(Photo by Dick Stouffer)

The Durand Mark V.

AERODYNAMIC CONCEPTS OF THE DURAND MK. V

By William H. Durand (EAA 31262)
84th And McKinley
Omaha, NE 68122

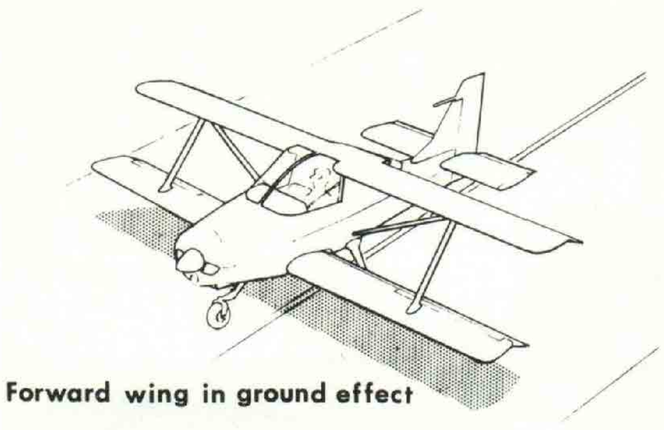
IT'S UNCANNY HOW one singles out some isolated remark from year's past to be remembered. For example, my high school physics teacher said to me many years ago that "any airplane is really just a bundle of forces," and I thought of this remark often while planning the general layout of the Durand Mk. V, trying to gather the many forces into as neat and orderly a bundle as possible. Of course, there were other considerations, too. Frankly, one of the prime "non-force" considerations was attractive styling, but this was entirely compatible. In fact, physics and aesthetics seem to have quite a strong affinity, giving rise to an old saying among pilots that "if an airplane looks right, it will fly right." And there is probably a lot of truth in that.

In designing the Mk. V my aim has been to arrange its individual masses and aerodynamic forces in such a simple and functional layout that neither awkward compensating dodges nor inflight improvising by the pilot would be required for maintaining equilibrium or achieving dynamic stability. I started with the C.G. itself, since it is the hub of reference for the leverages or moments created by all of the major forces.

To avoid the balance problem inherent in some types of airplanes, such as pushers, I placed the pilot and passenger (the largest individually variable loads) practically **at** the center of gravity and then proceeded to design the airplane around them. The thrust line of the propeller was then located to pass right through the C.G. (which practically coincides with the center of drag) so that there would be no leverage from this source to cause change in trim with variations in power. Airplanes with a high thrust line (amphibs for example) nose down with the application of power and then nose up when power is reduced. Airplanes with a thrust line passing below the C.G. behave in the opposite manner. Both require corrective forces that are unnecessary in the Mk. V design.

With the C.G. successfully confined to a very limited travel, force variations for balancing the airplane in flight were further minimized by selecting biplane wings of such narrow chord that their composite center of pressure could not stray far from a fixed position relative to a fairly constant C.G.

Also, one of the guiding principles in designing the Mk. V was to keep the major masses close to the C.G., hence side-by-side seating at the C.G., the engine close to the firewall, and the fuel tank in the fuselage instead of at the wing tips. Why? Because the inertia effect of widely spaced masses makes for sluggish control response and results also in slower damping of unwanted oscillations. Perhaps a more important aspect is the fly-weight effect that widely spaced masses exert during a spin. They tend to move outward from the spin axis like the fly-weights of a governor causing a spin to go flat and making recovery difficult or impossible.



(Drawing by Bill Durand)
Ground effect of the forward wing provides the pilot with a natural assist in both takeoff and landing.

Undoubtedly the most visible special feature of the Durand Mk. V is the exaggerated negative stagger of its biplane wing system and its clean strut bracing. Less obvious are other unconventional features such as the full-span flaps on all four wing panels and the use of spoilers in lieu of ailerons. Although these are all interrelated in this design, we shall consider them individually here.

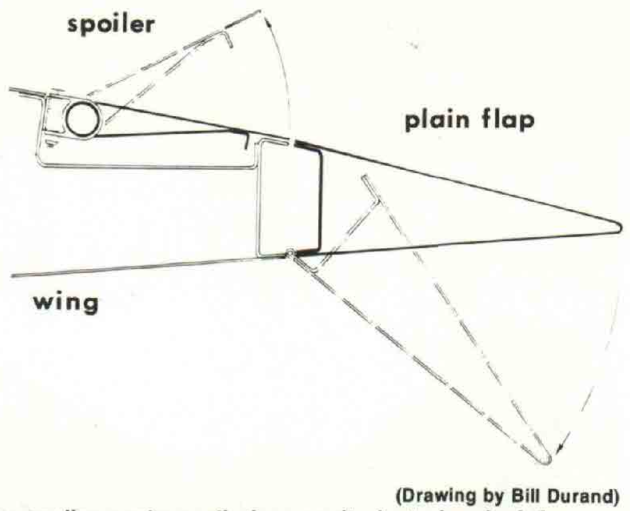
Negative Stagger

This opens some really interesting options in arranging aerodynamic forces to the pilot's advantage. It's almost a tandem wing situation, the lower wing being ahead of the C.G. and the upper wing being behind the C.G. Upper and lower wings have the same span, chord, and area and are mounted to the fuselage at the same angle of incidence. The actual angle of attack is different, however, because the rear (upper) wing is working somewhat in the downwash of the leading wing. This changes the lift contribution from a 50-50 situation to about a 53-47 basis with the lower wing being the slightly more effective one.

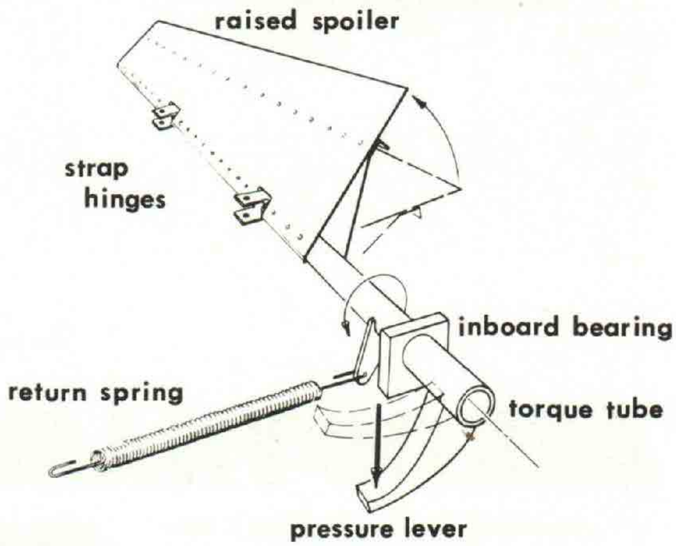
In assessing the wing system used here, it should be noted that the design's basic geometry permits the lift strut to be located **behind** the lower wing so that its presence does not cause any disturbance of the high velocity air flow across this wing's upper surface.

At high angles of attack approaching the stall, the staggered biplane layout demonstrates the wisdom of not carrying all of your eggs in one basket or, more specifically in this case, of not depending on only a single wing for all of your lift. Working at the greater angle of attack as previously noted, the forward wing begins to stall a few degrees before the rear wing would reach this condition. Now in this circumstance the rear wing takes over the position of being the more effective one, and because it is located aft of the C.G. its lift causes a nose down pitch while still working at or very near its own maximum lift coefficient. The result of the nose down pitch is to bring the forward wing back into full action almost immediately. So, in a jiffy both wings are flying again with scarcely any loss of altitude. In test flights it was found that holding the stick back at high angles of attack produces only a series of "nibbles" or quick little "bobbings" of the airplane.

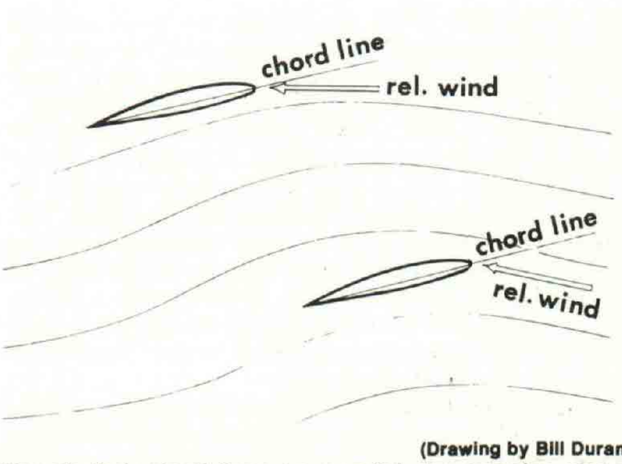
Another inherent advantage in the large negative stagger is found in landings. Because of the greater ground effect of the forward wing, its lift increases gradually as the airplane approaches close to the runway. Because this additional lift occurs well forward of the C.G. it gently raises the nose for what might be



(Drawing by Bill Durand)
The spoiler nests neatly in a cavity just ahead of the rear spar and full span flap.



(Drawing by Bill Durand)
Spoiler control can be very, very simple as seen in this schematic diagram of the Mk. V's system.



(Drawing by Bill Durand)
Though their chord lines are parallel, the negative stagger produces different angles of attack for the upper and lower wings.

termed an automatic flare requiring little, if any, help from the pilot.

The ground effect of the forward wing also assists takeoffs. It tends to relieve the nose wheel from some of its load during the takeoff run and holds the nose slightly high until the airplane is several feet above the runway. As the ground effect diminishes the nose gently drops, aiding the airplane in increasing its airspeed in preparation for the climbout. It's a natural!

The Durand Mk. V's spiral stability is enhanced because all of its dihedral is concentrated in a wing that is forward of the C.G. Here the dihedral performs a dual function. It not only raises the low wing but also raises the nose to guard against the development of a spiral dive should a wing drop due to a gust or other distrubance. The lower wing has two and a half degrees of dihedral. The upper wing has zero degrees. It's another advantage inherent in a biplane with larger stagger.

Full Span Flaps

The advantages of wing flaps in terms of landing approaches that provide a more accurate estimate of touchdown point combined with lower contact speed and reduced ground roll are generally recognized. With flaps occupying the entire trailing edges of both the upper and lower wings, the Durand Mk. V maximizes these advantages and at the same time eliminates the destabilizing effect produced by the more common partial span flaps.

Unfortunately in most instances the application of wing flaps upsets an airplane's balance. Usually the airplane becomes nose heavy because the center of pressure moves rearward with flaps down. Control pressures become uncomfortably heavy and require that the pilot retrim the airplane, adding another cockpit chore at a time when he is unusually busy with communications and traffic as well as negotiating the landing approach itself.

The basic geometry of my Mk. V design creates the opportunity for avoiding this situation by the simple expedient of proportioning the lift of the two staggered wings in the flap-down mode so that their composite center of pressure does not move rearward. This has been accomplished by rigging the lower wing flaps to deflect through a greater angle than the upper wing flaps. Full deflection of the lower flaps is 45° compared to only 40° for the upper flaps with intermediate positions similarly proportioned. The greater lift on the forward wing effectively balances the rearward center of pressure shift so that no correction in trim is required when the flaps are operated.

A secondary but convenient function of the flaps is ground adjustment for lateral trim. The Mk. V's all metal wings are very torsion resistant and not adapted to wing-warping like fabric covered wire braced wings. To correct a wing heavy condition any of the four flaps can be conveniently adjusted at the link rod ends inside the fuselage.

Roll Control by Spoilers

Frankly, the incorporation of spoilers into the Mk. V design was dictated primarily by my desire to occupy the entire trailing edge with wing flap. I wasn't really just carrying the torch for spoilers on the basis of their novelty, because nothing I had ever read in the textbooks was very complimentary. But with this wing layout I needed a substitute for ailerons. The more I really contemplated the alleged problems with spoilers used in this application, the more some of the criticism seemed illogical and perhaps mere superstition. But there was some sound experimental data in old NACA reports and also RC model tests by EAA member Dennis Brown that appeared encouraging enough to firm up my decision to go the spoiler route.

The simple type of spoiler designed for the Mk. V is a narrow metal flap 4¾ inches wide and 69½ inches long hinged near the leading edge and normally flush with the upper surface of the wing. Its full upward deflection is 40 degrees and its location chordwise is just ahead of the flap. There is a spoiler at the outer portion of each lower wing, and since their intended function here is to produce roll, only one of them operates at a time.

Roll is produced by a combination of effects when a spoiler is deployed. First, it reduces the wing's lift production by slowing the airflow across the upper surface, thereby adversely affecting the pressure differential and downwash. At the same time the drag of the raised spoiler near one wing tip causes a yaw around the C.G. which itself produces roll in the desired direction by reason of the difference in airspeed of opposite wings in a turn — lift varying as the square of velocity.

It is noteworthy that the drag of the spoiler helps the airplane turn in the direction corresponding to the bank. Not so with ailerons. The aileron that raises a wing also drags that wing back because of the increase in wing drag it produces. Eliminating this "adverse yaw" is one of the big advantages of spoilers.

There are other advantages. Unlike ailerons spoilers don't play tricks and surprise you at high angles of attack. Depressing an aileron sometimes actually precipitates an early stall of that wing and creates a roll opposite the pilot's intention. Also spoilers don't produce a structural twisting of the wing as ailerons do in the case of long limber wings. The down aileron has been known to twist relatively elastic wing structures to the extent that the wing's leading edge "tucks under" producing a negative angle of attack that results in a reversed roll. This last advantage, however, is lost on the Mk. V because of the inherent stiffness of the torsion resistant strut-braced wing.

If "spoiling" the lift were the only function of a spoiler, such as for increasing sink as a means of glide control, the device would be located at about one-third of the chord from the leading edge because that's where it causes the greatest lift disturbance. However, the NACA Technical Reports indicated that for roll control (instead of sink control) there was an undesirable lag in control response in that location. This lag diminished as the spoiler was moved aft, and at a location roughly two-thirds of the chord from the leading edge, the lag became negligible.

The 66% of chord location proved very convenient in the Mk. V, and the control system evolved into something very, very simple. With a little juggling while the design was still on the drawing board, the torque tube to which the spoiler is riveted could be run straight into the underfloor space so that its inboard control horn was exactly in line with the lower end of the control stick. A rigid horizontal extension on the bottom of the stick merely presses on the end of this horn to rotate the torque tube and deploy the spoiler. When the stick is moved to the opposite side, the stick arm lifts away from the one horn and its opposite member depresses the one on the other wing to operate that spoiler. When both spoilers are in neutral the levers are in light contact ready for action in either direction. There is no actual linkage in the system, just contact. Light horizontal springs concealed in the covered gap between the lower wing root and fuselage are used for spoiler return.

In spite of having flown many makes and models of light aircraft through the years, I had never had the opportunity to fly one using spoilers. And being a very conservative type of person I had no desire to be "thrilled" with unexpected behavior of the airplane when making the initial test flights. Fortunately, fellow EAAer, Larry Quigley, pilot and expert RC model builder and flyer, offered to build an accurate 1/5 size radio control model of the Md. V for research purposes which would answer some of the questions which had arisen.

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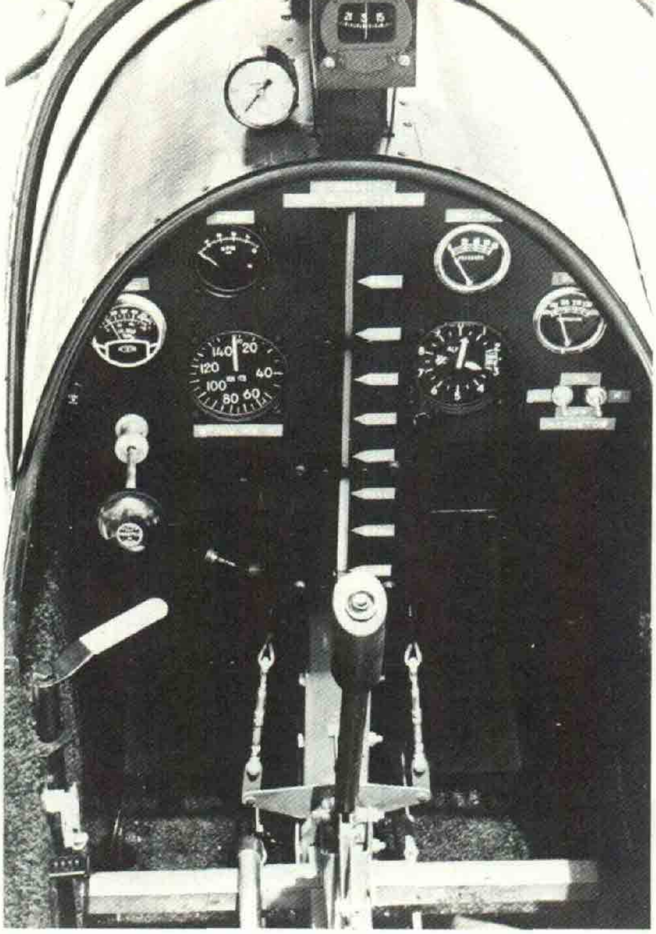

The Scamp "B" is powered with a Revmaster 2100 engine and even at full gross load of 920 pounds requires only 65% power to operate at field elevation of 3340 ft. and ambient temperatures of 80-90° F. Take-off distance is 550 feet. Tank capacity 15.8 gallons. Agro-chemical weight (15.8 gals.) is 155 pounds. Average spraying altitude over crop, 5 ft. Speed of application, 80 mph. Swath width, 28 feet. Under normal dosages 35-37 acres can be covered per tank load. Types of chemicals used: All ULV (Malathion, Heliothion, Ortho-Dibrom, Stam LV., etc.).

"The 'B' model is turning out to be a real work-horse sprayer as it is quick-highly maneuverable, yet not overly sensitive, and rugged enough to operate off the country roads and sod fields in Colombia," reports Sr. Tedesco. It looks like a "homebuilt" will be writing some new aviation history in South America.

Additional information can be obtained from: Sr. Maximo Tedesco, Agricopteros, Ltda., Apartado Aereo 1789, Cali, Colombia, So. America and Aerosport, Inc., P. O. Box 278, Holly Springs, NC USA 27540.

Cockpit. "ON-OFF" chemical dispersal lever on left just below throttle. Pressure gauge top of cowl below compass. Fuel quantity sight gauge runs through center of panel.

AERODYNAMIC CONCEPTS . . .

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Questions such as: (1) Will the spoilers as proportioned produce adequate roll? (2) What about inverted flight? (3) With spoilers on only the forward wing, will their operation cause a nose down pitch? Well, Larry built a really beautiful model (which we also employed to firm up the paint scheme on the prototype), and it flew beautifully. The spoilers were fine in every respect, thus allaying considerable of the general apprehension attending the approach of any first flights in a new and somewhat unconventional airplane. One of the myths that was disspelled by the model flights is that spoilers would cause the airplane to drop as well as roll. Not true! I believe that the propagators of that particular theory must have failed to reckon with the compensating additional lift provided by the higher speed of the wing on the outside of the turn.

One concern still remained to be dealt with in full scale testing. How much tension should the return

(Photo Courtesy Bill Durand)
Bill and Maurine Durand admire Larry Quigley's RC research model of the Durand Mk. V.

(Photo by Dick Stouffer)
Refer to this photograph as the author, Bill Durand, describes the geometry of his wing/flap/spoiler system.

springs have in order to prevent upward float of the spoilers? In the event that both spoilers would raise sufficiently to effectively dump the lift on my forward wing, the stabilator control just might not be effective enough to counteract the nose heavy condition. Playing it safe the return springs were first installed with a stretch of 1⅛ inches. This worked but was undesirable from the standpoint of initial stick pressure. Subsequently, since flight testing indicated the stabilator control to be relatively powerful, the tension has been relaxed with an initial stretch of only ⅛ inch, just enough to keep the springs from sagging. There appears to be no tendency whatever for the spoilers to float above their neutral position flush with the upper surface of the wing, and the stick force now feels normal.

Since it has been demonstrated that spoilers really do function well on our small airplanes as well as on the big jets and turboprop jobs, I predict that we shall see them with increasing frequency. Even on wings without flaps, the simplicity of construction and control makes them very attractive to the homebuilders.