FLIGHT

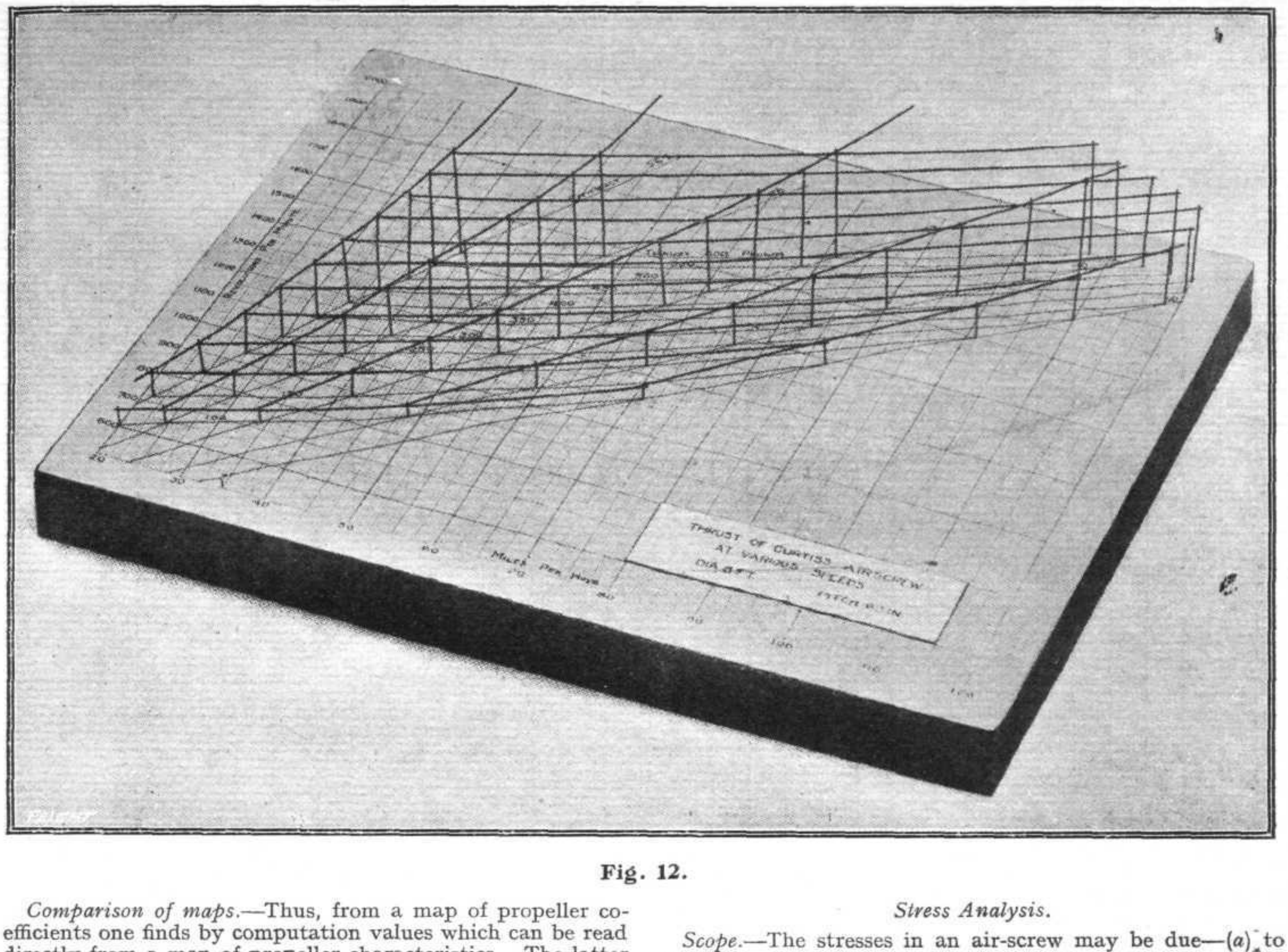

Fig. 12.

Comparison of maps.—Thus, from a map of propeller coefficients one finds by computation values which can be read directly from a map of propeller characteristics. The latter map is more expensive when seldom used; more economical when frequently used for hurried reference. Given either map the other can be produced from it through equations* 7′, 8′, 9′, 10′.

Relief map of propeller characteristics.—The efficiency and thrust values given in Fig. 6 are plotted in relief in Figs. 11 and 12 respectively. The efficiency surface—a species of cylindroid—has for equation $E = f'_5(V/N)$, and is generated by a right line rotating about the Z-axis, while oscillating along and perpendicular to it.† The thrust surface has for equation $T = N^2 f_1(V/N)$, and is generated by a parabola co-axial with Z and rotating about it with varying parameter. Similarly for the torque surface $Q = N^2 f'_2(V/N)$. The power surfaces are obviously generated by cubic parabolas rotating about Z with altering parameters. Viewed otherwise, the plane V/N = constant contains those generators of the characteristic surfaces and carries them with it while rotating about Z with varying parameter; the parabolas expanding and contracting; the straight line sliding to and fro along Z; and all their projections coinciding with the efficiency line or trace of the rotating plane on the reference plane VN.

If the form of any two of these functions, say $f'_1(V/N)$, $f'_2(V/N)$, were known, the equations to all the five surfaces could be written at once, thus furnishing complete mathematical expressions for the five propeller characteristics. Such functions can be derived analytically when adequate formulæ in terms of V and N are found to L and D, and the velocity and incidence of the air flow at each section of the propeller blade.

The efficiency lines in Fig. 6 are obviously projections of the intersections of the efficiency surface made by planes normal to Z and cutting it at distances from the origin equal to 56, 58, 60, &c., up to 73. Similarly the thrust lines are projections of intersections of the thrust surface made by planes normal to Z and cutting it at distances 100, 150, &c. Similarly for the power curves.

*From these equations it is seen that for ρ, D, V/ND, constant the thrust and torque vary as N^2, the thrust power and torque power vary as N^3, and the efficiency is a constant function of V/N. Hence if these five characteristics be known for one ratio of V/N they are determinate for all values of V, N, having that ratio. Thus all the curves of thrust shown in Fig. 6 are derived from a single one by the relation $T \propto N^2$. Similarly for the curves of torque, thrust power and torque power. The efficiency graphs are obviously all straight lines through the origin of V and N.

†The Z-axis is here assumed normal to the paper and co-ordinate with the V and N axes.

Stress Analysis.

Scope.—The stresses in an air-screw may be due—(*a*) to constant velocities of rotation and translation, or (*b*) to variations in one or both.

In ***steady rectilinear flight*** an air-screw with straight blades—the only form here treated—is subject to two kinds of loading: (1) centrifugal, which begets in the blades purely tensile stress; (2) aerodynamic, which begets bending stress.

To these must be added for ***unsteady flight*** inertia loads due to three kinds of change of motion: (1) translatory acceleration; (2) rotatory acceleration; (3) precession or nutation.

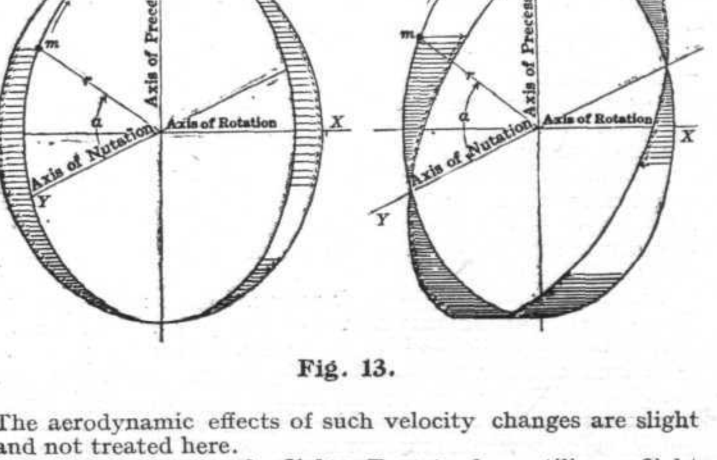

Fig. 13.

The aerodynamic effects of such velocity changes are slight and not treated here.

(*a*) *Stresses in steady flight.*—For steady rectilinear flight we may first find the centrifugal, then the bending stress, then by superposition find their resultant.

Centrifugal stress.—The centrifugal force F, at any cross-section of a blade, is found by the formula $F = Mv^2/r$, v being the peripheral speed, r the distance, of the centre of mass M of the blade segment tending to fly outward from the section in question. Usually this outward segment is mentally cut into smaller segments, whose mass and peripheral speed are first computed then substituted in the given formula