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dicator needle is on the same shaft as the vane. Spring tension causes the pressure-difference to be proportional to the vane rotation; the leak area may also be a function of vane position. In method of reading presentation and in time lag, the "Horn" is comparable to the Aircraft Indicators Company instrument.

The Total Energy Variometer With Venturi

If the variometer is connected to a venturi (giving a pressure $P_s - (\frac{1}{2}) pv^2$) instead of to static or cabin pressure (p_s), the instrument reading will be a function of airspeed changes as well as altitude changes (ρ is air density, v is velocity). A venturi with mouth area $\sqrt{2}$ times as large as the throat area turns out to be the desired configuration. With such a venturi, the variometer reads "rate of change of *available* height" rather than "rate of change of *actual* height." *Available* height is the altitude the glider could zoom up to as the airspeed dropped off to zero. Available height is of more interest to the pilot than actual height. It is a height which represents the actual height due to position and an additional height due to velocity.

With this venturi, "stick thermals" are eliminated. In still air the pilot cannot cause the variometer to show "up" even if he zooms upward or loops. The total energy variometer has its greatest use when the pilot is flying at high speed and trying to estimate the lift available in thermals he passes through. Without the venturi, "stick thermals" tend to hide the true thermals. The average effective cross country speed of a glider is increased roughly 5 per cent by use of the venturi.

Unfortunately, the simplest venturis are so greatly affected by yaw as to be unusable. In 1952, Mr. Frank Irving[5] devised a venturi which is practically unaffected by yaw to 25°; it has a plate at the downstream end which serves to keep the exit pressure constant despite yaw. More recently, Mr. Temple[6] has developed a smaller, more streamlined yaw insensitive venturi.[7] Bulges on the forward part of the fuselage have sometimes been used to provide the $p_s - (\frac{1}{2}) pv^2$ pressure. The method is successful, but requires careful experimental calibration of the particular installation.

The total energy variometer will respond to air velocity changes as well as glider velocity changes, since it is concerned only with the relative motion between glider and air. Thus, it does not completely separate vertical from horizontal air motions, but it does separate them in the way most useful to a glider pilot.

Sinking Speed Correction

In still air (at constant speed so there are no airspeed changes to affect a total energy venturi) a glider has a different sinking speed at each airspeed. In ordinary flying the pilot can mentally estimate the rate at which the glider sinks through the air—but it would be nicer if the variometer automatically added the sink rate, and thus showed the vertical air moion instead of the vertical glider motion. This can be done, approximately, if air flows continually through the variometer indicator at a rate proportional to v^2. The performance curve of a sailplane can be fairly exactly duplicated by such a v^2 curve; if properly adjusted it can be within a few inches per second of the true sink curve over the cruising velocity range (say 40-100 mph).

The correction can be made by a variety of methods. Probably the nicest is to utilize the total energy venturi and the dynamic pressure from the pilot tube. The pressure difference between these two is proportional to v^2. Connect the pitot tube which runs from the air capacity to the indicator device. In the tube just installed, add one or more needle valves to act as an adjustable air resistance. Later, when the glider is flown in still air, the valves can be adjusted exactly so as to cause the variometer to read close to zero over the cruising velocity range. If, for example, the air resistance in the valves is about 20 times the resistance of the indicator mechanism, and if the total energy venturi is altered slightly to give $p_s - 1.1 (\frac{1}{2}) pv^2$ instead of $p_s - (\frac{1}{2}) pv^2$, it is apparent that the pressure at the air capacity will be the desired $p_s - (\frac{1}{2}) pv^2$. Thus there is a steady flow through the variometer indicator proportional to v^2 (the flow from pitot to venturi) to cancel out the normal sinking speed, and yet the air capacity still has the $p_s - (\frac{1}{2}) pv^2$ pressure to work with. Actually the alteration of the venturi is too small to bother about.

This correction flow must be proportional to the pressure difference between the tube ends; therefore the flow in the tube must be laminar. Because the flow rate is so low even the needle valves should not cause the flow to differ materially from the laminar, provided the needles impede the flow for at least several tenths of an inch. If a restrictor tube is substituted for the needle valves, its dimensions can be calculated as a function of the size of the air capacity. For a typical case, where a quart capacity is employed and the glider calibration point is 5 ft/sec sink at 70 mph, one possible restrictor tube is about 2″ long with 0.01″ inside diameter.

The total energy of a glider is the potential (height) energy plus the kinetic (velocity) energy. The rate at which these two change, plus the rate at which energy is lost by drag, equals the rate at which an upcurrent is delivering energy to the glider. It is this last mentioned quantity that is of most value to the pilot. To find it out he must measure the other three—the rate of height change (variometer), the rate of airspeed change (total energy venturi), and the rate of drag energy loss (sinking speed correction).

A variometer that actually can measure vertical air motion makes an ideal instrument for use with the widely used Ring Scale Airspeed Selector, which tells the pilot the optimum speed for flight between thermals provided the strength of the next expected thermal can be reasonably estimated. The Selector is a ring around the face of a needle indicator variometer. Consider its use with a conventional variometer — when flying between thermals the pilot notes what velocity on the Selector the variometer needle points to. If the flight speed is higher, the glider should be slowed to give optimum results. The process is an iterative one because as the glider is slowed the variometer needle rises, so a new velocity is indicated. With the addition of the sinking speed correction device, the Selector can be simply redesigned and applied, and now the velocity indicated by the needle is the optimum one directly.

Audio Variometer

There is much to be gained if the variometer indication is presented to the pilot by sound. More than any other instrument except during blind flying, the variometer must be watched continually. If the pilot can get the reading by ear, he can improve his thermal flying by watching nearby gliders, and he can materially improve the overall flight by studying the cloud formations to be used next.

The Temple variometer can be immediately adapted for audio indica-

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