CALIBRATING VARIOMETERS

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In the past few years there has developed an increasing interest in flying for maximum cross-country performance using a table of air-speeds based on variometer readings. To use this table successfully it is necessary to have a variometer whose readings can be interpreted reasonably accurately, and this certainly cannot be said for many variometers in use, particularly after modifications for total energy have been made.

The relevant parts of my own instrument panel are:

(a) A standard 0-35,000 ft. Mk. XIV sensitive altimeter.

(b) A Kelvin Hughes KB 220/02, 10-130 knot, airspeed indicator.

(c) A "Memphis" variometer. This is a sensitive short-lag American instrument with pointer presentation similar to a Horn. It is not "total energy." It is graduated in knots from 20-up to 20-down.

(d) A Cosim variometer, which has been re-calibrated to read in knots. The capacity is provided by a thermos flask and by—

(e) a total energy device consisting of 2 standard industrial copper bellows suitably mounted in a casing which is fed with pitot pressure.

In order to check and calibrate the above panel the following rather elementary test rig was developed. It has proved so successful that it may be of interest to others who wish to calibrate their own panels.

The calibrator consists of an old paint can (2 gallon) with a screwed airtight cap through which it can be filled with water. At the top a pipe is soldered on, which is led to the instruments under test via a T-piece. The third leg of the T-piece leads to a short length of pipe with a clamp on it which is used for controlled flow of air into the system. The bottom of the paint tin is led via a four-foot length of hose to a cock discharging into a bucket. The principle of use is equally simple and consists of letting the water out at a controlled rate, thus progressively increasing the depression in the top of the can. If an altimeter and variometer are connected to this depression, rates of climb can be measured by timing the altimeter over a range of a few hundred feet while observing the indication of the variometer. Rates of descent are achieved by closing the water cock and *carefully* opening the air venting clamp. It is essential that all movements be made carefully to avoid getting indicated rates of climb in excess of the capacity of the instruments. It is recommended that all testing be done in the range 0-500 ft. on the altimeter to reduce the risk of damage to any instrument; it is also a good plan not to fill the tank to more than about three-quarters full so that there is always a good air space capacity.

Prior to testing, the pitot and static lines are both connected in parallel to the calibrator. The first test consists of a leakage test. The cock is opened until, say, 200 ft. shows on the altimeter; the cock is then closed and both variometers should return to zero and the altimeter should remain steady. If this does not happen, the leak can be found by squeezing off various pipes and watching the instruments.

When *all* leaks have been removed, test 2 is a calibration run on the variometers. Calibration can, of course, be made in ft. per sec. or ft. per min. or anything else one prefers, but my own variometers are calibrated in knots. This may seem a curious unit to choose; however, it means that one can make direct glide-ratio calculations, e.g. speed 50 knots, rate of sink 2 knots—glide-ratio=25; it may seem an even less curious unit when it is realized that 1 knot=100 ft. per min. — for all practical purposes. For this test the water cock is opened until some steady reading is obtained on one of the variometers, say 500 ft. per min. (5 knots). This reading is kept steady by small adjustments of the water cock while the altimeter is timed over a range of, say, 400 ft. A similar descending run is then made. By doing a series of runs, a calibration can be produced for both variometers.

Test 3 is a check on the total energy setup. For this test the pitot line is disconnected from the test rig, which is now fed only into the static system while the pitot line is left to atmosphere. The effect of this is to produce an apparent increase in airspeed at the same time as the height increases; this deludes the total energy system into believing that the aircraft is gaining kinetic energy as well as potential energy, and a little calculation shows that the net result is a total energy variometer reading which is exactly double that timed on the altimeter. For those who are interested, the mathematical reason for this is added as an Appendix. If the A.S.I. is connected while carrying out this test, care must be taken not to exceed its limits. On my own panel I do not exceed 500 ft. on the altimeter, which gives 105 knots on the A.S.I. Incidentally, should there be any doubt on the calibration of one's A.S.I. the test rig can be used to calibrate it from the altimeter. For all practical purposes the correct reading of the altimeter for a given A.S.I. reading can be calculated from

$$\text{h ft.} = \left(\frac{\text{V (knots)}}{1.48}\right)^2$$

Appendix

A total energy variometer does not in fact show the rate of change of total energy of the aircraft, but rather shows the rate of change of the sum of actual height plus "kinetic height;" this latter term is coined to mean the kinetic energy divided by the aircraft weight, and its units are feet.

In the case of test 3, the kinetic height (H) is given by

$$H = V^2 \div 2g \ldots\ldots (1)$$

where V, in ft./sec., is the apparent airspeed.

But this apparent airspeed can be obtained from

$$p = \tfrac{1}{2}\rho\, V^2 \ldots\ldots (2)$$

where p is pressure applied to A.S.I.

But in this case the same pressure is applied to the altimeter; hence

$$p = \rho g h \ldots\ldots (3)$$

Therefore from (2) and (3) we get

$$\rho g h = \tfrac{1}{2}\rho V^2$$
$$\text{or } V^2 = 2gh$$

Substituting this in (1) we get

$$H = 2gh \div 2g$$
$$\text{i.e., } H = h$$

Since the T.E. variometer shows the rate of change of H+h, it will in fact show the rate of change of 2h, or more simply, twice the rate of change of h.

(I am sure this is all painfully obvious and could be written in about two lines but I had to write it to prove it to myself!)