nificant and such that the sinking speed measurements in turbulent air are lower than in still air, then we must look to the mechanism of dynamic soaring for an explanation. As a matter of fact, the investigation of the nature of this energy extraction will yield valuable information on the little known science of dynamic soaring, whose aspects will be discussed later in this paper.

Up to now, all of our comparisons of bird aerodynamics have been within the family. The question naturally arises, "How good is the bird when compared with modern aircraft?" Obviously, trying to compare a bird cruising at 30 to 60 mph with a supersonic airplane would be absurd. But if we compare the bird with some of our subsonic airplanes, we still have the problem of scale and speed differences. Fortunately, we can rely on the well known Reynolds Number as a means for eliminating the objection that we are comparing vehicles in different domains of the viscous flow regime.

In figure 9, the drag polar of the black buzzard in its two modes, gliding and soaring, has been transformed into a plot of average skin friction drag coefficient versus Reynolds Number. On the same plot are shown the Blasius curve for pure laminar flow over a flat plate and the von Karman curve for turbulent flow over a flat plate. These two curves provide us a standard over the rather large scale and speed domain covered from birds to large airplanes.

It should be mentioned that the data for the airplane shown was also obtained in gliding flight, with propellers feathered after climbing to altitude on its engines. When we look at figure 9, we find that the black buzzard's skin friction coefficient is only 30 percent higher than that of the laminar plate, whereas our best man-made flying machine, a sailplane, possesses a skin friction coefficient 330 per cent higher than the laminar flat plate flow. And our best measured airplane has the poorest showing having 29 times greater skin friction than the laminar flat plate.

From this curve, we can conclude that the many generations of selective breeding have resulted in a flying machine, the bird, which still gives man a goal toward which to strive.

Furthermore, the fact that the high speed end of the curve of skin friction for the bird came from data points taken in calm air, gives some validity to a speculation that the bird must, through the porosity of its feathers, exercise some type of boundary layer control, i. e., that there must exist some automatic fluid mechanical process in the bird's make-up by which a good portion of the flow over the bird's surfaces is kept laminar. The difference in porosity measured by Victor Loughheed may be the key to this process.

In fact, based on this speculation, the author was inspired to attempt to duplicate the boundary layer control which he suspected the birds were achieving. By perforating a section of a sailplane wing with many small holes, and sucking the boundary layer air into the wing with a fan, he was able to measure drag reductions of the order of 50 percent when even the power required for the suction fan was considered as a loss (ref. 7).

Later on, it was also discovered on this sailplane that this same suction could increase the lifting power of the wing.

We may thus further speculate that the bird may be utilizing boundary layer control, both for high lift and low drag.

Recently, a very fascinating discovery was reported by Kramer (ref. 8) that there exists an automatic boundary layer control in the skin of the porpoise. Examination of the skin of the porpoise disclosed that the porpoise is completely covered with a 1/16 inch hydraulic skin that is elastic and ducted. Kramer was able to duplicate this natural boundary layer control device by a suitable selection of stiffness of a rubber s k i n and by introducing a damping fluid behind the skin. The stiffness was controlled by small rubber stubs. Between the stubs was the damping fluid.

It is not inconceivable that nature has not solved this problem for its members flying through the air in an analogous manner to that displayed by the porpoise.

The problem of trimming an aircraft for various speed regimes is particularly vexing on flying wing aircraft. Since all birds are essentially flying wing aircraft, it is possible that we can learn a trick or two from the way birds apply trimming moments for various flight conditions. We know that the bird's wing is in general fairly highly cambered. Therefore, we can expect large pitching moments. In order to achieve stable flight, these pitching moments must be balanced by aerodynamic moments developed by the tail of a conventional airplane or by twisting and deflected elevators at the wing tips on a swept flying wing.

Let us look at a comparison of a flying wing sailplane and the black buzzard, figure 10. Instead of plotting C_L^2 versus C_D as we did before for the linearized polar, we have plotted $C_L^2 \div AR$ versus C_D, which is in actuality a plot of the theoretical induced drag coefficient versus total drag coefficient C_D. The purpose in doing this was to be able to derive some information on the induced drag from aircraft of widely different aspect ratios, namely, 5.7 for the bird and 21.8, for the sailplane.

It is immediately apparent that the slope of the curve for the buzzard is much steeper than that for the sailplane. This means that if the two had the same aspect ratio, the bird would out-perform the sailplane, especially at the high lift coefficients used in soaring. In studying the reason for the high induced drag of the Horten IV flying wing sailplane, we found that the elevators at the trailing edge of the wing caused a severe induced drag due to the change in the spanwise lift distri-

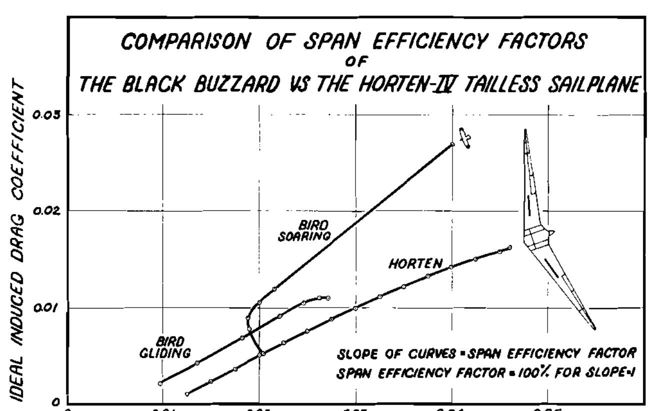

Figure 10.