is no longer a problem; with this aircraft it is possible to limit the angle of attack, and therefore the wing drag, to any desired value.



PHOTO NO. 9
1947 boat with Continental 65 aft of passengers.

Looking at the drag curve you will see the lift line at 18° begins to bend over and then descend. There is little to be gained by going beyond this 18° point for cut off. The drag curve is relatively low up to this point so by locating the hinge at 13 inches from the leading edge the lift is practically maximum and the drag limited to 0.16. With this sharp limit and a positive knowledge of what the maximum drag will be it is easy to design for it.

These curves show dramatically how, if it were not for this positive cut off, an increase in angle of one wing would not noticeably increase the lift but the drag could increase many times over. It should be noted that the center of pressure shown on this curve is not the conventional which is on the wing chord. Instead it is shown 2 1/2 inches below the chord on the plane of the hinge. The reason for this departure from the conventional is to show directly the restoring force available at any trim angle.

An often overlooked fact about adverse yaw is that if there were no resistance to roll there would be no adverse yaw. In other words, adverse yaw is a function of roll resistance.

There are two principal sources of this resistance in an aircraft. Aerodynamic damping of the wings and other surfaces about the roll axis and inertia about the roll axis.

In the conventional aircraft the first is usually the greatest while in the controlwing roll control does not have to overcome this resistance because the incidence of the entire wing is varied. In an aircraft having the engine in the fuselage, most of the inertia is due to wing weight because the wings represent a mass the farthest from the roll axis. The controlwing has some roll inertia but it is far less than the conventional because of the much lighter wing construction.



PHOTO NO. 8
Convair roadable after rebuilding. Photo taken at San Diego in 1946.

SAFETY OF FLIGHT

The advantages of an aircraft that will not stall or spin are too obvious to dwell upon. That published figures showing almost 70% of all private aviation fatalities are associated with stalling should be evidence enough of its importance.

Apparently, this aircraft is inherently stable, both statically and dynamically. When left to fly by itself, it will not go into the tightening spiral that makes blind flying dangerous. When the steering wheel is centered, it flies straight and level, except, of course, for wandering and the buffeting of turbulent air.

Longitudinal dynamic stability is most interesting. While flying straight and level, we have intentionally introduced quite violent disturbances by suddenly tilting

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the wing up or down, in this way giving the aircraft a violent surge up or down. The surprising thing is that this ascent or descent lasts only as long as the wing is held in this abnormal angle. As soon as the wing is released, the aircraft again flies straight and level, there is no oscillation or phugoid.

Disturbances in the hull have little or no effect because the wing is entirely independent. The center of gravity position is not critical to flight for the same reason.

In an aircraft controlled by vanes the control effectiveness varies with the speed squared. Thus, an aircraft having a speed ratio of three with adequate control at take off will have nine times too much control at top speed. Conversely if it is designed to have proper control at top speed, it will have only one ninth enough at minimum speed.

The controlwing has constant control sensitivity throughout the speed range. The fact that control sensitivity does not increase at high speed prevents stunting, another potent cause of fatalities. So far no one has found a way to loop, roll or dive this aircraft.

Occasionally, a fixed wing aircraft is lost because of structural damage from severe turbulence. According to NASA Report CR-1523, the effect of a sharp edge gust on the controlwing is only about one fourth that of the conventional wing. The same report also points out that lateral control is considerably more effective than ailerons, adding much to the safety of low level flying as well as landing or take off.

EASE AND COMFORT OF FLIGHT

Simplicity of control means much, particularly to the non-professional flier. In this aircraft no coordination of controls is required as there is only one directional and one up and down control. The transition from water to air and air to water is made with almost no change in control feel. In fact, when the water is smooth, it is often hard to tell whether the boat is on the water or in the air.

Several inventors have tried putting springs between the aircraft and its wings, finding it tends to soften the ride a little. The problem is that while this system works with car wheels, bumps in the road are finite in height and the springs can be designed to cope with them. On the other hand gusts in the air are all but infinite and a spring can at best only soften the shock when the gust strikes.

Floating wings can tilt as required to spill the gusts regardless of their duration. Sometimes a pilot flying this craft for the first time is disturbed by the apparent erratic fluttering of the wings while flying through turbulent air.

To anyone who has driven a car with exposed wheels over a rough road and watched these wheels, it is understandable for the action is very similar.

Occasionally, a gust strikes principally one wing tending to overturn the conventional aircraft. The only way to correct this is to attempt to push the wing back down with the aileron, a small vane to overcome the gust force on the entire wing. Should this same thing happen to the controlwing the attack of the entire wing is reduced so no additional lift is felt and the wing requires no pushing down against its will.

LIGHT AND SIMPLE STRUCTURE

For the same capacity this aircraft may be more compact because no tail is required and no minimum span is needed for adequate aileron control. Absence of gust loads allow a lighter and more simple structure. The weight of passengers and engine are either side of a fire wall directly under the wing permitting a most direct support structure. The control mechanism is simple, compact and centrally located so can be built ruggedly for very little weight.

BOAT CHARACTERISTICS

Hinging and therefore isolating the wing from the hull allows complete freedom of both hydronamic and aerodynamic design. For instance, the step may be designed to give optimum water performance, it is not necessary to rock the hull on the step to adjust wing angle for take off. Stability on the water is adequate without wing tip floats because the engine and passengers are low in the boat.

High speed water operation is improved by wing control being connected to the water rudder. The entire craft is stabilized by the wing and maneuverability is improved. There is no tendency of the craft to fly at the mooring because the wings may be locked at a slight negative incidence.

Take off is as simple as opening the throttle, allowing the boat to come up on the step and then fly off. The only effort needed is to maintain the correct heading with the steering wheel.

Landing is equally simple: The boat is lowered with the throttle until a few feet above the water. The throttle is then completely closed allowing the bow to come up gently, providing much additional lift in ground effect. Thus the hull bottom plays an important part in a soft landing at a speed even lower than minimum flying speed.

RECENT CONTROLWING DEVELOPMENTS

While we were flight testing N-910Z on the Chesapeake and in Florida, many observers became interested in this unusual little craft and some of these people started building their own versions.

On first thought this was fine because the more people working with a new concept the sooner it will become practical. It was only after looking over some of these attempts that I had second thoughts. True, This aircraft is easy and simple to build and fly. However, the apparent ease of design is deceptive. There is little help from the literature and few flyers or aerodynamicists fully understand the principle. The would-be builder is on his own with an aircraft that must be built to exact specifications in the area of the all-important wing pivot/control system.

It must be understood that the basic design philosophies behind the conventional aircraft and the Controlwing are at opposite poles—and that this enters into the construction of each. It has been said (in the case of the conventional aircraft) that the sole purpose of the rudder is to cover up the mistakes of the designer — this could also be extended to cover the ailerons and elevator. This was intended to imply that the conventional airplane was designed purposely to be partially unstable—with the re-

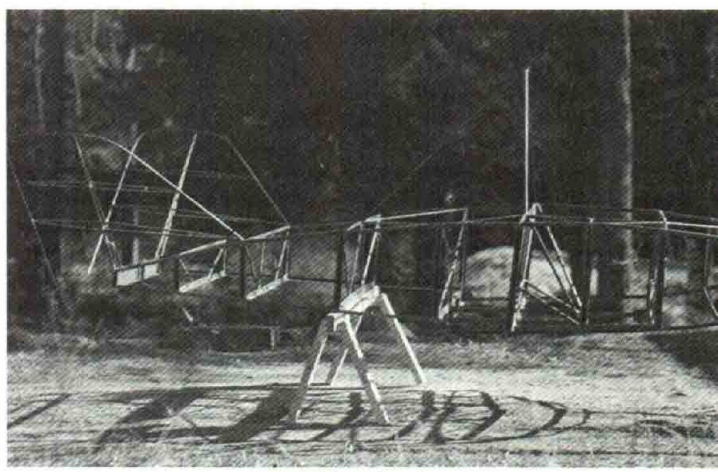


PHOTO NO. 10
Showing steel framework used to support the plywood skin in construction of N-3915A.

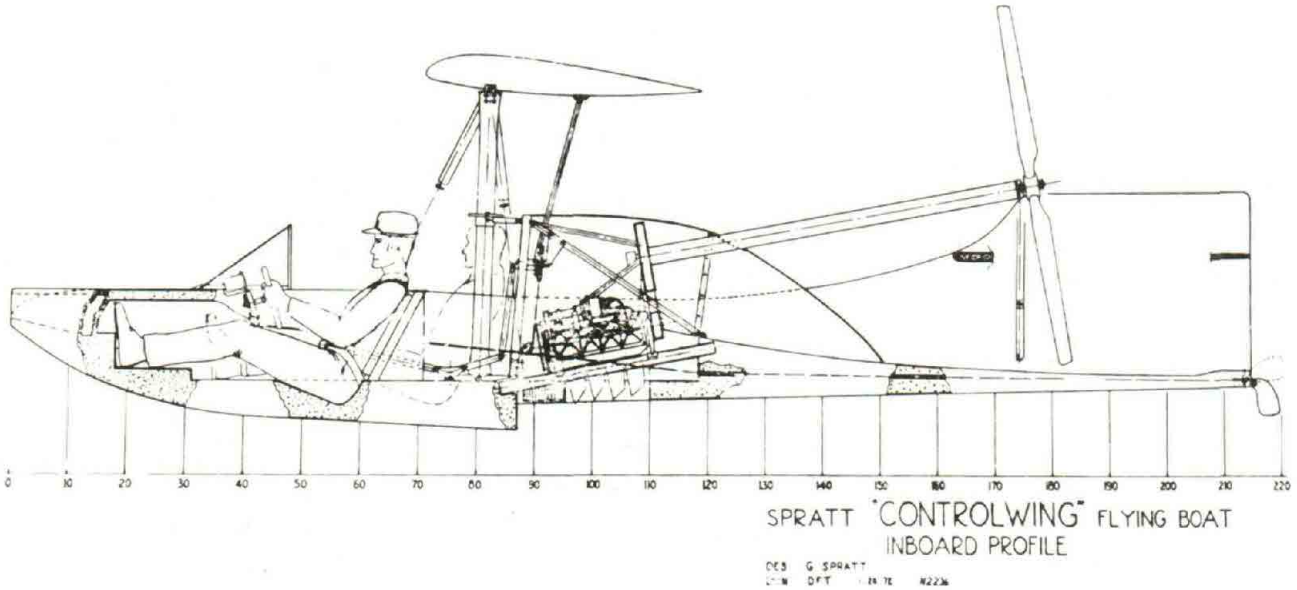


FIGURE II

mainder of control left up to the pilot. In other words, the designer did not complete his job.

The design of the Controlwing is complete, leaving little for the pilot to do other than pilot the aircraft. To do this he needs only one directional and one up and down control. Obviously, the design must be precise, the pilot has no means to cover up the designer's mistakes.

After much serious thought about what to do before someone got themselves into trouble, I decided to make an individual license available under these patents to the homebuilder for a reasonable fee. The builder would then have drawings of our latest prototype for free and our aerodynamic data would be available to him. His creative thought would not be stifled but, conversely, he would be given sound data upon which to build his own creation.

This approach appears to be working: Randall Mathues who flew the more difficult portion of the testing of N-910Z was the first licensee. His emphasis is on long range with good cruising speed. Dr. J. M. Fanucci (EAA 84024) in Westville, Natal is building his hull of wood because he likes working with this material. Victor Lenhart (EAA 82699) in Anchorage wants to cope with more rugged conditions so is designing for greater wing

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PHOTO NO. 11
Latest two place all plastic flying boat powered by Mercury 800.

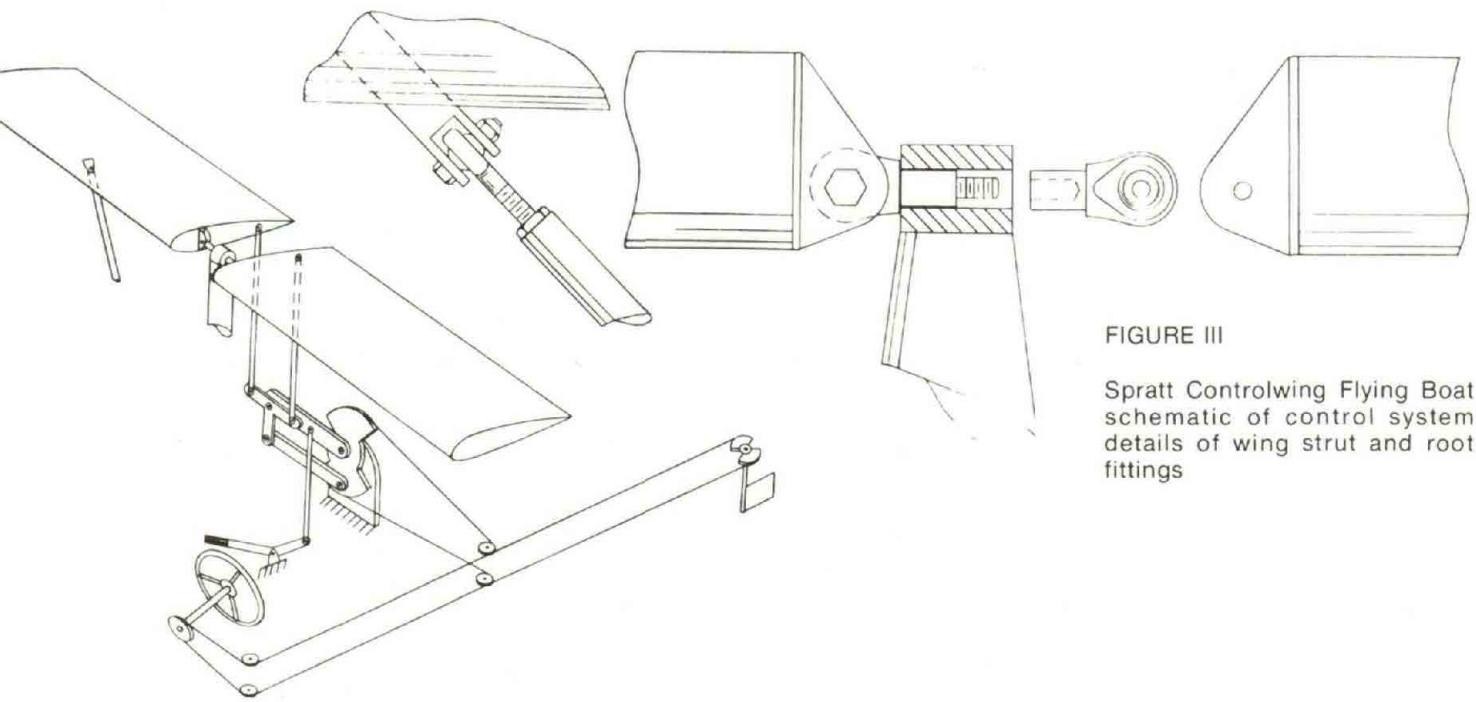


FIGURE III

Spratt Controlwing Flying Boat schematic of control system details of wing strut and root fittings

DESIGNEE CORNER . . .
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span and more power, a Mercury 135 h.p. Lynwood Smith (EAA 76160). a professional marine biologist in Bothell, Washington, is building a closed cabin version for comfort and protection from the weather in his area. In West Chester, Pennsylvania Joe March (EAA 70091) is attempting to use the ubiquitous VW for power. Many others who want only the joy of boat flying, away from the congestion and restrictions of large airports are building exact copies of N-2236.

The conventional aeroplane has had many millions of flight hours. The total experience of the Controlwing is measured in hundreds of hours.

It is my hope that as more of us build and fly this new concept that we will be able to work together in solving the many problems that are bound to appear. Only this way will a practical aircraft evolve to match the needs of the non-professional flyer.

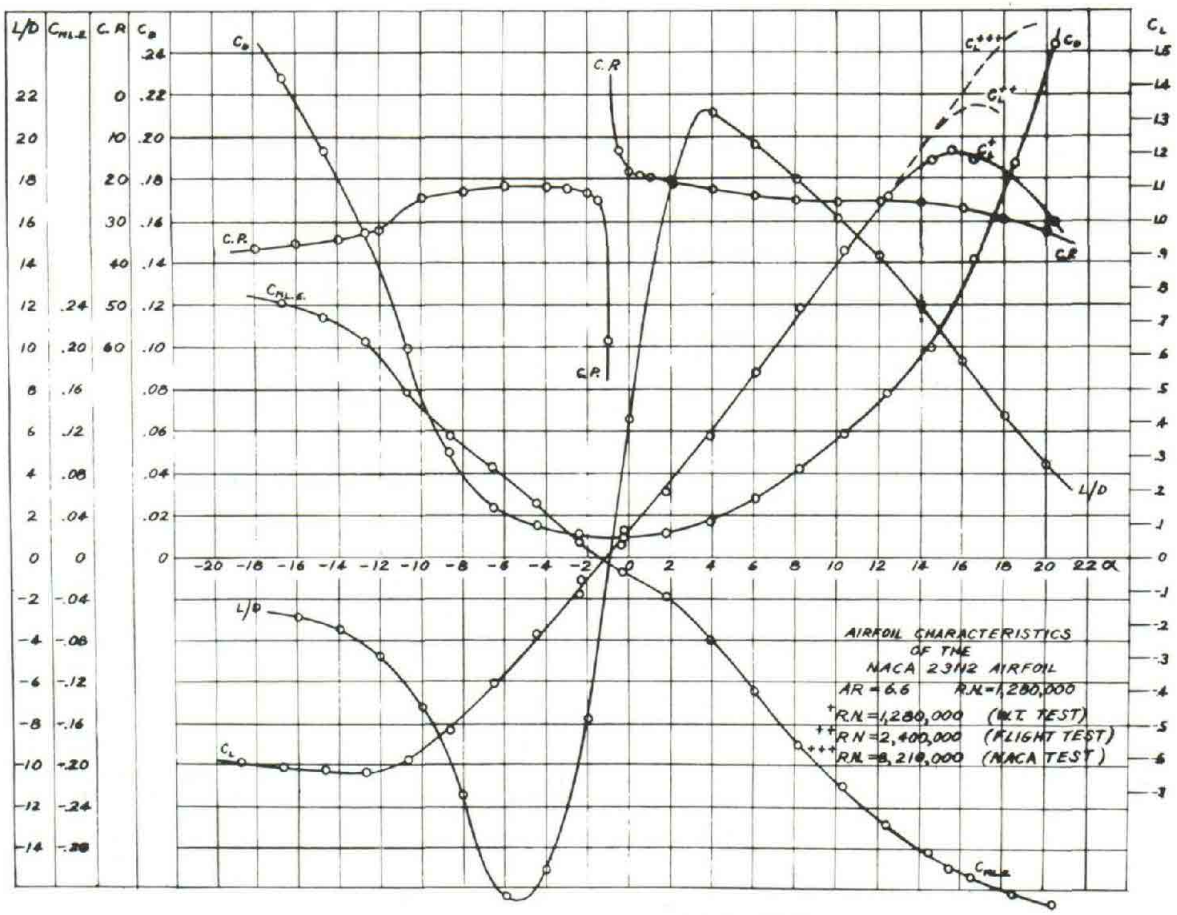


FIGURE IV

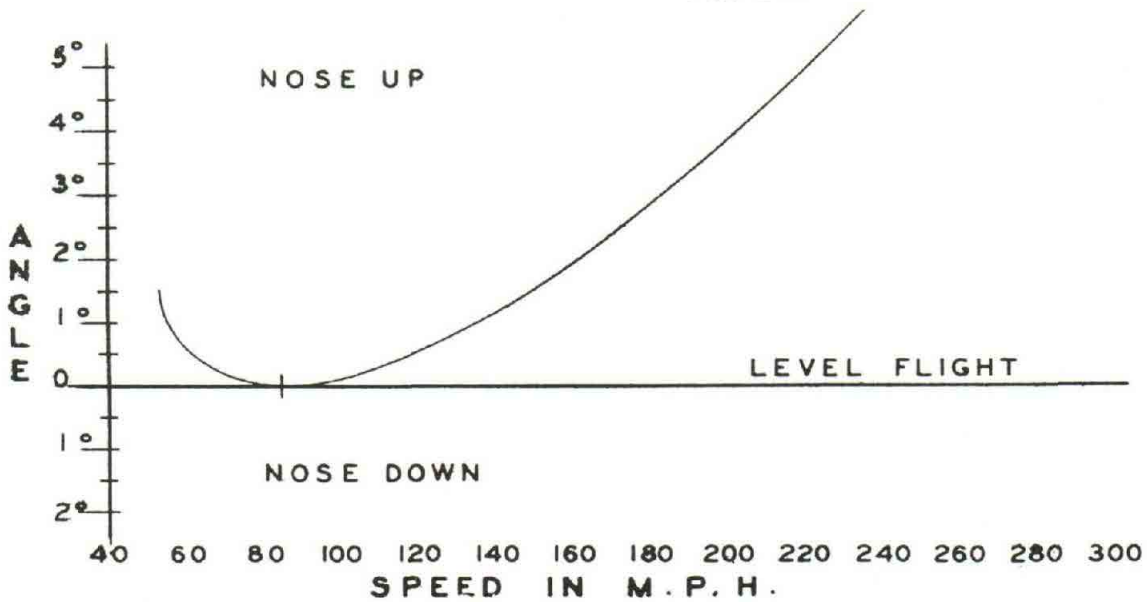


FIGURE V

"TITLE"
"BODY ATTITUDE"
(LONGITUDINAL)