A Glide Angle Indicator for Sailplanes

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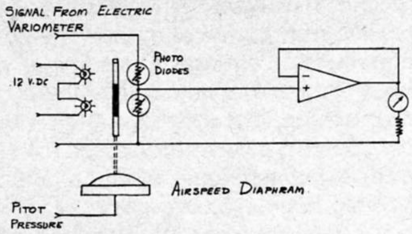

Fig. 1. Schematic

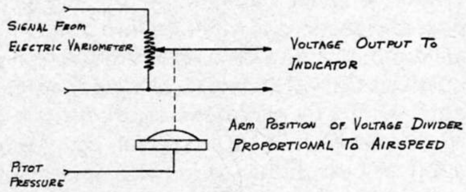

Fig. 2. Equivalent circuit

A practical method and hardware are described for measuring the glide angle continuously for a sailplane in flight. The device is a simple electro-pneumatic transducer which mechanically divides an electrical signal derived from an electric variometer by a linerarized pneumatic airspeed signal. The output signal is amplified and presented on a panel meter which is calibrated in units of glide angle. The accuracy of the instrument is 5% and the response time is comparable to that of the electric variometer used (1 to 2 seconds). The instrument can be built and calibrated by a person of average ability for less than $ 25. Power, space, and weight requirements make the instrument quite suitable for incorporation within the standard instrumentation for sailplanes.

Introduction

Many times while flying, I have made the mental division required to compute the glide ratio of the sailplane. The need for this information occurs very often during a typical flight, and several slide rule type devices are presently available for this purpose. For some reason there is no available instrument for automatically performing this task and displaying the information to the pilot. The instrument to be described in this paper does just this function simply and accurately at a very modest cost. The cost is held down by using a simple mechanical division technique utilizing a pneumatic diaphragm driven voltage divider. The rate of sink signal is taken from an electric variometer, and for the purpose of this paper is assumed to be available and perfectly accurate.

Description of System

Fundamentally, the glide angle of a sailplane is the ratio of airspeed to sinking speed. This involves the nonlinear operation of division – the most difficult operation to perform mechanically or electrically. For the purposes of this paper, it is assumed that a voltage proportional to the rate of sinking speed is available of sufficient magnitude (3 volts across 5 K ohms). All cost information is exclusive of this signal. The division process can be simplified slightly by dividing the rate of sink by the airspeed. This avoids the difficulty of dividing by zero. The indicator may then be calibrated in reciprocal units and then will read in the usual units of glide angle, e.g. 35 to 1. Of course, the scale will be nonlinear, but this is not a big disadvantage for presentation to the pilot. If desired, further processing by means of an operational amplifier with a logarithmic feedback element could be used. A voltage may be easily divided by mechanically moving the arm of a potentiometer. It can be easily shown that for an unloaded potentiometer, the output voltage can be made to be proportional to one divided by the arm position. Hence, if we were to move the arm proportional to the airspeed, we would have the makings of a glide angle indicator. Unfortunately, the force available from the pilot pressure for any reasonable size diaphragm is very small for the airspeed range we are interested in. Also the friction on any potentiometer is quite large and would cause large hysteresis. Some other type of voltage divider must be used. Strain gages could be used but much amplification would be required. The idea used here provides suitable division with almost zero friction (fig. 1 and 2). A voltage divider is made up of two photo resistive cells in series with the signal taken from the center connection. A shutter driven by the airspeed diaphragm alternately covers one cell and uncovers the other. As the uncovered cell is being covered, its resistance goes up and as the other cell is being uncovered its resistance goes down. With proper shutter design and actuation, the overall resistance can be made to remain reasonably constant. Hence this system can be made to operate exactly like a potentiometer with the exception that only a shutter moves, and it does so with very low friction. All that remains is to measure the voltage from the photo resistive cell divider without loading the circuit. As the generation of light for the photo cells is extremely power consuming, it is not economical to use lots of light to keep the resistance of the divider network low. Hence, it is necessary to provide an impedance match between the divider and the indicator. Little voltage gain is needed, but an impedance of at least 10 meg ohms is required to avoid loading the divider. A low cost integrated circuit operational amplifier connected in a follower arrangement provides the necessary power gain and also gives a very high input imedance. A suitable amplifier costs less than $ 4.

The most expensive item of the system is the indicator. A suitable meter may be found in a surplus store for $ 3 to $ 5 while up to $ 25 may be spent for a good meter. A 1 ma. meter is desirable, but the operational amplifier can supply sufficient current for a 4 or 5 ma. movement.

The only remaining problem is the airspeed diaphragm. The pitot total pressure is proportional to airspeed squared, and we must have a shutter displacement proportional to airspeed. Here we fall back on the standard technique used in airspeed indicators. By providing a series of adjusting screws which limit the travel of the cantilever spring, we can make the spring nonlinear and end up with the desired displacement (fig. 3).

Calibration

The first step in the calibration is to set up the airspeed diaphragm. The only equipment necessary is a pressure source which can be improvised as shown in the calibration setup sketch (fig. 4). The output indicator is connected as shown and 12 volts D.C. is connected instead of the variometer signal. The pressure to the airspeed diaphragm is then varied and the linearity adjusting screws are adjusted starting with the one nearest to the base of the cantilever spring until a reasonably linear voltage versus airspeed curve is obtained. The system is then ready for the glide angle calibration.

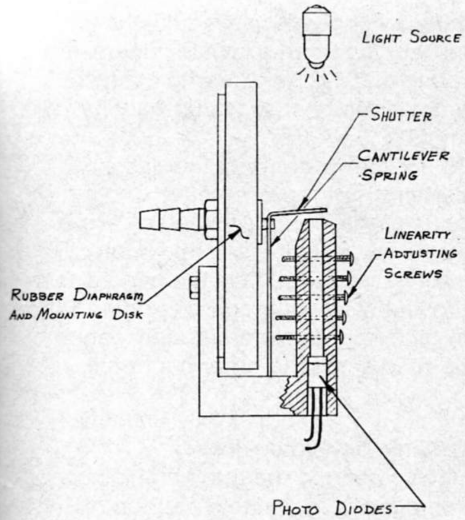

Fig. 3. Divider assembly-mechanical

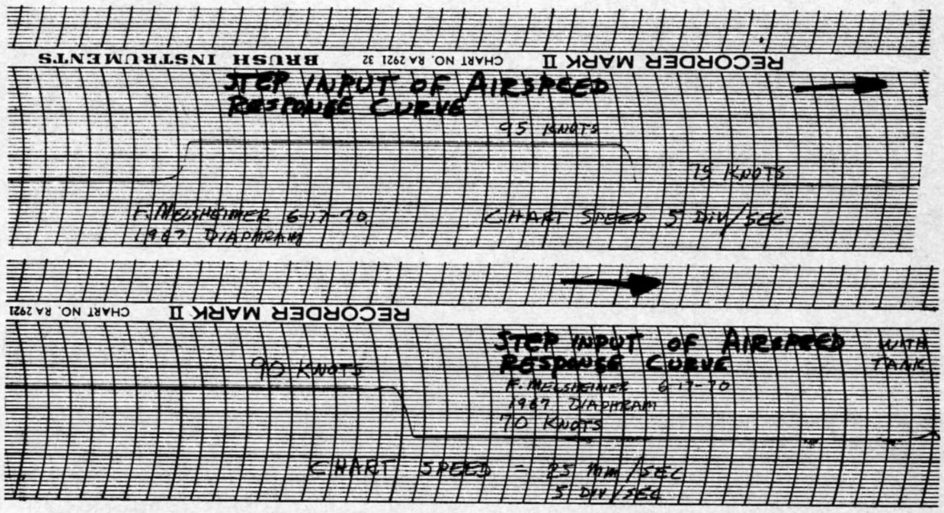

Fig. 5. Dynamic response curves for airspeed diaphragm

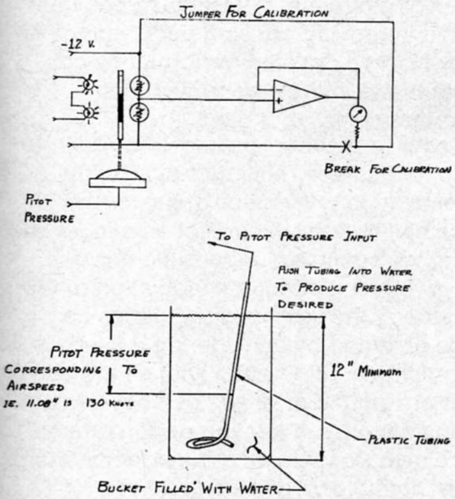

Fig. 4. Calibration set-up

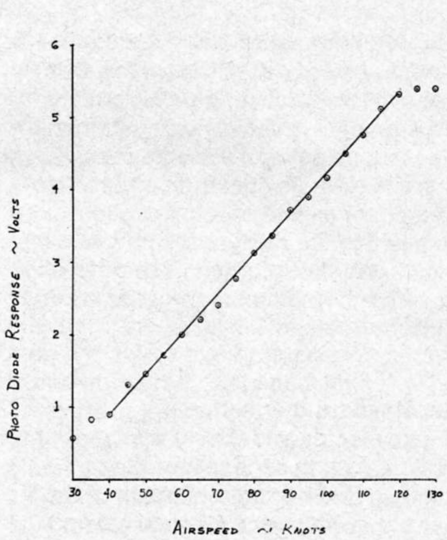

Fig. 6. Divider assembly calibration

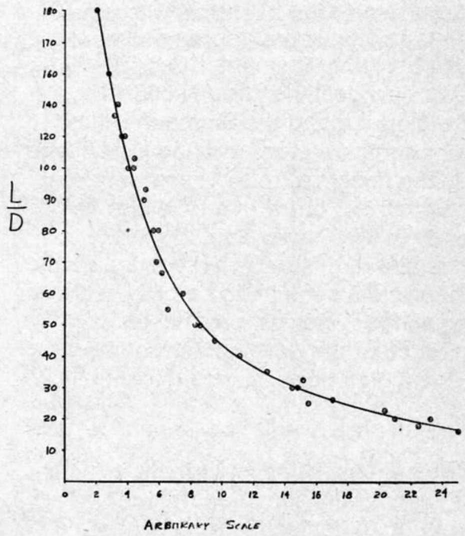

Fig. 7. Glide angle calibration

Glide angle numbers may be marked on the indicator by first setting a suitable airspeed pressure (60 knots) into the diaphragm and then varying the variometer signal. The corresponding glide angle numbers can then be calculated and marked on the indicator. By adjusting the signal level from the variometer, any suitable scale factor can be arrived at for the glide angle indicator.

Prototype Results (fig. 5, 6 and 7)
Only a simple flight test has been performed to date, so the real value of the instrument has not been proven. Laboratory tests have shown that even for a relatively crude diaphragm made from an auto mobile inner tube works surprisingly well for speeds above 50 knots. The scatter in the calibration data is quite respectable when the 45 and 50 knot points are excluded.
Dynamic response measurements have been performed for step inputs of airspeed and rate of sink. The response of the instrument for changes in the sinking speed are determined by the electronics, and are much faster than the indicator response or the pilot's response. The response of the system to airspeed changes is of the order of the indicator response time, and is faster than the pilot's ability to use the information.

Future Developments
A better and smaller diaphragm is desired. This will improve the low speed performance of the instrument and decrease the flow of air required by the instrument from the pitot static system of the sailplane. The effects of this flow requirement on the other pitot static operated instruments has not been investigated.
Range changing and expanded scale features are luxury items worth investigating. This could be easily done with additional operational amplifiers for little additional expense or power consumption.
While the accuracy of the system can be made to be very good, the system relies on accurate information from the variometer, and none of the manufacturers advertise the accuracy of their variometers, and usually for good reason. Temperature and altitude compensation are desirable as well as some means of incorporating an estimate of the head or tail wind into the calculation.