MEASUREMENT OF THE FORCES

by W. B. Klemperer

Ed. Note—The following is an excerpt from T.N. 753, National Advisory Committee for Aeronautics entitled, "Measurement of the Forces Acting on Gliders in Towed Flight," by Dr. W. B. Klemperer, The Soaring Society of America, Inc.

SUMMARY—The magnitude, the direction, and the fluctuations of tow forces exerted upon gliders by towing them aloft behind an automobile were measured under a variety of conditions covering a range from gentle to severe types of operation. For these tests, the glider towing force did not exceed 1.6 of the gross weight of the glider. V-G records obtained during the towed-flight period as well as during the subsequent return glide to earth showed accelerations in the range from 3g to —1g. The results of preliminary airplane tow tests are also presented.

INTRODUCTION—While gliders and sailplanes in free flight are exposed to air-load conditions similar to those of powered airplanes, a different category of load is introduced in towed flight. The towing of engineless aircraft has developed into an established technique for the purpose of (1) launching them into the air to a point from which they can glide down in training hops, (2) launching them into the air so that they can continue to soar in favorable air currents, or (3) ferrying them to a destination. Towing is effected usually by automobile, motorboat, winch, or powered aircraft. The tow force being an extraneous force, it can assume magnitudes and directions independent of the flight attitude of the towed craft. If excessive, it may surpass the design allowance for such a force for either craft. In the earlier days of towing, some accidents were actually attributed to excessive tow forces. It is therefore necessary for design use to establish reasonable limits of the tow forces that engineless aircraft may encounter in service.

It has been recognized that the towing forces and the loads which they can impose on the glider structure depend greatly on the towing method and technique. Statistical data on these forces under a variety of conditions are therefore a requisite for establishing practical design requirements.

Reference 1 describes a tow-force recorder built into a towing pole mounted on a high-performance sailplane ("Austria," weight 1,070 lb.) with a maximum accelerating force of 360 pounds, a maximum tow-force peak in flight of 200 pounds, and an average of 110 pounds. The use of a camera obscura for investigations into the climb of sailplanes in auto tow is also described.

Reference 2 gave samples of tow-force records of auto tow climbs of a primary glider ("Zogling," weight 340 lbs.) without wheels exhibiting sharp oscillations of a frequency of the order of 2 seconds and reaching peaks of 250 pounds in the hands of the instructor and of 450 to 600 pounds in the hands of the students. A sailplane ("Fasold," weight 650 lbs.) reached 300 and 450 pounds in auto or winch tow and but 225 pounds in aircraft tow.

Weak links were suggested in reference 3 for use in winch towing of gliders to be designed to fail at 700 to 800 pounds.

In order to confirm and supplement these tests, a program of tow tests under conditions meant to cover the varieties of American glider operation practice was instituted in 1937, under the sponsorship of the National Advisory Committee for Aeronautics upon the recommendation of groups affiliated with the Soaring Society of America. The present note is a report on these tests.

The auto-towed-glider tests were divided into two groups. The first group of tests comprises 16 test flights with a "Cadet" type of glider, all by one very experienced pilot on a busy and limited airport at Akron, Ohio, under a variety of wind conditions and piloting techniques to simulate both good and bad practices. This group of tests was conducted by the Akron Glider Council under the direction of J. Funk and H. Funk on October 30, 1937.

The second group of tests covers 8 test flights on a "Solvfuglen" type of glider by several pilots of varied experience on a desert dry lake bed (Muroc Dry Lake), the vast, flat, and smooth terrain of which lent itself ideally to towing for many miles and to a training routine. This group of tests was conducted by members of the Southern California Soaring Association under the direction of V. Jensen in August and September 1938.

In order to gain some preliminary information on the tow forces in aircraft tow and some clues regarding measuring technique for aircraft tow, which differs somewhat from auto tow, a third group of tests consisting of two test flights were conducted on May 21, 1939. These flights were made at the Compton, California, airport on a "Briegleb" Utility type of glider. Towing-force measurements were obtained in straight climbing flight.

RESULTS AND DISCUSSION OF TEST I—*Towing forces*—The maximum towline forces observed in these tests are of the order of 800 pounds, or 1.6 times the gross weight of the glider. This maximum, however, was reached or approached in deliberately steep climbs that were admittedly more severe than those recommended for normal practice. The value may be considered as extreme, although there is, of course, no guaranty that higher loads cannot be reached, for instance, by driving the tow car faster or against a stronger head wind. There is, however, no reasonable incentive to do this under "normal" operating conditions.

The highest tow-force component normal to the wing chord, as evaluated from the tow force times the sine of the corrected towline angle, that ever occurred during the tests is of the order of 550 pounds (1.1 gross weight). This value was attained on flight 9 and almost reached on flights 4, 5, and 6, which were the steepest climbs; on the other flights, the normal force stayed considerably lower and rarely exceeded 400 pounds (80 percent of gross weight).

The rate of climb noted during the phases of largest normal forces was of the order of 1,000-1,400 feet per minute, but it may be noted that forces nearly as high are reached toward the end of a tow when the line is