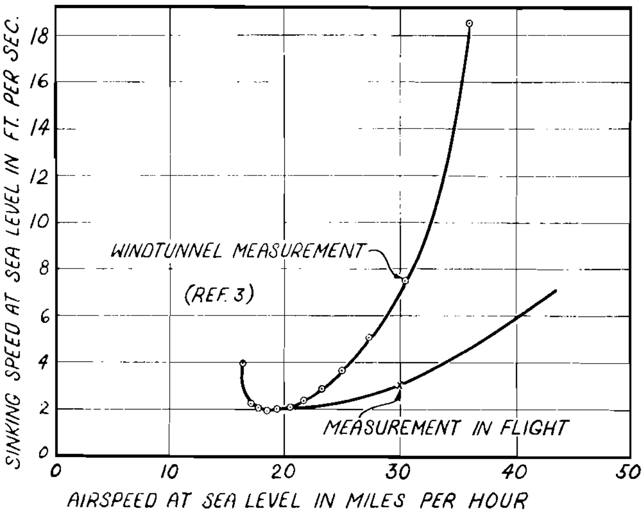

Fig. 2. Velocity polar of laughing gull.

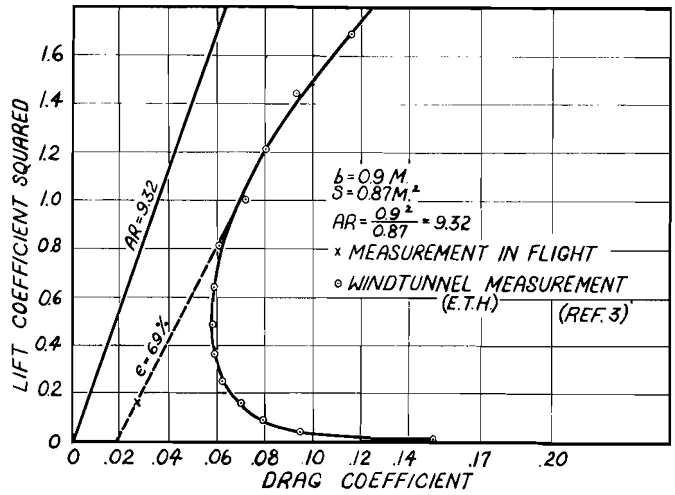

Fig. 3. Linearized drag polar of laughing gull.

oped to a higher state and used to get the complete measurement of the drag of a bird over the speed range of his flight in the gliding phase.

However, in order to determine the nature of the aerodynamics of birds in terms of the known parameters used in aeronautics, we must refer the drag to a non-dimensional drag coefficient:

$$C_D = D \div \tfrac{1}{2} \rho V^2 S,$$

where D is the drag in force units, ρ the air density, V is the velocity of flight, and S is the wing area including that intercepted by the body.

In a similar manner, we define the lift coefficient:

$$C_L = L \div \tfrac{1}{2} \rho V^2 S,$$

where L is the lift in force units. If now the velocity polar of figure 2 is transformed into a curve of C_L^2 versus C_D, we obtain figure 3. The reason for plotting against the square of the lift coefficient is quite evident when one sees that the induced drag coefficient, i.e., the drag due to lift, is a function of the square of the lift coefficient:

$$C_{Di} = C_L^2 \div ARe,$$

where ARe is the effective aspect ratio:

$$ARe = (b^2 \div S)\ e,$$

b being the span, and e, the span efficiency factor.

What one sees from the linearized drag polar of figure 3, is that the flight measured point lies on an extension of the linear portion of the windtunnel measurements. This indicates that the windtunnel results must be in error below a lift coefficient equal to 0.8.

Obviously, the clay model was not representative of a feathered bird in flight. In fact, it is doubtful that even a feathered model could accurately duplicate the aerodynamic properties ascribable to the elasticity and mobility of the feathers on a live bird.

However, one can admire the finesse with which nature has designed her flying machines by observing the neat intersection of wing and body in figure 4, which shows a drawing of the laughing gull taken from Feldmann's paper. In this drawing, the very pointed tips of the soaring birds of the sea are conspicuous. In a later illustration, the distinctly different tips of land soaring birds will be shown. The question then arises, "What is the function of this pointed tip as contrasted to the slotted tip of land soaring birds?"

It has been suggested that, since land soaring birds must land and take off from trees, a large span would be a handicap. Therefore, the slotted tip serves to diffuse the vortex flow at the tip permitting the land soaring bird to attain good performance in spite of limited aspect ratio.

The sea bird on the other hand is not compelled by his environment to suffer a limitation in aspect ratio.

However, an analytic investigation by Newman (ref. 4) disputes the premise that the slotted tip can reduce the induced drag over that of a solid tip. We are then left without a logical explanation of the slotted tip of land soaring birds. Windtunnel tests using smoke streams of a live bird trained to fly in a tunnel could add to our knowledge of this important distinction between land soaring birds and sea soaring birds.

In order to duplicate this complicated model, the live bird, one might freeze a bird and then test it in a windtunnel. This has been done at the Washington Naval Yard Windtunnel some years ago, but again we have the criticism that the elasticity of the support of the feathers, as well

Figure 4.