A THERMALLING TURN INDICATOR

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SUMMARY

An instrument has been developed to use the deflection of the wings of a sailplane to produce an instrument panel display that will indicate to the pilot the direction he should turn when entering a thermal. An additional application is to allow the sailplane to enter streaming/streeting lift a little earlier and stay in it a little longer. Design philosophy, experimentation, instrument details, techniques developed, comments, objective tests and an application to a 1000 km flight are discussed.

1. INTRODUCTION

1.1 What is a Thermalling Turn Indicator (T.T.I.)?

This a panel mounted instrument that indicates by meter needle sideways movement and audio/visual means, which way the sailplane should be turned when entering a thermal. The panel instrument draws its reading from a easily demountable sensor or transducer mounted on the wing stubs behind the pilot's head.

1.2 Uses of a Turn Indicator

In flying cross-country its first and main use is to increase the efficiency with which thermals are encountered and centered. The present method of assessing which way to turn into a thermal by means of the feel of the sailplane or ailerons as against using a sensitive turn indicator as described in the following, may be likened to using the old Cosim red and green ball variometer as against the modern electronic variometer, ie., the method is fairly effective but inefficient.

A second and associated use of the indicator is for time saving, the most sought after commodity for cross-country and competition flying. Assume that we have turned the wrong way, ie. we turn away from the thermal instead of into it, and instead of 600 ft/min (3.05 m/s) lift we turn into 600 ft/min sink for 20 seconds of a turn. We lose 200 ft (61 m) by the wrong turn as against gaining 200 ft for the correct turn. The difference is thus 400 ft (122 m) which represents (400/600) x 60 seconds, ie. 40 seconds. If 20 such thermals are used in a flight and only half of these are initially turned wrongly, then the total time loss from this cause would be 10 x 40 = 400 seconds. This is 6 minutes 40 seconds, a considerable time loss in competition and also badge or record flying.

A third use is assistance in moving the aircraft toward streaming/streeting and staying in it a little longer for additional time saving.

A fourth use is in moving a thermalling turn to be more concentric with the core or concentric with a newly developed core or the major core of a twin-core thermal. Finally the indicator can be used to demonstrate to student pilots the correct instant at which they should turn when entering a thermal and the feel of the controls and presence or not of wing uplift at this instant.

2. INITIAL THOUGHTS, OBSERVATIONS AND EXPERIMENTS

2.1 Observations

Soon after starting to fly sailplanes the author began to appreciate that one could see the glider being moved sideways as a thermal was approached, by the movement of the top the cockpit against the horizon. A correction the other way often helped to locate the thermal.

When one wing tends to lift or extra force is felt on the ailerons and a correction is made toward the lifting wing then the duration for which one could stay in lift was extended and/or a thermal could be located.

2.2 Initial Thoughts

It seemed to the author that these methods were good but that they were not sensitive enough and that sailplanes should be able to fly, especially interthermal, in the way that Ibises and other such birds fly, ie. not in a straight line but with a weaving pattern that will take it into any thermals in minimum time and with a minimum number of centering turns. This path would take advantage of any general lifting air encountered.

To put the above discussion in a more concise way, the MacCready ring allows the pilot to vary speed according to sink and lift essentially in the vertical plane, but an instrument was required that would allow the pilot to sensitively guide the sailplane movements in the horizontal plane. It is very important to note here that a good lookout (as always) is important for flying safety purposes.

2.3 Experimentation

When a thermal is approached, the wing on the thermal side should bend more than the other wing, even if only for a short time. To investigate this, strain gauges were first cemented to the wing spar stubs of a glider.

A portable strain gauge meter was not sensitive enough.

Also the strain gauges are applied to the surface of the wing spar stubs and this surface may consist of fibreglass (or other) rovings that have a protective as well as a structural function, with the result that the strain recorded is apparently not always directly related to wing bending. (This implies, of course, that the strain gauge should be set in the material at manufacture.)

Another practical difficulty with this approach is that since the wings are removable from the fuselage and the strain gauges are attached to the wings, a tedious system of electrical pin type connectors must be coupled for rigging and uncoupled for de-rigging.

For the above reasons, experiments were then begun into the measurement of the deflection of the wing stubs. A mechanical dial gauge type indicator was found to be impracticable for frictional and inertia reasons. A moving armature instrument was next tried with moderate success, but this was discontinued at that time because of bulkiness, weight and temperature problems.

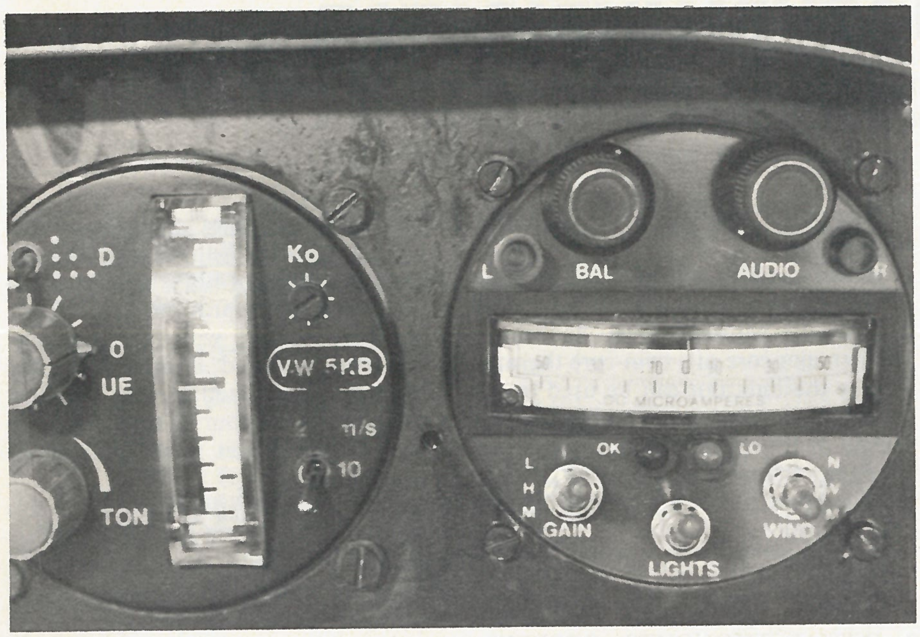
A strain gauge type sensor was then devised and this is being used with good results in a Mosquito 15 metre (racing) class sailplane. Additionally, a two seat Janus fibre glass sailplane has been fitted with an indicator and this also produced good results, and initial tests have been made on a Nimbus 3.

The above experiments have indicated that one wing does bend momentarily (impulsively) more than another, as above. This is apparently due to the mass centered about the longitudinal axis of the aircraft (mass moment of inertia) resisting the initial rotational acceleration caused by the lift being greater under the bent wing than the other wing. Although the mass moment of inertia (including air effects) has not been established, calculations using estimates seem to give a response time of the same order as that found in flight.

2.4 Instrumentation Details

2.4.1 General

As can be seen by the photograph, the panel instrument is mounted in a standard 3.1/8" (79.4 mm) cutout in the instrument panel and connected by cable to transducer or sensor mounted on the spar stubs behind the pilot's head. The 'BAL' knob is used for centralizing the meter needle after the transducer is placed in contact with the spar stubs and if necessary, during flight. The 'AUDIO' is an on/off switch and volume control. The small object to the left of 'BAL' is a red alert light and a green alert light is to the right of 'AUDIO'.



Turn indicator (on the right) mounted next to a variometer. When the central (turn) indicator needle moves to one side and the variometer moves up toward a chosen value, a turn is made to the side indicated.

The sensitivity switch is marked 'GAIN' and 'L', 'H', 'M' markings to the left of this stand for low, high and medium sensitivities respectively. The three position switch marked 'WIND' is to allow the audio/visual alert to be triggered when the meter needle has moved a chosen amount. The 'OK' and 'LO' lights are to signal when the battery is getting low. The panel instrument is easily disconnected from the sensor cabling and it is fitted with replaceable circuit boards for ease of maintenance. The sensor is easily disconnected from its cable and the wing stubs on which it is mounted, thus allowing ease of rigging and de-rigging.
The strain gauge signal causes a horizontally-moving needle pointer in an 'edgewise' meter to move to the left if the thermal is on the left or to move to the right if on the right. An audio/visual warning system is fitted so that pilots can keep their attention directed outside the cockpit for safety reasons.
The audio consists of a distinctive two tone 'beeper' that only sounds when the needle on the meter reaches a value chosen by the pilot. The visual warning consists of lights of different colours, one on either end of the meter scale and another to show when the audio sounds.
The indicator uses normal 12 volt supply and its current consumption is of the order of milliamps. However it is recommended that a 7-ampere hour (gel or other) battery be used for long (eg. 5 hour) flights when a radio is used also, and the relatively new 10-ampere hour battery for longer flights.

2.4.2 Filter
It has been found necessary to install an electrical filter to eliminate short term wing bending inputs from turbulent air and other such sources. The filter has eliminated an early problem where the indicating needle oscillated from side to side, so tending to mask the single sideways needle movement and audio/visual signal resulting from wing bending on the side the thermal is situated.

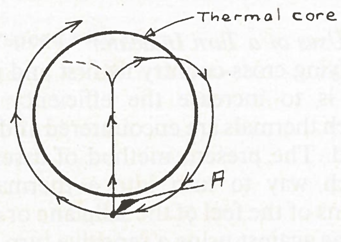
2.4.3 Sensitivity
Useable thermal strenghts may vary from say one knot one day to fifteen knots on another day. Also carbon fibre wings are stiffer than glass fibre wings. Thus the instrument sensitivity must be variable to alow for these factors. Three levels of sensitivity have been provided and found to cover all operation conditions.

2.4.4 Effect of Controls
Once the controls are used to initiate a turn, they induce additional wing bending and a false indicator signal in the opposite direction to the initial meter needle movement is registered. So long as this is understood the instrument can be used without compensation for controls, ie., the thermal is approached with as little control movement as possible until an audio/visual alert is displayed and the turn then initiated ignoring any indicator readings for a short time after the controls are applied. The false reading may be eliminated. This is being incorporated so that the indicator can be used with or without control compensation.

2.4.5 Zero Shift
During flight, the meter needle may change position and have to be re-centralized (on average once per hour). Although this is a minor adjustment, research is proceeding with the aim of eliminating this position change.

TECHNIQUES DEVELOPED, COSTS, COMMENTS, OBJECTIVE TESTS, ODD READINGS

3.1 Techniques developed
3.1.1 How and when to turn, and safety
Thermals may be flown into in three ways. The thermal core may be on the left hand side or the right side or it may be straight ahead. In the first case the meter needle moves left, the audio/visual alert is triggered, and if the variometer reading (audio preferably) is increasingly toward a chosen value, the pilot turns left or just veers left. In the second case the needle moves right and with the variometer increasing to the chosen value, the pilot turns or veers right. In the third case the pilot (unknowingly) is flying directly toward the thermal core. The variometer reading rises toward the chosen maximum value for the day the turn indicator needle stays central, ie., there is no audio/visual signal. The sailplane may then be turned left or right as shown in the diagram.



Assuming a right hand turn as shown, the initial part of the turn takes the sailplane away from the thermal core and so on turning 270° the pilot has to cross over the original track at A as shown to ensure that the thermal is centered as soon as possible.
Although detailed readings have not been taken as yet (refer section 3.2), the frequency with which 'dead ahead' thermals are met appears to be about once per a 3–5 hour flight. Assuming a 300 km flight and 6 thermals per 100 km, this means one in eighteen thermals or about 5% of the thermals encountered are met by flying directly through the core. (The above assumes a cloudless day, but with the pilot steering a course that will take the aircraft over the best thermal sources available).
If the above is taken to be reasonably correct, this means that left or right indications will occur and be significant most of the time and that only occasionally does the variometer rise toward the chosen daily maximum with the meter needle remaining central and no audio/visual alert sounding.

The meter needle is referred to above for explanation purposes, however for safety in flying, the turn indicator has been designed so that pilots can turn on audio/visual signals alone, eg., a low frequency tone and red light to turn left and a higher frequency tone and green light to turn right.

To give reasonable turn indicator readings, thermals usually have to be at least 1 knot (0.51 m/s) in strength and be reasonably well structured and organized. "Well structured" to me means that the lift on entering the thermal rises reasonably quickly (not 'pancake' type thermals) and "organized" means not a turbulent mixture of rising and sinking air. Another way of rating thermals is to talk of a gradation from lumpy to broken to rough. The lumpy thermal varies smoothly in strength around the core, the rough thermal varies rapidly in strength around the circle and the broken one has sections in which turbulent mixtures exist. To attempt to put the thermal classification on a more concise basis, the 'normal' thermal model proposed by Speight (1) 1982 seems to fit best what I consider to be a reasonable description of a thermal and this is adopted for all later discussions.

However, as a general rule, if the variometer is working effectively (ie., not 'puffy' thermals) then the turn indicator works also. One difficulty many pilots have is timing the turn (or making a decision to turn or not) when approaching what appears to be a thermal. The anguish of this decision can be minimized for normal thermals as follows:

If on a 5 knot (2.6 m/s) thermal day for example a reading of say 2 knots (1.03 m/s) is indicated on approaching a lift area (especially when toward the lower limit of the operating band) then unless the turn indicator either displays a left or right hand signal or the variometer increases toward 5 knots, a turn is not made. Subsequently, should the reading rise to say 2–3 knots and the turn indicator simultaneously displays for example a half full scale deflection to the left, then at this instant (with safe lookout) a left hand turn is made into the thermal. Thus the correct instant of turn is indicated by the simultaneous signals of the variometer and the turn indicator.

Further to the above, when the audio or other variometer warns of lift and the aircraft speed is reduced, there is usually a second or so while one waits for the correct moment to turn. This is a transitionary state between inter-thermal flight and a (possible) thermalling state. It is while flying straight ahead during this period that the turn indicator may give its audio/visual signal to turn right or left.

3.1.2 Use in approaching and leaving thermals

Occasionally when (unknowingly) approaching a thermal a turn indication is obtained on one side or the other and a small correction toward the indicated side will sometimes steer the aircraft into the thermal. Similarly on leaving the thermal, indications can sometimes be followed to maintain the aircraft in lift a little longer by using small control movements.

3.1.3 Use in streaming/streeting

In a similar manner to 3.1.2 above, occasionally small corrections can be made to maintain the aircraft in lift for additional time.

3.1.4 Single turn centering (S.T.C.)

In using a series of thermals when flying cross-country, the ideal is initially to gain height, fly in the best air possible until toward the bottom of the chosen operating band, strike a thermal and turn immediately into the best part of the thermal in one turn and regain height as quickly as possible and so on.

The process of striking and turning in the thermal involves the correct estimation of three position factors and three time factors: thermal on the right left or central, turn too early, at the correct time or too late. With an indicator the six factors can usually be judged correctly. Thus when the variometer is rising toward a chosen maximum daily value and the device indicates a left turn, for example, then a turn is usually initiated in the correct direction at the correct time to allow the thermal to be centered in one turn with minor corrections during that turn. (The above assumes 'normal' thermals as discussed in 3.1.1).

3.1.5 Re-centering a thermal

(a) A multi-cored thermal;

(b) When a stronger core develops during thermalling;

(c) When a thermal core shifts due to wind shear.

Each time a turn is made in a normal single cored thermal the meter needle stays relatively still. However, if a stronger core is adjacent to the turning circle, the meter needle will move toward it when it is approached and back again after it is passed. When thermalling alone, if the above is noticed during a turn, then each time the stronger core is approached the thermalling turn is progressively shifted over toward the stronger core at the moment the meter needle moves toward the stronger core. Alternatively, a quicker method for very strong cores is to initiate a turn in the opposite direction at the moment the meter needle moves toward the stronger core. The stronger core is then circled and fully centered. As a rough guide the stronger core needs to be about twice the strength of the first core circled for the effect to be readily noticed and easily used.

3.2 Objective tests

In the last few months an initial attempt at objective tests by the author has been made by taking the following readings for each thermal over a number of flights:

Time.
Left or right indication.
Was the turn indicator correct or not.
Height of entry into the thermal.
Height of leaving the thermal.
Average lift.
Thermal number (ie. first, fifth, etc.)

A simple counting device was carried for counting the thermals and a small tape recorder for recording the rest of the data for each thermal. A few examples follow:

5th March, 1983. A 200 km task.

Wind 5–10 kt NE, 2/8 to 8/8 (overcast). Cumulus with base varying from 4000 to 6000 ft (1219.2–1828.8 m). Thermals initially irregular in strength due to overcast but smooth although spread out.

The indicator showed a correct right hand turn for eight thermals (two of which died after one turn), two correct left hand turns, one thermal hit dead in the centre and one wrong turn. The latter was a turn taken on very slight indication when low. Thermal strenghts varied from 4 to 6 knots.

12th March, 1983

No cumulus, thermal tops 4000 ft (1219.2 m), wind 10–15 kt NE, thermals varied from lumpy to rough to broken (see 3.1.1) over a 200 km course. The indicator showed correctly five left hand turns and five right hand turns with average strength of about 4 knots, two thermals gave a left reading quickly followed by a right reading. The left reading was assumed correct but in each case the average lift was only of the order of two knots.

14th May, 1983

Wind 5 kt NE, with 2/8 cumulus with base 5000 ft (1524 m) but sometimes overcast. Thermals broken at times due to marine type air. The device showed two left, three right turns correctly and allowed one thermal struck centrally to be centered. One thermal gave a left reading quickly followed by a right reading but this died after one turn. Thermal strengths varied between four an six knots.

As seen from the above tests, experience so far has shown that if on entering a thermal it gives an indication to turn one way rapidly followed by an indication to turn the other, then the thermal is usually not worth using.

3.3 Comments

3.3.1 Entering a bubble

The question can be asked, "If the device works for a thermal that is continuous or semi-continuous from the ground to the height at which the thermal is entered, will it work for a bubble?"

A bubble after separating from the ground would appear to assume the cross-sectional 'doughnut' structure as illustrated in Helmut Reichmann's book "Flying Cross-Country". (This shape is assumed apparently to allow it to rise efficiently through the relatively still surrounding, air). This being so, if the aircrafts is flown above or below the bubble then no turn signal will be displayed because little or no lift is present. However, if the bubble is penetrated on its own level, then normal lift and turn indications will be obtained. Incidentally, from general flying experience and use of the indicator, the author now believes that a continuous thermal is made up of a series of doughnut type thermal rings stacked one on top of the other, a parallel being drawn perhaps with the human spinal cord and its vertebrae. The rings (except an occasional perfect thermal) are not placed symmetrically over each other but are shifted horizontally with respect to each other in many directions of the compass, this being partly controlled by the wind strength and direction at the various heights. Any vertical separation between rings will also vary. The author has on several occasions entered five knot and stronger thermals and struck (what appears to be exponentially increasing) lift without first passing through and sink. This would seem to indicate that it is possible to enter a thermal between the doughnut type rings.

3.3.2 Should the indicator work all the time?
Variometers are sometimes of little use on days when thermals are gusty, turbulent or broken. Similarly the indicator will not work well in these conditions, ie. when thermals are not well structured or organized.

3.3.3 Shouldn't sink affect the thermal indicator?
It doesn't appear to. This is probably because the indicator is designed primarily as a thermal striking and centering device. It relies on the concentrated or heaped energy of the thermal to cause one wing to bend more than another. Sink tends to be more diffuse, ie. spread out in larger areas and so does not appear to cause appreciable wing bending. (For turbulent sink, the filter used tends to eliminate signals generated due to this cause).

3.3.4 Can the body sense which way to turn?
Variometers came into general use apparently because most pilots could not sense the difference between lift and sink. Similarly, experiences so far have led the author to believe that (except when the wing is visibly lifted by a thermal) most pilots cannot consistently feel from personal body sensations (eg. accelerations) caused by small rotations or side thrusts on the aircraft, whether the thermal is on the left or right hand side. The author has many times entered a thermal and 'sensed' that the thermal was on one side only to have the audio/visual signal from the indicator show that the thermal was on the other side.

It would seem that the personal 'feel' that pilots receive when entering a thermal is due to side thrust on the aircraft and depending on the position that the thermal is entered, the side thrust could lead one to believe that the thermal is on the left or the right.

3.4 Odd readings when approaching thermals

On the average of about once per flight when a thermal is approached, the meter needle will register a half full scale reading to one side and then almost immediately a half full scale reading on the other side. The reason for this is not known at present but the thermal is usually found to be less than average strength (see 3.2).
When approaching a thermal from downwind, two or three small audio/visual displays to one side have been noted and a small correction to that side frequently allows the sailplane to be steered into the thermal.
This could perhaps be related to experiments conducted by Ingo Rennor and others of Tocumwal, Australia, which seemed to show that a thermal moves more slowly than the speed of the prevailing wind. A series of left bubbles could therefore exist downwind of the thermal due to Karman vortices or other effect. Alternatively, a general lift zone could exist downwind of a source/trigger point and this leads into the major source of lift, the thermal.

4. PRACTICAL APPLICATION TO A 1000 KM FLIGHT

A 1000 km flight was made using the turn indicator on 16th January, 1983 (see May 1983 "Australian Gliding" and April/May "Gliding International" magazines) in a 'Mosquito' 15 metre (racing) class sailplane based at the Darling Downs Soaring Club site at McCaffrey Field near Oakey, Queensland, Australia. (About the middle of the Eastern coast of Australia and about 200 km inland).
The flight took about ten hours. The first hour was flown at 2000–100 ft (600–300 m), the next six mainly in the 6000–3000 ft (1800–900 m) range and the remainder at 8000–5000 ft (2400–1500 m). Cumulus was present for about four hours and the wind strength was 5–10 knots from the NE.
Thermals were mainly of the 'normal' well structured, organized type allowing effective use of the turn indicator as described previously. By reference to the barograph trace, about 60 thermals were used and using the (conservative) time saving calculation described in section 1.1, this meant a time saving of about 20 minutes. As I landed at last light, the time saving most probably allowed me to complete the task.

5. CONCLUSION

The best summation of the author's experience with the use of the turn indicator is that the he prefers to fly with it rather than without it as it seems to make flying more concise, easier and more pleasurable. (The author has 2700 hours gliding time).

6. REFERENCES

1 *Speight, G.* Rate of Climb in Thermals. Australian Gliding, February 1982, pages 28–39.