# ACTING ON GLIDERS IN *Towed Flight*

steep and the rate of climb is no longer large.

*Porpoising*—Certain gliders, especially those having ing the tow hook far forward, exhibit a tendency to perform pitching oscillations when climbed steeply or when a steep angle of the towline is reached. This motion is known as "porpoising." A skilled pilot can readily damp it either by easing up on the towline angle or by suitably timed elevator maneuvers. The mechanism of porpoising is perhaps not fully understood; but a theory has been advanced that it is due to stalling of the empennage, which has to balance the strong diving moment of the towline pulling down on the fuselage nose. This diving moment can be much greater than any ever experienced in free flight.

The phase relationship between simultaneous oscillations of the towline angle and of the tow force, as shown by the present motion-picture records, would not contradict this theory. The peaks of the angle and the tow-force fluctuations often nearly coincide; the maximum force often lags a fraction of a second behind the maximum angle. The frequency of the oscillations was mostly of the order of one second (from ¾ to 1½ seconds). Flight 6 is the outstanding example, with oscillations of the tow force as sudden as from 700 pounds to completely slack in less than one-half second. It must be remembered that the cable-to-chord angle does not vary exactly like the true angle of attack because the sag of the cable due to its own drag and weight appreciably increases as the tow load slackens. There were at least three instances on flight 6 when the cable went completely slack. The towline angle immediately increased because the cable sagged back. The wing did not stall.

*Accelerations*—The extreme normal accelerations recorded were 3g and —1g, more frequently 2.2g and 0, but it is uncertain whether they occurred during the porpoising oscillations or in free flight (wing-overs). Since they are likely to have been negative when the tow force was highest (and vice versa), the actual load factors on the glider in tow must have been lower than the factors that would correspond to the normal component of the tow force plus the tail force necessary to balance it except where high tow forces lasted for definite periods. Considering this fact and estimating that the tail force may have to be almost half as large as the normal component of the tow force, it seems that wing loading equivalent to load factors of the order of 2.5 were probably reached during some of the test tows. On other flights, the maximum loads were much less.

*Yawing*—In flight 8 an effort was made to yaw the glider while being towed. The yawing oscillations could be well followed by observing the movement of the terrain appearing on the movie films. These yawing maneuvers, although decidedly excessive, did not cause tow-force peaks as high as the other steep climbs of other flights. The yaw angles were not evaluated but it appears likely that lateral-force components of the order of a third of the tow force or half the gross weight may have occurred.

RESULTS AND DISCUSSION OF TEST II—In 7 of these 8 test flights, the tow force as read by the pilot on the pressure gage never exceeded 150 pounds. Only on one occasion with the stick pulled to the pilot's stomach, did the instrument register up to 200 pounds. The maximum slope of the top end of the cable against the fuselage axis was estimated at 60° on the basis of some snapshots taken from the wing.

As another example of remarkably low tow-line forces, the following experience may be worth mentioning. Volmer Jensen reports that on one occasion he made a flight holding the upper end of the tow rope in his hand instead of fastening it in the customary release hook. The tow car speed and acceleration were kept low until the glider was off the ground. Once in the air the climb was accomplished rapidly and an altitude of 200 feet was reached with a towline length of only 300 feet. The pilot reported that by bracing his feet against the rudder bar he found it easy to hold the line. He estimated the load could not have exceeded 100 pounds at any time. Another pilot, Henry Richmond, repeated the experience.

RESULTS AND DISCUSSION OF TEST III—The tensiometer indications were read from the film frame by frame and converted into forces according to the calibration curve.

According to these observations, the tow force averaged approximately 65 pounds. Several peaks reach 100 pounds and the highest one, 130 pounds. Fluctuations are of two types, very short ones lasting only a fraction of a second and slower ones favoring a frequency of the order of 4 seconds. These longer fluctuations are presumably the result of elevator maneuvers of the glider pilot attempting to correct variations from the desired trailing level.

These tow forces are remarkably low. Since they act essentially in the drag direction, their contribution to the stresses in the lift truss is undoubtedly insignificant. This result may be interpreted to confirm the common belief that an aircraft tow, carefully executed, need not impose loads of any consequence for strength requirements of the glider. This result does not prove, however, that appreciable loads might not be encountered in towed flight maneuvers other than the straight climb during which the present films were taken or under other meteorological conditions or at higher tow speeds. These conditions are still to be explored.

CONCLUSIONS—1. The present tests indicate that automobile tow forces depend greatly upon the towing and the piloting technique. Under favorable circumstances, they are insignificant and stay below the weight of the craft. Under conditions of deliberately rough maneuvers or simulating extremely inexperienced handling, they reach value likely to produce load factors ranging from —1g to 3g.

2. It appears desirable in normal glider operation by automobile tow to use towlines of sufficient strength to assure a reasonable fatigue limit higher than 1½ times the flight weight of the towed craft. A weak link at the top end of the line would seem to serve its purpose well if it fails at approximately twice the gross weight.

(*Continued on page* 13)