HELMUT REICHMANN

CROSS-COUNTRY SOARING

(STRECKENSEGELFLUG)


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TO OUR FRIENDS

who helped and encouraged us
when the finish gate
seemed so far away

Paul Bikle
Hannes and Connie Linke
Bud Mears

ERRATUM

Copyright statement is amended to include:

FOREWORD

Surely, man's age-old dream of flying has found its purest and most beautiful expression in soaring. Nature opens up to the soaring pilot a world that would have been thought unreachable only a few years ago — a world of mighty forces, gentle or wild, majestic and mysterious. The pilot enters this realm, flies in it, makes use of its dynamics, and tries to explore and fathom its mysteries. The burden of everyday life is left on the ground and becomes inconsequential compared to the freedom that the wings of a sailplane can provide.

The better we understand nature, the more adroitly we can make use of her powers to fly higher, farther, and faster. The characteristics and performance of our sailplane set the bounds of our possibilities; we "feel" some things almost instinctively, while others must be laboriously learned and practiced. Our bodies are called upon to function under stresses for which they were not designed; our minds must constantly assimilate new situations, weigh new factors, and make decisions.

There are probably few other sports in which success requires not only good physical condition, but also correct recognition of natural processes — a fact which makes soaring a very special sport indeed.

The soaring flights of today, which would have appeared impossible some years ago, are due only in part to the improved aerodynamics of modern sailplanes. The development of the aircraft over the last 15 years has been as rapid and visible as it has been successful. The development of flying, of tactics and techniques, while perhaps not so obvious, has been equally important, if not more so. Mastery of the sailplane itself, that "feel" for its controls that used to be so highly prized among top pilots, has become merely another pre-requisite for performance soaring. It's true that talent still plays a role, but talent alone is no longer sufficient — it must be linked with a great deal of knowledge and practice. Talent and practice complement one another to some extent: the talented pilot may not need as much practice. There is no substitute, however, for knowledge. In today's cross-country flying, for example at contests, a pilot must have a good grasp of the theoretical basis on which his techniques and tactics are grounded, if he wants to have any chance of winning. These theories cover a good deal of meteorological knowledge, as well as somewhat more limited areas of mathematics and physics.

Many of these relationships are simple and easy to comprehend; others are quite complex in their ramifications, and lead to whole chains of logic that can play important roles in cross-country flight. This is the reason that there isn't any single secret to winning competitions or making long flights, even though some pilots still seek such a philosopher's stone. There's a tremendous number of factors that must be considered, weighed as alternatives, and used to make a decision. If the most important of our soaring decisions are successful ones, we have a good chance for success, even if it's impossible to make all decisions completely correctly.

It is quite common at large contests for top pilots to gain or lose large distances among one another, only to meet once again when crossing the finish line. Obviously each pilot has made different mistakes, but the end result remains the same. If it were really possible for a pilot to make optimum use of the weather and the properties of his sailplane, he would probably do 10 to 20 per cent better than even current world champions.

The quality of the good pilot, then, is largely that of making somewhat fewer — or less serious — mistakes than others. Heinz Huth had that in mind when he told a reporter who asked him about his "secret," "Well, the others let me win." I wonder if the reporter really understood what he meant?

If this book helps you to understand more of the factors that influence your soaring, passes on some competition experience, and thus leads to better decisions, it will have added to the joy of our sport and have fulfilled its goal.

— Helmut Reichmann

TRANSLATOR'S NOTE:

Some of the crew techniques described in the original — particularly those relating to the crew's proceeding ahead of the pilot and advising him of conditions, or making wind measurements, etc. — are standard only outside the USA, notably at world championships.

Use of such techniques in other local, regional, or even U.S. national competition is not only considered unsportsmanlike at present, but may actually be cause for disqualification.

OVERVIEW

It would seem reasonable that the soaring pilot is primarily interested in the "How," and only later in the "Why," of distance soaring. In order to avoid overwhelming the reader at once with diagrams and formulas, this book has been divided into two parts:

PART I: FLYING PRACTICE AND TECHNIQUES contains the information the pilot should have in order to participate successfully in distance soaring for badges or for competition. In addition to practical suggestions a certain amount of basic theory is included when unavoidable for complete understanding, and when it can be presented in a relatively simple and compact form.

PART II: THEORETICAL SECTION provides the basis for Part I and can serve to increase the depth of comprehension of the material altogether. It also includes individual points which are considered essential to a complete understanding of the problems of modern soaring. The division of this part into individual sections is based largely on that of Part I, so that direct correlations can be made between theory and practice even when they are not specifically pointed out in Part II.

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PART I:
FLYING PRACTICE AND TECHNIQUES

FLIGHT IN LIFT

Slope Soaring

There is a certain venerable patina on the words "slope soaring," but this technique — which brought some of the first sensational duration and even distance flights to the short history of soaring — still has its uses today. This doesn't necessarily mean that we'll try to drag ourselves across the landscape from slope to slope. There are still situations, though, largely in mountain soaring but also in general soaring when we get to very low altitudes and are praying for a save, when knowledge of slope soaring can make the difference. Moreover, since slope lift is an excellent thermal-triggering method, and slope lift combined with thermals (so-called "slope thermals") are far from rare, it is altogether appropriate that we start with a discussion of this type of lift.

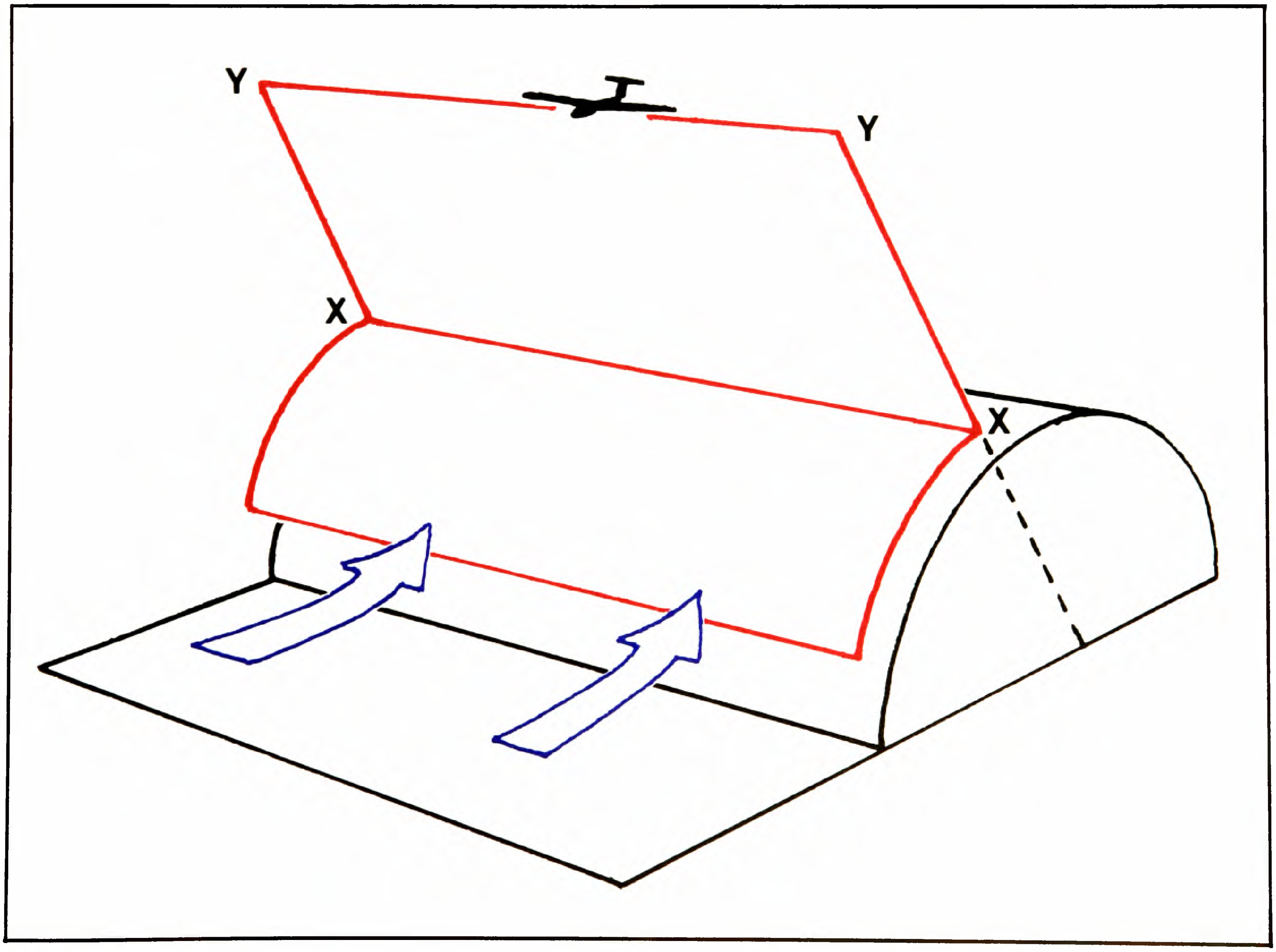
The cause of slope lift is about as simple as can be imagined: a horizontal air movement is forced upward in order to clear an obstacle (the slope), only to sink down again on the obstacle's lee side. In the idealized case of a hill of semicircular cross section and infinite length, situated exactly across the wind, the area of best lift will be a plane extending perpendicular to the slope surface and obliquely upwind (Wallington).

In order to gain height as quickly as possible, then, a sailplane should fly in this oblique plane.

The ideal flight path for a sailplane approaching the slope at a low altitude would thus initially be closely along the slope, with increasing rates of climb until reaching point X, and then along the radial plane with decreasing climb rates. The highest possible altitude, Y, would lie in this plane at a point where the vertical component of the rising airmass exactly equalled the sink rate of the sailplane.

Since the landscapes in which we fly bear only the faintest resemblance to this strict geometric example,

Schematic of slope lift showing best-climb zone



the somewhat disquieting fact remains that in the lower reaches of smooth slopes, the best lift is to be found quite close to the surface. Rougher slopes, on the other hand, cause a thicker turbulent layer near the ground, which makes flight in this area difficult or dangerous; in such conditions, better climb rates can be realized a bit further away from the hill, where the airflow remains more or less smooth.

As a basic rule, flight near the slope should always be carried out with enough reserve airspeed in hand to enable a pullout even in the case of a sudden downdraft. Rotorlike eddies, which can suddenly replace a climb of 800-1000 fpm with a sink of 1500 fpm or worse, are not at all rare in mountainous areas, and sufficient reserve speed to avoid them is imperative.

EDDIES UPWIND OF STEEP SLOPES

Such air turbulence occurs often at the foot of particularly steep slopes or portions of larger, gentler slopes. Thus, as steep a hill as possible is not necessarily ideal for the development of good slope lift; a gentler slope can be more effective if there is less tendency to form eddies. There's no absolute value we can hold to, since general airmass instability also plays a definite role.

The optical impression that steep slopes are dangerous and gentle ones are safe is something of an illusion, and has caused occasional accidents at relatively flat hills: on a steep slope, escape from a downdraft by turning away into the valley is much faster than the same maneuver over a gentle slope. Particular care should be taken around horizontal "steps" or ledges on otherwise steep slopes, since these can cause particularly bad eddies. These are areas where a good reserve of airspeed *and* distance from the ground are especially important.

CLIMB UPWIND OF, OR OVER THE SUMMIT

Somewhere prior to reaching the summit we can expect to climb better if we start to move outward, away from the slope. If we exceed the height of the summit, we may have to move even further upwind. This may not always be the case, however; the slope profile and the wind gradient can both make major differences.

IMPORTANCE OF UPWIND TERRAIN

For the development of good slope lift, the height and direction of the slope are actually not as important as terrain upwind of the slope that will offer the least possible resistance to the wind. Even tall, relatively steep mountains will not generate slope lift, if another mountain to windward has already disturbed the airflow too extensively. This effect is astonishingly common and particularly surprising to the flat-land pilot on his first soaring visit to mountainous terrain. It is seldom rewarding to approach slopes in the lee of obstacles; in fact, sometimes the effect is so pronounced as to cause local reversals in wind direction, and the unsuspecting pilot will find increased sink where lift could normally be expected.

CONICAL MOUNTAINS ARE UNSUITABLE

A solitary mountain, even one of sufficient height and appropriate orientation, may not produce workable slope lift even if terrain upwind is clear, since the air can pass around, rather than over, the mountain. On the lee side the air currents come together once again, and sometimes move up the leeward side of the mountain. In high mountains this upward-moving air can entrain snow and ice, which — together with the decrease in pressure with increasing altitude (adiabatic cooling) — cool the rising air to the point that banner clouds develop downwind of the summit. Mountains such as the Matterhorn are just about ideal for this phenomenon.

LONG, LOW RIDGES

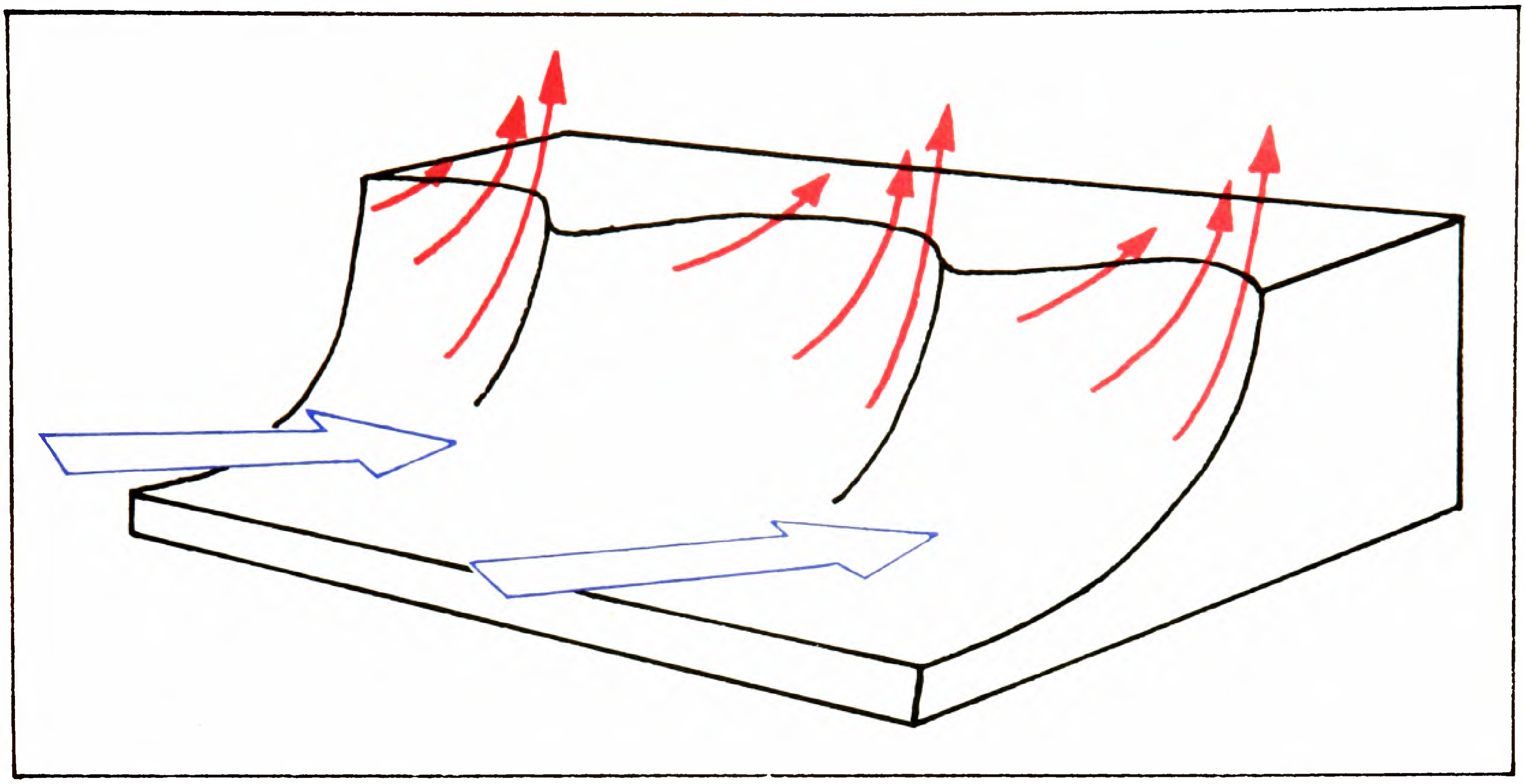
Long ridges, even those of modest height, can regularly generate good slope lift as long as they lie more or less perpendicular to the wind. Even ridges of less than 150 feet in height can provide usable lift if all other factors are favorable. A good example of such a ridge in America is the sand dunes along the coast of Lake Michigan, which were used for some early long-duration flights.

VENTURI EFFECT

If the ridge has a bend or jog such that it forms an open angle toward the wind, the airflow will initially be deflected by the sides toward the vertex of the angle, where it will then stream upward at greater speed, causing locally higher climb rates. It goes without saying that we should keep our eyes open for such formations in the ridge; often it proves worthwhile to fly tight figure-eights at such a point, rather than flying back and forth along the entire slope. It can be even more effective to circle, momentarily coming back to level flight each time the sailplane is pointed into the wind. However, this is a technique which should be reserved for highly competent pilots; in addition to a perfect command of the sailplane itself, it demands excellent judgement to avoid getting caught in a situation in which the circle cannot be completed without ground contact. In general, one should follow the rule of always turning away from the slope.

If the wind blows against the ridge at an oblique angle, each side ridge or protrusion will cause this venturi effect to a greater or lesser extent.

Venturi effect of cross-ridges in oblique wind conditions



AIRSPEED VARIATION

If it appears impossible or not worthwhile to remain in one of these venturi zones, one should still attempt to fly more slowly in these areas of better lift than in merely average areas. In fact, if the lift between the "good spots" is less than the sink rate of the sailplane, such airspeed variation can make the difference between gaining altitude or not. When reversing direction, we'll always try to make the turn at one of the best spots, both to remain in the best lift longer and to reduce the altitude lost in the turn when the sailplane moves further out from the slope.

NEVER CONSIDER SLOPE LIFT IN ISOLATION

Since our cross-country and contest flights generally take place in weather conditions conducive to thermal lift, we should always keep thermal possibilities in mind when we're working at low altitude, and try to form as realistic a mental picture as possible of local air movements. The available vertical air movements are a mixture of two very different energy sources. Slope lift owes its existence to the large-scale pressure differences that cause winds, while thermals are caused by solar energy acting on an appropriately unstable airmass.

Both of these processes can cause vertical air movements which can reinforce, weaken, or even cancel one another. The art of estimating these relationships is what can make the difference between a last-minute "save" or landing — assuming, of course, that the air is not completely "dead."

Thermal Soaring

Let us remain, at least for the moment, near the ground. When can we expect thermals, where do they develop, what "triggers" them, what gives them their form? In general, whenever we're considering flying tactics at low altitude we have to consider not only what the source of a thermal's warm air is, but also what will give the thermal its initial impetus or release. These are two different questions, and we will examine them separately.

THERMAL SOURCES

We can define a thermal source as an area in which the character of the air is changed to make it lighter than the surrounding air, such that it ascends, or at least would do so if it were given an initial impulse. To put it in different terms: thermal sources cause an instability of the air at the surface.

LIGHTER IF WARMER OR MOISTER

Normally, lighter air is warmer, the molecules move more rapidly and therefore take up more space; in other words, the volume of a given mass of air is larger and its specific weight is less.

Air is a mixture of gases which includes — in addition to nitrogen, oxygen, carbon dioxide, and small amounts of the "noble gases" — varying amounts of water vapor (gaseous water or "invisible steam"). This water vapor is lighter than dry air — by about three eighths. It is obvious, then, that air is not only lighter when it is warmer than its surroundings, but also if it contains relatively large amounts of water vapor.

A POOR CONDUCTOR OF HEAT

Air is an excellent heat insulator; that is why woollen sweaters or down comforters keep us so warm. Since air conducts heat so badly, once a "parcel" of air has been heated, it will tend to retain its heat for a comparatively long time unless it is mixed with other air or expands to compensate for the surrounding pressure, and is thus adiabatically cooled.

THE SURFACE — NOT THE SUN — HEATS THE AIR

On clear days, solar energy passes through the earth's atmosphere without significant warming effects. The temperature increase necessary for the development of thermals comes from heating of the ground.

FORMATION OF UNSTABLE SURFACE AIR

There are many factors which can aid or hinder the formation of unstable air at, or immediately above, the ground surface. A few of the more important ones follow since they are important aids to estimating the probability of thermals.

1) SOLAR ENERGY (INSOLATION)

— *Passing cloud shadows* interrupt the heating of the ground. Areas that have been in shadow for some time are not likely to produce thermals. Very weak lift that has been encountered at low altitude is likely to quit if a large shadow area covers the terrain, since the energy input has been cut off. Only if the airmass that has recently been heated by the sun is large enough is there enough energy stored to produce a healthy thermal in the face of the approaching shadow.

— *Extremely large-area shadows* (e.g. cloud decks) generally shut off everything; none the less, sometimes fairly usable thermals can be found under large shadow areas.

Local large shadows, such as clumped-together Cu or thunderstorm anvils, usually cut off convection further in their surrounding areas, while thermals continue around them.

— *Haze, dust, industrial smog* can, depending on their density, suppress convection, particularly in morning hours. For example, in Germany on days of relatively weak winds, the smoke from the industries in the Rhine Valley often suppresses thermals for miles around.

— *The angle of incidence* (the angle at which the sun's rays meet the ground) decides the size of the surface area over which a given amount of energy must be divided. This depends on latitude, season, time of day, and slope of the terrain. Generally, hilly terrain is better for soaring than flatlands, since the different heating effects on sunny vs. shadowed hillsides is more conducive to air temperature differences than the relatively even heating of flatlands.

2) DEPENDENCE OF SURFACE HEATING ON SURFACE CHARACTER

— *Water evaporates* from the surface of *moist ground.* This requires large amounts of heat, thus reducing actual heating of the surface.

— *Water is an excellent conductor of heat,* and conducts heat rapidly downward away from the surface.

— *The high specific heat of water* (i.e. heat storage capacity) causes the available energy to be stored in the water, rather than heating the surface.

— *Green plants evaporate water,* sometimes in astonishing amounts. For example, on a warm summer day any large leafy tree will consume about three tons (!) of water. Generally, plants standing on moist ground will use more water than those on drier soil; the drier the plants, the better the surface heating. Evergreen forests produce better thermals than deciduous ones, meadows and heaths better than wooded areas, and so forth.

— *Wind increases evaporation through plants* as well as from the surface itself. Currents and eddies constantly bring in new, relatively dry air; the moisture is spread, as is the thermal energy, over a thicker "boundary layer."

— *The energy absorption* of the surface depends a great deal on its character. A certain amount of incident energy is reflected immediately in the form of longwave (infrared) radiation. The less energy is reflected, the more is absorbed, and hence the more goes to heat the surface. Here is a rough sample of energy losses due to reflection (Wallington):

surface type	amount of energy reflected
various cereal crops	3-15%
dark soil	8-14%
moist sand, beaches	10%
bare ground, rocks	10-20%
dry sand, dry beaches	18%
various grass areas	14-37%
dry plowed field	20-25%
desert	24-28%
snow and icefields	46-86%

As in the case of the visible portion of solar energy (light), it becomes obvious that the reflection from smooth, light-colored areas is particularly great.

3) ENERGY TRANSFER TIME FROM GROUND TO AIR

— *Strong winds* and their associated turbulence cause so rapid a mixing of surface air with higher layers that the surface heat is quickly distributed throughout a fairly thick boundary layer. At the same time, the surface itself is constantly being cooled; thus, the formation of effective sources of overheated surface air — and hence of large, strong thermals — is less frequent.

— *Protected areas* increase the available heating time. For example, in cornfields the temperature measured between the stalks is often two or three degrees C higher than that measured a foot or so above the ears. In a potato field, temperatures among the vines were measured at from two to five degrees higher than one meter above the surface (Wallington). Tall, dry grass, heath, or chaparral have similar effects; houses and trees can also hold down larger air *"bubbles"* for longer heating. Often, surprisingly good thermals can be found on the lee side of slopes or ridges, where the air has had a chance to heat longer. Ravines and "bowls" in mountain areas are generally very good thermal producers.

— *Frequent thermal triggering* reduces the strength of individual thermals by exhausting the "energy reservoir." If conditions are not overly conducive to triggering (e.g. calm wind, flat terrain), thermals will be less frequent, but stronger.

4) INSTABILITY DUE TO MOISTURE DIFFERENCES

Unusually high local humidity can cause such localized phenomena as thermals over swamps or even small lakes. Soundings have revealed that temperatures in such "wet thermals" are sometimes lower than those of the surrounding air.

The various combinations of these individual factors cannot be measured technically; even the individual factors are very difficult to pin down. This makes it difficult to form an overall picture of all these effects, which can either reinforce or cancel one another. None the less, it is important to try to figure out the given weather and thermal situation, both to make the best use of the thermals that one finds and to build up a set of experiences and referents that will be valuable when weighing the possibilities of future thermals.

TAKE A MENTAL STROLL

One can make such "thermal sniffing" easier, particularly at lower altitudes, by imagining that one is walking along through the fields directly below. We can usually get a pretty good idea quite quickly of where warm air might be lurking. For example, although we might well scorch our bare feet on sandy soil, the air around our bodies would probably remain pleasantly cool. It would be even cooler in the forest, especially under leafy trees or along the stream; on the other hand, potato patches or wheat fields would be almost unbearably hot.

This "aid to imagination" has the advantage of concerning itself with the lowest layers of air, which are the deciding ones for thermal generation on relatively calm days. Moreover, just as one tends to be more sensitive to moister warmth, so moister air is more likely to produce lift. On the other hand, there is the influence of altitude to be reckoned with; in the mountains, we must consider the ground at a constant altitude.

Of course, whether the thermal then rises right over its source or elsewhere depends on still other factors.

WHERE ARE THERMALS "TRIGGERED?"

Even very hot "too light" surface air can remain "lying" precariously on the surface if there is no "triggering" impulse to set it loose. Fred Weinholtz has compared the process with the behavior of water drops on a wet basement ceiling, which do not drop off until one touches the ceiling with a finger, at which point a little rivulet runs down one's arm, fed from the immediate area on the ceiling. If there is enough hot air on the ground, even ridiculously small impulses can set off the mighty process of thermal convection which can lift thousands of tons of air aloft.

Junior contest, 1965. The task: 120 km triangle in the weakest possible conditions. I start too late, and by the first turn I've already lost a lot of time because a higher layer has cut off the thermals. Over the radio I can hear that there's still sunshine and moderate lift ahead of me, while everyone behind me has apparently already been shot down. I must escape into the sunlight! I finally reach the sunshine, but I'm down to 1200 feet. Despite promising terrain, fields, and meadows, nothing happens: the sun has reached this area only recently, and the air is completely dead. I call my crew to let them know where I'll land and fly further into the sunny terrain. Over flat, smooth country — ideal for landing — my course parallels a highway. At 600 feet, the air comes to life for the first time. I fly S-turns, but find nothing worth circling in. By 450 feet I'm sure that there must be a thermal developing somewhere nearby, but at my low altitude — I've already picked a field to land in — I won't be able to use it unless I can catch it right where it triggers. The landscape looks completely flat and featureless. On the downwind leg, at perhaps 350 feet, I decide — more so that I can say that I tried than with any hope of success — to make a slight jog over a little *cairn, a few stones piled up with a stake at the top: a surveyor's monument, perhaps ten or fifteen feet tall. And in fact I feel a surge, I start a left circle, make sure after the first turn that I can still make it to my landing field — I still lose 30 to 50 feet of altitude initially, but then center the lift better, hold my altitude, until the lift finally improves and I get away in a strong 400-fpm thermal. I heave a sigh of relief on the narrowness of my escape and fly off.*

Such experiences are far from rare. I have made it a habit to fly over every possible triggering point before I have to finally commit myself to landing, so as not to miss any chances of gaining altitude once again. Of course, one cannot risk the success of the landing in the name of searching for lift. During the German championships at Oerlinghausen in 1969, I was saved from landing out by the decision not to keep on circling in zero sink (or at least reduced sink) over the flat but shaded fields in the mountains near Paderborn. Instead, even though ships 1000 feet above me were apparently climbing, I flew downhill toward a sunny area with houses and bushes and reached there the triggering point of a powerful thermal. Several of my comrades in suffering, who had reached the fields at the same altitude as I had, ended up sitting in them, not more than a quarter mile from me. In Australia in 1971, I was once saved by a row of poplar trees, which I reached one full circle earlier than another pilot who'd been at the same altitude but had decided to try one more circle; he didn't make it into the lift. At the European Gliding Competition in Dunstable, England in 1972, it became established custom to fly over ridiculously small bonfires; with relatively calm winds and generally overcast skies, they were reliable producers of thermals.

Such a compendium of examples could be continued *ad nauseam.* We can make a basic assumption: *The more uniform both the air and the surface are, the smaller the irregularities need to be to work as triggering points.* Here are a few of the more common "triggers:"

1) TRIGGERING IMPULSES IN CALM AIR

— TEMPERATURE CONTRASTS
  mountain ridges (the slopes on either side will be unevenly heated)
  edges of wooded areas
  edges of snowfields in the mountains
  lake and river banks

— LOCAL VERY HIGH TEMPERATURES
  fires
  industries, especially steel mills

— TRIGGERING BY AIR MOTION
  surface vehicles
  winch launches of other sailplanes
  air movement due to already-existing convection

2) TRIGGERING IMPULSES IN WIND

These are very common, particularly over *slopes* which provide *slope lift* (even if not enough to be workable by itself). Note: *venturi effect* (see page 2).

— edges of cliffs, ravines, farmed areas
— edges of woods, etc.
— seacoast (with onshore breeze)

Strong winds, on the other hand, can change the relationships once again. The strong turbulence prevents the formation of reservoirs of warm air at the surface, and its heat energy is transferred to the entire (and now particularly thick) boundary layer. If this layer is unstable, its own internal turbulence will trigger thermals which will be, at least to a great extent, independent of surface features.

Only very clearly-defined, high hill or cliff edges will then cause "terrain-dependent" thermals, which will then tend to repeat themselves regularly at the same location for the entire day.

SEARCHING FOR THERMALS AT LOW ALTITUDES

If we get down to low altitudes on a cross-country flight — no matter what the reason — we should no longer base our search for lift on clouds, nor should we place too much reliance on our luckier comrades who are even now climbing away above us, since down near the ground the source of their thermal may well have been cut off some time ago. The sometimes astounding "herd instinct" of sailplane pilots has often been the cause of someone's landing directly below the rapidly-climbing "Judas goat," an experience which seems particularly painful. When the risk of landing out looms large we should realize we are on our own. This is when a quick review of what we have just discussed about formation and triggering of thermals can help us figure out the local conditions and find that saving thermal. If we don't find it right away at our first-choice location — and this is what will happen, more often than not — we have either figured wrong or have done everything right, but the hoped-for thermal triggered half an hour ago, and the reservoir of warm air isn't hot enough yet for the next thermal. We'll just have to try our luck at the next triggering point, or the one after that . . .

Of course, there is never really a certainty of finding lift; still, one's chances of finding an active thermal are much greater than if one grimly continues on course past various "save spots," bewailing the cruelty of a fate that has unaccountably failed to place a strong thermal directly astride the course line.

If we are at low altitude and find zero sink, so that at least we don't lose further altitude, it is a good idea — at least for the moment — to stick with it. If the sun is shining, it is likely that the situation will improve and we'll soon be able to climb. If not, at least we'll have gained a little time — we are hardly concerned with speed anyway at times like these — during which we can once again rack our brains to see if we might have better chances elsewhere. We may even be lucky enough to spot some unmistakable sign of good lift in the area, such as a circling buzzard or the like.

ABOUT BIRDS

The common buzzard or turkey vulture is only one of many birds of prey possessing superior "thermal finders." (Biologists still do not understand the mechanism of these birds' built-in "variometer," although there is reason to believe that the inner ear may be involved.) Other birds such as storks, hawks, seagulls, swallows, and in southerly countries vultures, pelicans, and such are excellent thermalers, that can center a thermal far better than we even with our meteorological knowledge, delicate instruments, and electronic gadgetry.

Special praise is due the cliff swallows and swifts, those swallow-like birds whose shrill cries we hear in midsummer and who dart with such precision about the corners of buildings and trees. Whether they seek out thermals because there are more insects in them or in order to fly more easily remains undecided; whatever the reason, if we're circling where they are, we can forget about our instruments and know for certain that we're in the best thermal in the local area. If a buzzard is circling in one thermal and there are swifts nearby in another, head for the swifts — it is certain to be worth it!

There is something else we can learn from these artists of flight: after we have flown two or three circles with them, they are gone. It is not because they are afraid of us — after all, they fly just as fast as we do, and their maneuverability is absolutely breathtaking. In fact, it would be interesting to figure out how much *g* they pull in their wild maneuvers. No, the reason they have moved away is that they are already flying in better lift, long before we even suspect its existence. If we were to make maximum use of the available lift, we would have to center thermals just as perfectly, maneuver just as abruptly, as these birds. Advanced as modern soaring may appear, we still have a long, long way to go.

Not nearly as good as watching birds, but still much better than any instrumentation, is the practice of watching other sailplanes flying *in the same area at the same altitude*. The pilot whose attention is riveted to his instruments is not only dangerous to himself and to others, but is throwing away very valuable information; watching another sailplane is a much better way to find out where the air is rising fastest.

In **zero sink** it is a very good idea to glance at the altimeter now and then. Otherwise, it can happen that we get so involved in centering the lift that we "rise above" other sailplanes only because we are not sinking quite as fast as they are, and we don't notice until too late that the whole "thermal" was worthless. It is when two or three sailplanes are sitting in the same field waiting for the arrival of their crews that we hear questions like, "Why didn't you fly straight ahead instead of circling? I'm sure I would have, but I saw you . . ."

On **calm days,** thermal triggering can sometimes actually be seen as motion of the wheat or grass in a field. In warm countries with loose soil, triggering thermals often entrain not only leaves and bits of paper, but also enough dust or sand to produce dust devils, which can be seen miles away through the hot, shimmering air. Both of these — the waving grass and the (not too small) dust devil — are absolutely certain signs of good lift, since they indicate a thermal in its initial phase.

TRAINS OF THOUGHT

When we try to figure out thermal sources and triggering impulses we should begin with a look at the wind's direction and strength. Then we can consider — perhaps using the "mental stroll" principle — where warm air may have been formed; the next question is where the heated airmass, pushed along by the wind, would be forced over an obstacle that could trigger the thermal. In general, such searching out of thermal locations is simpler and surer under a cloudless sky, with no shaded areas on the ground to complicate matters.

HILLY TERRAIN

In hilly terrain it's as good an idea as any to fly along the crests of ridges; like the anabatic winds in high mountain areas, thermals will tend to flow along the slopes until finally separating from them at the summit. If we are flying right along the crest, it does not seem to make all that much difference which side of the mountain the thermal is coming from, since the final "trigger point" is right over the summit. On the other hand, if we're below the height of the summit it is more than likely that any thermals will not rise vertically, but rather will follow the slope more or less closely depending on its steepness. Such slope thermals are especially common in light winds, and can be flown in a manner very similar to nonthermal slope or ridge lift. If there are definite ledges, benches, or other "setbacks" in the profile of the slope, the thermal can sometimes be triggered away from the slope at that point rather than at the summit.

If a slope thermal is carried up a slope and over the crest by prevailing winds, the sudden increase in wind speed at the summit will cause it to "lean" downwind as it ascends further. If we circle in such a tilted thermal we will have to level out momentarily each time we are headed into the wind, to prevent being blown out of the thermal and into sink. At low altitude we have to be especially careful to keep the thermal since even one bad circle will give us ample time and leisure to reflect on the error of our ways . . . while sitting at our ease under the wing of our sailplane in some field.

It is true that at low altitude the confluence of surrounding air that forms the base of a thermal may actually blow us right into its center without any effort on our part. This can be deceptive, though, when combined with our sailplane's own sink rate, even in thermals that are only slightly tilted. What happens is that the vertical vector V_v is canceled out by the sailplane sink rate, and we get a zero-sink variometer indication while the horizontal vector V_h drifts us very rapidly out of the lee side of the thermal. Thus, we can never capitalize on the fact that our sailplane may occasionally "center itself." It is just in these borderline or "last chance" thermals that we need complete concentration, perfect sailplane handling, and accurate total-energy compensation if we are to realize every possible foot of altitude gain.

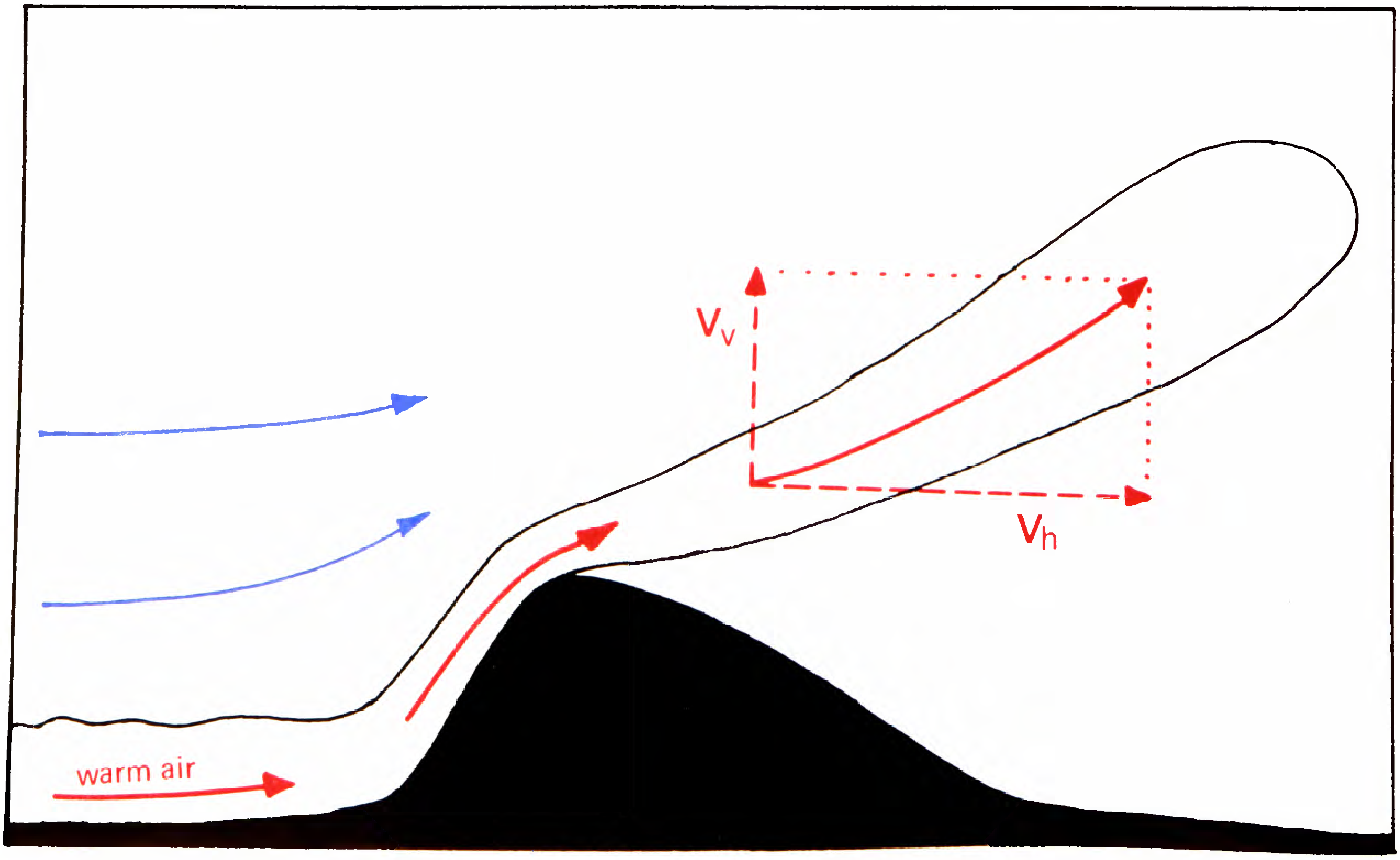
SAFETY WHEN CIRCLING AT LOW ALTITUDE

It goes without saying that mastery of the sailplane is not only decisive for success but an absolute requirement for safety. Unexpected turbulence is common at low altitude; beginners tend to fly too fast when headed upwind and — much worse — too slowly when headed downwind, because the ground is zipping by so fast. Since slips and especially skids are particularly dangerous near the ground, attention should be directed not only to the airspeed indicator but also to the yaw string — one of the most important "instruments" for the performance pilot. Many a serious crash could have been prevented this way. If we descend while headed upwind, we should be forewarned of a significant *decrease in airspeed*, since the air directly above the ground usually moves much more slowly due to friction. Safety must remain the primary consideration when searching for lift near the ground, and we should always be able to reach a *planned* landing spot, even if we suddenly fly into heavy sink.

V_v Vertical vector of the thermal

V_h Horizontal vector of the thermal

Slope-triggered thermal rising obliquely



ENTERING THE THERMAL

As we approach the region of a thermal updraft, we usually enter a zone of increased sink. This zone should be traversed as rapidly as possible in accordance with our speed ring or speed-to-fly indicator. If a sudden increase in rate of climb impels us to begin circling at once rather than continuing straight flight, our kinetic energy can be transformed back into potential energy by a steep pull-up. Just before the top of this pull-up we drop a wing in the desired direction of circle and should — if we've done everything right — have just the proper thermaling airspeed left. This pull-up turn maneuver should become entirely automatic for us before we even earn our C Badges; it goes without saying that the yaw string should remain centered throughout the maneuver.

It is obvious that a well-compensated variometer, which allows us to determine — even while we are pulling up — whether the thermal actually has the required strength or falls short by, say, half a meter per second, is more than essential. This is the only way to avoid unnecessary circling in too-weak lift, or even in sink.

Usually, though, things take place a bit less frantically. We've arrived in an area of rising air without knowing exactly whether the expected climb rate can be found. In order to avoid flying past or through lift, we have reduced our speed to around 60 mph or even less. If we now note the beginnings of lift, we won't start circling right away, but rather we will try to find the best area in which to gain the most altitude in the least time. We concentrate our senses on every possible cue, note every gust, and fly in gentle S-curves (holding the stick lightly and sensitively), correcting at once toward any side on which a wing is lifted. However, we won't start to circle until the indication of our (compensated) variometer is at least 75 fpm *better* than the minimum we have decided to circle in (because of the increased sink rate in turns). Now we wait for just that instant in which the rate of climb has reached its maximum and is barely beginning to decrease to begin our circle. (Cues: acceleration, audio variometer, etc.)

But in which direction should we circle? Some of the most interesting and widespread myths of soaring and meteorology are those concerned with the direction of rotation of thermals. Obviously it would be advantageous to circle against a rotating thermal, since the decreased groundspeed would lead to a reduction in centrifugal force and hence a tighter circle. Normally thermals only rotate for a short distance above the ground, with equal frequency in either direction (this has been proven by actual observation and measurements of over 100 thermals). Special cases such as, say, tornado funnels, are relatively infrequent. When asked a question about some obscure point of thermal rotation at a performance soaring seminar in Berlin in 1972, H. Jaeckisch replied, "Well, as long as the clouds don't rotate . . ."

Thus, all other factors being equal, we can choose whichever direction we prefer. The choice of direction which will lead to the best possible climb rate is our first actual centering maneuver. Those who have a definite "good side" in thermaling, and who are unwilling to circle the other way, often deny themselves the opportunity to immediately center the best lift. If the variometer does not exceed the 75 fpm value mentioned earlier (over and above the value we feel is worthwhile for circling) we simply proceed straight ahead to the next thermal, without wasting time on a single circle.

CENTERING AND FLIGHT IN THE THERMAL

Let us consider, once again, the buzzard — or, better yet, the cliff swallow. If these masters of thermaling hardly ever fly the same circle twice, they must have their reasons. The air in a thermal is far from homogeneous; on the contrary, we cannot tell whether especially warm air shoots us aloft, or whether air mixed with the surrounding air almost to the point of unrecognizability appears to let us down. Moreover, there are often significant horizontal movements — particularly near inversions or in areas of wind shear — which make life difficult for us. Of course, now and then we will find updrafts so regularly that we can make 5 or even 10 circles without correction, but this is certainly the exception rather than the rule. Thus centering is not something that one need do only once upon entering a thermal, so as to climb quietly in completely regular circles to the cloudbase; rather, it is a necessity during the entire climb. For the moment, we try to use our senses of acceleration, the sound of an audio variometer (TE-compensated, of course), or the needle *movements* (not just instantaneous needle position) of our regular variometer, as well as the air sounds of the sailplane, to determine whether we are flying toward better climb conditions. The "seat-of-the-pants" feel for acceleration is of particular importance here, since it allows the fastest possible reaction. Even the best possible variometer with a time constant of O (i.e. immediate indication of climb with no delay whatsoever) won't show any climb indication until the aircraft has actually begun to gain altitude. Seconds — or even only fractions of seconds — earlier, however, we have already perceived the acceleration and hence the presence of lift.

Surprisingly, even amid all the current hysteria about ever more advanced variometers and electronic computers, no one has yet developed an instrument that would include acceleration values among its inputs. (True, such a device would have to be very carefully compensated to eliminate the accelerations caused by "stick thermals," but it is entirely within the realm of current technology.) Until such time as this wonder instrument appears on the market, we will just have to make do with our own built-in "computer," whose billions of nerve cells still manage to do a more than adequate job even when presented with quite a few "inputs."

As soon as we have determined a direction of increased climb, we note it in relation to surface features, the cloudscape, or the position of the sun. If, as we continue to circle, our outer wing is soon lifted, our suspicion of the presence of a good thermal is reinforced. If we then fall out of the best area, we can still get a good idea of the "hot spot;" we then attempt — whether consciously or unconsciously — to create a spatial picture, one which we could compare with a relief map whose hills and valleys represent lift and sink, respectively.

THREE CENTERING METHODS

How we displace our thermaling circle so that it is exactly concentric about the "core" of the thermal isn't too important. What *is* important is that we do it quickly. Once we know where we want to go, we should not be overly concerned over performance losses caused by hard maneuvering or full control deflections. If we can save 10 seconds getting into 1 m/sec better lift, it is worthwhile several times over. We should be aware, however, that the old-fashioned centering method of leveling out in lift, flying straight for a short time, and then starting to circle again (method 1), is not as certain to hit better lift as other methods. Heinz Huth's technique (method 2) is as follows: as soon as the lift becomes weaker fly a half circle as tightly as possible, until climb begins to increase; then resume the original bank angle.

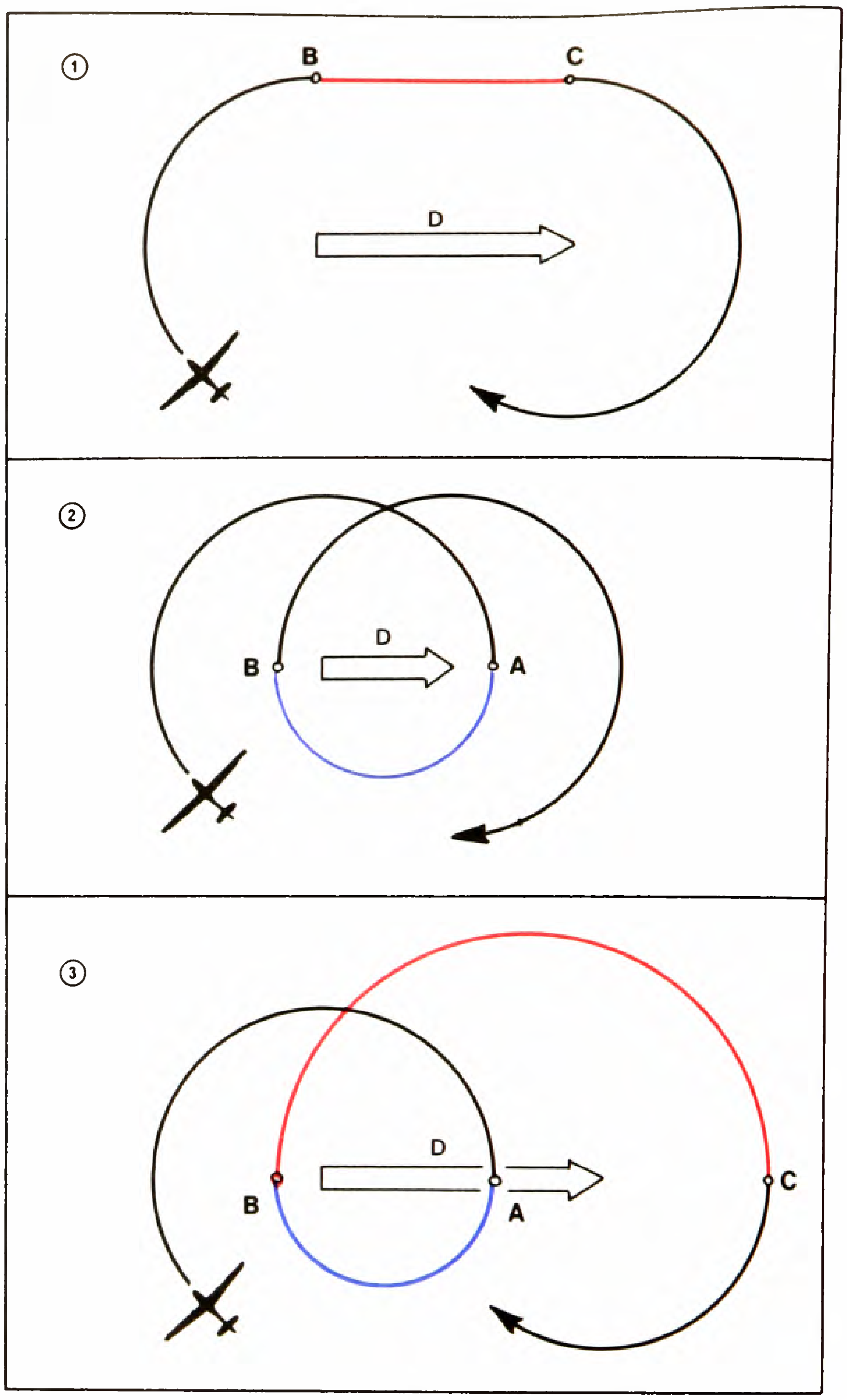
If we wish to displace the circle with a minimum loss of time and with the best chance of finding better lift, I feel that the best method is one that combines features of both of the others (method 3):

- As climb improves, flatten the circle (approx. 15-20°)
- As climb deteriorates, steepen the circle (approx. 50°)
- If climb remains constant, keep constant bank (approx. 25-30°)

Note: these rules are based on *changes* in rate of climb, not absolute climb rate as such.

As we can see in the illustration, method 3 allows a relatively large displacement. This means rapid centering (or equally rapid centering if the phase of steeper circling — from A to B — is not quite as steep). It should be remembered that bank angles in excess of 45 degrees cause significant sink-rate increases.

Centering methods



D = Displacement of circle

Method 1 : Decrease bank as climb increases (B-C) (Disadvantage: inexact)

Method 2 : As climb decreases fly ½ circle steeper (A-B)
(Disadvantage: less displacement)

Method 3 : As climb decreases, bank steeper (A-B)
As climb increases, reduce bank (B-C)

Any centering rule has the disadvantage of being somewhat rigid in light of a changing situation. The "recipes" given here should therefore be taken as basic techniques to be refined in the real world depending on such factors as gustiness, thermal strength, and so forth. They will serve, however, as a basis for further practice; ultimately, the ability to visualize thermals spatially should be of paramount importance.

The third method has the advantage of rapid centering while remaining feasible even if the bank is steep to begin with. Moreover, it is certain to take us in the right direction even if we misjudge the exact instant to change the bank angle. On the other hand, it is more susceptible to improper flying (skids, slips) than the method of two-time World Champion Heinz Huth.

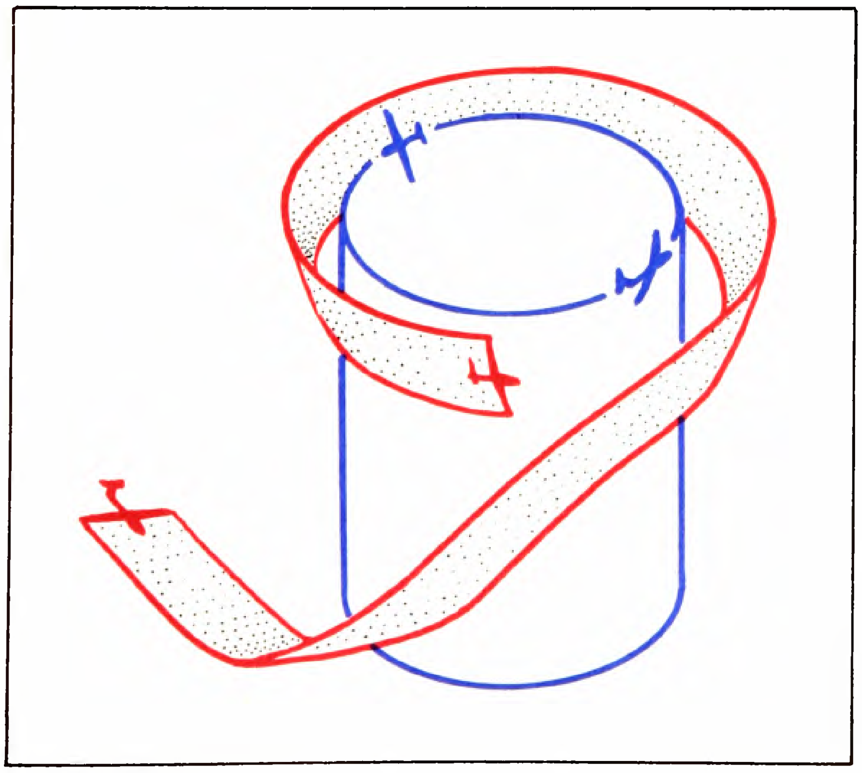
IMPORTANCE OF CLEAN FLYING WHILE THERMALING

Naturally, clean and coordinated flying is a prerequisite for decent thermaling. The yaw string is an irreplaceable and ultrasensitive "instrument" that immediately indicates even the slightest skid or slip. Nevertheless, it is more important to center the thermal rapidly; the most gorgeous textbook circle is of little practical use if only half of it is in the updraft. Therefore: first, center the thermal, *then* be sure you are flying in a clean and coordinated manner.

BANK ANGLE, AIRSPEED, DIAMETER OF CIRCLE

Since we can never fly in the strong core of the thermal, but can only circle around it, we try at least to stay as close to it as possible by flying tight circles. However, this means increased centrifugal force, higher airspeed, and a definite increase in our sink rate. If the core of the thermal is far stronger than its outer regions — if there is a steep climb-rate gradient between the edge and the center — tight circling is worthwhile despite its inherent inefficiency. If, on the other hand, the gradient is shallow, we fly wider circles at a lower sink rate. Thus, there is a single optimum circling radius for every thermal — actually for every thermal gradient — which in turn depends on the sailplane type. The circling polar of each sailplane is the important characteristic here; bear in mind that basically there is only one variable, since for each turn radius there is only one optimum airspeed and hence one optimum bank angle. For common European soaring conditions, today's sailplanes climb best at a bank angle of about 30 degrees, although considerable variance is possible.

Spiral approach to a "Gaggle"



Thus, it is imperative to fly at the best bank angle whenever possible. The best airspeed for each such angle will be a few mph over the stall speed for that particular bank angle.

It will be necessary in almost every thermal to change the bank angle — and hence the airspeed and circling radius — in order to optimize the climb for the changing characteristics of the thermal with increasing altitude. Often, thermals require bank angles of 40-50 degrees in their lower regions, while the upper third requires only about 25 degrees.

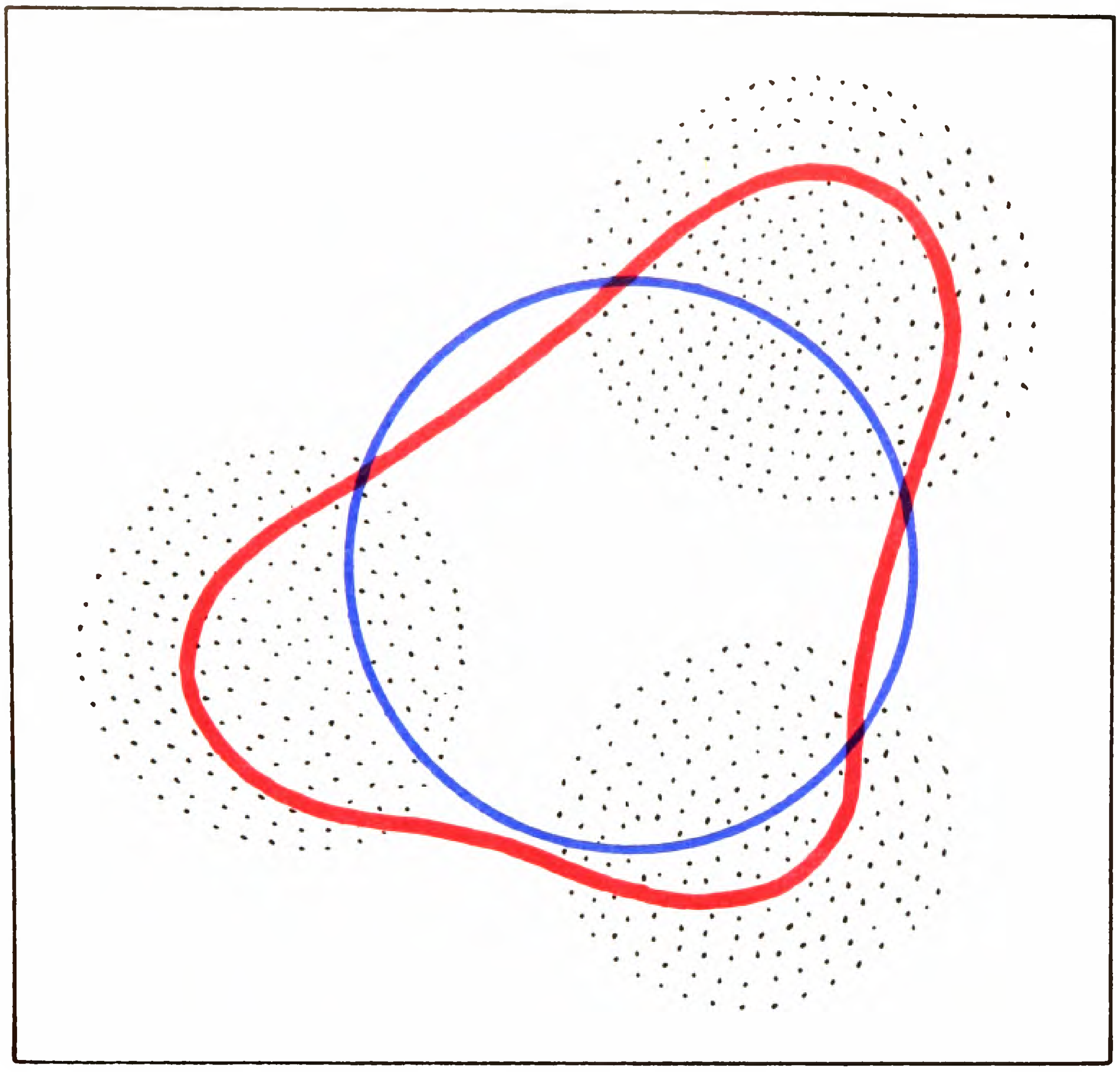
Frequently, thermals are narrowest at altitudes where the climb rate is fastest.

FLIGHT IN "UNCENTERABLE" THERMALS

Perhaps half of all thermals are sufficiently regular to allow a circling sailplane to climb at a constant rate. The others somehow kick us aloft with updrafts of continually changing strength and location. Even so, most pilots fly updrafts only by circling in them. This is counterproductive and ignores the example of soaring birds. To get the best from irregular updrafts, one should use "swooping circles": as climb increases, pull up and either steepen or decrease the bank, depending on the position of the other localized areas of better lift. Actually, an airspeed optimization equation exists for this situation which resembles the famous MacCready calculations for straight-ahead flight; unfortunately, the number of variables (different climb rates, g-loads, sink rates, etc.) is so large as to preclude the statement of even a general rule of thumb. Variations in airspeed (pulling up as climb increases, pushing over as climb decreases or becomes sink) cause an additional gain due to vertical air motion.

(For the case of steady-state straight flight, W. Gorisch of the Munich Academic Flight Group has calculated the change in energy over time as $dE/dt = M \cdot n \cdot g \cdot Wm$, in which M is the mass of the sailplane, n the load factor, g the earth's gravity, and Wm the vertical air motion.) Nonetheless, competition pilots should try to use this method to milk every last bit of lift out of a given thermal — as long as there are no other ships nearby at similar altitudes! It is almost impossible to judge or anticipate another pilot's swoops, dives, and turns in such a situation.

Moreover, this technique requires outstandingly good total-energy compensation; otherwise, the indications will be completely irrational and useless. Since, however, good compensation is such an absolute necessity in any case, this situation should not be considered a special requirement.



"Swooping" circle (exaggerated)

🟥 Swooping circle with 3 pulled-up-tight turns.

The time spent in the three areas of best climb is increased by

1. Decreased airspeed
2. Increased distance

(The very narrow turning radii in the lift centers are made possible by the sharp pullups immediately preceding them.)

🟦 Normal circle (optimally centered) for comparison.

THERMALING IN GAGGLES

First of all, a few important commonsense rules so that we don't get too close to one another and no one is endangered or inconvenienced:

1. First sailplane into the thermal sets the circling direction for all later entrants.
2. Newcomer must fly such that already circling sailplanes are not inconvenienced: that is, work your way into the circle spirally from the outside.
3. Anyone displacing his circle must not hinder other sailplanes in the old circle.
4. If outclimbing another sailplane, the worse climber must not be hindered.
5. As a general rule, never fly closely right below another ship; the other plane has almost no escape route, particularly at low speeds.
6. Always observe your airspace and know who is where, when.
7. Attempt to fly such that the other pilots can always see you.

Observation of other sailplanes in the gaggle is not only a required safety factor, but shows us clearly where we must move our circle for the best lift. If everyone is watching they'll all see, almost at once, *why* one sailplane has moved, and they'll all move over together, thus avoiding traffic problems. Rowdies who zip right through, and the "head-down-and-locked" type whose gaze is riveted only on the hypnotic dial of his variometer, are inconsiderate types who are obviously not yet ready for competition-caliber flying.

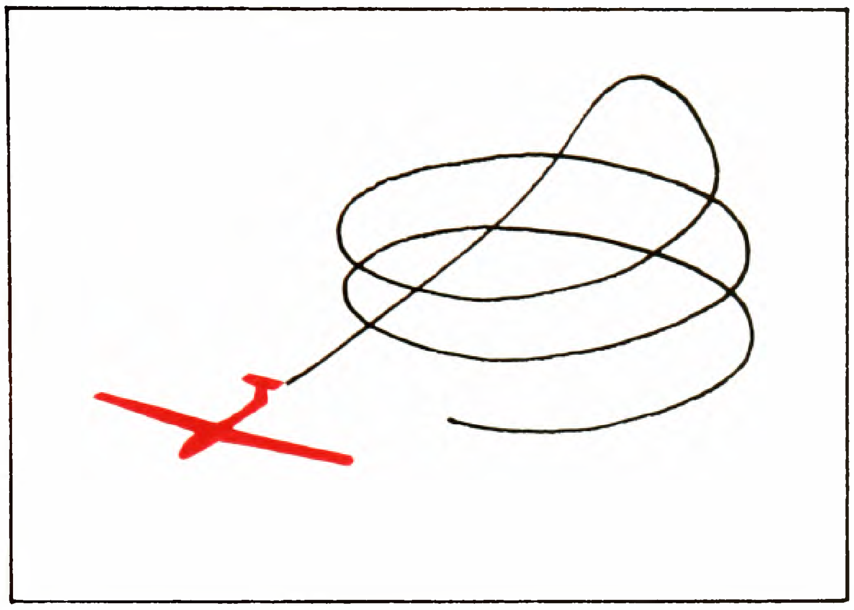
LEAVING THE THERMAL

When the thermal strength decreases despite our best efforts at centering, we leave, whenever possible, at the time when the rate of climb has decreased to the point where it equals the initial rate of climb we expect from the next thermal. It is important to understand this idea exactly. The decision to leave the thermal is *not necessarily* based on our average achieved rate of climb; it is the *next thermal* that is decisive, and its expected climb must be — once again — the result of estimation or of an educated guess. Nothing is more annoying than to leave a good 600 fpm thermal when the lift has decreased to 300 fpm, only to find nothing more than a miserable 100 fpm in the next thermal, where it will take three times as long to regain the lost altitude. Just as bad, if perhaps not quite as disheartening, is to laboriously work up in a 100 fpm thermal, then depart on course and immediately find 300 fpm lift in the next thermal, in which one could have gained the same altitude in one-third the time. It is seldom worthwhile to work up to near cloudbase, if the cumulus clouds are somewhat flattened; lift usually decreases markedly in the upper part of a thermal.

George Moffat, world champion in 1970 and 1974, recommends the thermal-departure technique of the Polish competition pilot Adam Witek: a type of modified split-S started on the side of the thermal away from the desired direction of flight, so that acceleration takes place while flying directly through the strongest core of the thermal, before encountering the usual increased sink around the thermal's outer edge.

Before leaving a thermal, we should always have our next goal — and, if possible, the one after that — in mind, so that we can set out at once without having to wander about.

Leaving the thermal



THERMAL SOARING UNDER CUMULUS CLOUDS

Let us imagine ideal soaring weather: one-eighth to one-quarter sky cover of cumulus clouds, with bases around 5000 feet agl. If we circle under every cloud on course, we'll soon realize that at best only every third cloud has a usable thermal under it. Thus, the distribution of lift is not an eighth of the sky — like the clouds — but rather one twenty-fourth, which is unfortunately much less. What we have to learn is as reliable a method as possible to decide from afar which are the good and bad clouds, in order to avoid both disappointments and useless detours in search of lift.

One of the most important ground rules is the fact that the thermal itself is the primary phenomenon, while the Cu is only a secondary characteristic which appears during the life of the thermal and which persists after the thermal has already dissipated. Thus, the presence of a Cu by no means always indicates a thermal beneath its base.

LIFE-CYCLE OF THERMALS BENEATH FAIR-WEATHER CU

(1) Warm air collects at the surface (as described earlier).

(2) The thermal is "triggered" by any one or more of numerous factors, and the warm air begins to rise.

(3) A more or less vertical "cylinder" of rising air is formed; if no further warm air flows in at the bottom, the "cylinder" can be cut off at the bottom and the air will rise as a bubble.

(4) As the top of the rising air reaches the condensation level (= base of other Cu), delicate wisps of vapor appear and rapidly become more visible (10 sec - 1 min).

(5) The cloud begins its existence as individual irregular clumps, which become thicker and coalesce.

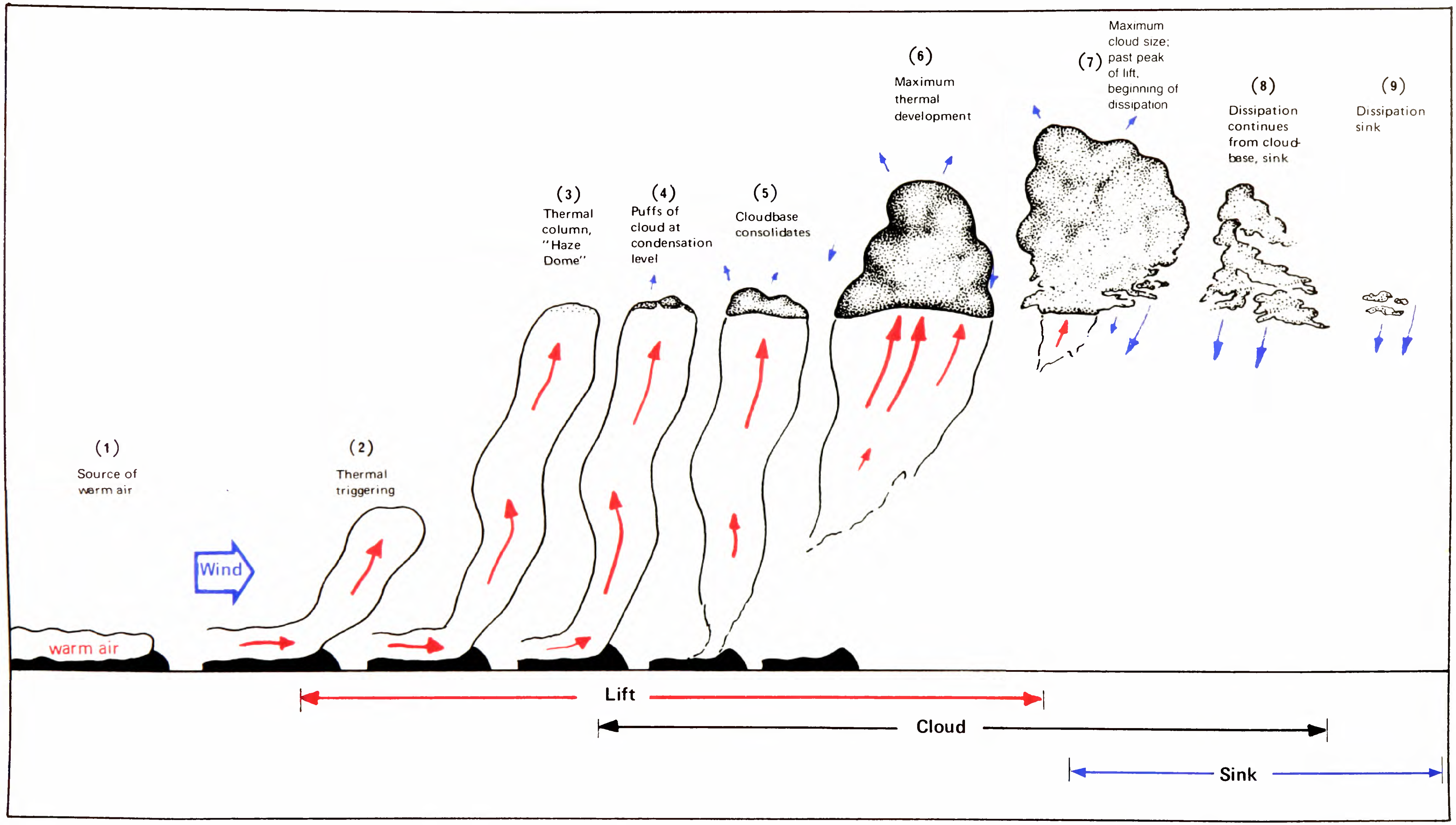
(6) The cloud becomes increasingly compact and its edges become more clearly delineated. Above the area of strongest lift, the cloud grows upward in domelike fashion and is blindingly bright, with very sharp edges; the darkest part of the base is directly below.

These formations, so beautiful aesthetically, are not only a feast for the eye, but also signs of the best development of lift. As pilots, we should also be aesthetes and try to reach the most beautiful clouds at their best stage of development. Especially dark areas at one side of the base or another may not only mean that that's where the cloud is at its thickest, but may also indicate an area where the cloud's water droplets are especially large and frequent. This in turn means that the local humidity is higher, indicating that the rising surface airmass in this area has remained moist and has not been mixed with drier surrounding air as much as other areas of the thermal. Moreover, this is the area where the most additional heat is released by condensation, further increasing thermal strength. If this darkest area of the cloud base is domed upward, it indicates particularly warm air, which only reaches condensation temperature some few feet above the general condensation level; this is an area where one can climb particularly well, often better than the expected rate that has been set into the speed ring. On the other hand, shreds of vapor which appear to hang down a few feet from the cloudbase actually form somewhat below the cloud and are sucked up into it. They, too, can indicate a maximum-climb area, since they are the result of air that is moister — and hence lighter — than the rest of the thermal. But back to our description of the life-span of a thermal:

(7) The cloud continues to grow as long as there's warm air available from below.

If the reservoir of warm air is exhausted, the growth process comes to a halt (fair-weather Cu). The edges of the base fall apart as they mix with the surrounding air and their moisture is absorbed. At this point, the "dome" of the cloud can still appear round and sharply defined, and can even continue to grow a bit; one can often recognize this phase of a dying thermal in that the cloudbase is a bit smaller than the horizontal area of the "dome." If the cloud is not growing, the thermal has dissipated in any case; as long as it

Life cycle of thermals with Cumulus clouds



is "alive," a cloud will continue to grow. If a split — or even only a little notch — appears at the top of a cloud, the whole formation will usually divide into two parts. If we're searching for lift at this stage, on no account should we fly under the split, but rather under one of the two halves, which will continue to develop or dissipate separately.

(8) The contours of the "dome" become less distinct; the cloud falls apart. As its water evaporates, the air is cooled to such an extent that sink develops and increases of its own accord — a "thermal in reverse."

(9) The remaining bits of cloud dissipate in this downdraft, which in turn persists for a short time after the last visible remnants of the cloud have disappeared. The drier the surrounding air, the more rapid the dissipation of the cloud.

CLOUD FREQUENCY

A large number of Cu certainly need not mean that there will be a large number of thermals. On the contrary, the usual cause for many Cu near one another is that the humidity of the surrounding air is high enough to slow significantly the process of cloud dissolution. With so many dying Cu in the area, it's the pilot's task to find the relatively few young, active clouds which alone can yield the hoped-for climb rate. In fact, due to the increased cloud shadows in such an overdeveloped situation, good lift may prove quite difficult to find.

THERMAL-SEARCH TACTICS FOR FAIR-WEATHER CU

The art of finding good lift in such a situation is — at least to a great extent — that of realistically judging the stage of development of those clouds that might come into question. To do this with any degree of certainty, we must observe all the clouds which we think we may use next for some little time, and this observation — and the decision based on it — should be made before we head for the chosen cloud. In other words: while we're climbing under one cloud is the time to decide which one we'll use next! A very helpful time-lapse effect is provided gratis, since we observe and compare the forms of clouds further along our course only once each time around while we're circling. While we glide between thermals we have another chance to check our choice, and an opportunity to change our mind early enough to head for the cloud we've already picked as our second choice while circling.

Those who feel that this technique demands too much of the pilot, who's already busy climbing, need more thermaling practice. For high-performance cross-country or competition soaring, this is "the only way to fly."

In our earlier discussion of the life-cycle of a Cu we've seen that the thermal exists even before any sign of a Cu is visible; thus, if we should happen to feel definite lift while cruising in the blue between clouds, we should go ahead and try a circle. If the sailplane climbs respectably, we'll stick with the thermal, since we can assume that it will increase and that its "ripe" stage is yet to come. Especially in the case of short-lived Cumulus humilis (which occur when the humidity is fairly low and the temperature distribution aloft limits upward growth), it's worthwhile to stay in these thermals found between clouds; they're usually the best of all. If we're able to definitely recognize an upward swelling of the haze layer, it is almost always worth a detour. Usually, a small cloud will have formed even before we reach the spot. The phase of individual clumps of cloud — before they merge together — should be taken with a grain of salt, since this stage is very difficult to distinguish from the final stage of dissolution. In fact, I'd suggest only flying toward such a cloud if we've had a chance to watch it — or its location — long enough to be sure that it is in the developing stage, in which case we will, of course, find good lift. As a rule, however, we'll unfortunately be forced to fly toward already-visible clouds.

Often we can use their relative size as a yardstick to determine their stage of development; this leads us to prefer smaller clouds with well-defined bases. When we're working at lower altitudes, we can see the bases better than the actual form of the clouds, and base our decisions largely on their darkness and sharp-edgedness. At altitudes near cloudbase, on the other hand, size and shape of the "dome" become the primary data. The upper parts of the cloud should be clearly smaller in area than the base; if not, it's a sure sign that the cloud is past its prime.

If scraps of cloud are hanging about near a relatively good-looking cloud, they are sometimes remnants of an earlier cloud which have been given a new lease on life by the newer cloud's supply of warm air; usually, though, they indicate only weak lift. If we're faced with a longer glide to a cloud of questionable virtue, we must juggle its current stage of development, the general life-span of clouds on that day, and the time it will take us to reach it. Otherwise we'll be treated to a splendid display ahead while we're cruising, but will arrive only to find a wilting cloud and increased sink.

At altitude it may be difficult to estimate the distance to the next cloud. The best way is to look for its shadow on the ground, taking the angle of the sun into account.

When we change course at a turnpoint we must become accustomed to the new "cloud picture." Those blinding, sharp-edged Cu that looked so seductive with the sun behind us may now be revealed as stringy assemblages in shades of dirty gray, even though they're the same clouds. Ideally, we'd have seen this even before the turnpoint, by looking back at the cloud we'd just left as soon as we started circling under a new one, thus seeing — for example — what a 600-fpm thermal might look like from the new post-turnpoint direction.

SEARCHING FOR THERMALS DIRECTLY BELOW CLOUDBASE

At cloudbase altitude we can expect to find the best lift right under the darkest part of the base, which in turn is usually located below the thickest, roundest part of the cloud. We should pay strict attention to unevenness of the base: if a given area is higher and remains dark, the lift will be stronger there.

The sun angle can sometimes affect the area of strongest lift by adding additional heat to one side of the cloud.

Of even more importance — and unfortunately usually unknown to us — is the wind profile at cloud altitudes, which tends to displace the best lift against the direction of wind shear. If, for example, the wind speed at or near cloudbase increases, the best lift will be found on the upwind side — especially if this is also the sunny side. Once we've determined that the best area of several clouds is consistently on one side, we can assume that this will be the case for almost all clouds on that day and save time by always heading for the good side of each successive cloud.

SEARCHING FOR THERMALS AT MEDIUM ALTITUDES

The higher we are, the more dependably we can base our decisions on cloud forms. As we slowly lose altitude we should on no account forget the fact that even active clouds may not have lift for more than a few hundred feet below their bases if they're being "fed" primarily from the side. This is particularly applicable to those Cu of somewhat "overripe" appearance. If the wind is calm, we can assume that the thermals will rise more or less vertically; sometimes it's even possible to identify the thermal triggering point on the ground and get a good overall picture of the entire thermal-cloud system. The lower we get, the more our attention should be directed toward the ground and possible thermal sources. If there is wind it will be much more difficult to locate the often curved or tilted thermals. There are many possible ways in which wind can affect the shape and direction of thermals; here are three of the most common cases:

(1) If a fixed point on the surface triggers a continual thermal from a large reservoir of warm air, the rising air will be driven downwind; hence, we can assume that a thermal stemming from a fixed surface point will lean downwind. The angle of such a thermal is not likely to be constant; depending on increases or decreases in wind strength (in other words, the wind profile) it can become steeper or flatter. Wind shears with changes in wind direction can change the tilt in any direction. Moreover, the speed at which the air rises is decisive for the form of the thermal: at altitudes in which the air rises faster, the thermal will be steeper. If the thermal is topped by a cloud we can attempt to link it with some prominent triggering point on the ground to get a better idea of air motion.

If the wind is strong, though, or if there are large or frequent wind shears, this will be almost impossible. On the other hand, if we're lucky enough to note some visible trace of the thermal (e.g. smoke, debris, other climbing sailplanes at lower or higher altitudes, etc.), we can not only get an idea of the angle, but can also expect to find better lift at the same angle below other clouds the same day.

At locations where large areas suitable for surface-air heating lie upwind of well-defined triggering features, such tilted thermals are the rule; they're well known at most slope-soaring sites, such as the Wasserkuppe, etc.

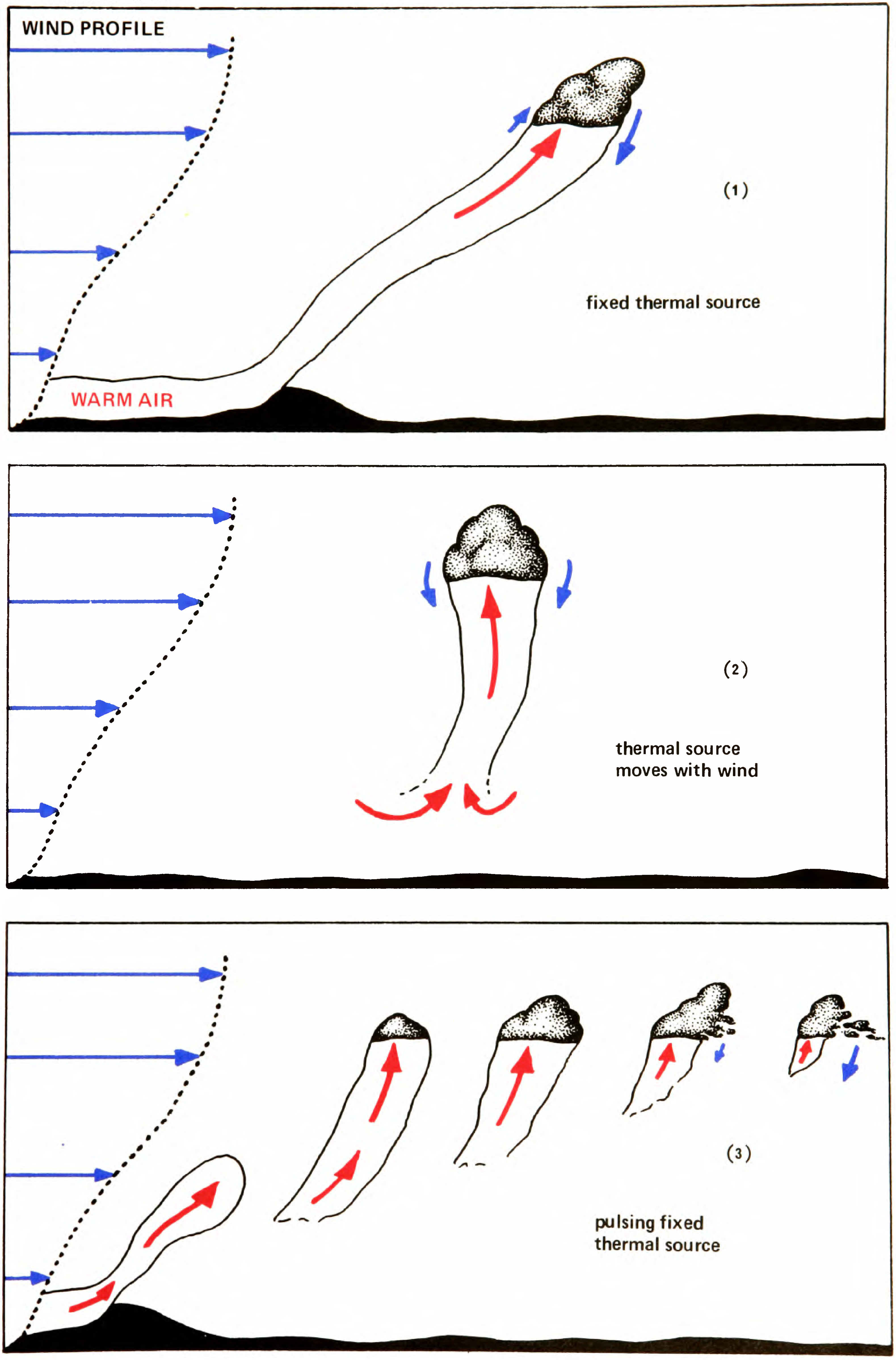
From a piloting point of view such thermals can be quite demanding. Not only do they tend to be gusty, but we must continually shift our circle upwind to avoid being "spit out" the lee side by the combined effects of the wind and our sailplane's intrinsic sink.

(2) If the wind is strong and the terrain below regular, the lower turbulent layer will trigger thermals without any particular surface feature. Such thermals are relatively vertical although, of course, they drift downwind with the airmass. They can continue until the unstable air mass from the lower layers is exhausted. In such cases we'll find lift more or less vertically below the cloud, just as when the wind is calm, and we can work the thermal in entirely normal fashion. We will, of course, continue to drift downwind, as will the cloud above us.

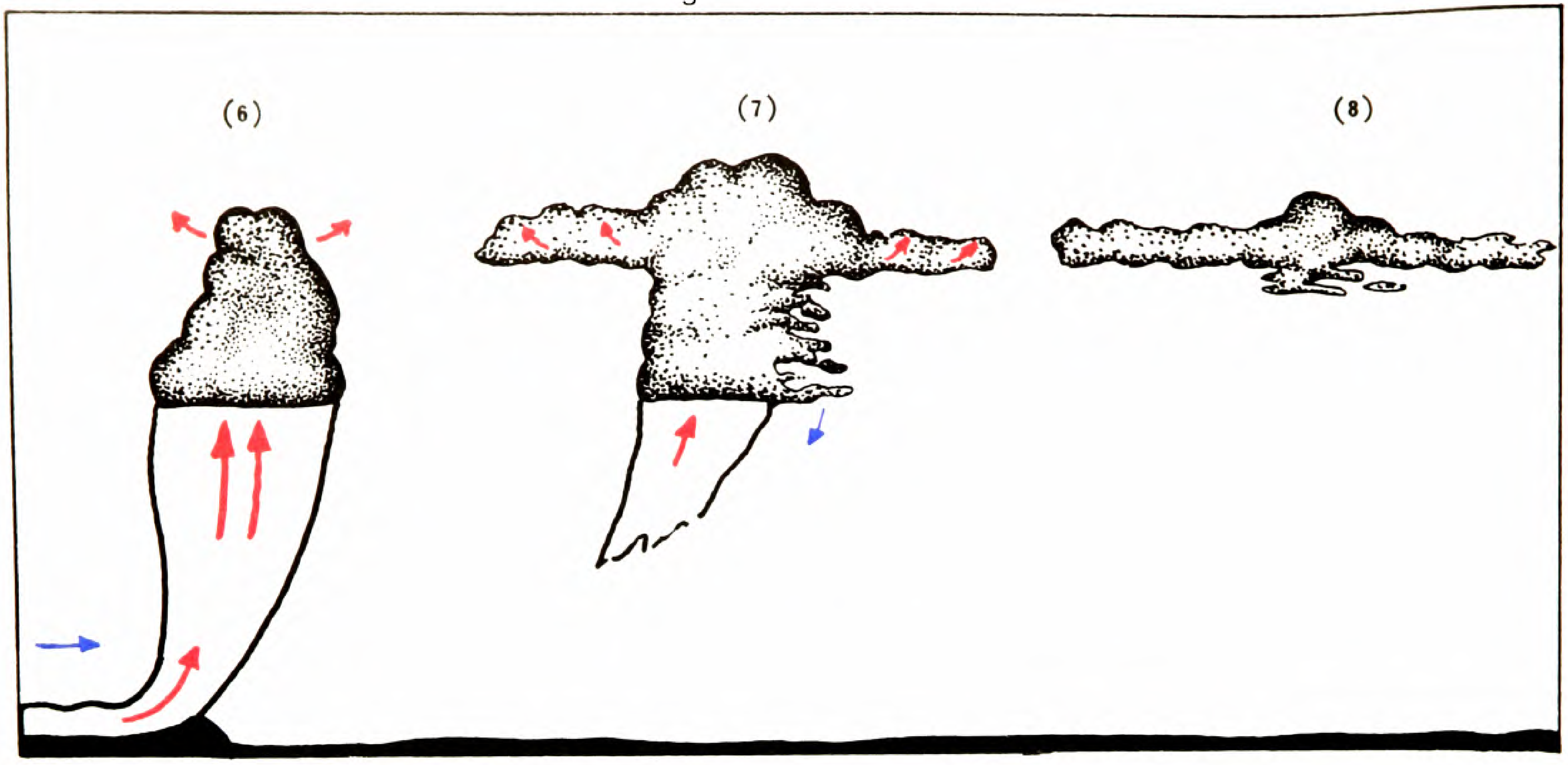
(3) A further possibility is that of a surface triggering feature that produces a pulsating, rather than steady, flow of warm air. In this case, each pulse — which can be of several minutes' duration — will form a thermal which will separate from the ground and behave as an isolated thermal as in example (2) above. A row of thermals will develop and will be aligned with the wind direction. The closer one flies to the source, the lower the altitude at which one can encounter lift.

These three different types of thermals can appear next to one another in appropriate weather conditions; the question of which form will appear where is a difficult one whose answer depends largely on surface features and terrain. The best chance of finding lift once we have lost it is to fly directly up- or downwind.

Thermals in wind



Formation of stratocumulus in moist surrounding air



LIFE-CYCLE OF CUMULUS IN MOIST SURROUNDING AIR

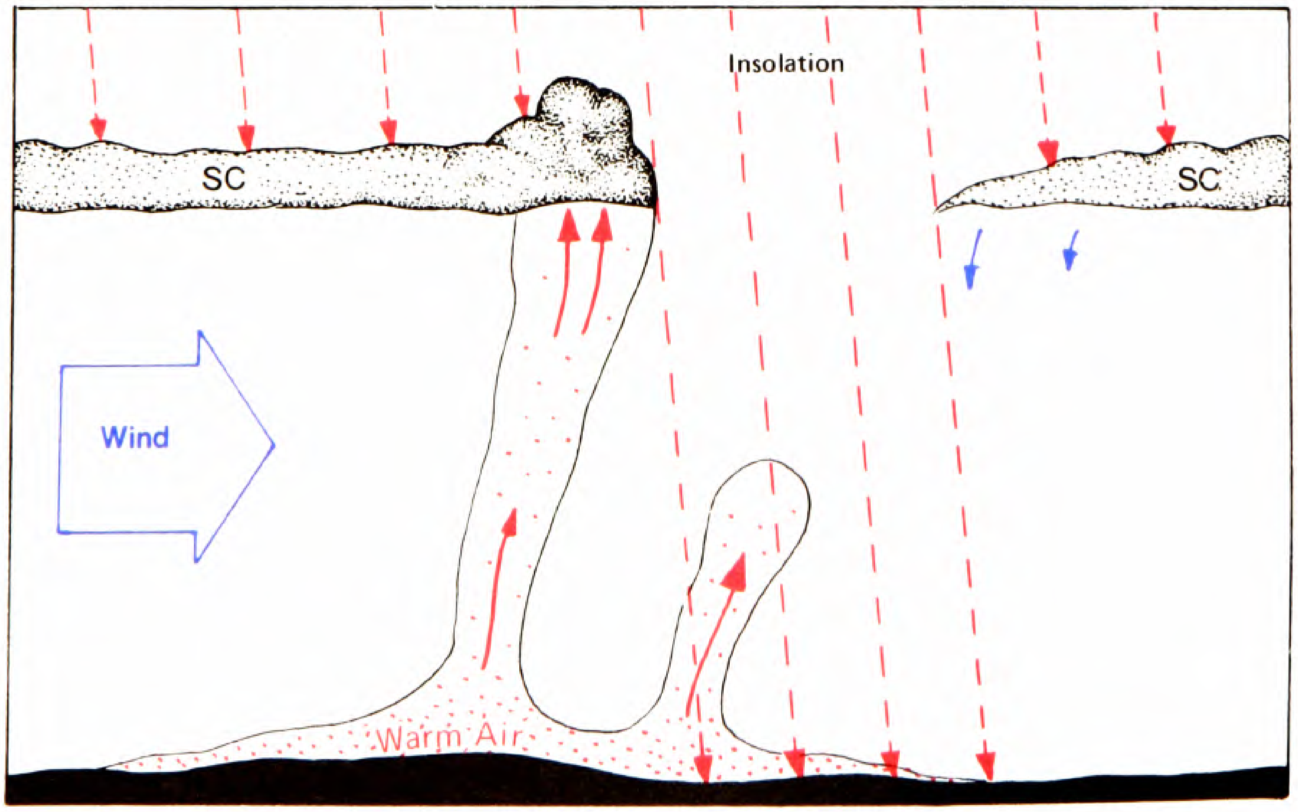
The early stages are similar to stages (1) through (6) of the earlier example.

If a layer of moister air exists above cloudbase and the Cu reach this layer, a sort of "chain reaction" can be initiated: the air in the vicinity of the rising Cu is "nudged" by the updraft and some of its water vapor condenses. This releases heat which causes instability, the air rises and causes further condensation. The Cu spreads out laterally, "nudges" more of the surrounding air, and so forth.

Often such layers of high humidity are linked to a temperature inversion which can be penetrated only by the warmest thermals. Most Cu which reach the inversion layer flatten out on top, develop laterally, and generate the horizontal gusts and turbulence typical of these inversion layers, which we sometimes encounter at the tops of cloudless "blue thermals."

The original generative Cu finally will degenerate and become a local Stratocumulus cover, which can persist for hours and prevent the formation of further thermals with its shadow. It may disappear through solar heating or by sinking to warmer air-temperature levels, or it may simply blow away in the wind.

Location of thermals underneath broken stratocumulus ceiling



FLYING TACTICS UNDER STRATOCUMULUS

Areas of stratocumulus can increase during the course of a cross-country flight to the point that they merge and only a few blue holes are left to admit sunlight. Assuming that we're lucky enough not to be on the ground already, we must reverse our tactics. Instead of flying toward the clouds, we'll head for the sun, estimating where it's been shining longest and searching for lift on the upwind side of the sunlit areas. Sometimes only the edges of these areas will still produce thermals. If we're stuck below the cloud cover, the only areas likely to be worth looking for thermals in are those in which a clearly thicker section of the cloud deck, with a darker base, indicates the presence of an updraft.

LIFE-CYCLE OF LARGE CUMULUS (*CUMULUS CONGESTUS*) OR TOWERING CUMULUS

Just as with *Cumulus humilis*, the development of this type of cloud includes the same phases (1) through (6) as described earlier.

(7) If the reservoir of warm air remains unexhausted, the cloud will continue to grow. Other factors, however, can also cause continued growth — for example, if the surrounding air at cloud height is cooler than that of the thermal. If such outside air is entrained, condenses, and becomes unstable in its own right, the thermal receives additional energy input. The lift now becomes independent of surface features, being fed primarily from the higher strata.

(8) The size that the entire formation may finally attain depends on the temperature layering of the surrounding airmass. In our model the cloud would tend to burst upward most rapidly in those areas where there had been the best lift to begin with. A powerful suction develops beneath the cloud, which even brings air in from the sides. Any other thermals that may be starting to develop in the area will also be sucked in and will join to feed this single huge thermal, which will continue to become larger and stronger. In the immediate vicinity of the cloud, strong downdrafts will appear, and will probably entrain parts of the cloud and dissolve them. Further from the cloud, smooth, almost imperceptible sink will replace the air being carried aloft. This gives rise to the unfortunate fact that the air in large areas around Cumulus congestus, or even Cumulonimbus, is adiabatically "stabilized" by the descending air and seldom generates new thermals. In other words, large updrafts suck other, smaller ones into themselves, providing superb lift, but tend to suppress the development of other lift in the area. This effect is particularly noticeable on those days when overdevelopment over mountainous areas kills the thermals over adjacent flatlands.

The larger the cloud becomes, the more complex its development may be. There can be one, or several, "cores" of the strongest lift, with adjacent areas of very strong sink; moreover, different parts of the same cloud may be at very different stages of development.

(9) If the cloud grows through the freezing level there will be the possibility of showers. Depending on the strength of the updraft, the size of the cloud, and its internal structure, these showers can be harmless light rain, very heavy deluges of huge raindrops, or even hail.

Heavy rain, and to an even greater extent hail, entrain the air through which they fall and carry it downward, whether it may have been rising or not. Thus, heavy rain or hail encountered below (or in) a cloud are almost certain to be accompanied by very heavy sink.

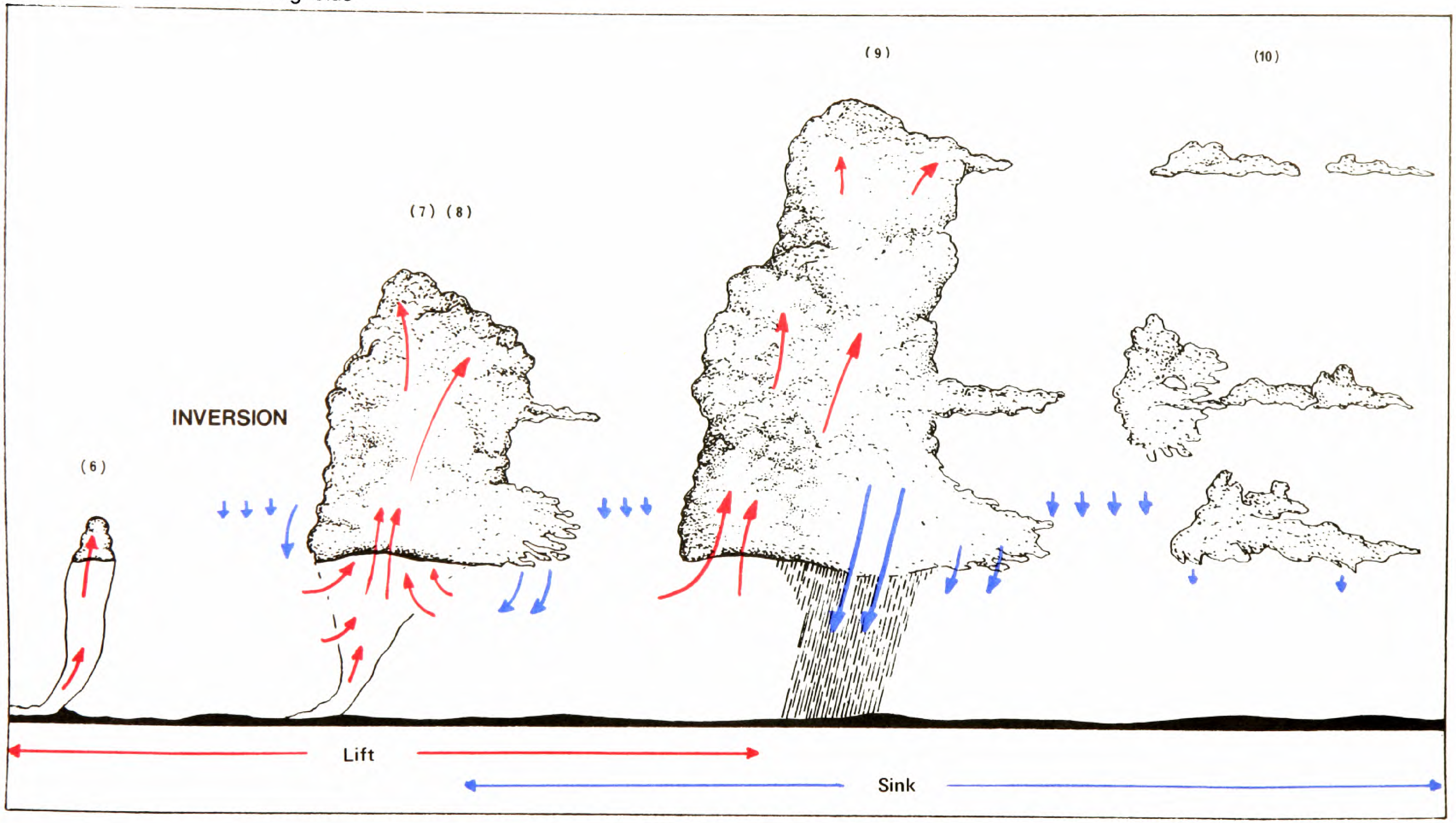
— *The 1972 World Championships at Vrsac vouchsafed me the dubious privilege of experiencing an extreme example of the above at first hand: Since I was fairly far behind after four contest days, I decided to delay my takeoff until I could climb on instruments in one of the Cumulonimbus that developed each day, then use the extra altitude to overtake my earlier-departing opponents from above.*

The first try is a failure; I don't get to the cloud in time, and am shot down. Meanwhile it's gotten pretty late, and there are numerous thunderstorms. I take off again just before the arrival of a squall, release at 1800 feet: 1600 fpm lift! By the time the towplane is back on the ground, I'm at 3600 feet, starting my run on the starting gate. 300 feet of altitude are traded for speed, but at 3300 feet and 115 mph I'm pulled irresistibly upward once again. In order to get a good start, I must go through the gate at or below 3300 feet (1000 meters), so I lower the landing gear and let the speed build up: 130, 150 mph! I have to hold the stick with both hands. I cross the start line, retract the gear, pull up — 3750 feet! Immediately, I turn, find the lift once again — it's actually still 1600 fpm! My despair turns to optimism; maybe I'll be lucky enough to be able to wipe out my earlier tactical error. Occupied with such pleasant thoughts, I switch on my turn-and bank gyro and artificial horizon and reach cloudbase at around 5600 feet . . . when it suddenly begins to hail. After half a circle, the variometer has gone from 1600 fpm up to more than 2000 fpm down. My sailplane falls like a stone into the abyss. The altimeter unwinds. I'm stunned; I search everywhere for lift, but absolutely nothing is left, I'm simply washed from the sky. At the end of eleven minutes I'm back on the ground . . . this time, for good.—

(10) Once all or nearly all the unstable air in the region surrounding the Cumulus congestus has been carried aloft, the areas of dissipation become more numerous and the cloudbase disintegrates.

Some remnant of the cloud may remain in existence for quite some time, especially in zones of

Life-cycle of a Cumulus congestus



weak inversion and at altitudes where the sounding reveals high humidity. These remains can cut off insolation for hours; such areas should be strictly avoided, since one generally finds only smooth, strong sink — or, at best, air with no vertical movement at all.

SEARCHING FOR THERMALS BELOW *CUMULUS CONGESTUS*

The weather conditions that give rise to giant Cu, with their terrific rates of climb, almost always bring with them the dangers of overdevelopment, showers, and large areas of shadow. Proper estimation of the clouds' stages of development may not only be necessary for high speed, but for completion of the task altogether. Success may depend on careful planning of the course to the next thermal, a well-chosen speed ring setting based on the distance, and sometimes large deviations from course. It is these weather conditions that can place the most critical demands on a pilot's decision-making abilities; the entire flight will be spent weighing alternatives against one another.

CONVECTIVE THUNDERSTORMS

Airmass, or warm-air, thunderstorms occur when the air is conditionally unstable (instability dependent on moisture) up to very high altitudes. These giant displays of our atmosphere's might should be avoided by everything that flies; even jumbo jets and fighters give these roiling cauldrons of immense thermal energy the widest possible berth. In addition to massive updrafts, we might encounter tremendous gusts, hail, lightning, and torrential rain that can reduce visibility below the cloud to less than a hundred yards. Below a thunderstorm, the cloudbase may descend thousands of feet almost instantaneously, and can obscure even minor hills. The thunderstorm's large expanses to the sides of the actual area of updrafts usually make it impossible for a sailplane at cloudbase to reach another thermal elsewhere; this rules out the use of such storms for VFR cross-country flight. Let us regard them, then, as dangerous obstacles which should be circumnavigated at a respectful distance — not only because of their own hazards, but because they will most likely shut off all lift in a wide area.

LINE SQUALLS, FRONTAL THUNDERSTORMS

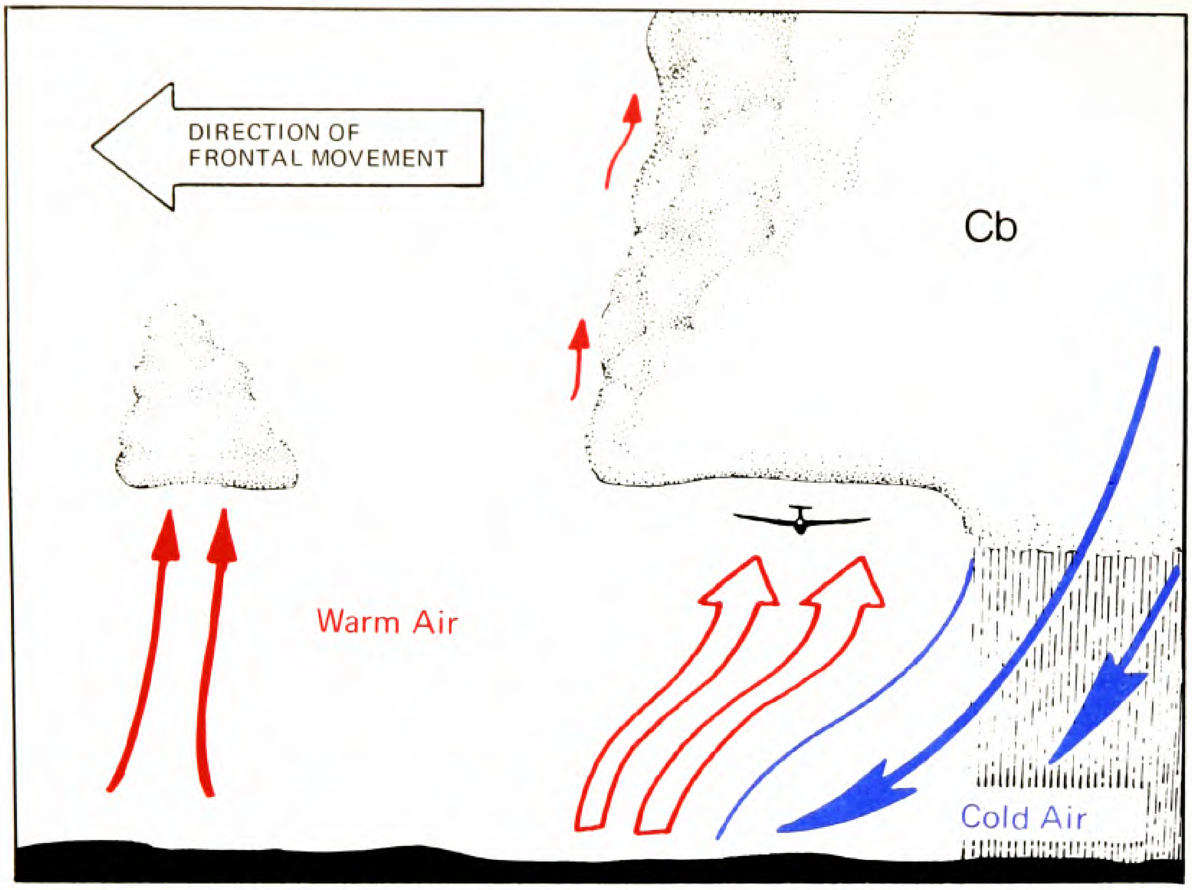
Showers and thunderstorms frequently will align themselves in a row running more or less across the wind. At this point, their appearance and behavior are very similar to that of a well-developed "classic" cold front. Experience suggests that such line squalls, whose relatively small size often precludes their inclusion on weather maps, can be treated by the pilot just as he would treat an actual frontal thunderstorm. On their upwind side we can expect strong, smooth lift, which will increase markedly as cloudbase is approached. If we now fly out ahead of the front, we may encounter thermals which it has "plowed up" and which allow us to climb above cloudbase altitude ahead of the advancing "wall" — especially if the front is a fairly fast-moving one. We'll encounter the highest cruise speeds, however, by remaining just below the upwind edge of the clouds and flying along the front in steady lift. Leeward of the "aerial race-track," we'll notice that the cloudbase takes a sudden downward jog, often linked with strong rain or hail, but always with heavy sink. Near the ground, frontal storms and line squalls are linked with gust lines; just before the first gusts arrive, one can often fly into the zone of rising air, with its smooth, wide lift, from surprisingly low altitudes. If we're lucky enough to be able to climb above cloudbase of the approaching front, the close-up view of the witch's brew of tremendous convection can be a glimpse of nature that will remain a high point of our soaring career.

As a cold front arrives on the ground, the wind veers suddenly (to the right in the northern hemisphere) and becomes a great deal stronger. Rain or even hail can reduce visibility to a minimum in seconds. A safe off-field landing under such conditions, where pilot and craft are most endangered, would be a piloting masterpiece (as several experienced pilots have found out at great cost). Their experiences should be sufficient reason for us not to trifle carelessly with such monstrous powers. Because of this our decisions have to be carefully thought out. If chances of finding further lift appear unlikely, we will use our altitude reserve to get well away (ahead) from the front before we land. As it is, we will usually have barely enough time on the ground to get the sailplane properly secured against damage before the first gust line arrives.

There is almost no point in attempting to penetrate below such a front against its direction of movement; not only is it dangerous, but it is hardly likely that there will be any usable lift behind it, at least within range of our glide angle.

THERMAL LINES AND CLOUD STREETS

In calm conditions and over regular terrain, thermals are more or less regularly distributed and, according to Prof. Georgii, are about 2½ times as far apart as they are high (convection height). On the other hand, any wind will tend to arrange them in rows. A major reason for this behavior is that certain good thermal producing and triggering areas will generate thermal after thermal, each drifting off downwind.



If the wind profile reaches a maximum within the convection layer — that is, the wind increases with altitude, but begins to decrease once again before the altitude of the cloud tops is reached — stable flow systems are established which are conducive to the formation of cloud streets. The lateral distance between such streets is, once again, about 2½ times the convection height; the terrain below has no influence except occasional disruptions of the pattern due to special circumstances.

Such cloud streets offer some of the best possibilities for cross-country flights, and assume their optimum form if the following conditions obtain:

— an upper convection limit due to stable temperature layering aloft (ideally, an inversion);
— a maximum wind speed within the convective layer;
— only minor potentially-disruptive terrain features (hills, etc.)

For an actual cloud street to form, of course, the requisite moisture for condensation must be present; however, the same conditions can give rise to thermal lines or "cloudless cloud streets."

FLYING TACTICS FOR THERMAL STREETS

When apparently endless bands of clouds cross the sky, the soaring pilot has cause to rejoice: these are the ideal weather conditions for goal flights, free distance, and, if the wind isn't too strong, goal-and-return flights. We set our speed rings so as not to climb into the clouds, but to achieve high cruise speeds. The landscape rolls away effortlessly beneath us, revealed at its most beautiful in the usually clear air of such soaring conditions.

The mathematician rejoices, since the regular distribution of thermals finally gives him a chance to calculate the best ways to fly, depending on given weather conditions.

In the following section, these mathematical theories will be taken for granted. A more detailed explanation, especially with regard to "dolphin flight," can be found in the "Speed-to-Fly" sections of both the first and second parts of this work.

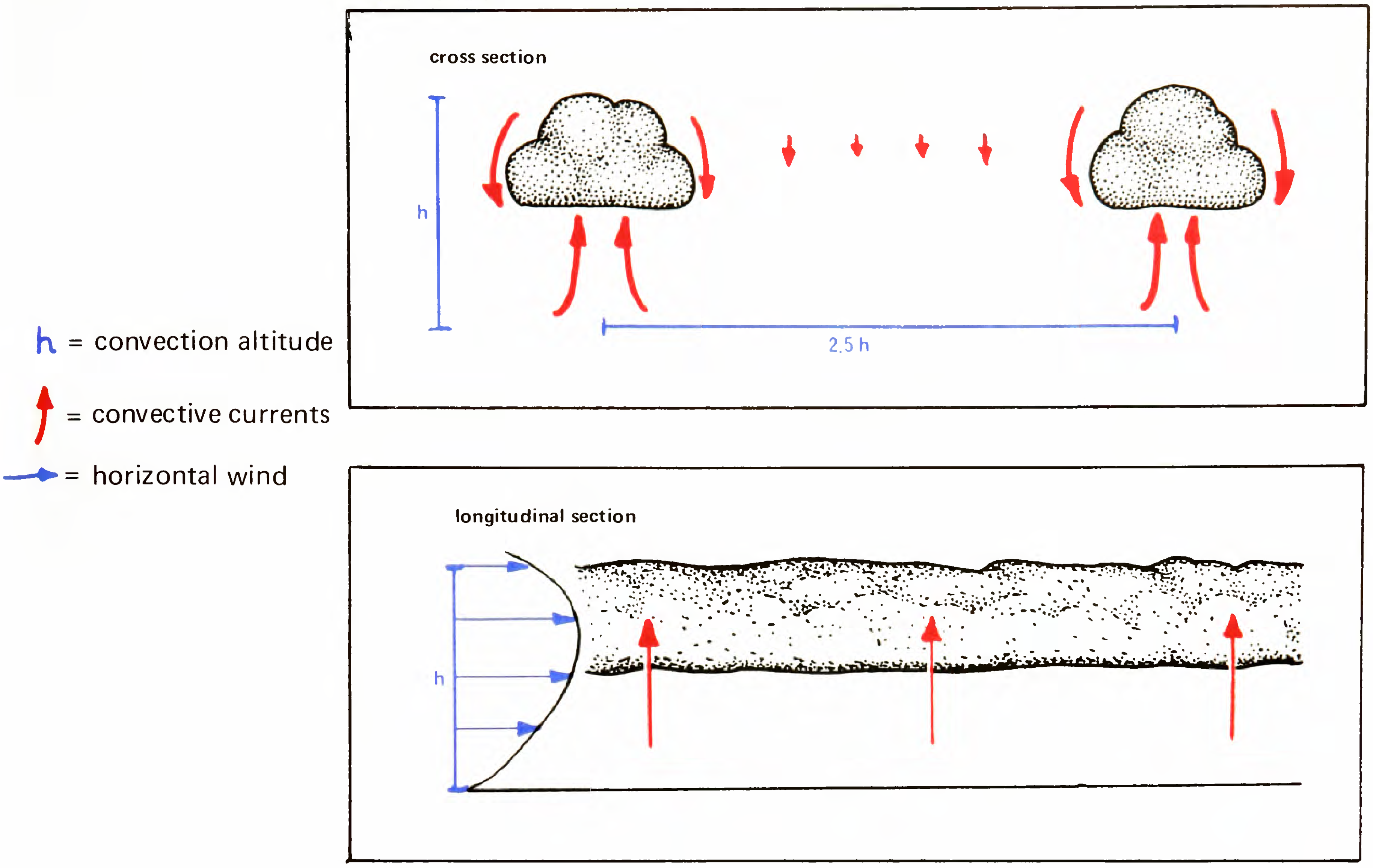
FLIGHT ALONG A THERMAL STREET

Let us start right out with a note about flying closely below a cloud street. After such experiences, you'll often hear pilots raving about the tremendous lift, and about how they had to speed up to avoid getting sucked up into the clouds. Only rarely, though, do they realize that this indicates how inefficiently they've been flying. After all, the underlying principle of the speed-to-fly theories is to *slow down* in lift, speed up in sink. Those who hang right below cloudbase at constant altitude are doing exactly the opposite, and giving up a significant amount of possible cruise speed. If we're working cloud streets, we should always have enough "headroom" to make proper and reasonable airspeed changes in accordance with our speed ring or speed-to-fly indicator.

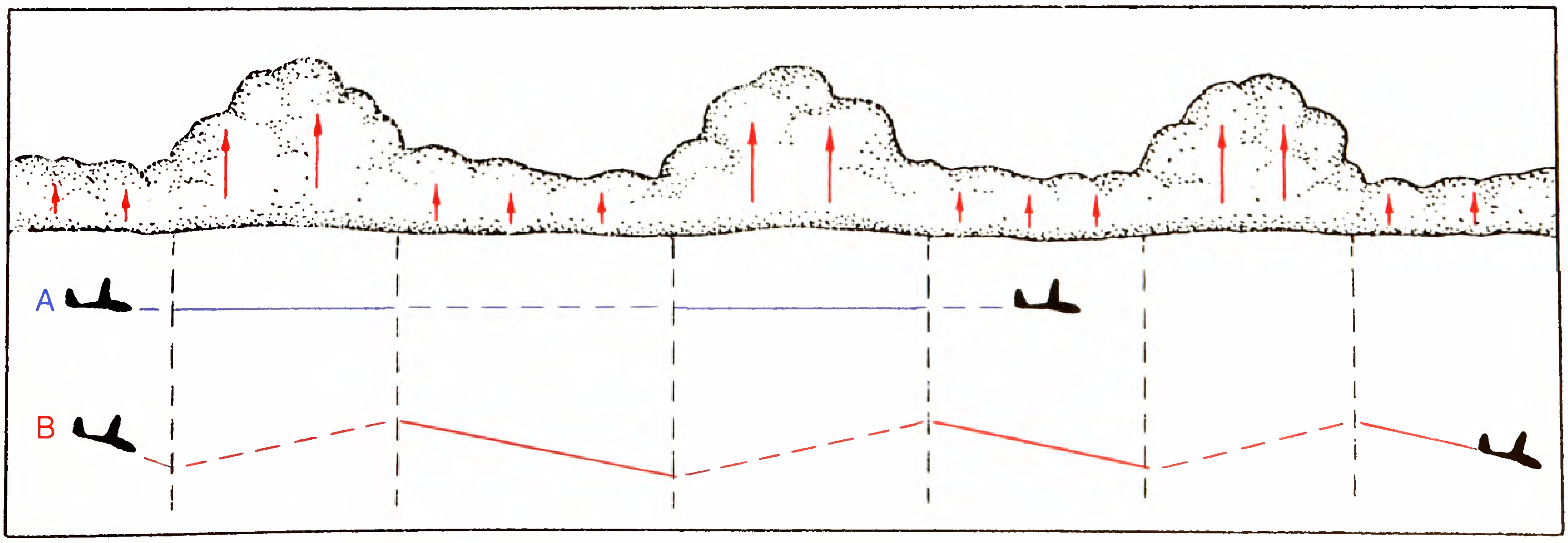
Flight along a line of thermals — or even in continuous lift of varying strength — is usually called "dolphin flight" or "pure dolphin flight." Unfortunately, these terms often remain unexplained. Let us define them at the outset:

Dolphin flight is straight cross-country flight based on the speed-to-fly theory, which is usually called the

Cloud Streets



Optimum speed under a cloud street
═ fast flight ═ ═ ═ slow flight
B achieves higher speed than A



MacCready theory but was in fact derived independently by several researchers, and which has since been elaborated by others. Such dolphin flight, with its zooms and dives, is a part of every modern cross-country flight. We can't really discuss speed-to-fly and dolphin flight theories separately, since the latter is nothing more than straight-ahead flight based on speed-to-fly theories.

Actually, a general speed-to-fly theory contains both a theory for "classic" cross-country flight, involving circling in thermals, and one for "pure" dolphin flight without any circling at all.

Such theories, when applied to flight along cloud streets, hold that the MacCready speed ring or other speed-to-fly indicators retain their full importance. Moreover, there are mathematical indications of the optimal speed-ring setting, and of whether or not to circle.

Based on the theoretical results, the speed ring is never set at any value less than the climb rate in any eventual circling climbs.

Ideally, this setting should yield a dolphin flight that will take us to our goal — this goal usually being the end of the cloud street at maximum altitude. Thus, the desired flight path is horizontal or climbing. In the special case of a final glide, though, it could also be a descending one.

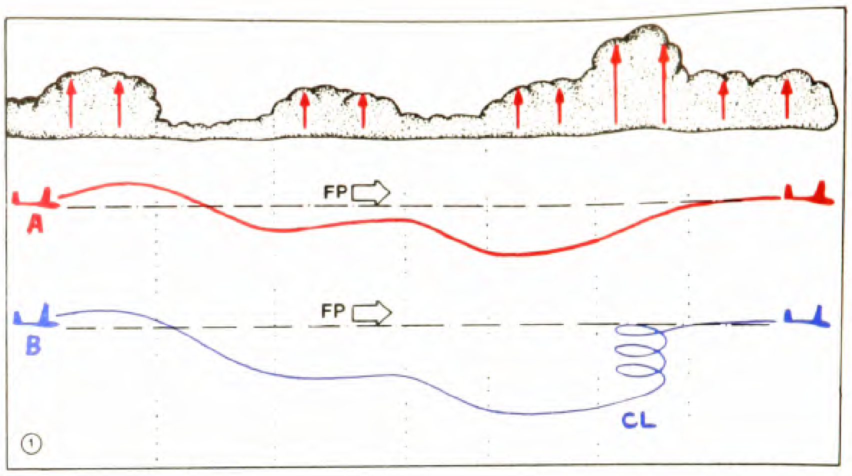
Perhaps, however, after attempting dolphin flight with the "theoretical" ring setting we'll accumulate an altitude deficit. In such cases, the desired altitude must be regained by *circling* in lift. It has been proven that this is more efficient than resorting to a lower ring setting.

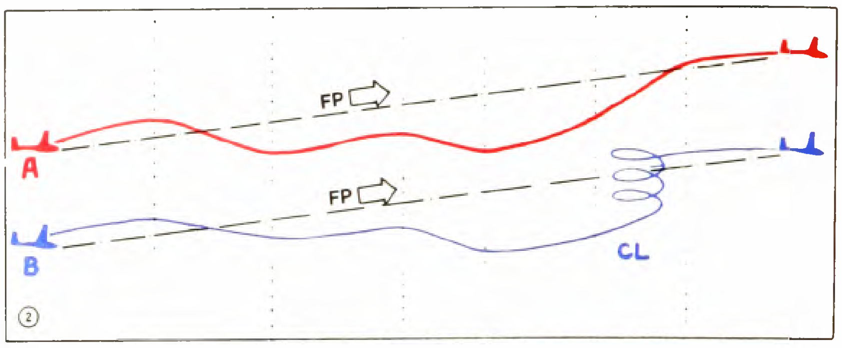
If, on the other hand, it becomes evident that we're gradually gaining altitude, the ring setting should be increased until the desired flight path is maintained, but at higher speeds. In such a case the ring setting for dolphin flight would actually be higher than that called for by the "classic" theory.

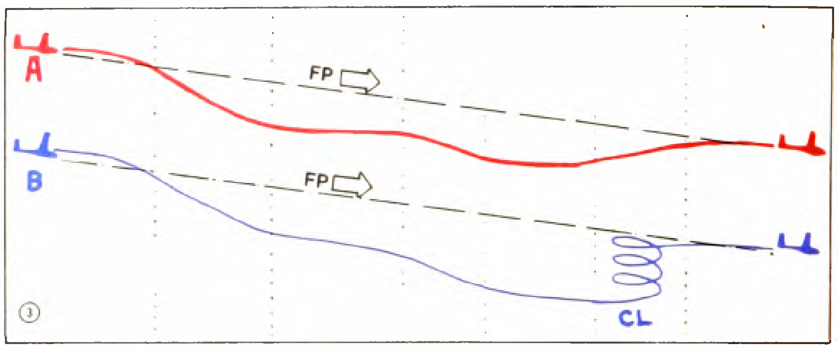
CIRCLING IS MORE LIKELY TO BE WORTHWHILE IF

- — we are well below cloudbase, or
- — we are about to reach the end of the cloud street, or
- — the climb rate at the location in question is clearly better than that of the street in general, or
- — we can safely assume that the lift in question, and other lift like it, is so limited in extent that straight flight will not suffice to maintain the desired flight path.

Experience suggests that it is advisable to depart from the ends of cloud or thermal streets at maximum altitude, since they usually end in areas without further thermal development. To cross these areas, we will need as much reserve altitude as possible.







OPTIMUM FLIGHT UNDER CLOUD OR THERMAL STREETS

Case (1): The desired flight path is horizontal:

The pilot of sailplane A sets his speed ring at the achieved rate of circling climb, or even higher, and makes good a dolphin-flight path that remains horizontal in the long run.

The pilot of sailplane B, which has worse glide performance, sets his speed ring the same way, but gradually loses altitude, which he must sooner or later regain by *circling in the best lift*.

Both pilots are flying optimally — that is, they're getting the best speeds possible with the given weather conditions and sailplanes. This is also the case for the two following examples:

Case (2): The desired flight path ascends:

Sailplane A uses the climb setting or greater and makes good the desired flight path in dolphin flight.

Sailplane B has accumulated an altitude deficit after considerable straight flight, which must be "repaid" by circling.

Case (3): The desired flight path descends:

Sailplane A once again maintains the desired path with the climb setting or better; sailplane B must circle again to cancel the altitude deficit.

COURSELINE OBLIQUE TO THE THERMAL STREET

If we assume that we can estimate the ratio between cruise speed beneath a street and speed directly on course, we can mathematically find optimum angles between the street and our desired course for varying wind speeds. The equations derived in these calculations can indicate exactly how long to continue following a street (assumed infinitely long) and the optimum angle at which it should be left. If the desired course crosses several streets, it is up to the pilot as to whether to stick with one street for a long time before departing on the optimal course, or to follow several streets for shorter distances, leaving each on the same optimum course. The distance flown will be the same in either case.

This problem has been attacked by H. Kiffmeyer (trial calculations without including wind factors), K. Ahrens and A. Wienen (mathematical derivation, again initially without wind), and again in 1973 by Ahrens and P. Sand, who finally developed mathematically exact formulae which included the effects of winds.

A brief summation of their results:

Continued flight under the street is worthwhile if:
— it is fairly close to the desired course, or
— one is flying *against* a relatively stiff wind, or
— cruising speed beneath the street is clearly higher than that possible elsewhere.

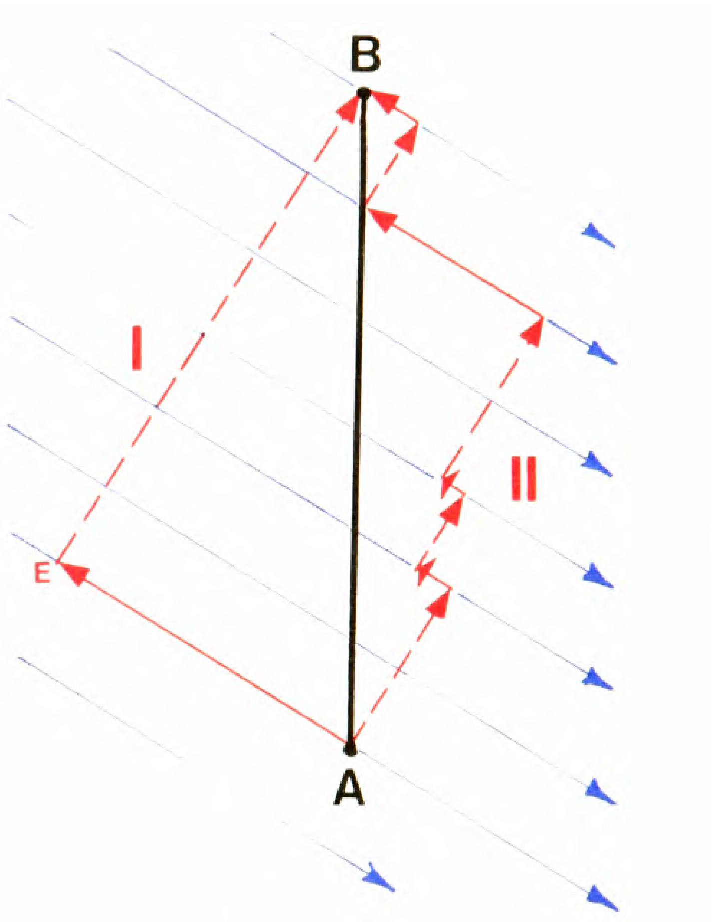
To be more precise:

— The *course* departure angle α_1 is the optimal angle between the cloud street and the new track over the ground. It is *independent* of the angle between the cloud street and the direct course to the destination or turnpoint, as long as this direct course is between crosswind and upwind. The size of the optimum angle depends on the ratio of cruise speeds under the street and in free air and the ratio of wind speed to the "non-street" cruising speed; that is, the angle depends on weather and sailplane type, but not on the actual "map" course. If the direct course lies between crosswind and downwind, a different, but still constant, optimal angle α_2 is calculated.

— The *heading* departure angle δ is the optimum angle between the cloud street and the sailplane fuselage. It takes into account any necessary drift corrections and remains dependent only on the ratio of street and non-street cruise speeds.

USE IN FLIGHT

We should have a clear picture of the situation and, based on it, try to depart from relatively good cloud streets at angles between 45 and 65 degrees. In general, however, it is a good idea not to immediately fly at the optimum heading, but rather to make our initial departure at a more acute angle in order to pass as quickly as possible through the "sink street" alongside the cloud street. By the same token, the last hundred yards or so to the new cloud street should be flown at a more perpendicular-than-optimum angle. We will continue under the street until our next goal — which could be the next street, or a turnpoint — lies at the optimum angle to the side. If the alignment of the cloud street is such that too large a departure angle would be required we won't fly along it at all!



Distances I and II are equal

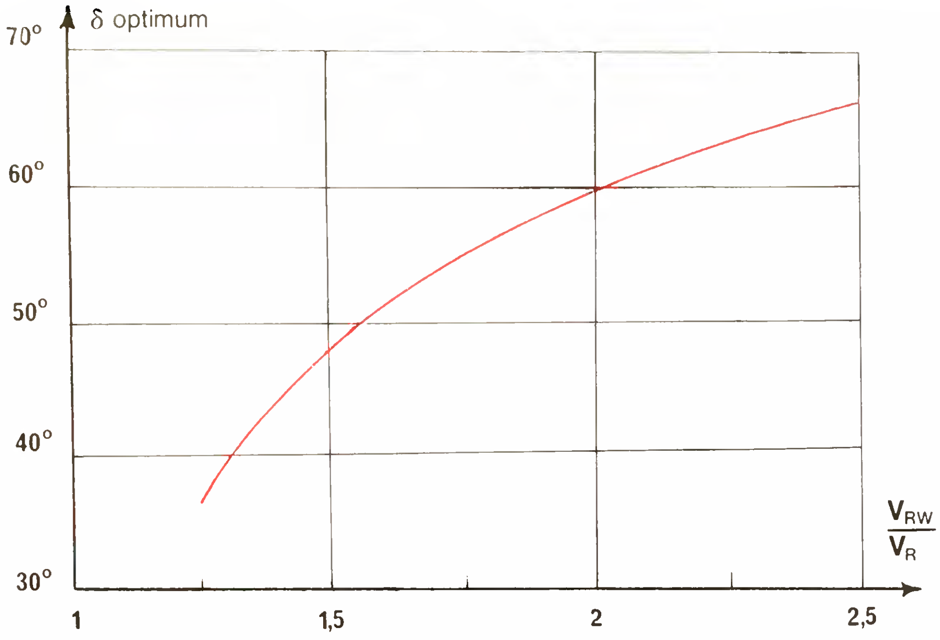
▲ Thermal Streets

| Direct Course

At this point it would be well to warn the more pedantic among our fellow pilots that the flyer who takes along a slide rule or computer in order to exactly calculate cruise speeds, angles, courses, and the like inflight is likely to fly right through the best thermals while involved in some abstruse mathematical process. The weather conditions are never really all that predictable in any case. None the less, the (mathematically calculated) savings in time that can be realized by flying the optimum, rather than direct, courses are quite interesting. For example:

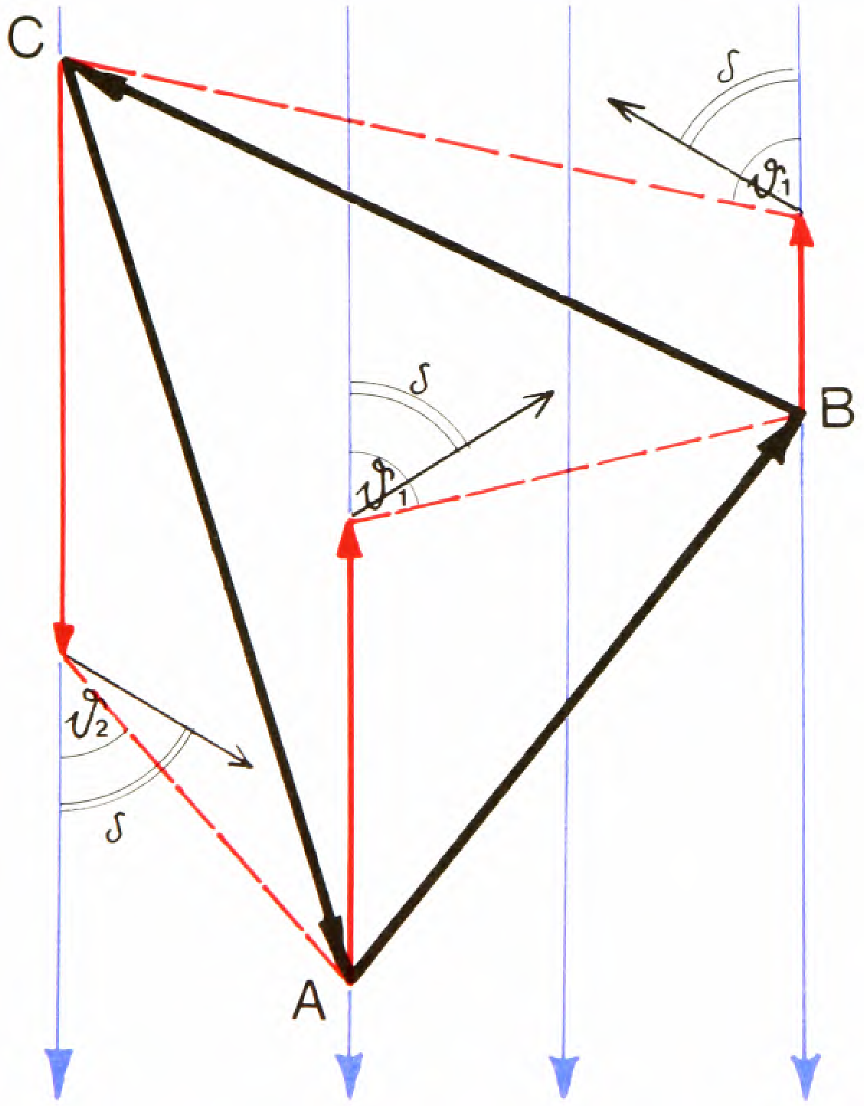
Given that we have a cloud street aligned at 30° to our desired course, and that beneath this street we can cruise at 87 mph, while between streets we can realize only 50 mph. The wind is along the cloud street and against us at 20 mph. The optimal departure angle is 55°, and we'll take 26% less time than the pilot who flies the direct course!

OPTIMUM DEPARTURE ANGLE



δ = Departure angle between cloud street and fuselage
V_{RW} = Cruise speed under cloud street
V_R = Cruise speed in other directions

OPTIMUM TRIANGLE FLIGHT UNDER CLOUD STREETS



ABC Triangle Task ▽ Direct Courses
↑↓ Rapid Flight along Cloud Streets } Optimum Course
╲ Slower Flight in Other Directions
ϑ_1 Headwind Departure Course
ϑ_2 Tailwind Departure Course
δ Departure Heading (including drift correction)

FLIGHT IN CLOUDLESS AREAS

— May 18, 1971, German Championships at Bückeburg. The task: 234-kilometer triangle

At first, cloud development is poor, but the conditions improve, as do our cruise speeds. Around 30 miles short of the finish, near Ith, we reach cloudbase around 3800 feet, in 400-fpm lift. One or two more scraggly clouds, and it's over: nothing but blue! Only over the mountains to the west of course can we still see a few miserable scraps. I decide to make a detour, five or six other ships follow. The rest of the competitors continue, constantly sinking, into the cloudless valley of the Weser. As we scratch our way back up to 3300 feet in the last weak thermals, the radio comes alive with the plaintive cries and landing reports of other pilots — which is, at least, a bit reassuring. But now we're not finding anything, either; the last remnants of cloud disappear altogether, then a couple of promising wisps appear once again — but unfortunately down around 1900 feet, which means only about 1200 feet above ground for those of us flying over the hills. As even the buzzards start to flap — making us envious — we hear over the radio that a couple of our colleagues who'd flown off into the blue so hopelessly have started to climb again. We fight as long as we can and finally land less than ten miles out. A few of the others are still airborne, toughing it out in weak thermals and slope lift. At the southern edge of the valley they work their way upwind and actually manage to reach Rintlen, make it over the crest of the Weser hills, and glide home.

Naturally, as soon as the rest of us arrived at the field we sought out the weatherman. His explanation: cold air flowing into the area had caused sudden decreases of the thermals, a northerly wind shift, and a lowering of the cloudbase. Our mistake lay in flying over the hills, since this didn't leave us enough radius of action. The others not only had more air under them, but found slope lift and slope-triggered thermals on the southern slopes of the Weser valley. This "slight difference" cost me 142 hard-earned contest points.

The events that took place that day are typical of slow intrusions of colder air. Such conditions are easily recognized by the increase in surface wind; wind direction and cloud cover usually change at the same time.

Cold Air Intrusions

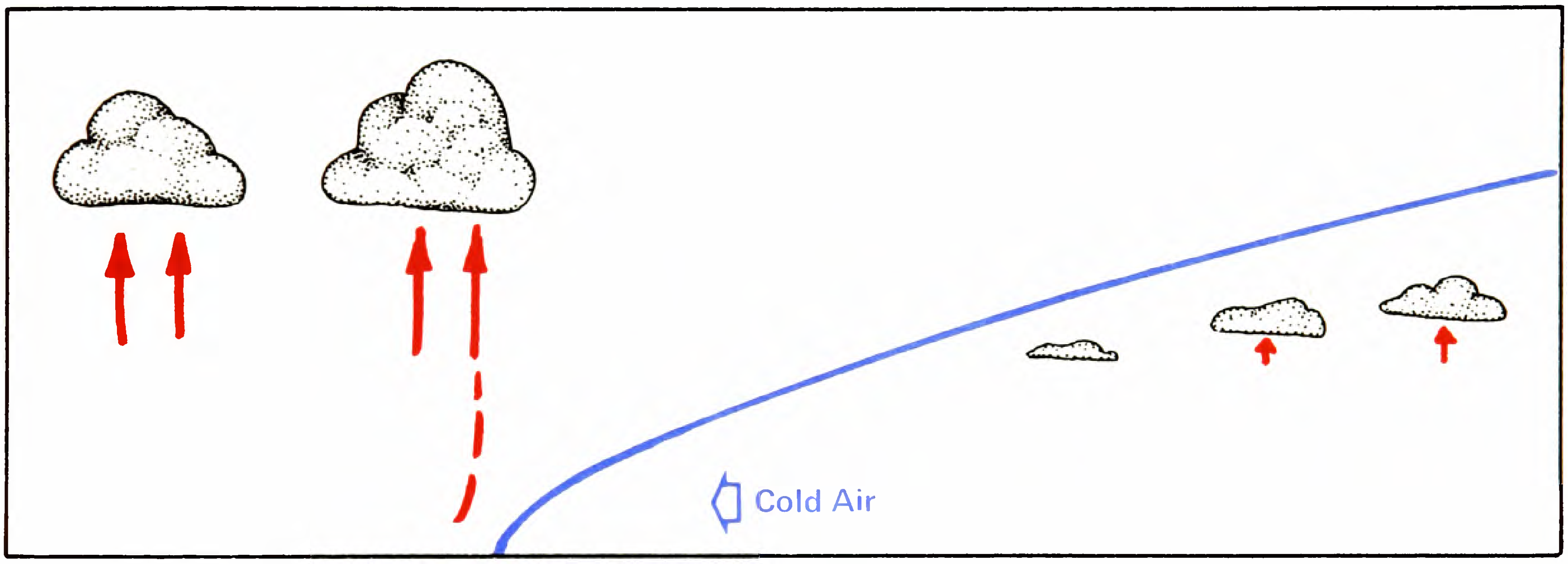
Such processes occur very frequently near seacoasts, where intrusions of cool marine air during the day can inhibit thermal activity 30 miles or more inland. Sometimes the border between marine and continental airmasses is clearly visible due to the absence of clouds and a change in visibility (less in the marine air), as well as the change in wind direction mentioned above.

In "blue thermal" conditions, intrusions of cold air at lower altitudes, which "cut off" thermals from below, are difficult to recognize in flight. Usually, though, the causes of the dreaded "blue holes" are less serious. If earlier cloud cover was thin, it may be that in a given area there's simply not enough moisture in the air to condense into a cloud, even though the thermals are as good as elsewhere. Or perhaps the surface air is warmer and hence no longer cools to the dewpoint (condensation temperature). On the other hand, though, the surface temperature may simply be too low to produce thermals, whether because of surface character (swamp, water, etc.) or because of an earlier rain shower.

If such blue areas are so large that we cannot be sure of traversing them safely even at best glide, we examine the possibilities of circumnavigating them. The earlier we make the decision to take an unavoidable detour, the better. A sufficiently early decision requires much less acute angles away from the desired course — and hence a smaller increase in air distance flown — than one put off until the last moment.

If it's impossible to go around, or if the cloudless area is too large, we have no choice but to carefully feel our way out into the blue to see if any turbulence indicates the presence of lift. Once we've found the first thermal we can continue to fly as we would for ordinary "blue thermals."

Incursion of cold air



INDUSTRIAL THERMALS

The immense quantities of dirty industrial smoke from the stacks of refineries, chemical works, steel mills, and power plants are not only bad for our health, but reduce visibility, and hence solar energy arriving at the surface. They can shut down thermal activity for miles around, especially on windless days of high-pressure area type weather. The soaring pilot can take some small consolation, however, from the fact that these smoke sources represent heat sources that are largely independent of the sun and which, depending on the "quality" of the industry in question, can form thermals — sometimes only in the weakest winds, and in fact sometimes only in combination with other, natural factors. These odiferous thermals sometimes flow steadily, sometimes pulsate, and can be particularly valuable as a means for extending flight toward evening, when everything else "goes to sleep." To climb in such conditions is hardly the epitome of soaring pleasure; some smoke clouds contain rather virulent poisons, whose effects usually reveal themselves as malaise and nausea. Of course, what's important here is to keep a close eye on yourself to observe any symptoms and leave the danger area — usually easily defined by the visible smoke cloud — before your flying abilities are adversely affected.

THERMALS WITHOUT CONDENSATION

If the rising air is too warm or too dry to permit condensation and the formation of clouds, the convective flow will remain invisible to us. Of course, all the mechanisms of thermal development we've already discussed (thermal sources, triggering processes, streets, etc.) function exactly the same whether clouds form or not.

FLYING "BLUE THERMALS"

From a pilot's point of view the problem is that of achieving more or less correct flying tactics without visible signs of lift. It's obvious that to simply glide off hoping to hit lift — like a blind man in a forest who knows that sooner or later he'll run into a tree — is far from optimum. None the less, over regular terrain that's sometimes just about all we can do. Straight flight, then, should remain our last resort, when all else has failed. In general we can improve our chances of finding lift by paying particular attention to several factors:

— *Terrain heating*

Cloudless skies make it particularly easy to estimate where reservoirs of warm surface air will develop.

— *Triggering areas (ridges, etc.)*

— *Tilted thermals due to wind*

— *Thermal lines and streets* occur just as they do in the case of cloud streets, and should be flown using the same tactics and techniques.

— *Visible signs of thermal triggering*

Movement of crops (especially cereals) in fields, streams of smoke from fires or chimneys suddenly turning upward, several different streams of smoke merging, wind socks at an airport pointing in different directions, or a column of smoke pointing other than downwind, dust devils, and so forth.

— *Soaring birds, other sailplanes*

— *Haze "domes" at the inversion level*

These domelike "bulges" in the top of the haze layer are sometimes quite easily visible and allow a systematic approach to lift, just as if clouds were visible. They are more visible through brownish or yellowish sunglasses than through blue ones; Polaroid glasses are susceptible to interference effects with the Plexiglas canopy and I flew off to a number of nonexistent haze domes before I caught on and banished the expensive spectacles from my cockpit.

Flying tactics for blue-thermal conditions do not merely decide the success of our private cross-country ventures, but can often be the factor that separates victor from vanquished in regional, national, and international competition, since any day with thermals — even blue ones — is likely to be a contest day. Thus, it's extremely valuable to devote a certain amount of effort, both on the ground and in the air, to learning about cloudless conditions — particularly if one has competitive ambitions. During the German championships in 1973 a number of excellent pilots lost their high standings by adopting an overly sanguine "press on regardless" attitude; at the same time, though, one pilot's too-cautious attitude ended up costing him not only 300 precious speed points but a place on the German team that went to Australia! The second-to-last contest day of the 1969 German championships at Roth was another such situation, and one that caused excitement and anxiety during final glides: after a final 800-fpm thermal, some of the competitors fell short of the finish, while others were hard pressed to cross the finish line below the 300-meter (1000 feet) maximum altitude without exceeding redline speed. The reason: invisible thermal streets had formed aligned with the final-glide course. Those lucky enough to blunder into one were rewarded with strong lift, while those who flew between them encountered strong sink that persisted until they either landed or assessed the situation properly and deviated to one side or the other.

AIRFLOW OVER CONVECTIVE BARRIERS

In windy weather, freshly-risen thermal airmasses can form meteorological "obstacles," which the general wind will flow over and/or around just as if they were hills or ridges. Such "convective barriers," however, remain effective for only a short time, since over a period of time the wind at various altitudes will distort and ultimately dissipate them.

Surrounding air mixes to a greater or lesser extent with the air of the convective barrier Even so, a number of very interesting flights can be best explained by applying to these conditions the same principles we have learned from slope and wave soaring.

It is not too uncommon to fly upwind (or, more exactly, against the wind shear) below cloudbase and encounter smooth, constant lift. One can often climb several hundred feet in this laminar flow, which is similar to that along a slope, while remaining upwind of the cloud and maintaining visual flight. Sometimes it's even possible to climb above the top of the cloud.

The requirements for the development of such "slope lift" in the atmosphere include:

— *Convection of sufficient strength to form "barriers";* (the greater the extent of such barriers across the wind shear, the better the "convective slope lift")

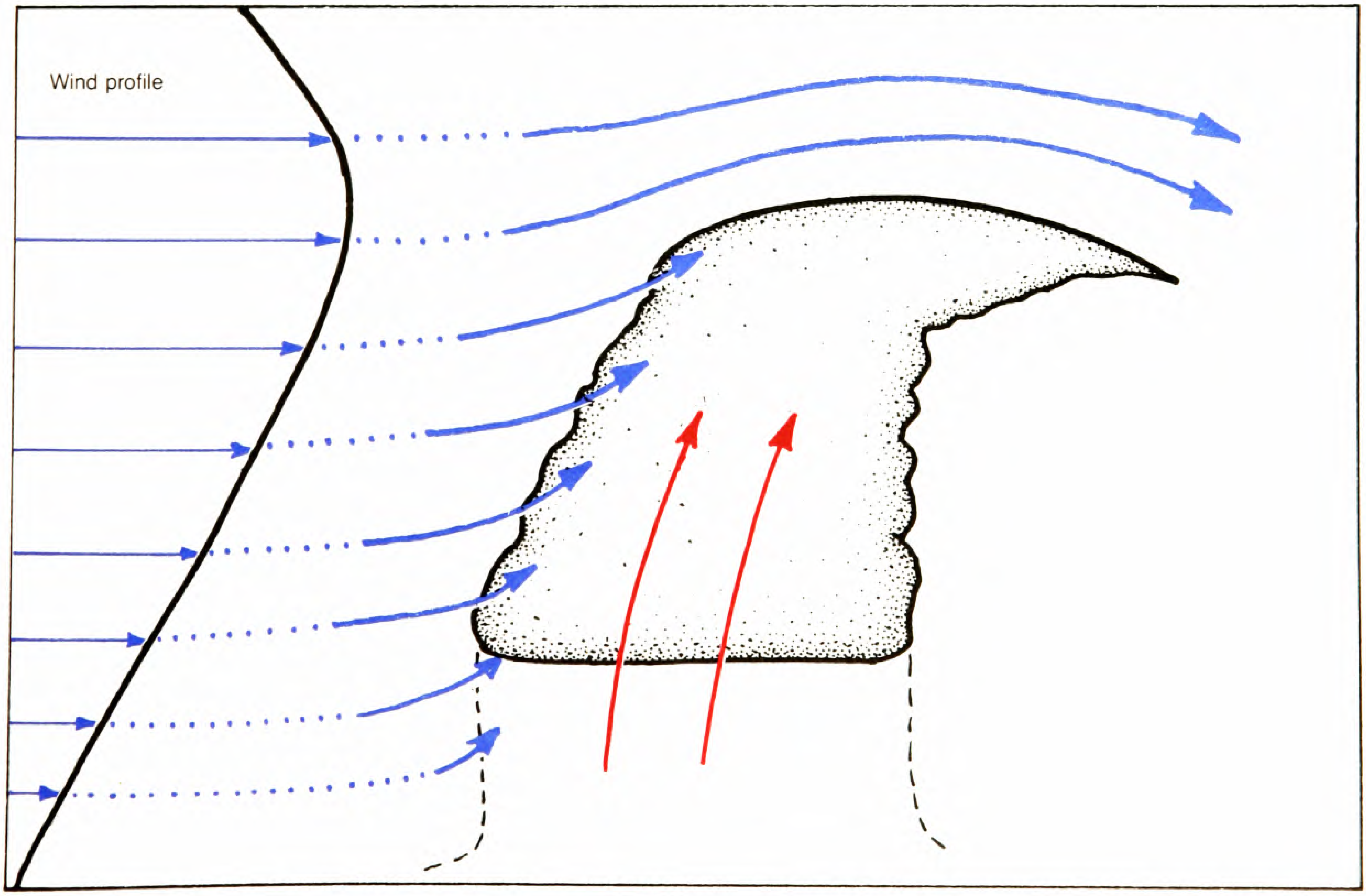
— *Definite wind shear (increasing wind speed with altitude)*

— *Stable airmass layers above the convective zone*

The latter two requirements are also those for the formation of lee waves in mountainous areas. Convective barriers can produce similar orographically generated "convective lee waves."

Often, the upwind (and upward-moving) side of the first of such lee waves generates a further convective cell, which in turn generates a further wave, and so on. This can generate a system of waves beneath which thermals will be found in rows aligned across the wind shear. The German pilot Carsten Lindemann has observed and flown in such wave-generated systems over the flat terrain behind the Teutoburger Wald (a rather low mountain range in Germany), which served to trigger the initial line of thermals that caused the wave.

Convective "Slope" Lift



THERMAL-STREET WAVES

Cloud and thermal streets are usually limited in their upward development by inversions. There is often a wind-direction change at the inversion altitude.

These are conditions which can cause the formation of convective waves.

The first well-documented flight in such hitherto unknown thermal waves was made in 1964 by K. Lamparter. Further flights (A. Eckart, H. Huth) in 1971 finally provided sufficient data for a meteorological derivation of the conditions required for thermal waves. In recent years, Ingo Renner has made some spectacular cross-country flights in thermal-street waves high above the cumulus clouds in Australia. Ideal conditions include:

— *A somewhat stable flow lying above the convective layer in which clouds develop, and oriented more or less perpendicular to the cloud streets and lower-layer winds;*

— *A natural wavelength of the upper layer (dependent on temperature gradient and wind speed) which closely coincides with the average cloud street spacing (resonance).*

FLIGHT IN CONVECTIVE WAVES

In general, the relatively weak lift of the laminar flow over the convective barrier is not strong enough to enable a pilot to save time on a cross-country flight. Even so, the possibilities we've just discussed can be a source of remarkable and impressive flights, which fascinate through their beauty and ease. If the climb under well-developed Cu is consistently better on the upwind side it is worthwhile to try to climb in clear air upwind of the cloud. Cloud street waves are indicated by the same phenomenon of better climb on the upwind side of the cloud, which is also the location of the wave's ascending side. The upper clouds in such situations are often somewhat tattered in appearance due to the wind shear.

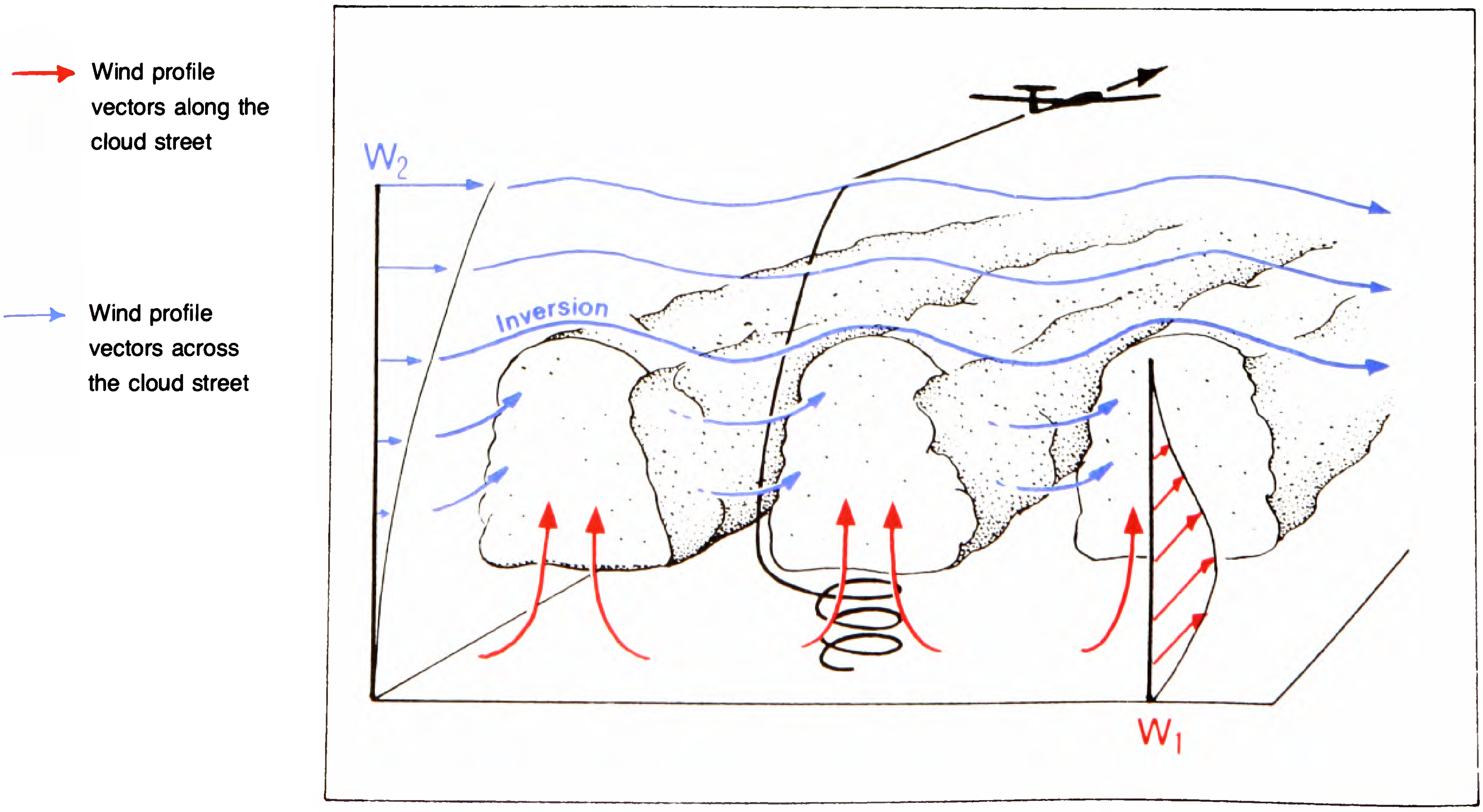
Inversion and Shear Waves (moving waves)

From Wolfgang Itze's description (in Deutscher Aeroklub's *Aerokurier* for January, 1963) of his flight of September 16, 1962:

"I took off from Kassel-Waldau airport at 5:35 pm, one hour before sunset, for a local flight in the club Ka.8. Release altitude from a winch launch was 1050 feet. The last remnants of evening thermals allowed me to gain a further 330 feet in 50-fpm lift. When I could no longer maintain more than zero sink in very slow straight flight, I gave up circling and decided to fly about a little before landing. After about 3 miles of straight flight I still hadn't lost any altitude.

I continued to fly S-turns to determine the direction of the inversion wave and by about 6:00, when the air had become completely stable after the last evening thermal, I was still climbing at a good 200 fpm, flying back and forth for about six miles as if I were flying a ridge. When I reached 2200 feet, the bottom of the inversion, the lift reduced to zero sink. I could have remained aloft indefinitely, and I suppose I could also have flown for long distances, but the approach of darkness forced me to land. Some 3½ miles away,

"Cloud Street Wave" (after Dr. J. Kuettner, 12th. OSTIV Congress 1970)



parallel to the wave I was flying, I discovered the next very intense inversion wave. I landed after determining the direction of this second wave."

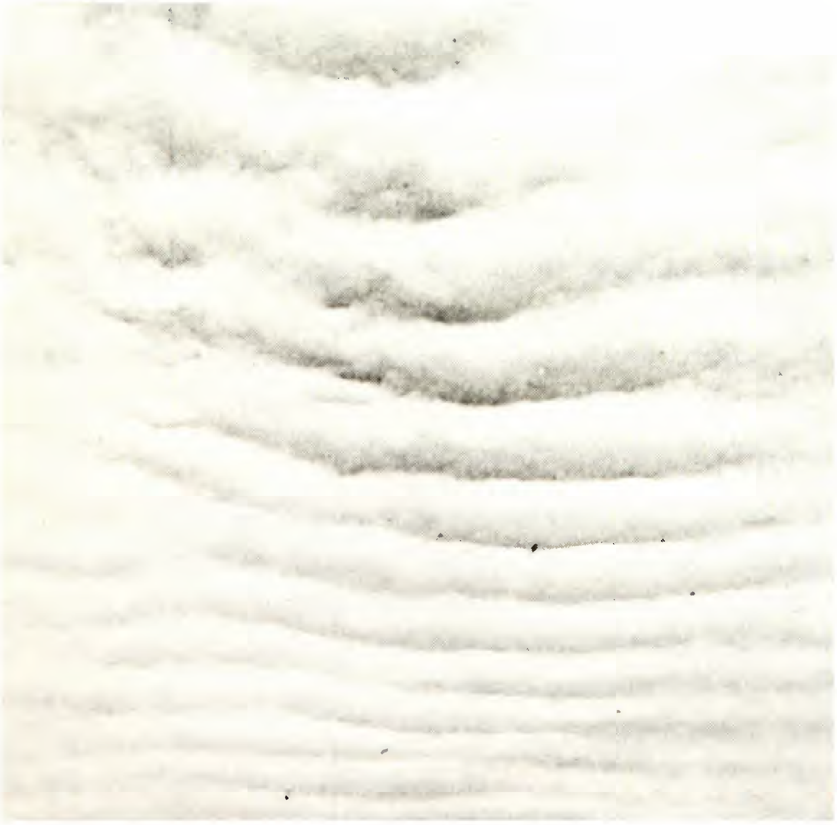
Itze had remembered the theoretical representation of an inversion wave in Georgii's book, *"Meteorological Sailplane Navigation,"* and had used the information in flight.

Inversion waves are formed if there is a strong wind shear at the inversion altitude. They are independent of any obstacle, whether terrain or convective, just like waves at sea; their direction is across the wind shear. Itze provides the following data for the day of his flight: Surface wind 210° at 5 kt, wind at the 850-mb surface 270° at 15 kt. Assuming that the shear occurred fairly abruptly at the inversion, it would have a resultant of 110° at 13½ kt, in which case the waves would have been aligned 20°   200°. Itze's inflight estimate of 10°   190° tallies closely with this. At the same time the waves must have moved in the shear direction — that is, 100° — since they travel like waves on the water surface.

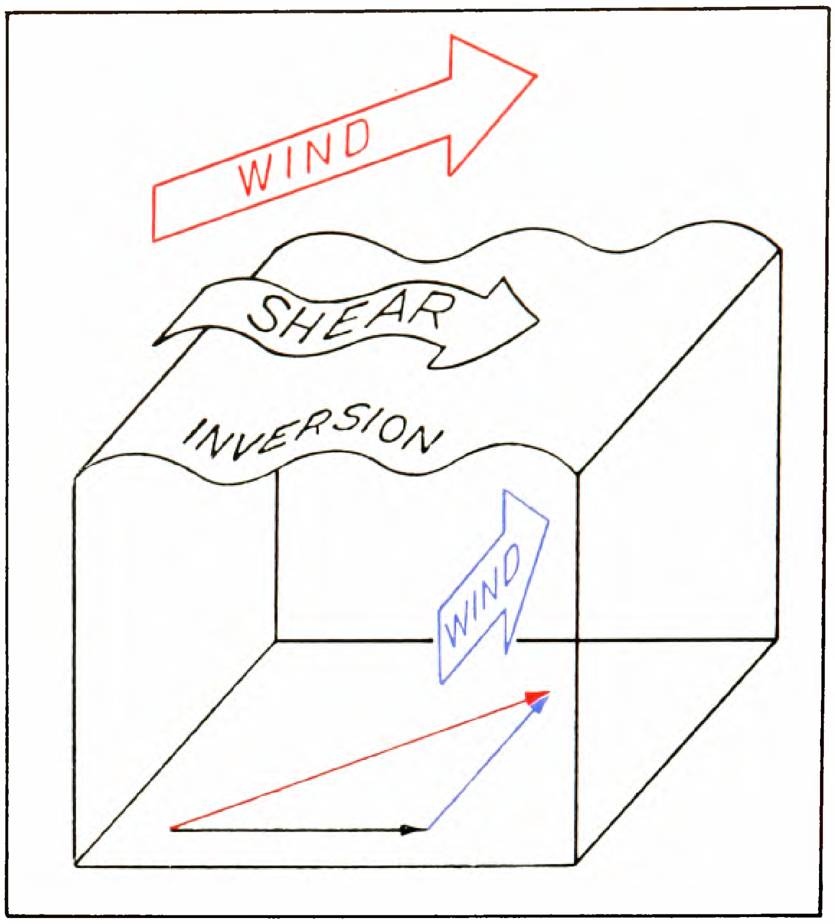
The description of 3½ mile wave spacing is difficult to understand, though, since inversion (or Helmholtz) waves could only develop such wavelengths under extreme conditions. (Wavelength increases with the abruptness of wind shear and decreases with the strength of the inversion. Since strong shears and strong inversions usually go hand in hand, wavelengths are usually less than 3000 feet.)

A flight made in 1960 by Kolde and analyzed by H. Jäckisch seems to fit the model more exactly as far as wavelength is concerned.

Inversion waves are limited to a shallow layer, are difficult to locate (since they move), tend to "break" like water waves, and hence usually exist only for short periods. It is doubtful that they'll ever have much practical use for cross-country soaring.



Inversion Waves



Direction and strength of the wind shear are obtained by subtraction of the wind vectors

Lee Waves in Mountainous Terrain

DEVELOPMENT OF LEE WAVES

Just as ripples form downstream of a submerged rock, ripples form in the air to the lee of a moving ship, allowing gulls to follow the ship at a fixed distance without flapping. They can also soar further from the ship in the second wave. If they wish to reapproach the ship, they speed up sharply in the second wave (speed-to-fly!) so as to pass quickly through the sink on the lee side of the first wave. As simple and clear as this may appear, the physics of wave flow are actually very complex. It's taken years for sailplanes to explore the phenomenon of lee-wave lift, and it's only recently that mathematical calculations — some of them extremely complex in their own right — have started to reveal accurately the processes taking place in the wave. We'll discuss a few of the most important meteorological bases in order to better acquaint the pilot with the information needed to estimate the probability of successful wave flights.

TERRAIN INFLUENCE

The first important fact in this regard is that the terrain has, for all practical purposes, no influence whatsoever on the wave*length*. Rather, it functions only as an initial "generator" for the wave tendencies of the airmass, and can generate stronger or weaker waves, but cannot affect the wavelength, which is dependent only on meteorological conditions. In general, the closer the shape of an obstacle approaches that of the ideal form of a potential wave, the more effective a wave generator it will be.

Thus, the following are favorable circumstances:

— *An obstacle with relatively steep lee side*
(The topography of the lee side is far more important than that of the upwind side. Very steep lee sides are conducive to the formation of rotors, as well.)

— *An obstacle with a relatively smooth surface*
(Particularly important for smaller generators.)

— *As long a ridge or mountain as possible,* so that the air doesn't simply flow around its sides. (Short coneshaped hills are unlikely to produce waves.)

— *The ridge line should be as perpendicular to the wind as possible*
(Deviations of up to around 30° from the ideal right angle will still allow the formation of waves which will lie parallel to the obstacle, not at 90° to the wind.)

— *A further obstacle located one wavelength, or an exact multiple, to leeward, with no major intervening barriers to airflow*
(This causes a reinforcement of the wave amplitude, or wave height, due to resonance. As a rough rule of thumb, wavelength in statute miles can be estimated as one-fifth the average wind speed aloft in knots — for example, if wind aloft is around 50 kt, the distance from crest to crest or trough to trough would be around 10 statute miles. More exact results require consideration of other factors such as stability of the wave airmass.)

WEATHER REQUIREMENTS

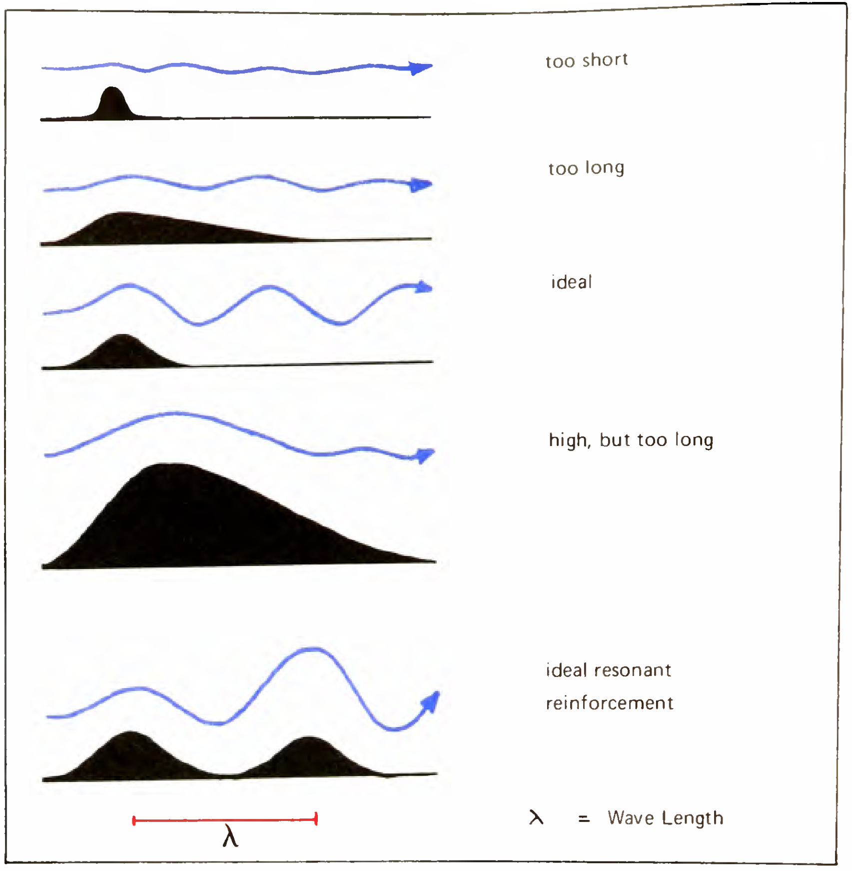
The airflow in the wave is laminar (smooth) and hence is not compatible with the formation of thermals or other convective effects. Thus, waves usually form only in stable airmasses. The best conditions occur when an extremely stable layer is "sandwiched" between two less-stable layers on which it can "bounce."

Again, a few of the most favorable conditions:

— *A stable airmass*
(Ideally with a stable layer between two less-stable ones; greatest climb rates can be expected in the most stable layer.)

— *Wind speed at ridgecrest height of at least 15 knots*

Influence of shape of Wave Obstacle (after Wallington)



— *Wind direction more or less constant to the top of the stable layer*

— *Wind speed increasing with altitude*

Those who find these four guides to wave probability too vague can make use of the more exact "Scorer Parameter" as a description of the atmospheric conditions required for a wave; this is the meteorological part of the very complex lee wave equation. If an airmass layer is suitable for waves, the Scorer Parameter will decrease with altitude.

$$I = \sqrt{10^6 g \cdot \frac{\gamma_a - \gamma}{T \cdot V^2}}$$

I = Scorer Parameter
g = earth gravity
γ_a = adiabatic temperature decrease, and
γ = actual temperature decrease in the given altitude layer
T = absolute temperature
V = wind speed

Thus, the Scorer Parameter will be smaller, if

— Stability decreases with altitude

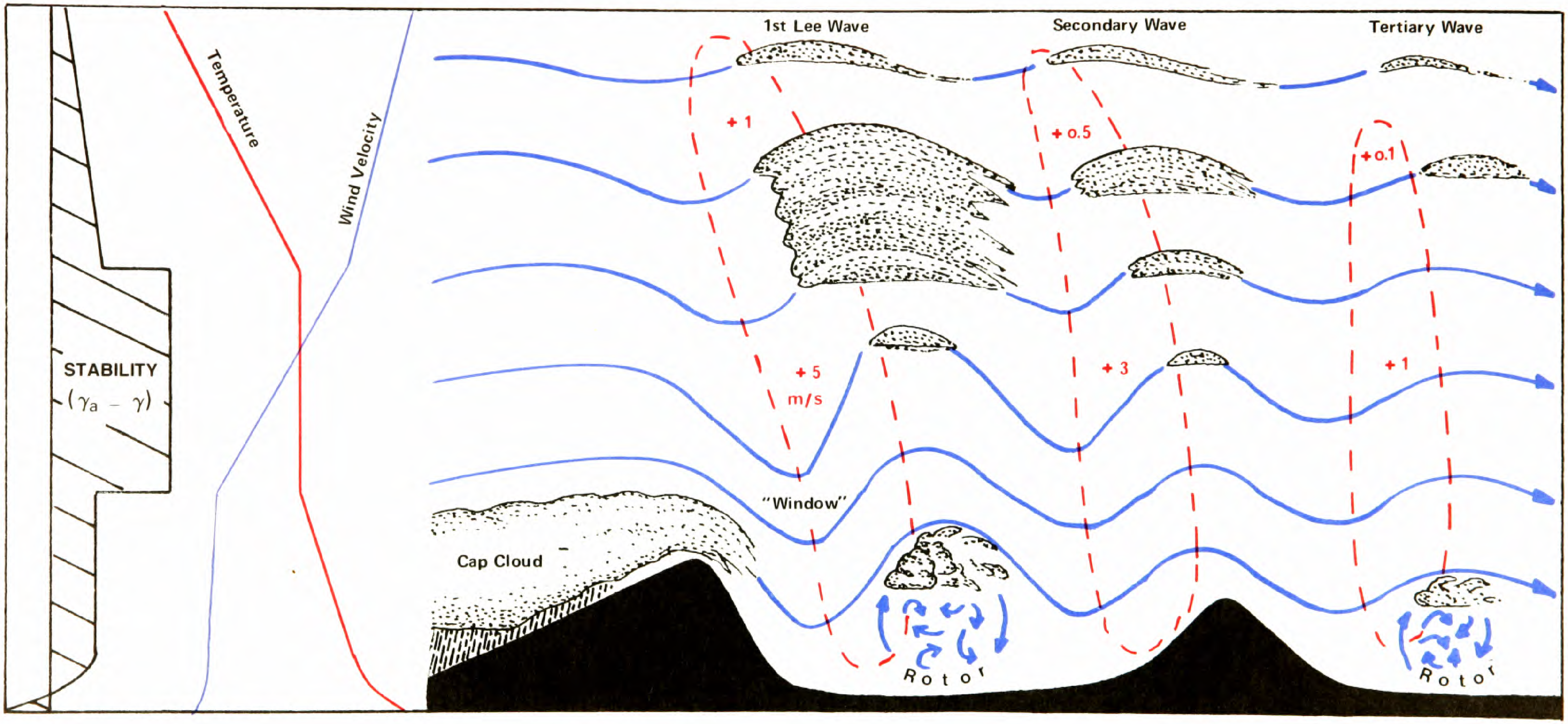
— The relative temperature remains fairly high

— The wind speed increases.
(Since wind speed appears squared, it is especially important in this equation.)

FLOW MODEL OF LEE WAVES

If the Scorer conditions are met, the wind speed is sufficiently high, and the terrain suitable, lee waves will be generated. This can occur downwind from seaside dunes, from smaller mountains like the Alleghenies, or from large mountains such as the Rockies, Sierra Nevada, or the Alps; naturally, the flow patterns will differ. The illustration represents the Alpine "Foehn" as a typical situation.

Mountain Lee Wave



CLOUDS ARE NOT INDICATIVE OF LIFT STRENGTH

The development of clouds depends on moisture and wave amplitude and has no direct influence on the wave structure. If clouds have formed on the upwind side of the obstacle they will dissolve as the air descends on its lee side, causing the typical "wave window." This is often the only sign of wave lift. Depending on the terrain, one or more rotors may also form, in which air from the valley "rolls" over and over. This "rolling" causes strong instability in the rotor zone due to adiabatic heating and cooling of the rotating airmass, and the resultant convective flows stir up the air in the rotor region in a chaotic fashion. The greatest wave amplitudes usually occur in the most stable layer, and this is where the greatest climb rates are usually found. The "quality" of various lee waves may differ depending on terrain and position, and the best lift may not necessarily be found in the primary wave. Cloud formation depends on moisture; visible clouds may include fractocumulus in the rotor as well as the characteristic lenticular clouds in the wave itself. These latter can have flat, concave, or convex bottoms. Ice clouds can form at very high altitudes, and can extend far along the wave, dissolving only very slowly. If the overall humidity is high a massive wall of cloud may form downwind from the wave window, revealing its wave character by lenticular-like protrusions from its upwind face.

Wave clouds can be easily recognized in that they remain stationary over a given point, constantly forming at their upwind edge and dissipating at their downwind edge. They occur at the "summit" of wave flow in their particular layer, and grow symmetrically upwind and downwind from it.

Rotor clouds consist of scraps of cumulus, often carried off to leeward by strong winds and dissolved in their higher reaches. If the humidity is high, they can take the form of compact rollerlike structures.

FLYING TACTICS FOR LEE WAVES

Various terrain and weather conditions require widely differing behavior on the part of the pilot. While the waves produced by lower mountain ranges are usually less fearsome, certain flights — for example, through rotor areas in high-mountain waves — require our utmost competence.

We take off dressed as warmly as possible and with our sailplane well equipped. We should carry a good three to four hours' supply of oxygen and should be strapped in tightly, aware from the outset that we may encounter extreme turbulence in rotor areas.

At some sites one can make a winch launch, fly at once into strong and usually turbulent slope lift, and try to climb as high as possible. Then we can fly upwind, through the strong turbulence of the descending side of the rotor, into the rotor's ascending side, where we can attempt to latch onto the (usually very narrow although strong) lift. Instant changes of ± 1600 to 2000 fpm are not at all unusual. Above a certain altitude it suddenly becomes glassy smooth: we have reached the wave.

More commonly, though, we will be aero-towed through the worst of the turbulence directly into the wave. Such tows require quick reactions and good nerves of both the sailplane and towplane pilots. On the other hand, some waves over "milder" terrain can be reached without encountering major turbulence.

Once in the wave, we make sure our oxygen equipment is in order and explore upwind for the best lift by flying extended figure-8s — never by circling. We fix our position with regard to some easily-recognized feature on the ground and guard against being carried back into cloud, or into the descending side of the wave, by the increase in wind speed as we continue to climb. We may elect to move to a different wave, either upwind or downwind, if it looks like we'll climb better there. If there is a large cloud bank, we climb upwind of it, just as in slope soaring, always turning away from the "hill" and always making sure that we have a safe escape route into the valley.

Generally, the area of best climb will tend to lean upwind with increasing altitude. We should also keep an eye on the time, since the long twilight at high altitude can fool us into thinking there is still sufficient light on the ground for a safe landing. And it is a good idea for us to keep moving our feet, since the external temperatures of 30, 40, 50 or more below zero always bring with them the risk of frostbite.

Other than those hazards directly related to flight at high altitude (hypoxia, cold, "bends," etc.), the major risks are due to improper estimation of wind strength, the approach of darkness, or cloud cover. The types of wave cloud which can form if the humidity is high, and which can close below the sailplane if the wind decreases, are the most dangerous. Depending on the circumstances, it may be necessary to make an emergency rapid descent — spinning if necessary — through what's left of the window, to try to wait for the window to reopen (if early in the day and at high altitude), or to use one's altitude to flee downwind into flatter terrain, since it's less likely that clouds there will continue all the way to the ground, and chances are better for a safe landing.

It goes without saying that instrument descents through cloud over mountains are out of the question unless we are certain that there is sufficient ceiling below the clouds, and that they are thin enough so that they can be penetrated quickly. Gyros are a must, of course, for any such operations.

Until now, wave flights have played a secondary role in cross-country soaring. Weather conditions

conducive to waves are not nearly as common as those which produce thermals. Probably the most spectacular wave cross-country flight so far is that of the French pilot Vuillemont, who flew from Vinon via Cannes to the island of Corsica in the Mediterranean, reaching 26,900 feet. Later, numerous wave cross-countries across the wind have been carried out in the Alps. Mountain ranges such as the Andes in South America look promising, but remain unexplored thus far. The world out-and-return record even if flown mostly in ridge lift by Karl Striedieck on May 9, 1977 (1015 miles) suggests the fantastic possibilities of such flights.

Dynamic Soaring

Inspired by the splendid flight performance of the Albatross, a large sea bird whose refined use of horizontal wind shear near the surface allows it to cross entire oceans without updrafts, several theoretical explanations have been advanced in the last decades which have attempted to make these sources of lift available to sailplanes as well. Since these have remained only theoretical until now, many of these hypotheses have gotten the reputation of pointless physical and mathematical problems with no practical application.

However, Ingo Renner, World Standard Class Champion in 1976, has actually made dynamic-soaring flights, thus proving that long flights are possible even without lift as we know it, as long as a wind shear of sufficient strength exists.

THE PRINCIPLE

Let us imagine that a sailplane flying in still air at a speed of 200 km/h decreases its speed to 100 km/h. This will result in a certain gain in altitude, let us assume 50 m. Overall, no energy has been gained; kinetic energy has merely been converted to potential energy. In fact, some energy will have been lost due to air friction. In an actual maneuver of this sort, the total-energy variometer will reflect this with a "down" indication.

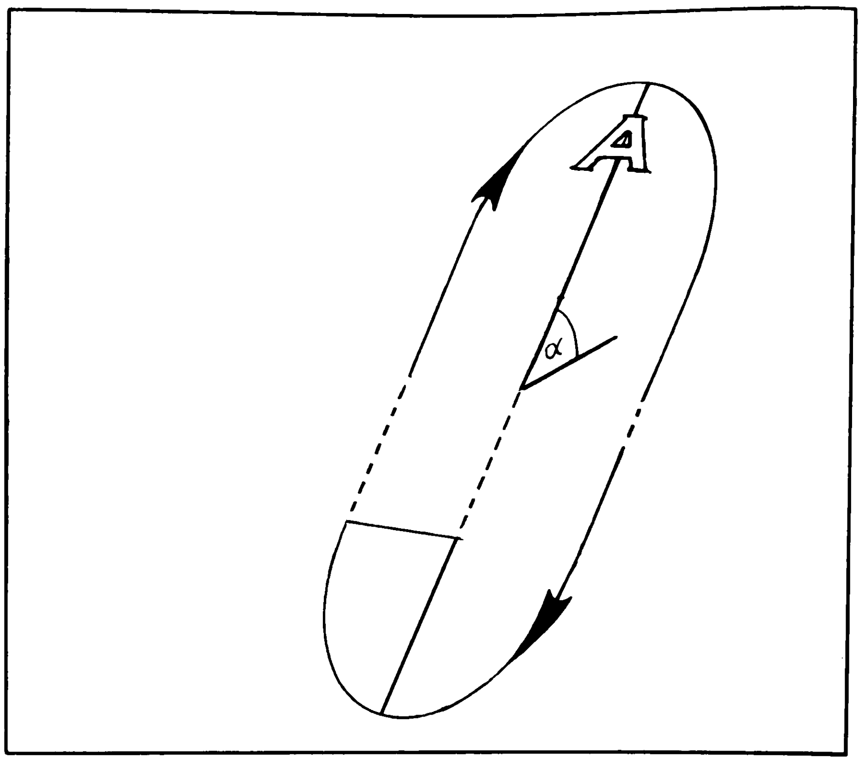
However, if the air layer entered during the pullup is not still, but has a wind of 100 km/h blowing opposite to the sailplane's direction, the speeds would be additive: the sailplane has its residual airspeed of 100 km/h, as in the first case, and an additional 100 km/h gained from the headwind. The airspeed indicator would show 200 km/h once again, and the total-energy variometer would reflect the gain in height as an energy increase ("up").

A PULLUP AGAINST A WIND SHEAR RESULTS IN INCREASED TOTAL ENERGY

In the same manner, a sailplane flying in the region of higher wind speed can gain energy by flying downwind and descending into a layer of lower wind speed.

A DESCENT WITH A WIND SHEAR ALSO RESULTS IN INCREASED TOTAL ENERGY

Dynamic soaring is based on the technique of combining such ascending flight paths into the wind shear with descending paths away from the wind shear. This can take the form of ovals tilted obliquely into the wind shear (A), figure-eights (B), or zigzags (C).



PRACTICAL APPLICATION

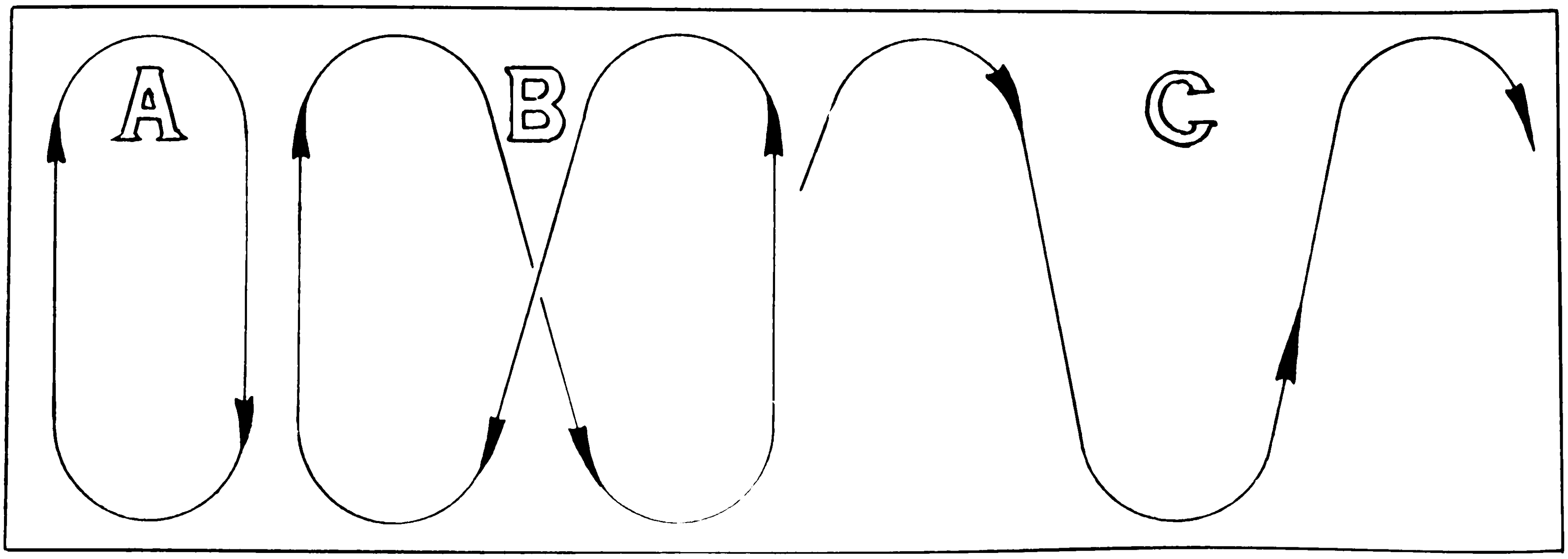
Natural wind shears are hardly ever so abrupt as in the above example, but even weaker shears can result in sufficient gain in energy to cancel out the sailplane's friction losses and allow cross-country flights. Strong shears are found in the region of the jet stream, but also near the surface and in the region of temperature inversions.

The Albatross, a bird with narrow wings of some 3 meters span and very high wing loading, performs its maneuvers in the lower 50 meters above the ocean surface. As it climbs against the wind, it reduces its airspeed distinctly, turns back at very low airspeed, and continues to dive downwind with constantly increasing airspeed. Directly above the water, it turns once again at high airspeed and high g-loading, in order to climb upwind once again.

For the sailplane pilot, such aerobatics so close to the ground can be considered out of the question. Dismissing for the present the wind shears near the jet stream, we are left with those in regions of temperature inversion.

Our current sailplanes have a sufficiently wide speed-range (80-250 km/h) in which their performance is adequate for the required flight maneuvers. The sailplanes of the new racing class appear to be particularly well suited due to their high maneuverability.

Renner began his research with a flapped H301 "Libelle." According to his reports, the wind was almost calm on the surface at Tocumwal, Australia, the morning of October 24, 1974. After takeoff, the sailplane and towplane penetrated an inversion (clearly visible due to the top of the haze layer) at an altitude of some 300 m. Above the inversion the wind was strong; sailplane and towplane were able to fly upwind only slowly, and Ingo Renner estimates the wind speed at 40 kt. (!) At a position about 3 km upwind of the airfield, Renner turned downwind from an altitude of about 350 m and began a steep dive through the inversion. At an altitude of about 250 m, with an airspeed of 200 km/h, he started a steep 180° turn (acceleration: 3g) and climbed at the same angle (30°) as his initial dive, headed upwind. He reattained his original altitude, made a second 180° turn at low airspeed and g-load, and started the process again. In this manner he was able to main-



tain altitude for about 20 minutes, but the wind drifted him downwind so far that he finally had to abandon the flight in order to be able to land at the airport. During later flights with a PIK 20 he gradually gained sufficient proficiency to be able to continually work his way upwind and remain over the airport.

Renner reports that the technique described in figure (C) was the easiest for him to fly; the horizontal eight (B) is probably still easier than the oval.

If the energy increase is large enough, one can vary the climb and dive angles together either toward or away from the wind to allow for crosswind motion; flying zigzags as in (C) allows sideward translation as well.

Wind shears of the strength reported by Renner in Australia may well be a specialty of that particular continent. If the wind speed changes 40 kt over a vertical distance of 100 m, the wind gradient is about 0.2 m/sec per meter altitude. Dr. Trommsdorf and Dipl. Ing. Wedekind at Aachen have calculated that even a seventh of this value — i.e. a wind gradient of only 0.03 m/sec/m — would be sufficient for a Nimbus or similar sailplane.

Perhaps in the European countries, a Foehn that does not continue all the way to the surface would be ideal for such flights. When the high-altitude winds pass over a cold airmass lying in the bottom of a valley, one might try one's luck at dynamic soaring instead of a wave flight. The aero tow above the valley inversion would be a fairly major commitment to make, but an eventual successful dynamic flight would be far more interesting than an altitude diamond.

NAVIGATION

Flight Preparation

THE AERONAUTICAL CHART

— Excerpt from transcriptions of radio traffic during a 1972 competition:

"I'm in good lift and have caught up with the leaders."

— "Great, Klaus; keep it up."

"I'm in great shape, almost at the turnpoint, and I've passed everybody . . ." (five-minute radio silence)

— "Klaus – your location?"

"I should be right over the turnpoint . . . stand by one . . that's odd . . . I don't see anyone else . . ."

— "Can you see the stacks of the power plant?"

"No, Otto, I'm over a bunch of little lakes. Where do you think that might be?"

— "I think you've gone too far, but you ought to be able to see the railroad. Check on your map."

"I can't! That's the part you glued together, and I can't get it apart . . ." (further radio silence)

This was followed by a period of further radio explanations of what was where and what could be seen in which direction. The crew's efforts to vector their pilot to the turnpoint were ultimately successful, but only after so much hassling that the pilot's nerves were jangling, and the competition had long since made the turn and flown on.

One of the pilots during the 1973 German championships experienced other difficulties. He unfolded his map inflight, and it seemed to become larger and larger — after all, it encompassed half of Germany in 1:200,000 scale — before he could locate his position. True, he could see the markings on the map very well; unfortunately, that was all he could see, and after only a few moments of uncontrolled flight and impromptu practice in "recovery from unusual attitudes" he was overcome by rage, balled the entire cartographic masterpiece together, and stuffed it behind the seat, where it remained for the rest of the flight.

To avoid drowning in paper on one hand, or, on the other hand, to avoid flying off the edge of the map only at the cost of complex problems in origami that must be solved in flight, the most practical type of chart is the standard ICAO format in 1:500,000 scale. (In the United States this requirement is met by sectional charts.)

For shorter flights and/or areas of difficult navigation, for bad visibility, or just for safety's sake we should also carry a smaller-scale chart. For the United States, the standard sectional aero charts are ideal, although near larger cities they are somewhat cluttered with airspace information. Earlier editions of the German Auto Club's road atlas used a very clever folding scheme which we can do well to copy: if we cut a chart from east to west, fold based on the Auto Club system, and stick the backs together, we end up with little paperbacked books which can be read from east to west (or vice versa) with no interruption. This system is particularly valuable for large-scale maps. (Unfortunately, the U.S. Government Printing Office's practice of printing northern and southern halves of each area back-to-back on the same sheet necessitates buying two copies of each chart to use this system.)

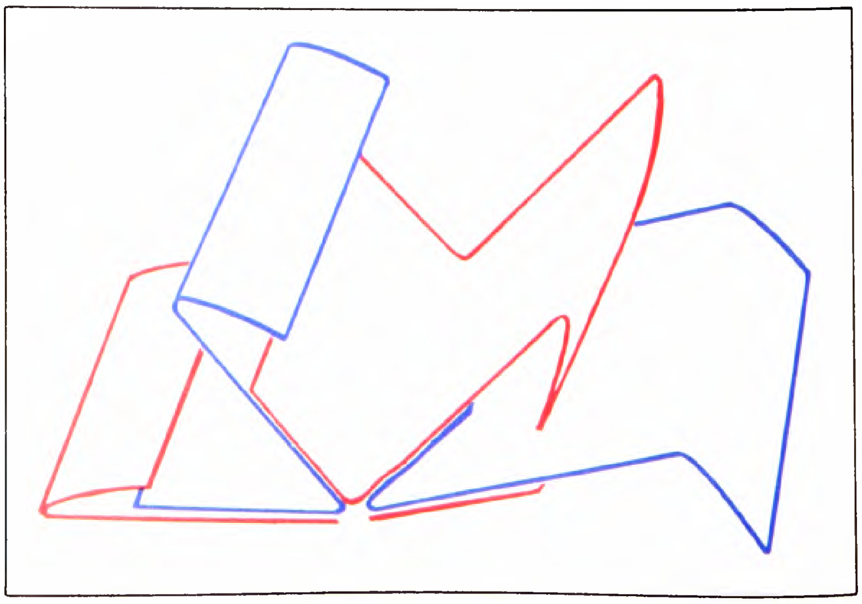
Holighaus and Hillenbrand recommend the addition of polar coordinates using *thin* pencil lines. Rings are drawn at ten-mile intervals, centered on the home field; within the 20-mile ring, radials are drawn every 30 degrees, from the 20-mile to 60-mile ring every 10 degrees, and beyond that every 5 degrees, giving us a coordinate grid that allows us to make position reports even over very monotonous terrain — for example, a radioed "270/84" means that we're on the 270° radial from the home field, 84 miles out. Moreover, we always know the direct course back home. This system has proven its usefulness in many flights, although it has the minor disadvantage of cluttering the map to some extent.

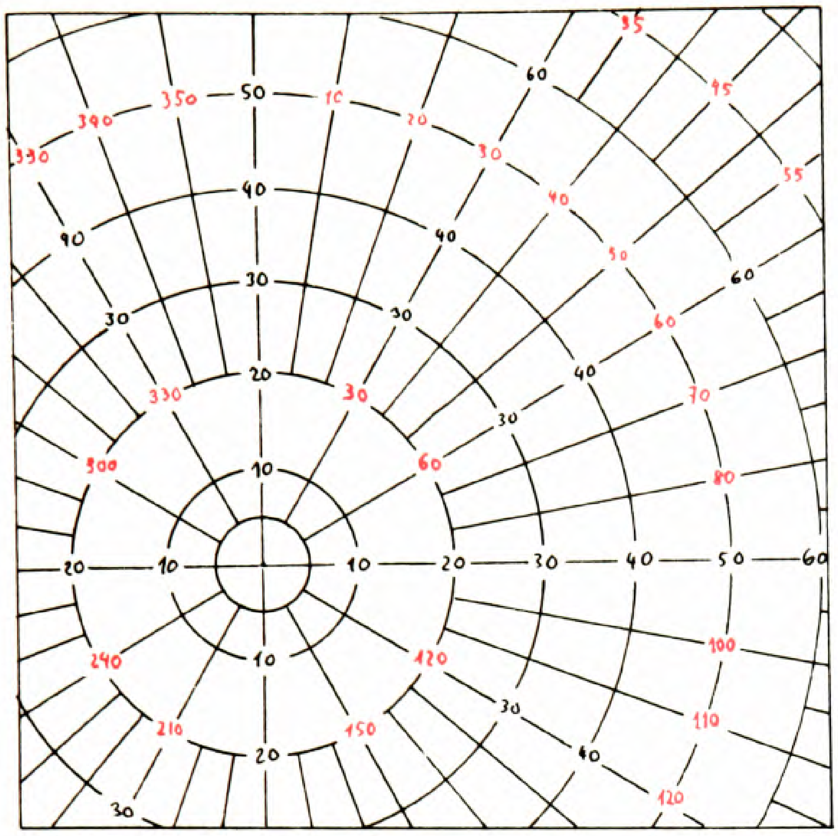
For each given flight, further map preparation is in order. Since our folding system keeps the size of each segment down to around eight by twelve inches, we can take along enough charts to eliminate the danger of "flying off the map," even in the event of large unplanned detours.

PLOTTING THE COURSE

Unless we're flying in a contest, it is up to us to "set the task." Since we're usually in a hurry on any actual

Map - folding method (based on German Auto Club atlas)





flying day, it is a good idea to make up a list beforehand which contains the various goal, out-and-return, triangle, or whatever that we may have in mind at our home field. This avoids last-minute decisions forced on us by areas of known poor lift, or by restricted and prohibited areas, leaving us only good, "flyable" tasks of various sizes, directions, and degrees of difficulty. The lengths of each leg, the total length, and all the magnetic courses have already been noted for each task.

Our first stop on a cross-country day is at the weather bureau or FSS (or, of course, the telephone). We have already gleaned what weather information we can from yesterday's TV or newspaper weather map, or from any soaring forecasts prepared by FSS.

If we now eagerly ask the weatherman, "Is it good enough for 300 kilometers?", we're unlikely to get a very satisfactory answer. It is hard enough for him to produce an accurate general weather forecast; the specialized information we want to get from him goes beyond his normal duties. Our request usually means extra work for the weatherman, and he'll most likely be glad to undertake it if time and his regular workload permit — as long as we do not demand the impossible. How should he be able to know if the caller — usually unknown to the weatherman — can make 300 km, even if he gets all the weather information? How can the weatherman estimate thermal strength if he is not a soaring pilot, and never gets any feedback from those he informs with regard to the accuracy or inaccuracy of his predictions? We should attempt to establish an ongoing dialogue with our weather briefers, try not to demand more than is technically possible, nor to demand absolute accuracy, and give them the opportunity to express uncertain opinions when they're faced with uncertain data. As often as possible after either a good or bad flying day we should get back in touch and give them a brief idea of how things went, either complimenting them on the accuracy of their prediction or diffidently asking what may have changed to cause a given difference from their forecast. This is where some tact is handy to avoid giving the impression that we are attacking their professional competence.

Any good meteorologist will be grateful for data from which he can learn to improve the long-range accuracy of his forecasts. We can learn at the same time how difficult it can be, despite all our technological aids, to accurately forecast as complex a process as that of thermal development, influenced as it is by so many factors; and this teaches us ways of improving our flights. In Germany we've developed a standard form for weather information; the master of this form is prepared by the weather office, and duplicates are filled out during telephone calls and posted on bulletin boards at each gliderport. This method has proven very practical, both because it presents all the applicable information to the pilot in one place and because it eliminates the repetitive calls to the weather bureau from individual pilots. Each gliderport should have someone who is responsible for making the call to the weather office. The system lets weathermen feel that their extra work — usually about an hour to prepare a really complete soaring forecast — has been worthwhile. It is best to make two calls (note that these are to the actual weather bureau, not to an FSS, although the same phone number may serve both): one to request the information, and another anywhere from 15 minutes to an hour later to allow the meteorologist to assemble the information. After all, he has other things to do, as well.

Based on both forecasts and our own visual estimates of weather conditions we can make good guesses with regard to the day's lift, the best time to fly, and the most promising direction for cross-country flights. However, we should avoid the trap of basing our assumed cruise speed on the published polar of our sailplane and the apparent rates of climb we can expect: factors such as lift distribution, the presence or absence of streets, and our own skill (or lack thereof!) can modify our cruise speed either favorably or unfavorably. We should base our expected cruise speed on other flights we have made in similar conditions.

Armed with an idea of how long the lift will last and roughly how fast we'll cruise, we can calculate our "total flyable air distance." Depending on personal feelings — that is, how sure we want to be of reaching the goal — we can now choose an appropriate task from our already-prepared list of possible cross-country flights, always taking the wind into consideration. If we are planning an out-and-return or triangle, we should try to arrange things so that we'll be flying into the wind during the period of best lift, so that if necessary we can use weaker late-afternoon lift to keep us aloft while we drift back home with the wind. Predictions of cloudbase and extent of sky cover help us decide whether to plan a flight over flat land (if bases are low) or over the mountains if there's not too much cloud to permit us to take advantage of their better thermal conditions.

PREPARING THE MAP

Maps that will be used more than once should be covered with clear plastic. Using as thin a grease pencil as possible, the course lines should be entered on the chart; however, the turnpoints and/or goals should be left uncovered. (I've come to regard the indelible sort of felt-tip marker with a jaundiced eye; if left on the map too long, the lines won't come completely off the clear plastic, even using alcohol.) If felt markers *are* used, the lines should be drawn on transparent tape which can easily be removed after flight. The last 20 miles before a turnpoint, as well as the last 40 or 50 before a goal, should also be marked with ticks every 10 miles.

This whole map preparation should be done with as much restraint as possible; many a pilot has had problems in flight because a thick course line covered some landmark on the chart. Actually, it is just as good to merely place a dot every 10 miles without an actual course line; one can get a better overall view of the terrain. At some conspicuous spot on the map an arrow should be drawn to indicate the wind direction. Finally, all grease pencil lines are covered with transparent tape to prevent smearing in flight.

COURSE CALCULATION FOR CROSSWINDS

Determination of drift correction angles and headwind or tailwind components is very important even for fairly light winds, not only as an aid to navigation but especially to minimize detours and lost time at turnpoints and to allow accurate final-glide planning. These values can be obtained by graphic construction, with a slide rule, or — the best way — by the use of a special wind calculator, which is described here and which can be mounted on the back of our final-glide calculator. It can be used just as easily in flight as on the ground (translator's note: in the United States, a very similar calculator can be found on the back of the CR-type flight computers manufactured by Jeppesen and other companies).

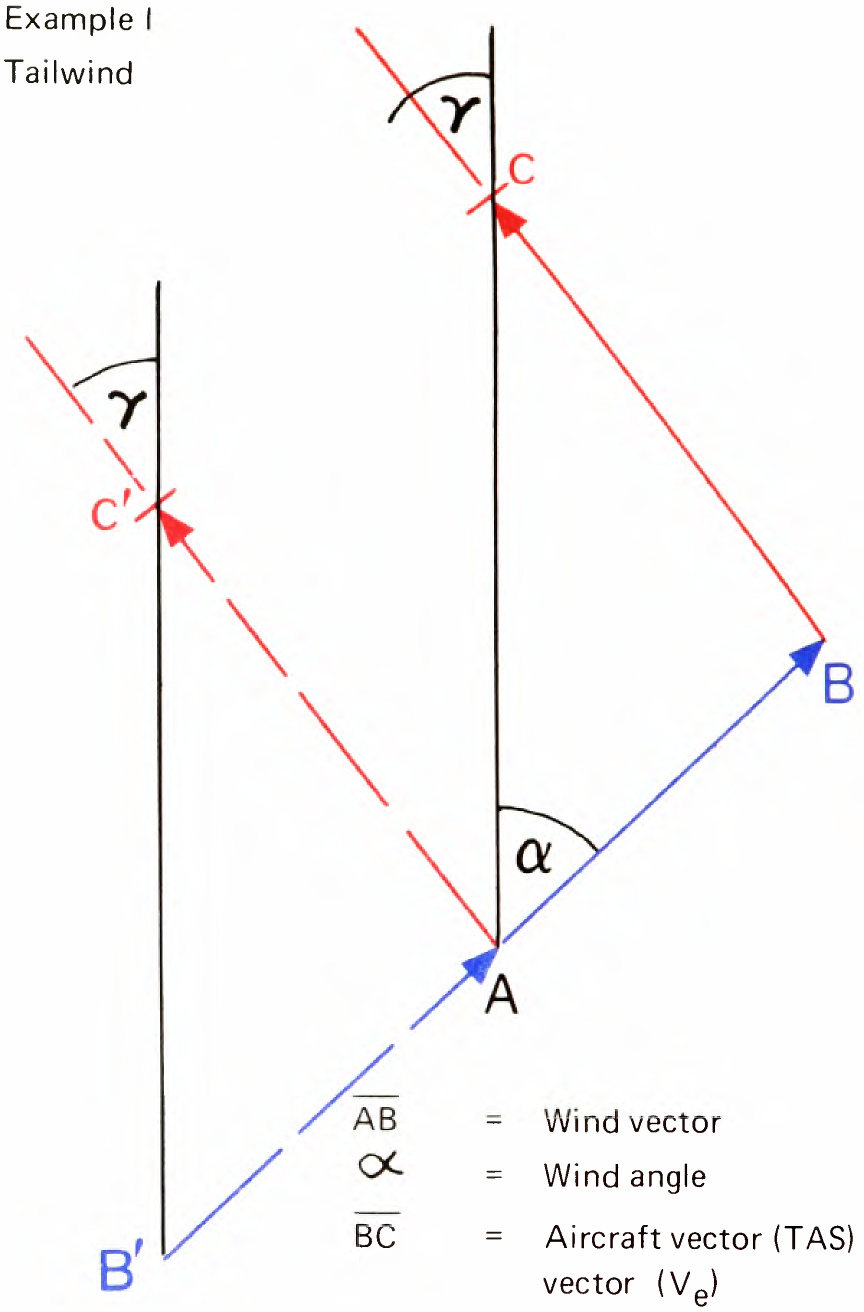
Requirements for course calculation:

GIVEN: desired course
true airspeed
wind speed
wind direction

TO FIND: drift correction angle
(heading to fly to achieve desired course)
ground speed

Example I

Tailwind



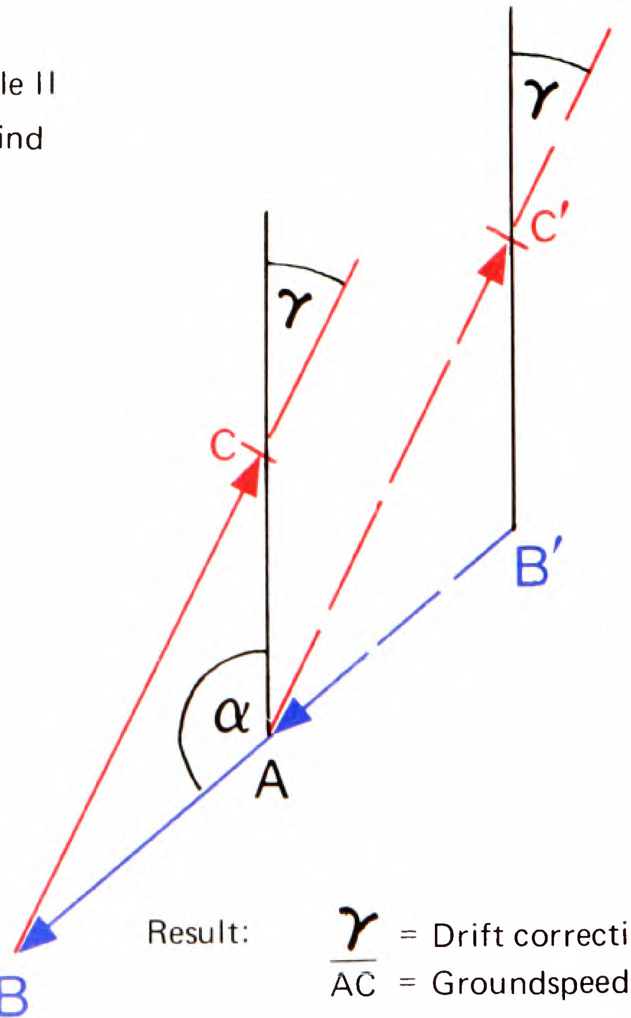
$\overline{AB}$ = Wind vector

α = Wind angle

$\overline{BC}$ = Aircraft vector (TAS) vector (V_e)

Example II

Headwind



Result: γ = Drift correction angle

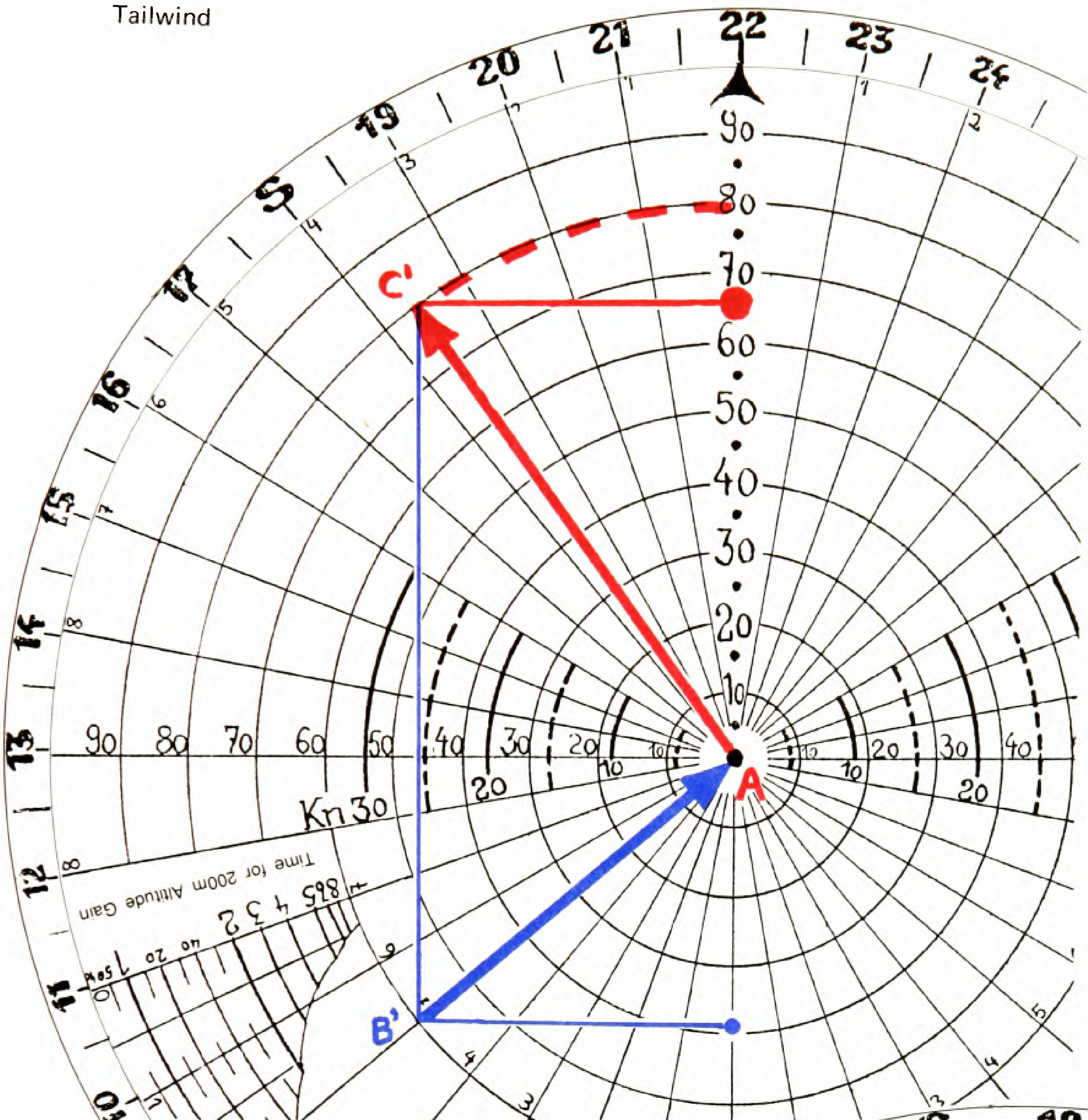
$\overline{AC}$ = Groundspeed

Since triangles ABC and B'AC' are congruent, the same values obtain in B'AC'

This is the principle used in the computer.

Example I

Tailwind



USE OF CROSSWIND CALCULATOR

1) The compass rose is set so that the arrow points to the desired course. (Example 1: 220°, example 2: 188°)

2) The wind vector is considered to come from the direction of the wind, as it is usually presented in winds-aloft reports. (Example 1: 90°/60 km/h, Ex. 2: 238°/50 km/h)

3) The circle with radius representing true airspeed (both examples: 80 km/h) until it intersects a line drawn parallel to our course and through the endpoint of the wind vector B′.

4) The desired heading-to-fly is read off the compass rose by extending the vector AC′. (Example 1: 184°, example 2: 216°)

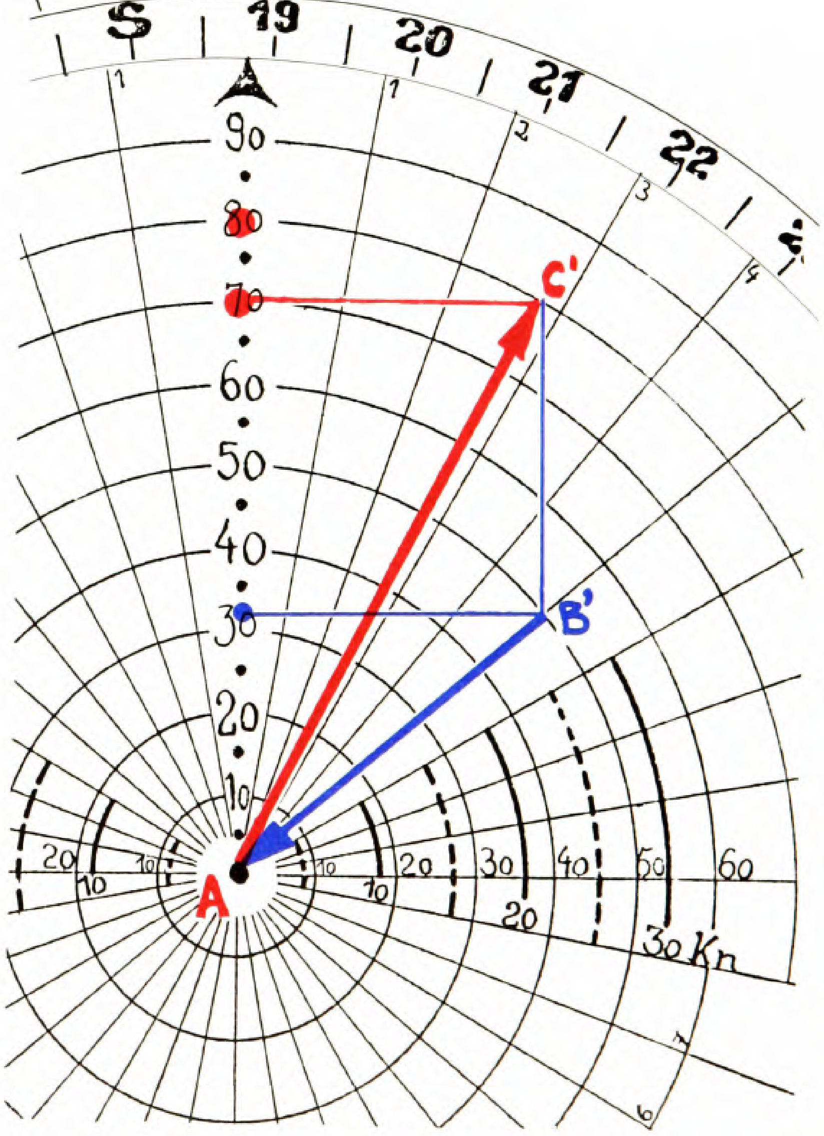
5) The groundspeed is obtained by summing the true airspeed component aligned with the course with the similar wind component. (Example 1: 65+ 38 = 103 km/h, example 2: 70 − 32 = 38 km/h)

This also results in the head or tailwind component, which is the difference between groundspeed and true airspeed. (Example 1: 103 − 80 = +23 km/h, example 2: 38 − 80 = −42 km/h)

For construction of the wind calculator, see page 122. It forms the reverse side of the final-glide calculator.

Example II

Headwind



The correct heading to fly should be calculated in advance for each leg of the task, taking into account thermal development with time and its expected effect on cruise speeds; head or tailwind components should also be noted. These data are also necessary for the final glide, and should be based on true airspeeds from 55 to 100 mph.

VARIATION

The variation between magnetic and true north is added to the course if westerly, subtracted if easterly. It is published on aero charts; the compass roses around VOR or VORTAC navigational stations are aligned with magnetic north.

DEVIATION

Deviation is caused by masses of metal, magnetic sources (meter movements, loudspeakers), or flows of electric current (electric variometers, gyro instruments) near the location of the compass. If possible, the compass should be installed as far as possible from error sources, for instance on the Plexiglas canopy. (Even an inexpensive suction-cup mounted car compass isn't bad.) Smaller deviations can be compensated out of aircraft-type compasses; large ones are unpleasant in that they require preparation of a compass correction card and can further complicate the already problematic behavior of most types of magnetic compasses in turns or accelerated flight.

Once we have calculated all the factors involved in heading (course, drift correction angle, variation, deviation), we should have a number representing the exact indication we'll see on our magnetic compass; and this is a great help! We can always make significant deviations in flight if it looks like better lift to one side or the other; but now we know how large these deviations are with respect to the desired heading, and can search an area of, say, 10 to 30 degrees on either side. Without this information many pilots tend to be "one-sided," perhaps making overly large detours to the left while ignoring better lift to the right that may lie right on the (unknown) ideal course but appear too far away. After all, one can hardly ever fly right along the ideal courseline in any case, but is much more likely to fly a narrow zigzag between sources of the best lift.

KNEE-BOARD NOTES

The minimum information on our kneeboard (or on some other suitable piece of paper if we don't use one) should include:

- *wind direction and speed*
- *for each leg of the task:*
    - *direct course compensated for variation and deviation*
    - *heading-to-fly, compensated as above*
    - *rough wind direction relative to flight direction (headwind, crosswind, quartering tailwind, etc.)*
    - *head or tail wind component*
    - *distance*
- *total distance*
- *heading and wind components for the final glide*

It is interesting to note — and perhaps worth copying — that pilots like A.J. Smith, 1968 World Champion, set up a sort of "flight plan graph" or "howgozit chart" which includes not only the course information but such goodies as expected meteorological developments enroute, fronts, contest factors like takeoff time and opening time of the start gate, planned turnpoint times, special terrain features, and so forth. Some form of "howgozit" is particularly valuable for large tasks or record attempts, in order to be able to check one's progress in flight against the "timetable" and decide whether to continue or abort the task. Whatever the individual knee-board notes may include, the information printed in italics should be considered a minimum.

ALTIMETER SETTING ON CROSS-COUNTRY FLIGHTS

When we were learning to soar we probably got into the habit of setting our altimeter to indicate zero at the home field; for cross-country flights, the altimeter was set to the correct pressure, so as to read height above sea level. On the other hand, this is not always ideal for cross-country flights. Of course, if we use any setting but QNH (standard altimeter setting resulting in readings above sea level) we must be able to convert back to the standard at any time such information is necessary for safe or legal flight (for example, over control zones, restricted areas, etc.). Thus, we must at least jot the altimeter setting down on our kneeboard. The calculation of final glides can be greatly simplified by setting the altimeter to read height over the goal, rather than above sea level; for goal-and-return flights, it would read height over the home field. In Europe, pilots approaching controlled fields can obtain the QFE altimeter setting via radio, which will result in their altimeters reading zero on touchdown; while the FAA does not provide such information in the United States, a "homebrew" QFE can be obtained by contest management or a pilot's crew by setting a good (i.e. recently and properly calibrated) altimeter to read zero and relaying the figure visible in the Kollsman setting window to the pilot. However obtained, a QFE setting can greatly simplify the calculations required during the already hectic moments of a final glide.

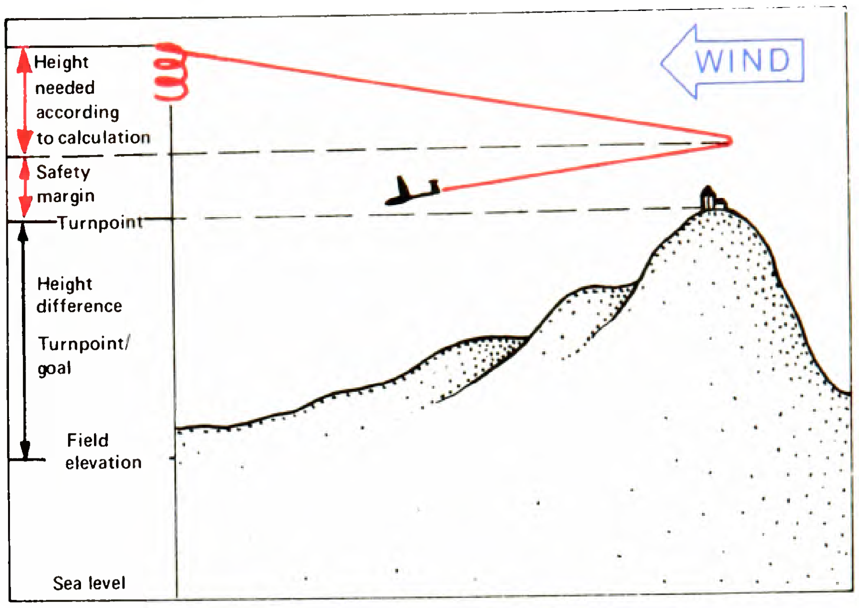
I noted a handy aid in Walter Schneider's sailplane: a rotatable ring, installed on the altimeter similar to a speed-ring installation, on which the QNH value could be set in while the altimeter continued to display the QFE figure.

If the course crosses significant mountain ranges, it is a good idea to use the QNH setting, since this makes it easier to determine separation over obstacles with heights listed on the chart.

Turnpoints situated at high altitudes (e.g. mountaintops, etc.) should generally be rounded at as low an altitude as possible, provided they are approached upwind. The approach should be calculated with the final-glide calculator; this time, however, the goal altitude is that of the turnpoint plus a reserve to allow a search for lift. If we have an adjustable ring on our altimeter we can set it for the turnpoint's altitude. If we don't have such a ring, and if we're using the QFE setting for a later final glide, we must make a note on our kneeboard of the altitude difference between the turnpoint and the home field, and take the difference into account in all of our calculations.

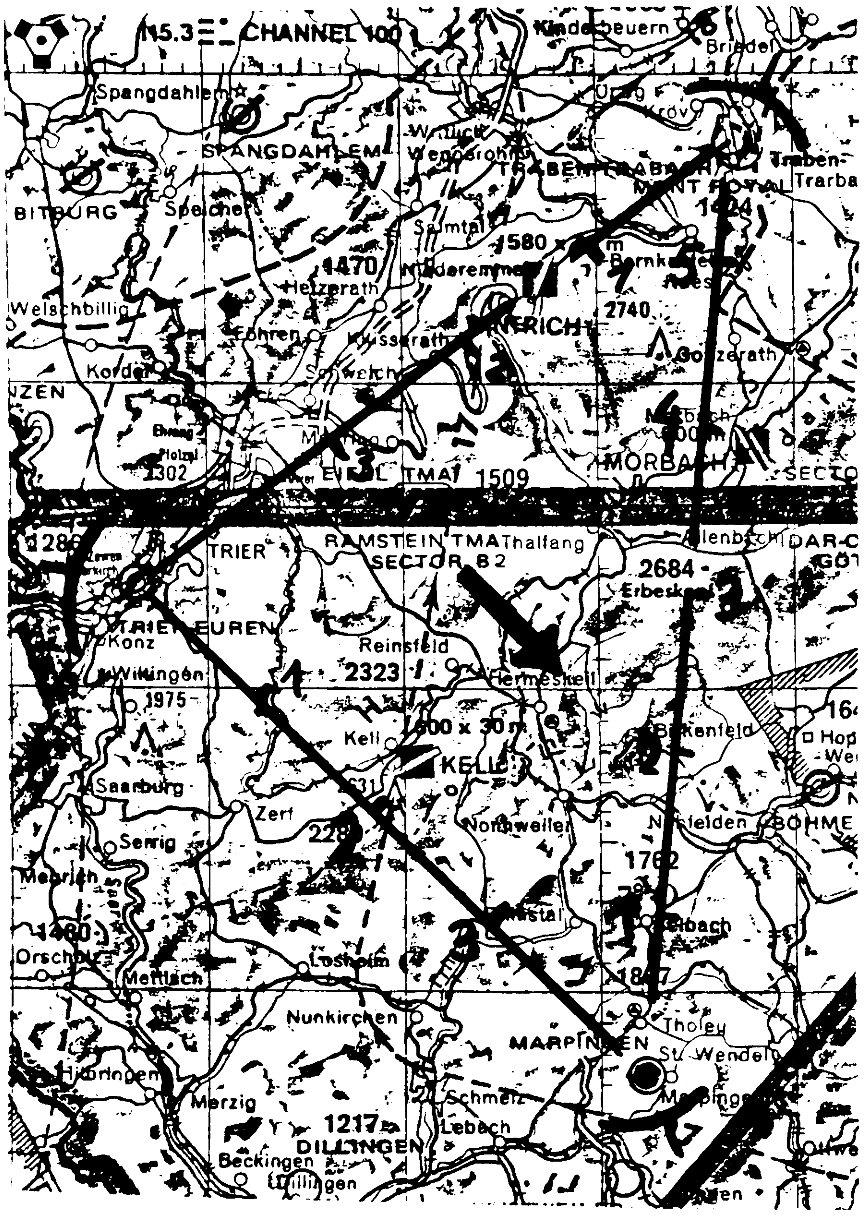
Translator's Note: For those unfamiliar with standard ICAO abbreviations, QNH means the standard sea-level altimeter setting, while QFE means the setting which results in an altimeter indication of zero at field elevation.

Calculation of height needed at turnpoint with headwind



MAP STUDY BEFORE FLIGHT

We should try to find 5 or 10 minutes before takeoff to study our course on the map. In our example, we note (refer to map p. 44) that for our task of Marpingen-Trier-Traben Trarbach-Maripingen the first leg passes almost directly over the dead-end railway yard at Primstal and close to the radio tower on the Hunsrück near the airport at Kell. Trier itself can hardly be missed, although once past the Hunsrück we won't have much in the way of distinct landmarks; the size of the town, the railway lines on both sides of the Moselle, and the concrete airport itself help distinguish it from other towns on the Saar or the Moselle. (Rivers that meander widely are not particularly suitable for navigation.) On the second leg we'll fly along the Moselle. The town of Bernkastel, with its bridge crossing the river, alerts us to the nearness of the second turnpoint (airport on a narrow hill around which the river flows, town in the crook of the river bend). After rounding this turnpoint we will pass the radio tower at Gonzerath on our left after 15 km, fly close to Morbach with its almost-invisible grass airfield, and aim for the highest point on the Hunsrück, the Erbeskopf with its radar domes. Here we prepare for the final glide, and expect to see Birkenfeld with its barracks, railway line, and Autobahn 17 km short of the goal. As our last aid to orientation we have the tower on the otherwise undistinguished Schaumberg hill near Tholey. We know that with a sufficient tailwind, clearing this hill assures us of a landing at the home airfield. Such map study before takeoff is very important for later inflight navigation. One has an idea of what surface landmarks will appear and knows what to expect, rather than having to search the map while flying to try to recognize leading marks (features running parallel to the course) or checkpoints.



Inflight Navigation

AFTER RELEASE

As soon as we've released, we check the visibility; it will later serve as a handy measure when we are estimating distances to goals or thermals. A look at the movement of cloud shadows on the ground, smoke from chimneys or fires, and our drift while circling in lift will give us a good idea of the wind at our altitude and will allow us to verify and, if necessary, correct the information on our kneeboard.

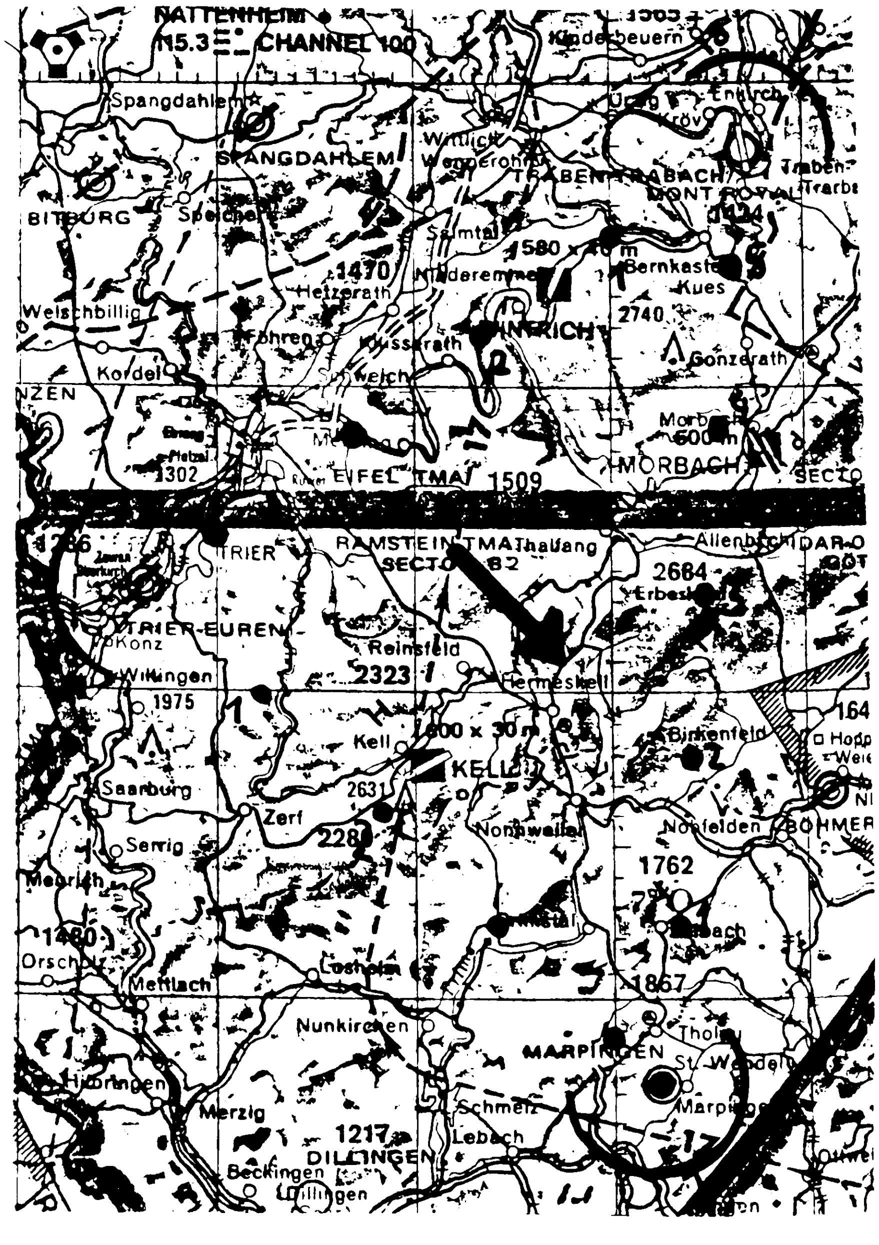
We sight along the direct course to get an idea of the terrain, and fly in that direction for a moment; then, for comparison, we fly the required heading (calculated to compensate for wind) to familiarize ourselves with it. We note nearby landmarks, the angle of the sun as seen on course, and the cloud situation. When we actually depart, we already have a goal in mind: a promising cloud lying as close as possible to the *heading* — not the course — that we'll be flying. It is easy to fall into the trap of looking for clouds along the direct course; remember that clouds move with the airmass, just as we do. In addition to this first goal, we have laid out the most direct course that would allow, if necessary, a small deviation to get under other less-ideal clouds along the way that might still help us reach the goal a bit higher. More important, though, is that we've picked out second and maybe third choices further away along the appropriate heading, toward which we can continue if our first choice turns out to be a dud.

NAVIGATE AS LITTLE AS POSSIBLE UNDERWAY

The better our preparation, the less attention we need to pay to inflight navigation. Ideally, a few glances at the map now and then should suffice to reassure us that we are within a few miles of the right course; this leaves us free to concentrate on such matters as estimating thermals, optimizing our flying speed, centering lift, and so forth — in other words, all those things that might increase our speed. As far as performance is concerned, the best navigation is that which requires the least pilot work-load. This is the reason that it is not necessary to verify passage of every one-horse town on the map.

On the contrary, our navigation should be based on unmistakable features, and not be concerned with smaller surface objects, even if there may be stretches of 10 or 15 miles during which we won't know our exact location. Only if we're approaching a turnpoint — or, of course, the goal — is it important to know our position down to a mile or less.

Features which are ideal for navigation include freeways, large rivers and canals, railway lines,



large wooded areas, prominent mountains, cities, or large industrial areas.

We should avoid using such things as small highways, small towns, flat mountains, and small rivers and streams. Mountains and hills in particular become harder to discern the higher we fly.

The map can be oriented either "correctly" — that is, with north at the top, which makes it easier to read printed information and relate it to given localities; or it can be held so that our course points forward. This makes it almost impossible to read names and numbers, but has the advantage of placing features on the map in the same relationship as in the outside world. The map must be turned whenever we round a turnpoint, which sometimes leads to a few moments' confusion; thus, both methods have their advantages and disadvantages. Even those who usually leave the map "north-up" are advised to turn it to correspond with their course if they are following, for example, a meandering river. It is much easier to match up curves in leading features running more or less parallel to one's course.

DURING CLIMBS

A glance at the map can reassure us that we're in the right place. If in doubt, it's always better to look at the landscape first, *then* check the map. If we use the reverse order, our desire to be someplace in particular can sometimes distort our perception of the outside world to the point where we will forcefully match it to the area where we'd like to be, even in the face of discrepancies that would normally stick out like the proverbial sore thumb. After checking the map we can once again check outside to see if we can further refine our position.

DEPARTURE AFTER CIRCLING

We should be aware of the fact that the magnetic compass can be trusted only under very special conditions in anything other than straight unaccelerated flight. The turning errors of standard types of aircraft compasses due to the inclination of the earth's magnetic field are such that in a left circle they will only indicate accurately the instant in which the nose passes through an east heading, with only the west heading indicated accurately in a right circle (in the northern hemisphere; the opposite is true in the southern hemisphere). Any other indicated direction will be in error to a greater or lesser extent depending on a number of factors. (For an exact discussion of compass errors, see page 138.) If possible, we should estimate our new course based on terrain features and landmarks; if this is not possible, we can use the sun angle, which we noted while gliding between thermals on the proper heading. If the sun is not visible, we "guesstimate" the departure heading based on how far we have turned past east (left circle) or west (right circle) compass indications, then make any necessary further corrections once we have leveled out and the compass has settled down.

While circling, we have kept an eye on the thermals further along the desired heading ("time-lapse effect"). Before leaving the thermal, we will already have decided on our next goal, the course required to get there, and our alternatives. We never leave a thermal without a definite plan of action!

DURING LONG GLIDES

We should check our course from time to time, but most of our attention should be devoted to speed optimization and the search for our next source of lift.

COURSE DEVIATIONS

Course deviations due to weather conditions or the need to circumnavigate unlandable terrain must be made where necessary. As long as they are less than 10° from the original course, their effect is negligible. Deviations of from 10 to 30 degrees are also well worthwhile if they contribute to a definite increase in cruise speed. In general, the farther one is from a goal or turnpoint, the larger a deviation one can make without overly adverse effects, since one can plot a new course (and heading) which does not differ greatly from the original one. In other words, after a deviation we should not attempt to get back onto our old course, but rather should fly the shortest distance from our new position to the goal.

Longer deviations at angles greater than 45° can only be countenanced in extreme situations — that is, if we will get shot down by continuing on our original course — and serve to teach us how unfavorable our original course must have been.

If worst comes to worst and we are forced to fly at 90 degrees to the original course, we not only lose all the time spent deviating, but must spend more time regaining the altitude we have lost during the deviation

We should never actually retrace our path at all except as a last resort to stay aloft, for example to return to a slope where we are sure to find lift.

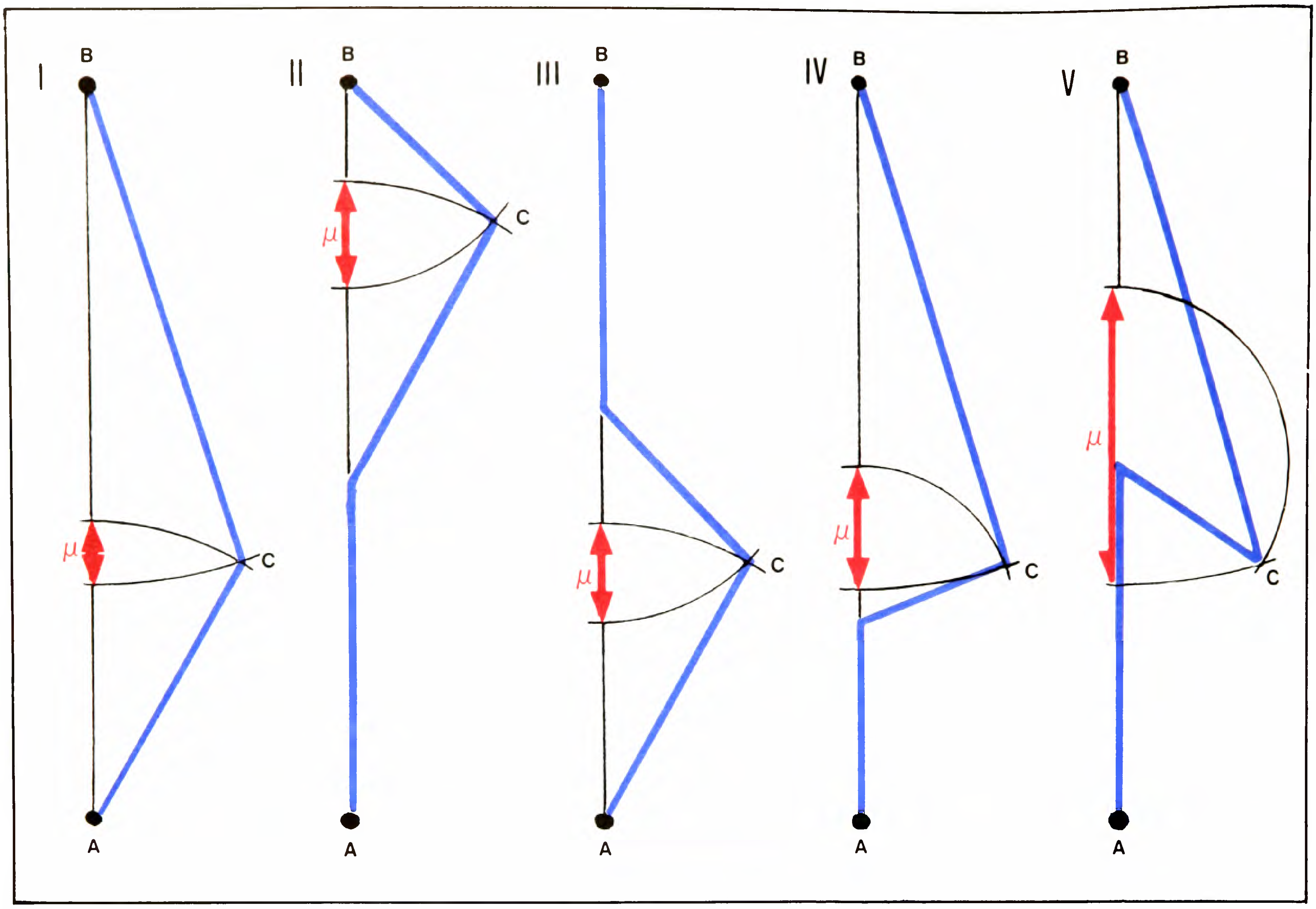
Recommended course deviations when flying a course that does not correspond with cloud or thermal street alignment have been discussed earlier (page 25).

TURNPOINTS AND GOALS

Turnpoints and goals should be sighted from as far out as possible.

At the same time, the distance to the goal should be determined (this is where proper chart preparation can pay off) and rechecked from time to time during the approach. If the turnpoint is difficult to locate it

Distance increase caused by detours (A–B = direct course, μ = increase)



I = Visualization of increase in distance
μ = Increase caused by flying via point C
II = Comparison: increase caused by same-size detour closer to goal
III = Unnecessarily large increase due to returning to original course too soon
IV = Unnecessarily large increase due to recognizing need for detour too late
V = Especially large increase due to backtracking

may be necessary to choose some easily located point as close as possible to the turnpoint as an initial point from which one can fly an exact course and time period to the turnpoint itself. This technique is very accurate, but requires a certain amount of effort and considerable concentration.

If we're setting our own task we should attempt to avoid such difficulties by choosing easily-located turnpoints in the first place. Contest directors usually try to use easily-recognized points so as not to degrade the contest to a battle of navigators rather than pilots.

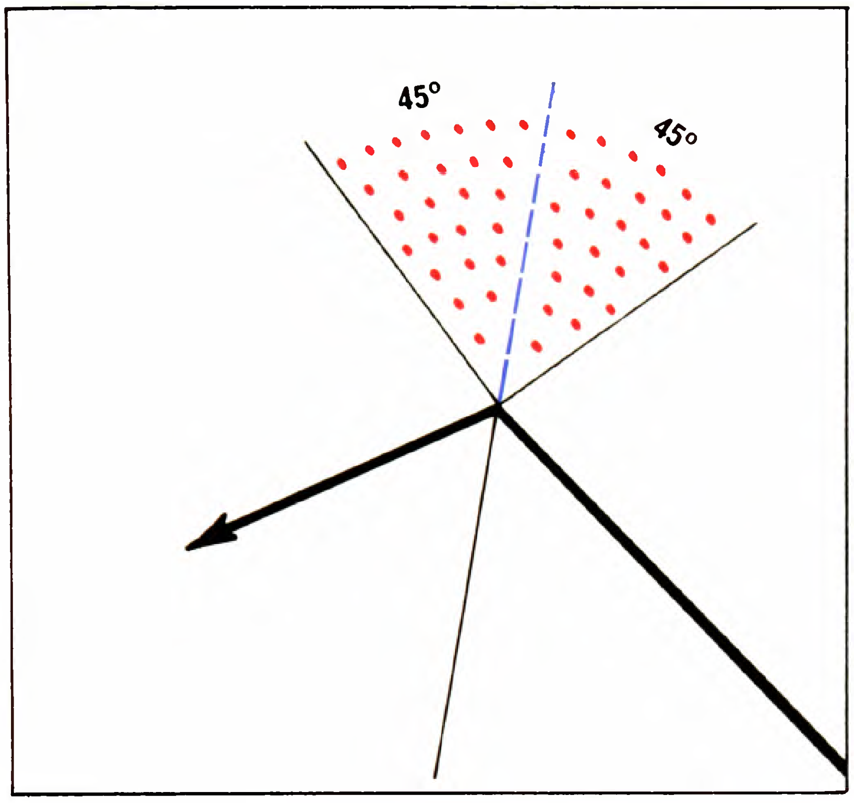
TURNPOINT PLANNING

Preparations for the rounding of a turnpoint should be made long before it is reached. Clouds which have until now appeared to be rather inferior may change to gleaming castles promising fantastic climbs as soon as we've turned so that the sun is now behind us, but they won't produce any better lift than before. If possible we should examine the direction in which we're going to fly after the turn before we reach it so as to get an advance idea of the landmarks and terrain features. Prior to reaching the turn we should already have picked out the first source of lift we are going to use after rounding the mark. This is particularly important because we will be seeing different patterns of sunlight and shadow after we have turned. There is an added psychological danger: one tends to think of turnpoints rather like goals and approach them with a certain feeling of accomplishment — finally made it! — much too low and with no further plans for finding lift. While this is understandable, we should always be planning — and flying — ahead. After all, a turn is nothing more than a jog in our course line. During contests, it is astonishing to see how many good pilots get shot down at or near turnpoints — could this be because they seldom plan far enough ahead?

TURNPOINT ALTITUDE

An important factor in speed optimization is the practice of rounding turnpoints as high as possible if approaching downwind, and as low as possible — tempered by wisdom and perhaps fear — if approaching into the wind. A thermal of 200 fpm worked while drifting downwind on course can prove much more useful than one twice as strong worked while drifting back the way we came! In extreme cases one can save from five to ten minutes if one only keeps this fact in mind.

Extreme or unusual weather developments also can influence turnpoint-rounding altitudes. For example, if a front is bearing down on the turnpoint it is of the utmost importance to get in and back out early enough — even at low altitude if necessary — before the bad weather arrives. This is particularly true if it looks like rain.



THE PHOTO SECTOR

In order to be accepted as proof of turnpoints, photographs must be taken within 45° to either side of a given line through the turnpoint. According to FAI regulations, this line is the extension to the outside of the course of the line bisecting the angle formed by the inbound and outbound courses. An actual curve flown about the turnpoint itself is not necessary, but at least one acceptable photo showing the turnpoint itself must be submitted for each turn.

The best technique is to fly right along the angle bisector directly over and past the turnpoint itself, then bank into a steep turn and shoot knowing for certain that we are at the correct location.

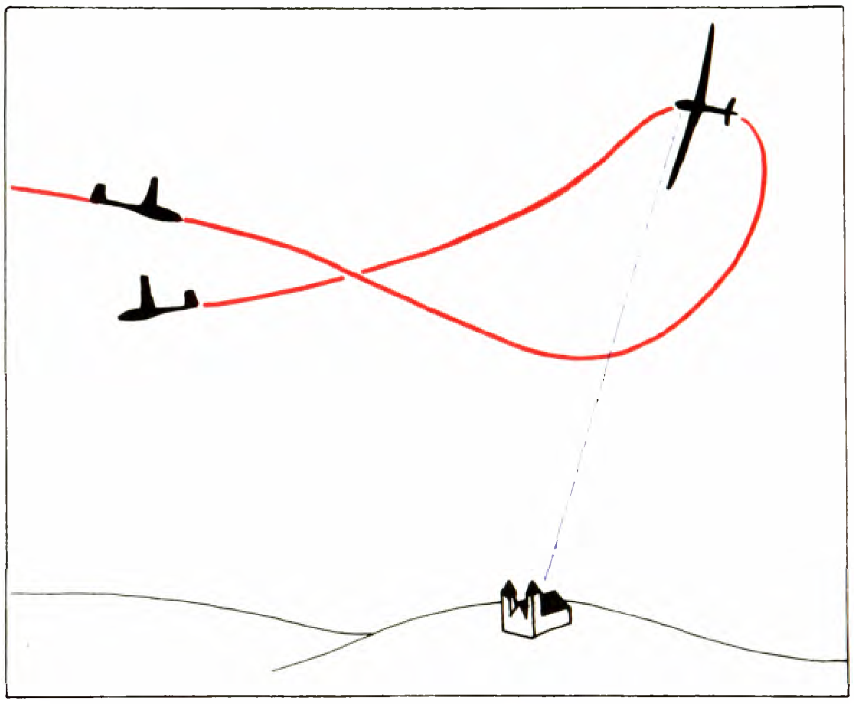
However, we can save time by not flying right over the turnpoint at all, but rather right from our course into the photo sector, although this increases the chances of error. To simplify this, our map preparation should include drawing the ideal photo line through the turnpoint. Normally, this line can be located against the terrain with sufficient accuracy to prevent gross errors.

HOW FAR TO FLY PAST THE TURNPOINT?

It is obvious that it is easier to be sure of being in the photo sector the farther past the turnpoint we fly. However, this requires additional air distance to be flown, at a cost in time and speed that can be quite significant. If our navigation over the turnpoint is accurate, around 600 feet past the turnpoint is usually sufficient. The giant curves flown by inexperienced pilots are absolutely unnecessary, and if the weather is bad these pilots may not only lose time, but may be able to photograph the turnpoint with absolute accuracy and from very close range . . . after being forced to land on it.

BUILT-IN OR HANDHELD CAMERA?

The photograph must be taken at the proper instant during the turnpoint curve; with a handheld camera this is very difficult. One has to be something of an acrobat to be able to fly a more or less steep turn — perhaps with the left hand — while at the same time holding the camera steady in the other hand, peering through the finder, and releasing the shutter at the right moment. One or the other factor almost always fouls up; if the pilot realizes that he has blown his chance, he must fly another circle, losing time all the while. Usually one sees the sailplane sliding down along a wing while the pilot struggles with the camera; altitude losses over the turn of several hundred feet are not uncommon!



In the future more and more competition rules will require fixed cameras. This just about eliminates any possibility of blurred pictures, since the movements of the sailplane even in a steep turn are not nearly as large or as fast as those of a handheld camera. One can fly the sailplane normally using the wingtip as a "bombsight," and one can be just about certain of getting a good photo every time. Even the steep bank angles which may be necessary are far less harmful than shallower uncoordinated turns encountered when shooting "offhand." A large number of pilots have used fixed cameras with excellent results.

A simple camera mount which has proven itself in many contests and which can be built with a minimum of effort is described and pictured on page 147.

In the case of turnpoints for goal-and-return flights or very narrow triangles it is best to fly straight out past the turn, pick up some extra speed, then pull up in a quasi wingover, point the lower wingtip at the turnpoint, and shoot. While this is the most efficient method, it allows only one shot at a time, and hence must be executed perfectly each time to avoid doubts about the success of the photo. As usual, practice makes perfect.

SPECIAL RULES FOR COMPETITIONS

Various international and foreign contests, as well as some world championships, have used a further development of the photo system:

— the cameras must be fixed on the left side of the sailplane;

— the photo must be taken from a single point, rather than anywhere within a sector. (This position is the actual turnpoint; the photo "target" is some distance to the side of the turnpoint proper);

— the "photo target" is similarly fixed and situated abeam the position from which the photo is taken.

The point of all this is that any pilot returning from a given flight will bring in essentially the same photos; only differing altitudes can cause very minor perspective changes. This causes a tremendous simplification of photo examination and — a feature of great importance to the pilot — makes it possible for each competitor to be given a drawing of each turnpoint together with a sample photo of what he should see through his canopy when he trips the shutter. This is a very effective system whose adoption cannot be recommended too highly.

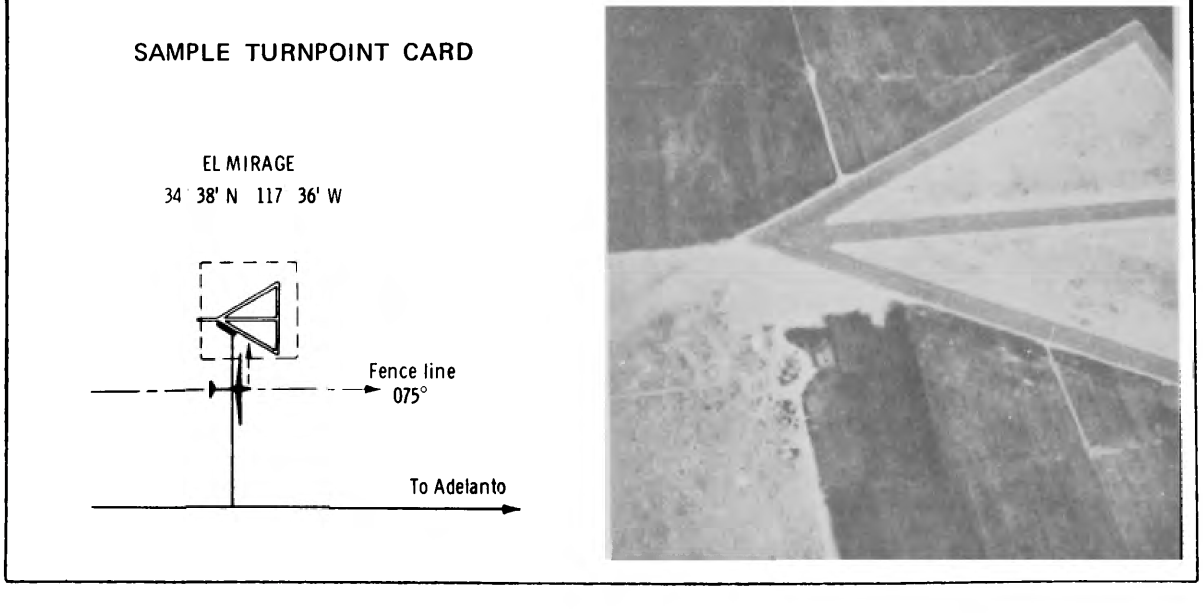
CAMERA TYPES

Anyone is free, of course, to use whatever complex special cameras he may prefer. As far as simple proof of turnpoints is concerned, though, simple "Instamatic" types are just as good, if not better, since they offer fewer possibilities to ruin a photo by an incorrect setting. Any adjustment, after all, will tend to be maladjusted! It's best to install two cameras in the sailplane; this offers additional safety, especially if one sets one for "sunny" and the other for "shadows." Electric eyes can also help, but are not absolutely necessary. For other cameras, a good setting for film of 18 DIN (125 ASA) is 1/250th at f8, focus set for infinity, except in heavily shadowed areas under large rain clouds, where 1/100th at f5.6 is better. The pictures, while perhaps not of professional caliber, will always be good enough for recognition of the turnpoint. Recently, simple Instamatic cameras (translator's note: the older type that use size 126 film, not the newer "pocketInstamatics" that use size 110) have become available incorporating a spring-wound system that enables the pilot to take several shots of the same turn in quick succession.

On hot days the cameras and film should be protected while on the ground from direct sunlight with aluminum foil or some similar arrangement to avoid temperatures that can damage the film or — in very hot climates and desert areas — melt the plastic cases or lenses of the cheaper models.

NAVIGATION OVER MONOTONOUS TERRAIN, IN POOR VISIBILITY, AND IN CLOUDS

If difficult conditions require particularly careful navigation, a good practice is to note time of passage over any exactly identifiable location on the kneeboard. Even better is to enter not only position and time, but to actually mark the course made good on the chart itself with grease pencil; this improves the clarity of orientation. If we have a clock or watch with movable marker, this can be used to mark the time of passing the last position. Time spent in subsequent straight flight can be read directly from the adjustable bezel and the minute hand. Incidentally, this is just about the only really useful part of the impressive stopwatches and chronographs which so often capture the hearts — and purses — of those who read the back pages of pilot's magazines. Apart


SAMPLE TURNPOINT CARD

from dazzling the uninitiated with the skill and bravery of the wearer, these triumphs of the clever Swiss — and now Japanese — contribute little, if anything, to the navigation of a sailplane.

As we continue to glide we keep tabs on our compass course and average speed so as to be able to use these data, together with the elapsed time, to calculate our position with considerable accuracy. Checking *and writing down* times for straight flight is especially important, since the excitement of being unsure of one's position can cause one to lose track of time. Five minutes of turbulence or in cloud can seem three or four times as long and contribute to further uncertainty and stress unless one continues to check the time and course.

DEAD-RECKONING

If the areas of poor visibility are particularly large, or if cloud cover is relatively thick and one plans on using instruments to continue to use the thermals to their full extent by flying in cloud (assuming that the pilot's ratings and local regulations permit it), only exact dead-reckoning navigation can keep us from getting completely lost — especially if the weather conditions force us to deviate from our planned course. For this, we need a plotter for measuring distances on the chart, and we may elect to fly only at speeds that allow the simplest mental arithmetic for calculation of time, speed and distance. (For example, 60 mph = 1 mile/min, 80 mph = 4 miles/3 min, 90 mph = 3 miles/2 min, etc.) Better yet, we can make up a "dead-reckoning plotter" as described on page 147. It is very simple and as nearly foolproof as possible.

Recently, devices have been developed both in Switzerland and in Germany which operate from total (pitot) pressure and a wind component set in by the pilot, as well as altitude, to read out "distance flown." Such "odometers" are certainly particularly helpful for dead-reckoning navigation. They can also be used for final-glide calculation; however, they appear to be less valuable in this application, as the conventional calculators now in use are not only sufficient, but actually superior in some cases.

DISORIENTATION

Inflight navigation should be sufficiently accurate that we are never unsure of our approximate position, since once we're "at sea" the steadily increasing nervousness makes it difficult to estimate flight times and distances realistically. The stress of the situation causes us to make judgements that we would normally avoid. One tends to search wildly in the immediate neighborhood for some identifiable checkpoint, and can end up on the ground even in good weather Therefore: remain calm, find some lift, get some altitude, then examine the last part of the flight in a sort of "mental instant replay." Systematically figure out any possible wind shifts, identify the larger area in which one *must* be, and only then start looking for surface features that can be used to "narrow down" your position. This situation requires calm consideration, not panicky searching.

THE FINAL GLIDE

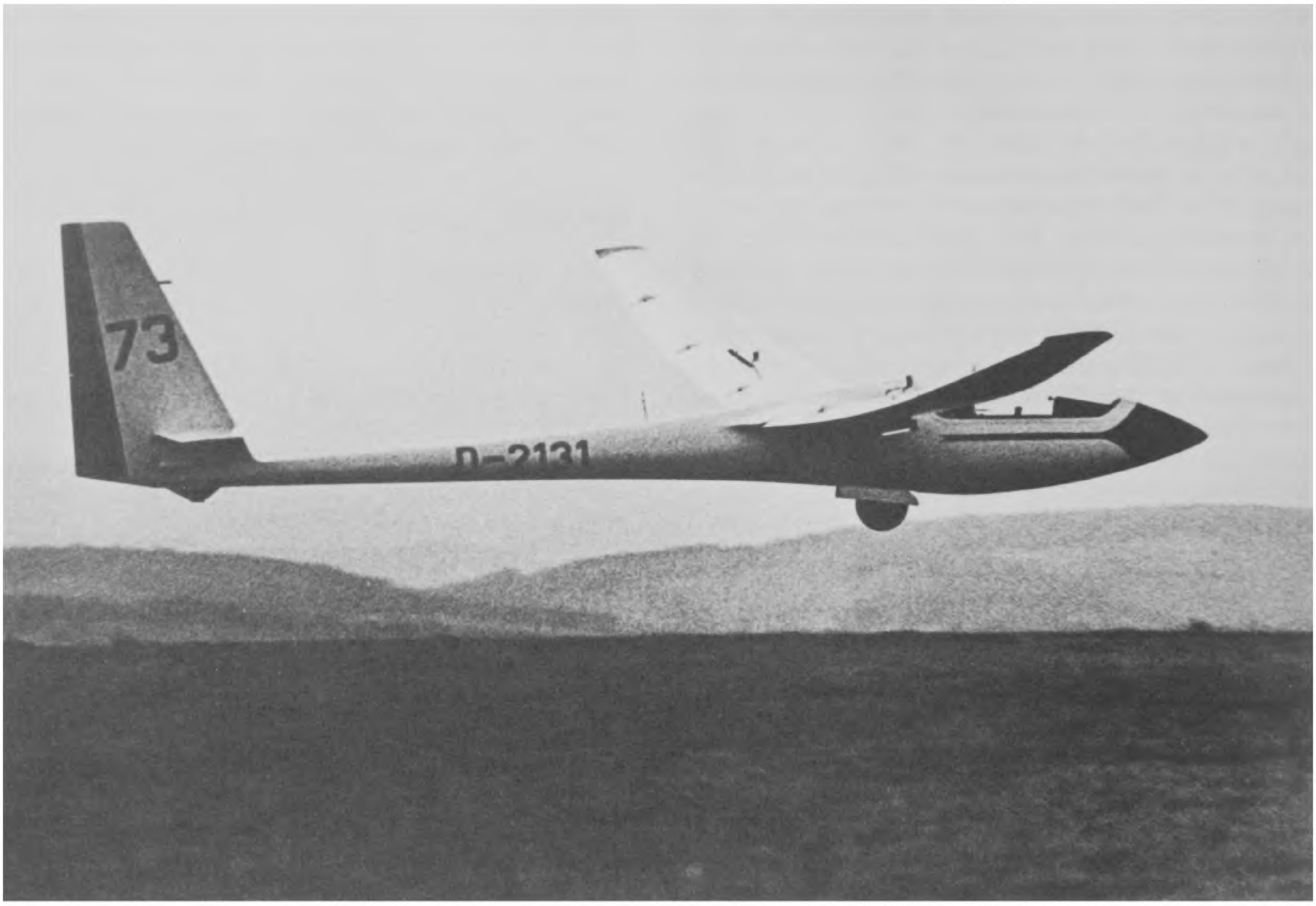
If fate has spared us an outlanding, we end our soaring day with a well-planned and calculated final glide. The speeds and altitudes that may be optimum for the circumstances, and the methods of calculating them, will be discussed in the next chapter. From a navigational standpoint the final glide means that we will have to observe smaller and smaller surface features for the most exact possible checks — to the mile or better — of our position and distance from the airport. While climbing in the last thermal we plan to use we will calculate the required optimum height, check our final glide course, and pick landmarks which will allow us to continually check our distance from the goal (railroad lines, small villages, transmission lines, etc.) As the glide continues, we'll compare our actual and required altitude at each checkpoint, modifying our speed-ring setting if there are major deviations.

LANDING OUT

Not only is there a proper technique for landing out once we have been shot down; there is even a proper technique for getting shot down — the slower, the better! The longer one can remain in the air, the better one's chances are for a last-minute save instead of a landing which definitely ends the day's activity. Of course, the entire process must be considered a normal part of the soaring pilot's life, and should be taken into account as a possible ending to *any* cross-country flight. The fact that so many outlandings lead to damage can almost always be traced back to a bad estimation of landing possibilities or, as the case may be, to (completely unnecessary) nervousness. To repeat: getting shot down is normal, and landing out — if one holds oneself to proper guidelines and techniques — is a perfectly safe part of cross-country soaring.

IF IT LOOKS LIKE WE CANNOT MAKE THE NEXT THERMAL

We will start by checking the landing possibilities further along our course. We'll look for as many fields as possible that our glide angle will allow us to reach. If things look reasonably landable ahead, we can look for fields even farther away — but also for some closer in to cover the possibility of flying into sink. We



must always, of course, have enough reserve altitude for the actual approach. Unlandable areas (forests, cities, rockpiles, etc.) should only be approached or overflown if we're absolutely sure that we can make it back to the nearest good landing spot, come what may: headwinds, terrible sink, rain, all of the above, or whatever. There is no fixed altitude below which any attempt at prolonging flight should be given up in order to devote full attention to landing. Such a fixed height has no sense, not only because of the wide variation in altitude required for various types of terrain, but because of equally wide variations in sailplane performance, and especially in skill, experience, and landing-out techniques of various pilots. Since our altimeter is useless anyway if we do not know the exact terrain elevation, we must depend on our judgement and our skill at estimating heights and distances.

Thus, while always continuing to look for lift, we will press on from one landing spot to the next.

CHOOSING A GOOD FIELD

As a basic rule, we should always land on the level or uphill: there is nothing less pleasant than to glide along a gently sloping downhill field, unable to get any closer to the ground, watching the fences and trees growing inexorably larger in the canopy. If at all possible, and always if there is significant wind (check smoke, drift while circling, motion of crops), we'll land upwind. The field itself must be long and wide enough for our sailplane type and our own level of skill. If at all possible, the approach should be free of obstacles and the surface smooth and level. Freshly mowed fields, smooth pastures, and newly-sown areas — in other words, fields that are being worked for crops — are highly recommended.

If we have several safe landing fields picked out, we pick the one that appears to be the closest to a telephone (look for a farmhouse with phone wires) and allows easy access for our trailer. It goes without saying that such conveniences play an entirely secondary role to safety.

THE NEED FOR CAUTION

Particular care is required in estimating the slope of fields from the air; one can easily be fooled, and the field that looked like a billiard table from above may look like a roller-coaster as we turn final. A useful aid to estimation is offered by contour plowing, which runs across the slope to catch rainwater. Fields that have not been worked can conceal all sorts of unpleasant surprises, including ditches, rocks, irrigation pipes, almost invisible wire fences, and animals.

— *About cattle:*

It is certainly hard to be overjoyed at the sight of a broad line of slobbering, snuffling cattle trotting *slowly but inexorably toward the just-landed sailplane; but all is not lost if we keep our heads and don't panic. There is no point in trying to shoo them away; all we'll do is arouse the ire of these honored bucolic brethren. It has been proven that cows are actually relatively intelligent animals, who tend to be both curious and cautious. Usually, they'll inspect this new addition to their very own private territory, lick it thoroughly — saves washing it later — and, after a short time, wander off. In general, that's all that ever happens, even though we may sweat blood while we watch. It is best for us to remain at a little distance from the sailplane. We can offer our new friends something delicious to eat or try to arrange some other interesting attraction which will not only captivate, but also distract the attention of these ambulatory pot roasts. As long as the sailplane isn't actually moved about by their attentions, the major danger to the pilot is boredom. Even bulls don't automatically attack a sailplane, if they don't feel threatened. Moreover, the red paint required in some countries does not enrage the bull; in the arena, it is the motion of the matador's cape, not its color, that incites them to charge. Friendly passers-by who hurry to help us with the sailplane are well-meaning, but should be politely and firmly asked to remain out of the field ("... otherwise you may have to pay for any crop damage you may cause ..."). After all, at the circus you never see more than* one *lion-tamer in the cage at a time.*

When picking a field we should avoid those with too-high crops or grass; they are particularly hazardous for ships with conventional tails.

T-tails, on the other hand, are more likely to be damaged by ground-loops, which can occur very abruptly in tall grass, wheat, or even rye if one wing is lowered even a small amount. Asparagus fields, which are completely unsuitable for landing, unfortunately look like normal fields from the air. Vineyards and cornfields are equally bad choices. Power and telephone lines are hard to spot, and can usually only be seen by their poles — i.e., we must always check the vicinity of landing fields for phone poles. In the mountains — particularly in Europe — the cables of aerial tramways, which are not always marked on the maps, represent a particular hazard. In some areas, portable tramways are used to bring crops from higher fields to the valley floor, and are moved about from place to place. These very thin lines often cross entire valleys with no pylons or towers, and are almost impossible to see against forests and other dark areas.

THE APPROACH

The safety belt and shoulder harness should be pulled tight. In general, the approach should resemble that of a cautious new student at the airport: abeam the touchdown point we should have about 350-500 feet of altitude. Until now, we have constantly been searching for any possible lift; now we're committed to landing. We should *always* include a base leg — nothing else provides such an excellent chance to gauge the wind as our eventual drift while flying crosswind. Depending on how much we drift we can correct very easily by either extending or shortening our final approach. At the same time, we can always see our landing field and can make one more final check. Those who make a continuous 180° turn rather than a square pattern lose sight of the field and stand a good chance of turning in either too soon or too late; in either case, since one is heading back the way one came, the effect of the mistake is doubled. This is one of the most common causes of damage in off-field landings.

Once established on final approach we cannot change our minds and switch to another field, even if it suddenly appears better than our first choice. There is simply not enough altitude reserve to reach the new field, make a decent approach, look it over, etc., and still maneuver safely for a landing.

Headwind, gust factors, and possible sink due to downhill air motion require some reserve airspeed. If there's a crosswind we'll have to crab an appropriate amount, waiting until immediately before touchdown to "kick out" the crab angle. If we slip during the approach, we should lower the upwind wing.

SPECIAL APPROACH TECHNIQUES

— Steep uphill landings:

Uphill landings require plenty of excess airspeed, at least 20 mph faster than normal. Fly right down to the ground before zooming up along the slope. Despite the high approach speed, the landing and rollout will always be very short — especially if the dive brakes are extended.

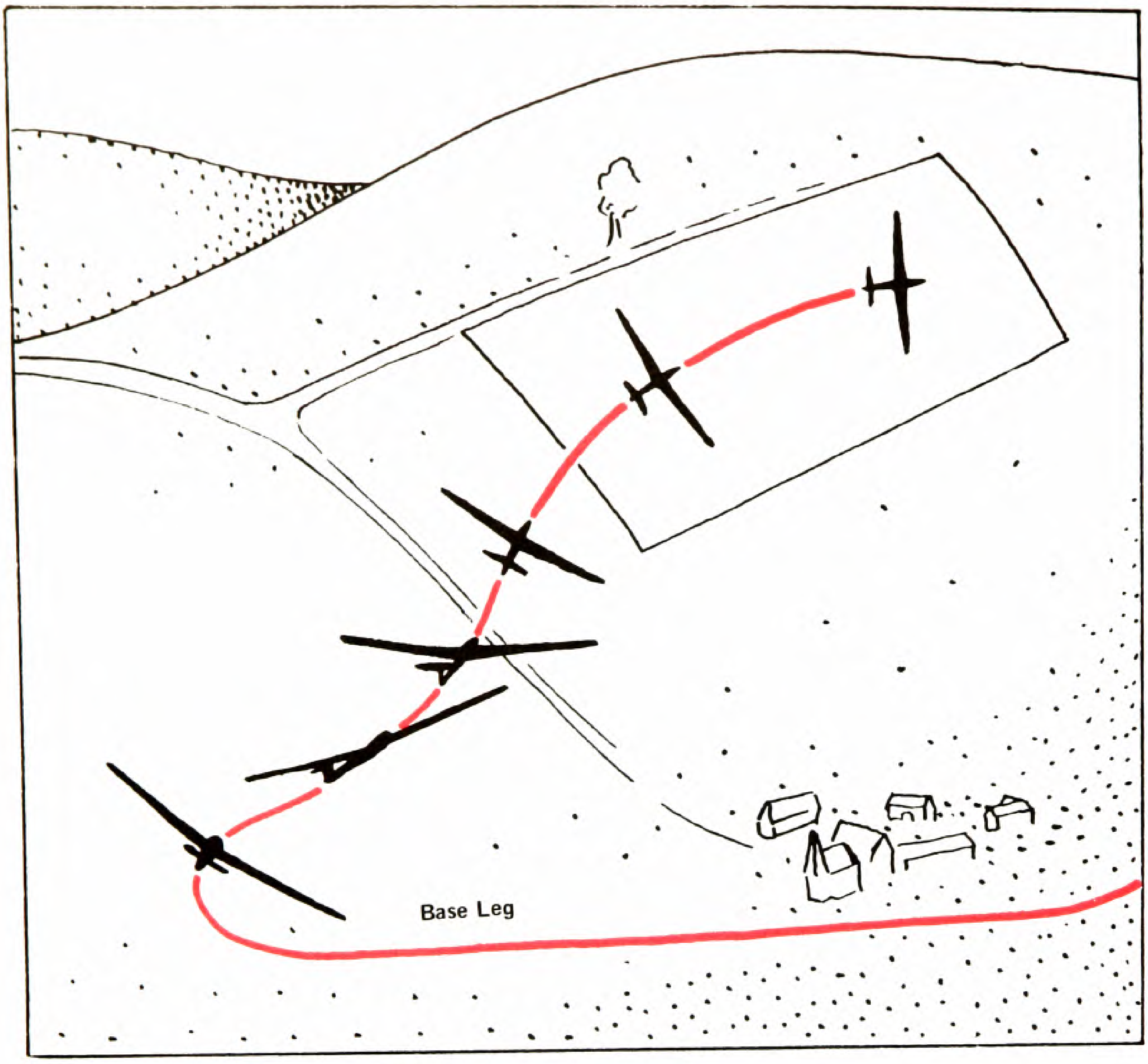
— Landing on the side of a hill:

Base leg should be flown from the downhill side. A slight S-turn on short final can be used to align the wings parallel with the ground just before touchdown. Without this S-turn procedure, which is highly recommended, one must wait until the very last instant before lowering the downhill wing to avoid a sideslip downhill.

If the wind is blowing uphill strongly enough, we can simply initiate a downhill sideslip on final approach, kicking out the crab angle at the last moment.

— Clearing an obstacle:

If a short field makes it necessary to approach as low as possible over an obstacle, one should use dive brakes and a sideslip, bearing in mind that the lowered wingtip and perhaps the rear of the fuselage may well protrude considerably below the rest of the sailplane.



Landing approach with S-turn onto a hillside

— Barely clearing an obstacle:

If we do not have sufficient altitude or speed to clear an obstacle, we may still have a chance if we gain a little extra speed before reaching the obstacle — even if this means more or less diving at its base — and then pull up over it, possibly getting well below normal stall speed, then immediately applying forward pressure and finally recovering just before touching down. This technique may appear both contradictory and dangerous at first glance, since speeding up and slowing down cannot help but further reduce the already-insufficient glide angle. The advantage lies in the fact that the obstacle is overflown in a more or less ballistic curve which reduces the wing loading to the point that the flow remains attached even at speeds far below the normal 1-g stall speed. This curve is only possible because we gained extra speed short of the obstacle, and the sailplane will end up beyond the obstacle at a lower altitude than if it had approached normally. This emergency method is particularly appropriate if the landing is made into a fairly brisk wind, since both the wind shear and the reduced wind in the lee of the obstacle work in the pilot's favor.

— Landing field too short:

Do not land in the center of the field, but along one side to allow room for an intentional ground loop at the far end if necessary.

SPECIAL TOUCHDOWN TECHNIQUES

Normally, when landing in fields of sufficient size, one should touch down at minimum speed to reduce rollout distance.

— Landing in tall grass, cornfields, etc.

One should touch down at the absolute minimum speed possible (dive brakes *retracted,* camber-changing flaps fully positive, drag chute deployed.)

— Very steep uphill landings:

While rolling out — not too late, since the rollout will be very short — one wingtip should be lowered to the ground to turn the sailplane 90° and prevent its rolling backward.

— Field too short:

One should touch down as early as possible, even if at too high a speed, and brake as hard as possible. In sailplanes with no wheel brake (some older two-seaters) forward pressure should be applied after touchdown to press the skid into the ground.

— Landing across small ditches:

Damage to the sailplane is unlikely — especially on wet grass or soft fields — as long as the gear is left retracted. The fuselage will slide along and can easily cross small ditches (up to about a foot across) in which the wheel might get caught. In any other situation, though, the wheel should be extended, since in modern fiberglass sailplanes there is only about ½ inch of structure between the bottom of the sailplane and the (rather more fragile) bottom of the pilot. Any blows will be transmitted directly to the pilot's spine — which is both more difficult and more expensive to repair than the sailplane — unless cushioned by the gear's shock absorbers (or by its tearing away).

— Landing in brush or water (ditching):

One should attempt to "land" just as in a cornfield, at minimum touchdown speed. In a forest, the same technique should be used unless it is possible to penetrate one level lower and aim the fuselage between a couple of trees.

— Landing in completely unlandable terrain:

If one is forced to set down on a rockpile or some similar horrible spot, one might as well resign oneself to the fact that the sailplane will be a complete write-off. The pilot, however, has a good chance of escaping more or less uninjured by sideslipping into the ground; the low wing will absorb the major impact while being destroyed.

AFTER LANDING OUT

As the pleasant silence surrounds us after a smooth landing and easy rollout, it would be nice to be able to enjoy this moment of peace and quiet, to recover from the concentration of that final battle to stay aloft and perhaps also from our disappointment at having landed out. Unfortunately this is usually impossible; the first spectators will be here any minute, and we'll also have to get to a telephone to report our landing. It is time now — despite the hunger and thirst that we've only now started to notice — to take care of all the necessary details despite nervousness or any other problems.

ONLOOKERS

We explain to everyone in friendly fashion everything they want to know about the sailplane, why "there isn't any engine in there," the reasons for our "crash," the causes of "air pockets," and whether we were forced to land because "the wind quit." We make clear to everyone possible the astonishing fragility of our bird, show them the instruments, let a few of them sit in it for a moment and — this is the hard part — remain cheerful and friendly as they excitedly point out to us the other sailplanes that circle over our landing spot, gain altitude, and fly away. Of course it was bad luck that we had to land here; our fans don't want to be deprived of their hero that quickly, though. The most responsible member of the horde of small boys which invariably appears is designated official guardian of the sailplane; we explain it to him particularly clearly, get his name and address. As long as we are away from the ship he must keep others away from the sailplane, since only he knows where it can be touched without damage, and he is responsible for its well-being.

OWNER OF THE LANDING FIELD

We ask the adults where we can find the owner of the field. Should he arrive on his own we are especially polite and explain to him, if he complains about crop damage, that the sailplane carries full liability insurance; he need only notify the appropriate authority to inspect the field and advise the insurance company, whose address we provide. " . . . unfortunately we are not permitted to make any cash payments ourselves . . . " The owner is usually satisfied with this and helps to keep the spectators out of the field to avoid further damage to the crops. Only our designated guardian is allowed to remain by the sailplane.

SECURING FOR BAD WEATHER

If bad weather approaches our behavior is, of course, different: we try to entertain as many spectators as possible so as to get them to help us secure the sailplane. The wheel should be retracted and the sailplane placed on the ground, the upwind wing lowered, and everything secured with the sailplane's tiedown kit. This helps avoid the sort of situation (this has actually occurred) in which the pilot returns from the telephone to find the sailplane reclining on its back in the field next to the landing field, somewhat the worse for wear. In fact, securing the sailplane against both weather and spectators should be our first action after landing — only then can we think about telephoning and/or our personal well-being.

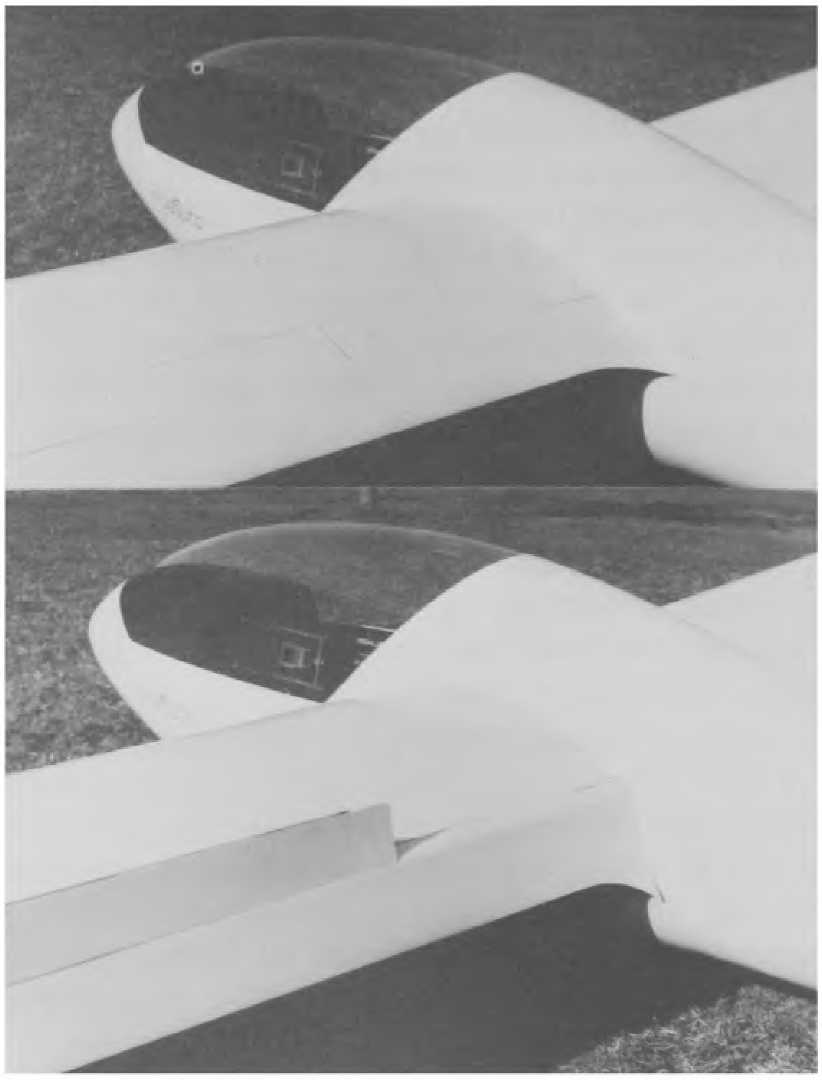
TELEPHONE PROCEDURES

We ask "motorized" adults exactly where we are, and find out from them how one gets here. We also try to get a ride, if necessary, to a telephone. The nearest phone is not necessarily the best: phone booths are not very good, since we should leave a number where we can be reached in case our crew needs more information, cannot find us, has car trouble, or any of the other difficulties that crews are heir to. If we are really far from home it may be worthwhile to make the call from a farmhouse and explain the situation to the (usually very friendly) farmers with as much charm and humor as possible; this can often spare one having to ask where one can eat or spend the night! The splendid hospitality one sometimes encounters after landing out is the source of some most fondly-remembered "vagabond adventures."

I landed once in western France and found myself helping the farmer chase some cows that had broken *loose; I was later wined and dined like a king, while another pilot, who had landed in a village with a shortage of eligible young men, narrowly escaped being married to the daughter of his host. One could write a whole book of such experiences, and it would be worth the effort! Erich Hetzel had to land next to a burning farm — apparently it wasn't burning hard enough to produce lift — during the German championships, and was celebrated as the "Savior from the Skies" by the local paper, since he helped free some pigs (!) from the burning barn. Hartmut Lodes landed on the grounds of a distillery . . .*

The actual telephone report can be made most efficiently if we use a preprinted information form which we fill out before placing the call, and which has proved its value at many contests. A pad of these should be placed next to the telephone at every gliderport, and we should always have a few tucked away behind our pilot's license or in the sailplane logbook. Such forms save not only time and phone money, but avoid annoying callbacks for more information.

We ask two adults to witness our landing form, and obtain their addresses and telephone numbers; the barograph is turned off, but remains sealed until it can be opened by our Official Observer.



Sample landing card

Landing report to* .... Date .... Time ....

Pilot's name .... Contest number ....

Landing place and time ....

Landing coordinates: Latitude .... Longitude ....

Distance and direction from ....

Witnesses ....

Turnpoints claimed ....

Remarks** ....

*Enter base telephone number at pilot's briefing.

**Enter such information as: pilot may be reached at (telephone number), pilot is/is not with his crew, any special retrieve instructions, etc.

Required Flight Documentation, FAI Sporting Code

For a flight to be valid for badge, record, or competition purposes, it must meet the national and international rules presented here. All such rules are based on the most recent version of the FAI sporting code prepared by the Federation Aeronautique Internationale in Paris.

To avoid unpleasant surprises, a table of required documentation is included.

Code Sportif Reference	Information Required	Claim Statement	Launch and Start	Declaration of goal and Turning points	Evidence of reaching each turning point	Landing or arrival at goal	Barogram	Barograph calibration
	Date of flight	x	x	x	x	x	x	x
	Name of pilot	x	x	x	x	x	x	x
4.3.	Nationality of pilot	x						
4.1.	Type & Class of Record claimed	x	x					
4.6.	Performance being claimed	x						
	No. & expiry date of F.A.I. license	x						
	Type & number of barograph						x	x
2.9.1.	Date of calibration of barograph							x
	Type & identity no. of glider	x	x	x	x	x	x	
2.9.	No intermediate landing						x	
1.5.1.	Place of take-off	x	x					
	Type of launch		x					
	Pressure at ground level at time of take-off (1)						x	
1.5.2.	Departure point	x	x	x				
1.5.4.	Starting Altitude		x					
1.5.5.	Start Time	x	x					
	Tug pilots name, license number & registration of tug		x					
	Time of release		x					
	Duration of tow		x					
1.5.2.	Position of point of release		x					
	Release Altitude		x					
1.5.6.	Name of Goal & Turning Pt.	x		x	x	x		
	Time of declaration of above			x				
1.5.12.	Recognition Time Interval							
2.7.	Time of glider at turning points (2)				x			
2.7.	Estimated height of glider at T.P. (2)				x			
2.7.1.	Uncut film of T.P with points signed by Off. Obs.				x			
1.5.10.	Time of landing at goal or finish time	x					x	
1.5.9.	Landing Place, if not a Goal	x					x	
1.5.11. 1.3.2.	Distance and speed of flight	x						
2.8.1.	Distance Penalty (if any)	x						
	Date and signature of pilot	x		x				
	Date and signature of calibration lab. official							x
2.1.	Date and signature of Official Observer (3)	x	x	x	x	x	x	
	Date and signature of Tug pilot		x					
4.5.	F.A.I. Sporting License	x						

(1) altitude claims only. (2) Ground Observation Only (3) If the glider does not land at the goal, the landing certificate must be signed by two independent witnesses who give their addresses.

ADDITIONAL CERTIFICATES AND PROOFS FOR MOTORGLIDERS

9.4.1.	Power source stopped prior to crossing start line	x	x				x	
9.7.	Power source not re-started in flight following the crossing of the start line	x					x	
9.9.2.	Power source incapable of being restarted in flight	x						

SPEED TO FLY

We can choose our glide speed anywhere within the sailplane's permissible speed range. To fly more slowly usually means to lose altitude more slowly, while higher speeds allow more rapid progress only at the cost of a higher sink rate. During a cross-country flight we always choose a speed appropriate to the situation; in other words, we strive to find the exact speed that will be the optimum for our purpose, the "speed-to-fly." Depending on our situation we will base our determination of the correct speed-to-fly on one of two objectives.

These are, first, the achievement of maximum *glide distance* from a given altitude (for example, the last glide before landing out either before completing a task or on "free distance"), and second, the achievement of as high a *cruise speed* as possible during the cross-country flight.

The graphic and mathematic solutions to this problem are treated more rigorously in the second part of this book; the graphs, at least, should be understood for a better grasp of the principles involved. Here in the practical section we will limit ourselves to the results and their effects on our flying tactics.

How Do We Glide Farthest?

If the weather on a cross-country flight deteriorates and we're fairly certain that we won't find further lift, we can convert our remaining altitude into as great a distance as possible.

CALM WIND CONDITIONS

Only if the wind is calm will the zero setting of the speed ring (which corresponds to a zero indication on a speed-to-fly variometer or similar indicator) result in the greatest possible glide distance. This assumes that the ring or indicator is properly calibrated for the sailplane's actual wing loading. If this is not the case, the ring should not be set exactly at zero, but at about 20 fpm higher for every 0.2 psf increase in wing loading, so that the ring commands higher speeds for the heavier aircraft. If our sailplane is flying at too light a wing loading, the reverse is true. Although this procedure does not result in exactly the correct speeds, it is not too far off, especially in the lower speed ranges. If the wind is calm the choice is up to us whether to retain any water ballast we may have until just before landing or to drop it right away. If we dump at once (don't forget to reset the speed ring) we will fly slower and remain aloft longer, if we keep it we'll be faster but on the ground sooner. The glide angle and glide distance are the same in either case. Since one usually will hope for one last thermal, though, the lighter sailplane not only gives us more time to figure out where it may occur, but will also climb better if we actually do encounter it. Moreover, ballast should always be dumped before landing out for safety reasons.

HEADWINDS

The longer we fly, the longer the time during which the headwind has a chance to adversely affect our glide distance. It becomes obvious that in such cases it is well worth our while to fly somewhat faster than the speed indicated by a zero setting of the speed ring. The proper setting can be arrived at by the optimization theory: the ring should be set to the rate of climb that would just maintain your net position over the ground in such a headwind. For this ring setting to be completely correct, we must assume that there are no vertical air motions. Actually, in rising air we should fly a bit slower, in sinking air a bit faster, than the speeds indicated by the ring.

For an ASW 15 (5.75 psf) and similar glass Standards, the ring would be set as follows:

headwind	ring setting
15 mph	+ 50 fpm
25 mph	+100 fpm
35 mph	+200 fpm

We can see that these increases in speed-ring setting are not all that great; for normal winds they're usually 100 fpm or less. If we have water ballast, this time we should keep it as long as possible, since the higher penetration speeds are more favorable for headwinds. If the ring doesn't match the actual wing loading we must make the same compensations as discussed above. The same is true for speed-to-fly indicators.

TAILWINDS

In a tailwind we should always get rid of all ballast at once. If the wind is strong the ring can be set just below the zero mark, allowing us to fly a bit "too slow" and let ourselves be drifted along by the wind.

How Do We Achieve High Cruising Speeds?

If we plan to not only complete the task as planned, but do so at the highest possible cruise speed, it becomes a problem of cruise optimization. To calculate this requires us to juggle a number of factors which can be mathematically expressed with greater or lesser degrees of accuracy and whose relationships to one another must be properly weighed if we are to achieve decent results in flight. The values which must be considered include *climb* rate, which depends on the weather, the type of sailplane, and the pilot; the *glide* between thermals; and the *final glide* to the finish of the task.

WHICH IS MORE IMPORTANT, CLIMB OR GLIDE?

In order to point out the importance of both climbing and gliding, and their relationship to one another with regard to the overall cruise speed, let us examine a simplified example of a situation which occurs very often in real life.

We will assume that there are weak thermals every 5 mi (8 km) in which our sailplane (an ASW 15 flying at 5.75 psf) can climb 200 fpm (1 m/s). However, somewhat farther away — about 23 miles (37 km) — we see a truly splendid cloud below which we'll be able to climb at 600 fpm (3 m/s). The air between the clouds is calm. We start out from cloudbase at around 5000 feet (1500 m) and try to decide on an appropriate speed ring or speed-to-fly indicator setting. Now, before reading further, make your own decision on what *you* would do!

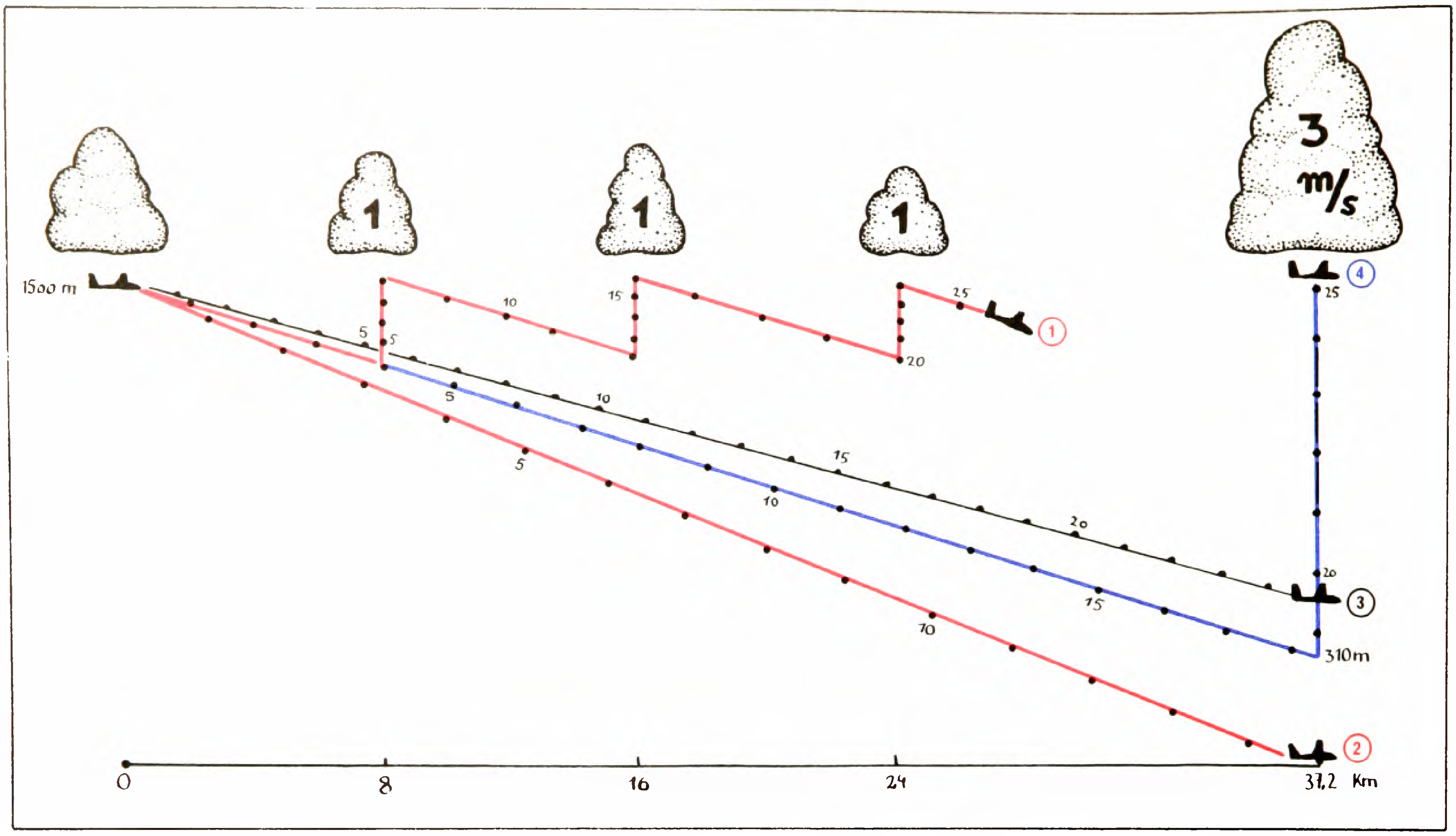
In our example, we will look at the different results obtained by four different pilots.

Pilot (1):
— has decided to fly as "correctly" as possible. He sets his speed ring at 200 fpm, flies to the next cloud, circles back up to 5000 feet, flies on to the next cloud at the same setting, circles, and so forth. When he reaches 5000 feet under the third small cloud he sets his ring at 600 fpm and heads for the big one.

His technique is that of a conscientious "classic speed-to-fly" pilot.

Pilot (2):
— has decided that the 200-fpm lift isn't worth trifling with, and tries to get right under the big cloud. He sets his speed ring at 600 fpm and roars off.

Pilot (3):
— he, too, doesn't want to trifle with the weaker lift, and wants to head straight for the big cloud. However, he's the cautious type: he sets his speed ring for zero and heads off at his best-L/D speed.



For highest average speed it is most important to reduce time spent climbing.

Pilot (4):

— has the same ideas as pilots (2) and (3), but feels that a ring setting of 600 fpm is too risky, since the high speed will reduce his glide distance too much. On the other hand, the setting of zero is too conservative and too slow. He estimates his altitude and the distance to the good cloud in comparison with his glide capabilities and decides that a ring setting of 200 fpm will get him there at adequate altitude even if he doesn't circle in lift. He sets his ring and flies straight to the strong thermal, like pilots (2), (3), and (4).

Which pilot makes the best speed? The envelope, please . . .

Pilot (1).— who is convinced that he is doing everything correctly — is still some 6 miles short of the big cloud after 25 minutes, at an altitude of 2100 feet. His overall speed will end up around 42½ mph.

Pilot (2) has really missed the boat. True, he can make it as far as the big cloud, and gets there in only 15 minutes, but arrives there at ground level and has to land right under it. If only he'd run into 600-fpm lift along the way — then his average would have been 58½ mph — but as it is, he is on the ground — although it must be admitted that he is ahead of the others!

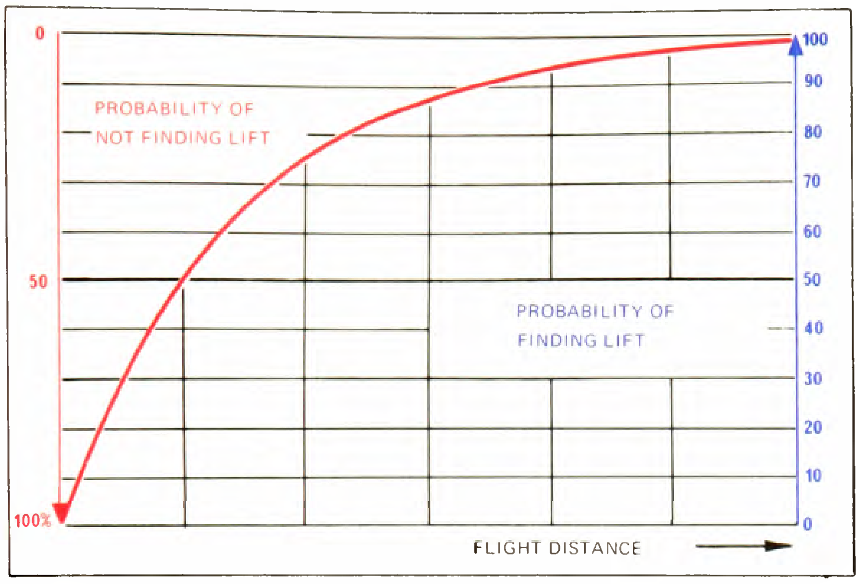
Pilot (3) arrives under the good cloud at an altitude of 1700 feet after 24.7 minutes. After a further 5½ minutes he'll be back at altitude for an average of 45½ mph

Pilot (4) arrives under the big cloud at a bit over 1000 feet after 18.6 minutes. His calculation has been successful; he has sufficient altitude to get into the 600-fpm lift. At the end of 25 minutes he is back at cloudbase altitude. Pilot (3), 3000 feet lower, is just entering the thermal; both of them can look straight down and observe pilot (2) standing in a field next to his sailplane and shaking his fist. Pilot (1) is not only some 600 feet lower, but so far back (around 6 miles) that pilots (3) and (4) can't see him at all.

The illustration shows the situation at the end of 25.2 minutes. The dots and numbers along the various flight paths represent minutes; the differences are striking!

What appears particularly surprising in this example is that our star pilot (4) does not owe his good fortune to a speed ring setting based on his earlier average climb; on the contrary, it would appear that the choice of 200 fpm was an arbitrary one, yet he left the competition far behind!

Only thus was it possible for him to cover the desired distance as rapidly as possible while still maintaining an adequate margin of safety. He did not need to work the weak lift that he encountered, he flew on. The hoped-for strong lift was more important to him than a speed-ring which reflected the expected climb rate accurately. In this case, his cruise speed was affected by a factor which is simply ignored by many pilots in their optimizations, or even intentionally disregarded in order to simplify calculation: probability.



PROBABILITY

The greater our radius of action, the greater our (weather-dependent) chance of encountering a thermal of given strength.

Let us assume that a sailplane with a 20:1 glide ratio flies off a mile of altitude, covering 20 miles of distance, and the weather is such that there is a 50% chance of hitting a good thermal in this distance.

If it flies twice as far — either by starting from 10,000 feet or by having a glide ratio of 40:1 — the same 50% probability holds for the additional 20 miles. For the entire distance of 40 miles, the probability has increased — but not to 100%, which would require an infinitely long flight.

Of course, this asymptotic curve is valid only if the weather conditions along the distance flown remain the same. Even so, we can see clearly that relatively slim chances become even slimmer with alarming rapidity if too high a ring setting further reduces glide distance. (This is the altar on which pilot (2) was sacrificed in the earlier example.)

On the other hand, if our chances are good to begin with — say 90% — the distance increase achieved by slightly lower ring settings will not increase them much further. (Pilot (3) lost too much time by flying slowly, but hardly gained any additional safety compared to pilot (4).)

INITIAL AND FINAL RATE OF CLIMB

Thermals (and other sources of lift) often yield varying rates of climb at different altitudes. Optimization calculations usually are based on an average rate of climb arrived at by dividing the altitude gained by the time not spent cruising straight ahead on course (including searching for lift, centering, climbing, and leaving the thermal). This is actually an inaccurate procedure; René Comte has refined it.

A pilot who flies (cruises) rapidly not only arrives at the next thermal at a low altitude, but often encounters an initial climb rate that will differ from that encountered by a slower pilot who enters the thermal at a higher altitude. Once he has worked himself up to the altitude at which the slower pilot entered the thermal their further climbs are identical.

Consequently, to optimize cruising speed — which will directly influence the altitude at which we enter our next thermal — we must base our calculations on our expected *initial* climb rate; by the same token, when we leave a thermal we should use our *final* climb rate as a basis for how high to climb and for setting the speed ring.

Here are two examples that may make this more evident:

1) Let us assume that the climb-rates achieved in a "blue thermal" decrease from 600 fpm through 400 fpm to a final 200 fpm as altitude increases. If the next thermal were to deliver a steady climb of 400 fpm it would be senseless to depart the first one when it had decreased to 500 fpm, since we would not be able to regain altitude as easily in the next thermal. It becomes obvious that the time to leave the thermal is when its climb rate has decreased to 400 fpm; in other words, when the final climb exactly equals the initial climb of the next thermal.

2) We fly from a constant 400-fpm thermal to one whose climb rate increases from 200 to 400 and ultimately to 600 fpm (this actually is the case quite frequently at lower altitudes). If we leave the first thermal too soon, we're forced to spend a long time scratching around at 200 fpm, because we entered the next thermal at too low an altitude. On the other hand, if we wait too long we'll reach the new thermal at too high an altitude to take advantage of most of its 500- and 600-fpm lift. Thus, we see that ideally the initial climb rate of the new thermal should be the same as the final climb rate in the thermal just left.

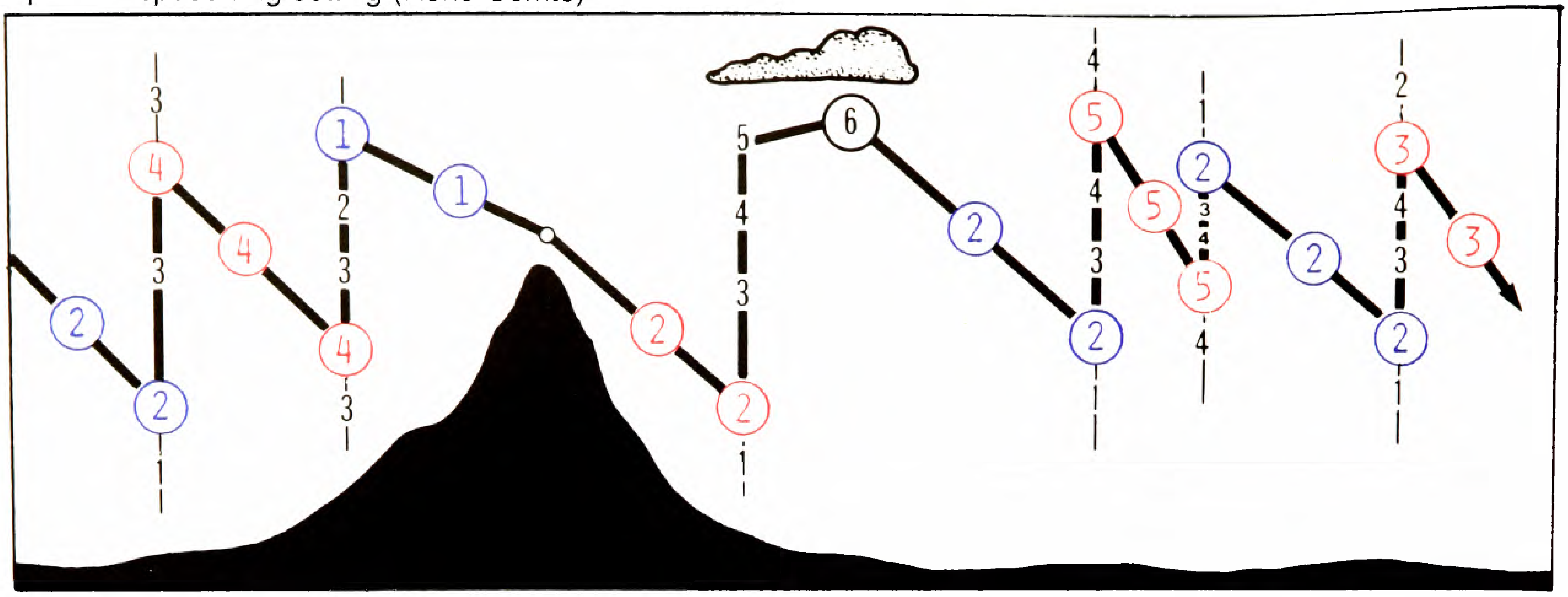
Both examples illustrate the need to climb to an altitude in which the final climb rate is equal to the initial climb rate of the next thermal. The appropriate speed-ring setting for the glide between thermals is thus the final climb rate (which equals the initial climb rate in the next thermal).

SPEED-TO-FLY RULE

One should fly so as to maintain the equation: FINAL CLIMB = INITIAL CLIMB. The altitude to which one must climb in a particular thermal is thus a definite value determined by rate of climb *and* the distance to the next thermal. If it is impossible to conform to this rule (due to high terrain, low cloud base, etc.) the ring must only be set according to the final (or, as the case may be, initial) climb rate.

The illustration shows how such a flight is carried out. The vertical lines represent thermals, with indicated rates of climb. The circled numbers indicate initial and final rates of climb, and hence also speed ring settings for each glide. The change in rate of climb with altitude has been intentionally exaggerated for clarity.

Optimum speed ring setting (René Comte)



Of course, if we ask ourselves exactly *how* we can conform exactly to the above rule, we'll find that it's impossible. Using earlier theories, it was already hard enough to set the speed ring exactly for our average climb; this new theory makes the situation even worse! The distance to the next thermal, the exact altitude at which we'll reach it, its initial climb rate — these cannot be estimated closely enough. Even so, we should try to gain altitude in the best possible lift — that is, based on the tendency that final lift should equal initial lift. As the lift in which we're climbing starts to taper off, we should ask ourselves if we are likely to do better in the next thermal, and depart at once if we are. This is the way to increase cruise speed, even if the actual speed-to-fly rule represents an unreachable ideal.

There are other factors which also influence our answer to the question of "to circle or not to circle."

On days of heavy wind shear the wind distribution at different altitudes plays a very definite role. It is sometimes possible to remain at favorable altitudes so that we can benefit from a tailwind; however, the wind shear levels themselves are usually unfavorable, since the thermals are usually "torn up" at those altitudes.

In general it is not worthwhile to work too many thermals if one is already at or near maximum altitude (cloudbase or the altitude at which climb rate decreases markedly) since one always loses some definite time while centering. Altitude should not be regained in too many small increments, but rather in fewer large ones.

A pilot who could actually always make the right decisions would probably make good average speeds from 10 to 20% faster than those of the task winners of a world championships!

Since we cannot conform exactly to the speed-to-fly rule, we must consider which "errors" can be allowed because they do not cause too drastic a speed reduction, and which are simply too "costly." The first example, with four pilots and thermals of varying strength, has showed us that climb rate can play an extremely important role. What about gliding speed (or, as the case may be, the setting of our speed ring or speed-to-fly indicator)?

SPEED LOSSES FROM INCORRECT SPEED RING SETTINGS

The second part of this book will present a method for graphic construction of speed loss for erroneous ring settings. E. Kauer has done further research on this subject and has prepared computer printouts for speed losses in both the Standard Cirrus and Nimbus II. Both sailplanes show essentially the same data, despite the variation in their performance; the illustration shows the (calculated) flight-time increase for the Standard Cirrus against ring-setting error in per cent.

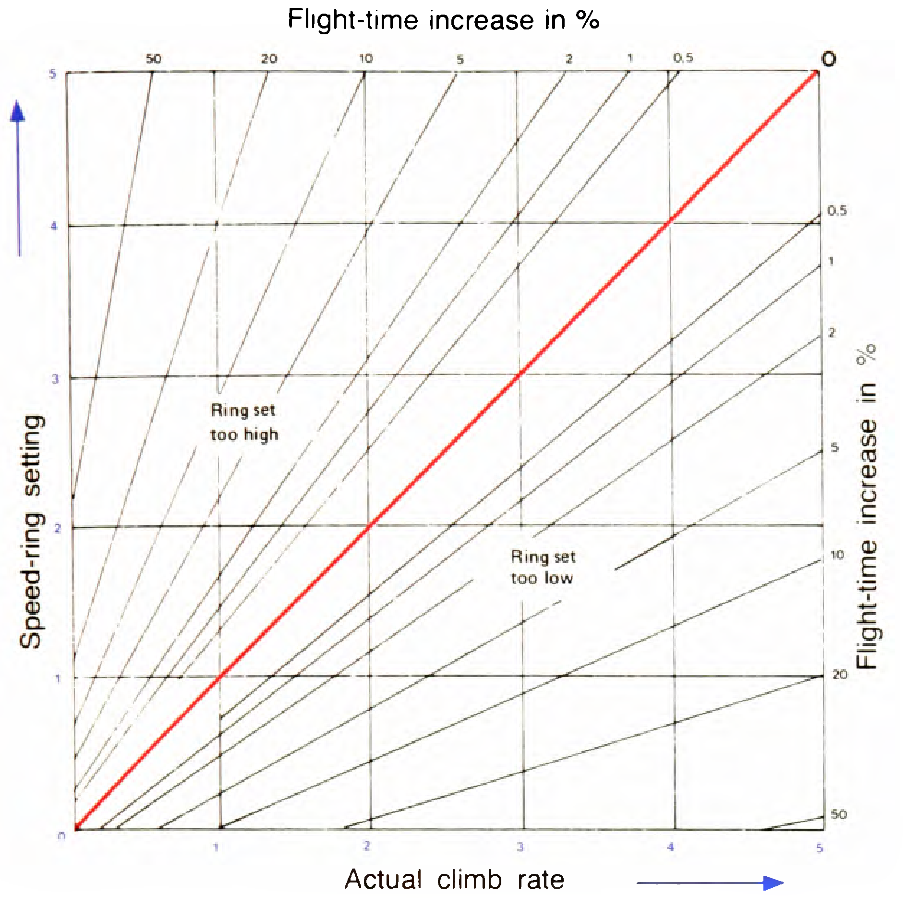
The red line in the diagram shows the ideal condition — that is, no error — in which actual achieved climb and the ring setting are identical. Above the line we find the losses for a too-high setting, below it for too low. We can see that a setting 25% in error still results in an approximate speed loss of less than one per cent!

It also is evident that leaving the ring at zero as climb rate increases leads very rapidly to large speed losses.

This graph is very reassuring; even if we set the ring at 400 fpm for an actual 800 fpm climb the actual speed loss will only be around five per cent. This might be fatal in a contest, but normally our errors of estimation are not quite so gross. Remember, a 25% error only causes about 1% speed loss! If this is the case, we really can dispense with fancy electronic rate-of-climb integrators and the like — since they indicate average climb they do not conform to the speed-to-fly rule in any case. We can simply make a rough estimate, as accuracy is not necessary

Kauer summed this up in a pointed, but very opposite, comment in his article, *MacCready Flight Without Illusions*: "The secret of using the MacCready

Flight-time increase due to incorrect speed-ring setting (Standard Cirrus)



principle does not lie primarily in the exactitude of its use, but rather in the adherence to the rule of not using lift below the speed-ring setting except when absolutely necessary."

Nevertheless, the speed-to-fly variometer or MacCready ring remain very important devices for glide optimization; their settings, however, can be more or less freely chosen depending on the circumstances.

Another technique, used by 1976 World Champion Ingo Renner, is to use a table of interthermal speeds based on climb rate and no vertical air movement between thermals. He flies these speeds with only slight variations depending on air movement; his success indicates that this is possible without prohibitive losses.

For example, if we see a tremendous Cumulus congestus building on course ahead, we could expect either 800-fpm lift . . . or rain and heavy sink. If we conservatively set our speed ring for 200-fpm lift, the worst that can happen is a 14% speed loss — and that only for a short distance. On the other hand, if the lift really fails to materialize we will still have enough altitude to get to the next thermal. In a ten-minute glide we would lose around 90 seconds if the huge cloud failed to produce any lift. Pity, though, the "brave" pilot who sets his speed ring for 800 fpm only to find rain and sink; due to his large altitude loss, he will be forced to land.

We can see from the graph that the zero setting causes larger losses if the lift is strong. This highly "economic" setting should be used only as a last resort.

Otherwise, the speed-ring setting becomes a matter of tactics, and should be chosen to allow us to reach the strongest possible lift with an adequate margin of safety. This can allow our flights to become more interesting and exciting than some of the "average-climb" enthusiasts of past years could have dreamed. If the weather is fairly constant and we are in no danger of landing out we can strive for the closest possible approximation to the speed-to-fly rule so as to squeeze the last few available percentage points of speed from the conditions at hand.

Contest flights, on the other hand, are not won because the pilot always set his speed ring with mathematical precision. The climb is the determining factor. The faster pilot is the one who climbs in only the best thermals and does not waste time in others, spends less time searching for lift, centers it better when he finds it, and whose course deviations make the best possible use of any available streets of lift.

DOLPHIN STYLE FLIGHT

As we fly through areas of rising or descending air while gliding, our speed ring or speed-to-fly indicator commands various changes in airspeed. Often these airspeed changes, whether to speed up or slow down, are quite abrupt. In the air this appears similar to the swimming and leaping movements of a dolphin.

If the flight path is cleverly chosen to run along areas of lift such as slopes, cloud or thermal streets, etc., it may be possible to fly considerable distances without circling and without losing altitude — perhaps even climbing. This has led to sensational reports of flights with very high average speeds, especially in the last few years.

In the meantime the world record for speed around a 300-km triangle has risen to 95 mph (Walter Neubert, Germany), that for the 100-km triangle has reached 102 mph (Ken Briegleb, USA), and Hans-Werner Grosse made a spectacular free-distance flight of 905 miles. The "magic word" that's being whispered throughout the soaring world is "dolphin flying."

According to the usual method of calculating cruise speeds based on the sailplane's polar, such speeds would require lift that would strain the limits of our credulity — even with today's high-performing sailplanes; but let's have the pilots speak for themselves.

Hans-Werner Grosse describes the beginning of his 514-mile triangle flight on May 16, 1973: "Takeoff at 8:45 a.m. (!), release at 3300 feet. Cloudbase initially at around 1500 feet, rising rapidly to 2100 feet. The low cloudbase brings with it thermals spaced so closely that I almost never have to circle and can fly straight ahead with airspeed variations. Thus, I am able to attain a cruise speed of 56 mph despite lift of less than 200 fpm . . . "

— We can see, then, that even weak lift can lead to high cruise speeds if other conditions are appropriate.

Grosse has not been the only one to prove that high cruise speeds are possible even in less-than-ideal conditions. Contest results of recent years show speeds that would have been considered impossible just a few years ago, especially when one considers that many contest tasks are flown on days of rather poor weather. To some extent, of course, this is due to the improvements in sailplanes — but by no means entirely! Although the steep upward trend of sailplane performance in recent years should not be underestimated, a larger influence on the enormous performance increases we have seen must be credited to the continued development of flying tactics, and especially the development of dolphin flight. The most spectacular successes are almost invariably due to this method; if we ask the pilots of these flights, though, what "recipe" they've used, when they circle and when they don't, we get widely differing answers. In fact, some of the top flyers actually contradict one another.

It is far from simple to express the theory for dolphin flight as unequivocally as various researchers — primarily Karl Nickel and Paul MacCready — have done for the "classic" cross-country flight based on circling in areas of lift. Since not only the strength of up or downdrafts must be considered, but their horizontal extent as well, additional elements of complexity are introduced. Various meteorological models can offer some aid in a mathematical approach, and four such models will be presented in the second part of this book. While the results of each are only exact for that particular model, in combination they provide adequate data for entirely usable conclusions. Interestingly enough, the "classic" (i.e. MacCready and others) speed-to-fly theory fits in as a special case for this new, expanded speed-to-fly theory, if one assumes that no distance is covered during a climb. We can then reasonably define dolphin flight as the straight portion of a flight based on speed-to-fly theories; thus, the straight portions of even a "classic" flight are, in fact, dolphin flights. (This will be covered more exactly in the second part of this book.)

Before we start examining the rules for dolphin flight one point should be made perfectly clear: what's really important is the ability and talent of the pilot to make small course deviations into areas of the best possible net "profit" of up- and downdrafts. Thus, and only thus, can we explain Grosse's cruise speed of 56 mph in lift of less than 200 fpm.

DOLPHIN-FLIGHT RULES

1) The speed ring or speed-to-fly indicator should generally be set at the *circling* climb rate encountered in strong lift.

2) In case flight along the (suspected) lift street results in loss of altitude, occasional circles in the best possible lift are required.

3) If we threaten to exceed the maximum altitude (cloudbase) the ring setting must be increased to obtain an overall level flight path.

4) If a climb, rather than level flight, is desired, points (1) through (3) are just as valid; however, (2) and (3) now govern the flight path to achieve the desired climb rather than level flight.

5) Dolphin flight should not be "forced" by a lower speed-ring setting; if the weather is appropriate, it will happen by itself, especially if the thermals are close together, as is often the case if the convective layer is not too high or under cloud or thermal streets. In other words particularly strong thermals are not necessarily favorable to dolphin flight, since they are usually too far apart.

6) If the weather is favorable for dolphin flight, high wing loadings are recommended (ballast). (See also "Flight Along a Thermal Street," page 22.)

SPEED-TO-FLY CONTROL TECHNIQUES

Ideally, one should fly at the proper speed corresponding to every vertical air movement encountered. If these air motions change while we fly straight and level, the actual speed will tend to deviate from the ideal to a greater or lesser extent. Such deviations naturally cause speed penalties, especially if up- and downdrafts are in very close proximity to one another.

Factors which combine to cause these errors in speed include:

— the lag in variometer indications
— the pilot's reaction time
— the inertia of the sailplane

THE LAG IN VARIOMETER INDICATION

The lag in variometer indication depends on the type of instrument used. Commonly-used vane-type variometers (e.g. Winter, PZL) are already considerably faster than the older rate-of-climb indicators, while the newer taut-band instruments and electronic units are faster yet. Even so, it's doubtful if the extra expense of especially fast instruments is worthwhile if they prove too "nervous" for the pilot's taste and end up being damped by restrictors in their connections or electronic damping. Even an ideally fast — i.e. instantaneous — variometer, however, would have a certain lag displaying vertical air motions, since for example, a climb cannot be displayed until the sailplane's sink has been halted and it has already started to climb. However, for this to occur it must first be accelerated (up or down). Ideally, we should base our flying on these accelerations — that is, on "seat-of-the-pants" feel, using our compensated total energy variometer or speed-to-fly indicator as a check for the size of our (acceleration-based) speed change. If we keep an eye on the *trend* of its needle, rather than its instantaneous position, we can deterine if the climb or sink becomes stronger or weaker, and thus if we're still approaching its maximum or have already passed it.

THE PILOT'S REACTION TIME

The pilot's reaction time depends, of course, largely on his own bodily tendencies and condition; one can improve it if one is well rested, well fed (but not bloated with hard-to-digest food), in short in that condition of physical and mental well-being that leads to both enjoyment of and concentration on the task at hand. Enjoying one's flight improves one's attention and reduces the reaction time; we should cultivate our sense for acceleration. Of course, it is difficult to differentiate between those accelerations caused by air motions and those we've caused ourselves by control movements; the only way is to practice and refine one's "feel" if we don't want our speed corrections to lag too far behind. We can train our ear to react quickly to the tone of an audio variometer — or better yet, an audio speed-to-fly variometer — so as to avoid the need for constant scrutiny of the instrument panel.

THE INERTIA OF THE SAILPLANE

The inertia of the sailplane cannot, of course, be overcome, but will cause less delay the more abrupt and rapid our control movements are. Unfortunately, rough or abrupt control use can lead to aerodynamic losses which vary with airspeed as well as with the g-load we apply. At higher speeds, it's not wrong to pull as much as 2 or 2½ g, since the increase in lift occurs at entirely favorable values of C_L and at rather low angles of favorable values of attack. Only at low airspeeds do we encounter significant losses from g-loads, a fact which we can verify by observing our total-energy variometer. Thus, we can pull harder at higher speeds.

"Pushing over" for higher speed is a different situation. The airfoils of a sailplane are generally inefficient for flight at less than one g; if we force the situation by too much forward pressure the angle of attack is far from favorable. If we go so far as to induce negative g-loads, so that charts, cameras, and anything else loose in the cockpit fly against the canopy (it is astonishing how much dirt, grass seeds, etc. can collect in the "bilges" of even the best-kept sailplanes), we have reached an extremely inefficient condition: we are forcing a wing designed to produce lift to produce sink instead, with a marked drag increase. Thus, we should always temper our forward stick movements to the point that there is always perceptible pressure from the seat.

Generally, our pitch corrections should be more abrupt the stronger the *changes* in vertical air motion are over a given distance. Put more simply: in smooth weather fly smoothly, in rough weather fly roughly.

WATER BALLAST

"CLASSIC" FLIGHT

Any increase in wing loading decreases the circling performance of any sailplane. Circles can be flown in various fashions: a given diameter can be maintained at low speed and gentle bank angle, or at higher speed and steeper banks. When circling, we tend to "juggle" airspeed and bank angle by feel to obtain the lowest possible sink rate for a given diameter. In other words: there is an optimum airspeed and bank angle for any circle diameter.

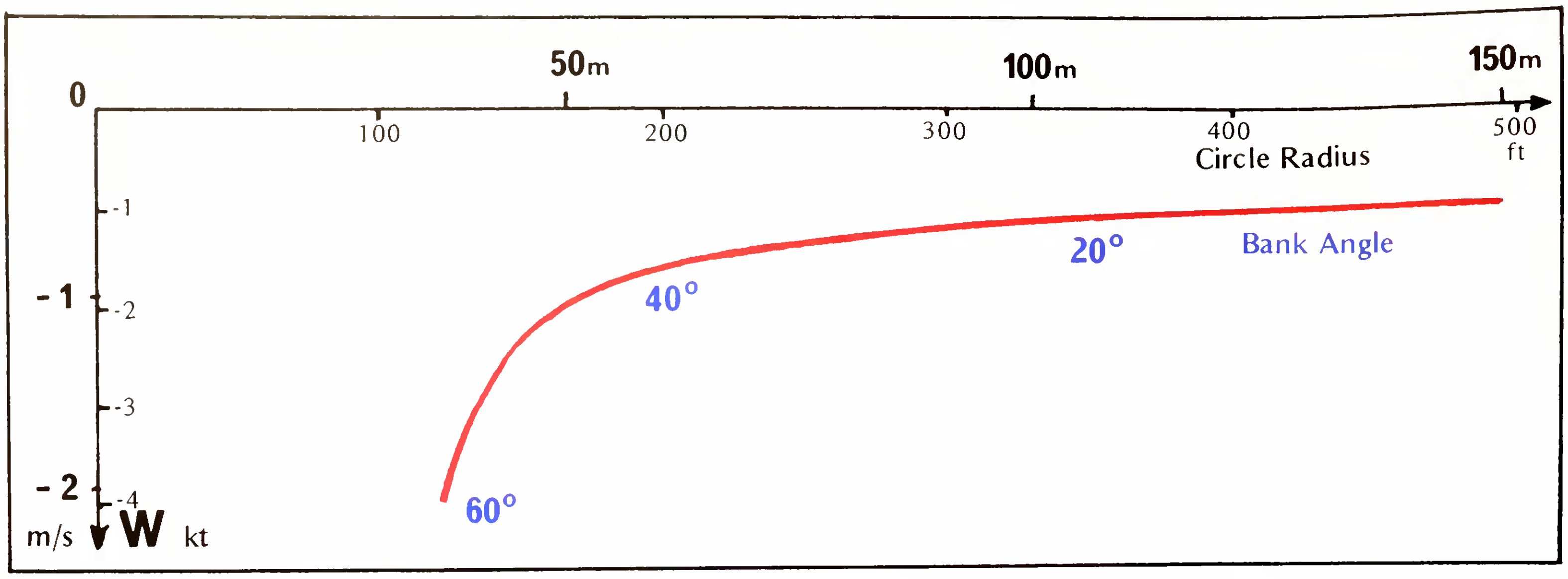
To characterize the circling performance of a sailplane one can examine a special circling polar. The illustration shows how the sink rate of the sailplane — in this case an ASW 15 flying at 5.75 psf — increases as the circle's radius decreases (assuming that the optimum speed and bank angle are flown at all times). If one increases the wing loading to 6.5 psf, the sink rate for a circle of about 450 foot radius increases only about 0.3 fps, but for a circle of 150 foot radius the sink rate would increase by about 1.5 fps. The changes in performance for straight flight are similar; performance will be poorer at speeds less than best glide speed and better at higher speeds. If one expected to be forced to use only narrow thermals, dropping all the ballast would be the proper course of action in order to climb better, even at the cost of some high-speed performance. If the lift is weak, our speed-to-fly indicator won't command high inter-thermal speeds in any case, so we might as well get rid of whatever weight we can so as to reduce the time spent gaining altitude. After all, we have seen earlier that good climb rates are the most important requirement for high cruise speeds. The luxury of a high wing loading is only worthwhile when the penalty one must pay in climb remains a relatively small one. On the other hand, if one's climbing in a gaggle a small climb advantage is hardly a telling point, since the necessity for avoidance maneuvers while outclimbing other sailplanes will cost the pilot a large part of his advantage. The advantages of heavier wing loading are evident in glides without a similar disadvantage.

IN DOLPHIN FLIGHT

In dolphin flight on the other hand, the situation is different, as there is no need to circle. Since the increase in sink rate is much smaller for straight flight than for circles, a higher wing loading can be used to its fullest advantage. If longer stretches of dolphin flight are expected it is advantageous to carry ballast.

STARTING

Starting in contests with full water ballast is always a good idea. If the run through the start gate is made at



Circling polar ASW 15 5.75 psf - optimum circle

high speed, heavier sailplanes will gain more height than light ones in the subsequent pullup; if thermals don't look good, the ballast can always be dumped on the way to the first one. One usually arrives at the first thermal at a higher altitude if one uses this system than if one had decided from the outset not to use ballast. If we are actually circling, of course, we must not drop any water if we can expect other competitors to enter the thermal below us, let alone if any are already in it. To wash someone out of the air like that is very unfair, especially if he is already fighting to stay airborne. Anyone who still has water aboard in such a situation must not have been paying attention to the situation earlier, and doesn't have the right to correct his mistake at the cost of another pilot's chances.

WATER BALLAST RULES

- High wing loading is advantageous for fast flight and is worthwhile if:
  - the thermals are large
  - the thermals are strong
  - cloud or thermal streets suitable for dolphin flight exist or are expected.
- Since heavier sailplanes pay a climb penalty, ballast should be dumped if:
  - thermals are small
  - thermals are weak
- Contest sailplanes should carry ballast on takeoff, if for no other reason than the speed advantage in the start gate.
- Never dump water on other sailplanes while circling!

THE FINAL GLIDE

It is always interesting for the spectator at smaller contests to observe how some pilots dive on the finish from a great height, whistle across the airfield on the deck at redline speed, and then make a breathtaking pullup to another great height. While this may well look very impressive, such a display — in addition to being dangerous to other pilots who may be finishing at the same time — serves to inform the initiated that this pilot calculated his final glide incorrectly — if, indeed, he calculated it at all. After all, the altitude for this airshow had to be gained back on course somewhere, and that costs time. Calculation of the final glide is an essential part of every speed flight and often makes a difference of five to ten minutes — sometimes, in fact, it makes the difference between making it home or landing out.

The speed-to-fly rules still hold true for final glides, of course; they are flown with the speed ring set for the final climb in the last thermal. This is a value which we know quite exactly, and, in combination with the wind, it gives us a definite glide angle over the ground, which in turn is used with the distance from the goal to determine the altitude at which the final glide will commence. Our capability for estimating distances cannot meet the demands of a final glide; this is why it must be calculated.

The entire final glide procedure is roughly as follows: still far from the goal, we try to decide approximately where we may be able to begin a final glide, based on our (thermally limited) operating altitude. At some point before reaching the final glide starting point we may obtain the winds aloft by calling FSS. If the wind information we receive corresponds more or less with that on our kneeboard, we can use the head or tailwind component we noted earlier. If not, this component must be calculated or estimated anew.

As our continued flight brings us to a thermal that appears to be good enough to make the climb to final glide altitude worthwhile, we calculate: starting with our climb rate and wind component, we find the optimal altitude for our distance from the finish. Our initial calculation will be based on an arrival at the finish line at zero altitude; that is, with no reserve. If the weather ahead looks good, and if our last climb was 600 fpm or better, we'll leave it at that, since the basic calculation leaves some margin; this is particularly true if we're flying at a higher wing loading than

that used as a basis for the calibration of our final glide calculator. If the rate of climb has been less than about 300 fpm, we should add around 300 feet for safety; this should be sufficient unless things look uncertain up ahead (danger of rain, downslope winds, sink streets between invisible thermal streets, uncertain winds aloft information, etc.) in which case we add even more safety reserve.

This corrected altitude is now the goal for our final climb. If the lift increases as we climb higher, we recalculate and climb even higher for a faster final glide. If it decreases, on the other hand, we calculate a slower final glide with a lower departure altitude. If we can't make it to departure altitude at all (cloudbase) or if the thermal weakens to the point where it's no longer worthwhile, we proceed on course to find a new "final thermal," which will require another calculation of the glide.

After leaving the last thermal we'll check our position and altitude from time to time and compare them with what our calculator tells us is necessary. If we're consistently too high we set our speed ring for a higher speed, which we arrive at — again — by recalculating our glide from our present position. If we are too low, we set the ring for a lower speed by the same method. We should arrive at the airport at normal airspeeds and around 350 feet of altitude, plenty for a good landing pattern — as long as the landing area itself isn't too far from the finish gate. A further point: sometimes at contests one can see absolutely catastrophic landing patterns, patterns that wouldn't be flown by the rankest beginner, flown by normally excellent pilots. It's as though the stress and strain of competition had drained them completely and they just shut off their minds after crossing the finish — after all, nothing left to do but land at the home airport . . .

It is this effect that caused, for example, three out of four of the German team at the 1974 World Championships at Waikerie to make immaculate belly landings — and we were joined in this exercise by a veritable United Nations of the greatest names in soaring. At least not all the sailplanes were damaged. Rather, we must force ourselves, if necessary several miles before finishing, to plan our landing and to make a regular before-landing check. The earliest that we can "shut down" is after our ship has been pulled clear of the active runway.

PHYSICAL CONDITIONING

It should be clear to us that long cross-country flights, which allow hardly any bodily movement, place demands on the human body which are very different from those for which it was designed. Not only do we want to withstand these demands, but we also would like to feel comfortable in flight, so as not to be distracted when making important decisions. Thus, our comfort is not only essential to our enjoyment of the flight, but to our performance as well.

Such comfort starts right with the pilot's seat. A little ingenuity and foam rubber can change even the iron maidenlike seats of older types into fairly comfortable ones. Special attention should be paid to a strain-free position of the spine, which reacts very unfavorably to uncomfortable seats and could even be damaged by too much time spent in them! We should also assure that the cockpit is free of drafts. Leaky areas around the canopy or tow hook can be sealed off with foam weatherstripping or with rubber flaps. The cockpit ventilation should be capable of being turned completely off; when on, it should direct a perceptible stream of air along the inside of the canopy to the pilot's upper body. This not only prevents overheating, but acts to stop the canopy misting over in cooler weather. For hot days we should have either a very effective ventilation system, or an additional openable window in the canopy. The effectiveness of a marginal ventilation system can often be improved by arranging an air exhaust at the aft end of the fuselage.

A pilot's endurance depends both on his general condition and on any specialized training or conditioning he or she may have undertaken. On any given day, endurance and performance also depend on such things as sufficient sleep and easy-to-assimilate food. I certainly don't want to recommend any particular diet for soaring pilots, if for no other reason than that there are so many different possibilities which all arrive at the same end: preparing the body for long flights. Moreover, it would be a mistake to make radical changes in one's eating habits shortly before the beginning of a contest. A week before a major contest — even earlier if desired — one should change the main meal of the day from luncheon to supper, so as to set up a "digestive rhythm" more in keeping with flying days. If a no-contest or rest day comes along, any celebratory feasts should also take place in the evening — in other words, don't break the pattern. Eliminatory habits can be controlled in much the same fashion, at least to a great extent; all that's necessary is to allow the body sufficient time to become accustomed to a new schedule. Before a flight we should eat only easily-digested food, so that the blood supply is not diverted from the brain to the intestines later on. In fact, it has been medically proven that mental abilities are not affected by hunger even if we eat nothing at all — but not everyone is that dedicated.

There is certainly no reason not to take along a snack to eat in flight. While one pilot may extoll the praises of jerky or granola, another his bag of "space food," and yet another swears by his sandwiches, the actual menu of such a snack is not as important as it's being what the pilot is used to. Moderate amounts of dextrose, either in candy form or in such drinks as Gatorade, can be beneficial; too much can cause dangerously high blood sugar levels.

Inflight drinking arrangements are not only permissible but essential: without sufficient water the functions of the kidneys are impaired, waste products remain in the bloodstream, and the accumulation of these "poisons" cause headaches and nausea, as well as exhaustion. Of course, if one drinks a good deal, one will have to deal with the same liquids later on in the flight. It would be a mistake to attempt to "hold one's own" until landing; the results of such attempts can include such problems as renal colic, as a number of pilots have found out the hard way. Various relief arrangements (bottles, funnel-and-hose, etc.) can eliminate the problem.

Flights in hot, dry air will cause us to lose a lot of water through our skin — especially if we are the type that perspires heavily in any case. Since sweat contains a great deal of salt, we must ensure that it is replaced to avoid upsetting the balance of electrolytes in our bodies. Salt tablets are available at any drugstore and can be taken before — or even during — flight. There is no severe danger of ingesting too much salt — besides needing more water — the tablets are completely harmless; in fact, we could just as well eat table salt by the teaspoonful if it weren't so unpleasant to swallow.

Our clothing should be porous and easily adjusted with zippers or snaps — remember, we may be battling to stay aloft at low altitude, with the sun beating into the cockpit and 100-degree temperatures, only to be at cloudbase in the shade with 40-degree temperatures a few minutes later. Clothing depends on weather, of course; there is really no need to climb from the cockpit after landing either blue with cold or dripping with sweat. A hat of some sort is essential; light-colored linen or terrycloth tennis hats reflect heat and keep the brain at an efficient "thinking temperature." It can be dangerous to fly without a hat; a number of pilots have made emergency landings, just barely conscious from the effects of heatstroke.

COMPETITION TACTICS

Under this heading we are going to discuss all the techniques we should know *in addition* to the general rules of optimized cross-country flight if we're going to be flying against other pilots. It should be clear by now that what's really important in competition is a thorough understanding of cross-country techniques, rather than any more or less refined secret tricks or special tactics.

Let us take good cross-country technique for granted, then, and see what else may be useful:

THE CREW

A well-functioning and harmonious crew is probably the most important "foundation" for good contest flying. If possible, the crew should consist of two or three people who get along well with one another and with their pilot. If necessary, though, a single reliable person can be better than a larger number of people who are unsuitable for either technical or personal reasons.

The absolute ideal crewperson might be like this (and these are just the most noticeable of a large number of desirable features):

Easily satisfied; free from personal demands; perspicacious and diligent, performs all major and minor duties without being asked by the pilot; always cheerful and satisfied with the pilot's performance. If the pilot should make a bad showing due to unforgivable errors, the crew does not mention these, but rather sympathizes with and consoles the pilot, looks toward the morrow with contagious optimism, and works even harder to ensure that everything runs smoothly. Although possibly an experienced contest pilot in his or her own right, a good crew performs only what is required, and does not offer suggestions of what he or she would do. The crew knows not only the pilot's strengths, but his weaknesses, although the latter are never mentioned; knows how to keep him cheerful and protect his nerves from the rigors of competition while preparing him for a flight. Radio messages are always polite and informative, never unplanned or — worse yet — uncontrolled.

Based on the above, the ideal crew should be female and is likely to be the pilot's "better half" — assuming, of course, that he has one who really deserves the name. Moreover, it would seem to make little difference in the long run whether one introduces one's beloved gently to the rough life of a crewmember or the other way round. Since the presence of one female usually rules out the presence of any other such pinnacles of creation, the other crew members are men – a grouping which has wondrous effects on the improvement of courtesy within a tight group that may spend weeks together. (Lady pilots, of course, will have to make similar but slightly different arrangements.)

Like so much in life, the dream crew is likely to remain a dream; but sometimes it can almost be attained. A relationship based on trust and free from any strains is fundamentally important. Usually, the mood of the helpers depends largely on the pilot's behavior; there are some real despots who make tremendous demands, are never satisfied with anything, and — worst of all — don't let their crews "take part" in the day's flying experiences. A pilot who walks off after a flight, leaving the crew to take care of the sailplane, and shares his experiences only with the other pilots, should not be surprised if crew morale and performance decline. The more a crewmember can take part in the competition, the more information he or she can provide, and the better they will be able to distinguish between what is or is not important when working with the pilot as a team member rather than a servant. The job of a good crew requires much knowledge of the subject, as well as lots of work.

Not only is the crew responsible for the daily preparation of the sailplane and all that's connected with it, such as cameras, barograph, trailer, etc., he or she is also our "intelligence service" for important questions that can often mean the difference between winning and losing a contest:

NOTE: In international competition, crews are allowed — among other things — to aid their pilots inflight with radio messages. Some countries have differing national rules; the discussions in this book are based on the currently-accepted International Sporting Code.

— *The crew keeps an eye on the development of the day's weather,* checks with the met man or FSS if necessary, perhaps even keeps a record of temperature and humidity to see how closely it conforms to the forecast for thermals. Should it differ widely, the crew informs the pilot without waiting to be asked.
— *The crew keeps an eye on the progress of competition, as well,* notes who has started or finished, and when; and makes such information available to the pilot on request.
— *In case of really bad weather conditions* the crew can drive — if possible — several miles ahead of the pilot's position, allowing itself to be directed from the air, in order to observe if anyone else is circling on course, and if so, how successfully.
— *The crew should have a cloud mirror along* to determine the wind at cloudbase height (speed and direction). Normally, this information is relayed to the pilot before the beginning of the final glide to allow optimal calculations. (Use of the cloud mirror is described on page 87).
— *At the finish,* the crew observes other finishers and relays weather information for the last few miles to the pilot, based on other finishers' speed and altitude.

This is only a small selection of the tactical functions of a well-trained crew. Specialized sailplanes, contest terrain, or daily tasks naturally require special discussions and further planning. Every team member has special jobs and is responsible for their completion; the day's activity is planned and organized in advance. The more intensively the team "thinks along" with the pilot, the more effective it is; the crew becomes a sort of "switchboard" for all information that the pilot may need, although the members always keep in mind that the final decision must be the pilot's, based on the wider view of conditions and situations he or she has from the air.

The pilot who considers his crew only as "retrievers" is not only underestimating the value of a real team, but the capabilities of the individual crew members as well. At any rate, he is certainly giving up a competitive edge by not using the crew to the fullest.

THE "WAR OF NERVES"

Since the process of weighing possibilities, estimating, and making decisions depends on the mental equilibrium of the pilot, some pilots have resorted — particularly in recent years — to all sorts of (often very original) tricks to make the competition nervous. This is not difficult, since most soaring pilots conceal beneath their often gruff exteriors very sensitive natures, not to mention the stress that comes from a major contest.

— World Championships, 1970: Henri Stouffs (Belgium) arrives and registers his sailplane as an LS 1 g, while A.J. Smith (USA), one of Stouffs' most dedicated competitors, believes – fully correctly – that his *LS 1 c represents the newest type of this series. As expected, he comes across Stouffs' registration in the entry list, becomes uneasy, asks (with studied casualness) other competitors, but does not get any useful answers. After several days he "just happens" to be standing near Stouffs and asks him personally. Stouffs pretends at first not to understand, then reassures Smith in remarkable fashion: "Well, you can see it's the same sailplane — same fuselage, same tail, same wings — well, yes, the airfoil* is *just a* bit *different — but that can't really make any difference, can it?" After this shock Smith needed some time to recover before he finally realized that he'd been very skillfully taken for a ride.*

Such inventive and effective methods of "psyching out" the opposition are rare. Usually, the would-be psycher is working alone against everyone else, and succeeds only in psyching himself out — exactly the opposite effect! This is the reason for my advising those pilots who themselves are prone to nervousness not to participate in the "war of nerves"; one can do just as well without it. In particular, the primitive attempts characterized by spurious radio messages do nothing but impair concentration and irritate one's own crew.

STARTING

Information gathered by direct inflight observation is far more important than what one may hear from competitors, and less likely to be biased as well. During practice days at the contest site we can make a list of the better pilots, fly with unknown newcomers and see how we do against them, particularly in climb; and we can note names and contest numbers that may be of interest later on. By the time the actual contest begins we can have a pretty good idea of what and whom we are up against.

When we watch the gaggles near the starting gate we can observe whether the pilots we have picked earlier as likely prospects are simply flying around and feeling out the thermals, or if they feel the press of time and wait near the gate so as to be able to make a start as soon as conditions look good on course.

While still on the ground we estimated how long the day's task would take us and figured out a weather-based optimal departure time. Now that we're actually flying, we can get a more exact idea of the lift and weather conditions, correct our departure time if necessary, and then make every effort to stick to the schedule.

It is obviously nice to have a couple of good pilots along or out ahead on cross-country, to whom we can "attach ourselves" if the need arises. By the same token, parasites who use *us* as leaders, glue themselves to our tails, and never fly out ahead of us are annoying and unpleasant, but are usually pilots whose abilities are average at best, and shouldn't irritate us. Usually, these pilots are so dependent on the moves of others that they'll drop down the scoring list at some point without our having to concern ourselves with them.

There is no hard and fast rule regarding departure time in relation to other competitors; a reasonable tendency, however, is for less-experienced competitors and those who feel that they may be somewhat slower to depart earlier, since they'll probably need more time on course. Faster pilots tend to pick later departure times.

Such reflections regarding the best possible departure time compared to that of our comrades are important, but should never take precedence over weather conditions — the weather and the optimum time of day for departure which it dictates are all-important.

During the actual start, we'll try to cross the line barely below the maximum height of 1000 meters at high speeds and — whenever possible — with full water-ballast tanks. This should gain us some 350 feet of altitude as we bleed our speed off to the appropriate speed-to-fly value. If the weather looks so weak as to make further use of ballast inadvisable, we should start dumping early enough so that we'll enter the first thermal at light weight. Moreover, the jettisoned ballast tends to discourage those sticking too close to our tail. Any time, but especially if we think we've hit a really good departure time, it's worth giving up a few feet of altitude in the gate rather than risking a bad start (too high) or even overstressing the sailplane.

If, as we approach the starting line, we feel we're going to be too high, simply extending the landing gear can sometimes be sufficient. Pilots of ships with camber-changing flaps can intentionally use an "incorrect" flap setting (but must take care not to exceed flap speed limitations). In extreme cases we can reduce speed and apply the dive brakes momentarily; in general, good discipline at the start avoids both hassles and bad starts. The start altitude is

measured geometrically from the ground, but the sailplane altimeter is pneumatic; extreme temperatures can cause errors which must be taken into account. If the task is fairly long, a good start, even if not right at the top of the gate, doesn't hurt the average speed too much; on the other hand, if the task is a short one, every second counts. Even so, there have been some perfectionist pilots who've kept trying new starts to better their time until suddenly it's evening and everyone else is finishing. Again, then: the weather and the weather-based departure time are of paramount importance, even if one has to start a few hundred feet below the top of the gate.

TACTICS ENROUTE

It is much more important to concentrate on one's own best possible performance than to try to use any sort of trick to fool or irritate other competitors. Primarily, we should fly for ourselves rather than against anyone else; in fact, it's even better to engage in informal "team flying" with dedicated competitors met on course, thus out-distancing the rest of the pack, rather than trying to shake them off, since everyone on their own won't make as good an average speed. Whomever we meet in the air can become a "team partner" if he wants to play along, since a small group of pilots working together in reasonable fashion can almost always do better than single pilots on their own. He who always tries to let someone else fly out ahead places all the risks on some other pilot in very unsportsmanlike fashion, while at the same time denying himself the advantages of team flying, and thus giving up the chance of better performance. One can find out quite quickly if a "partner" wants to team-fly or not. If he always remains invisible in straight flight, and reappears only when circling, he is evidently flying against us. One can rid oneself of such people at points where there are two possible directions of departure by waiting to make our choice until our parasitic opponent can't see us. Of course, it is never worthwhile to make an undesirable choice at such points, even if we feel we are being used unfairly

Making the mental shift from all-out competition to such "team flying" is still difficult for many pilots. However, its value was proven very clearly, for instance at the world championships in Australia, during which small groups and gaggles managed astonishing speeds on weak days, speeds which even the best pilot flying alone could not have reached. On the other hand, nothing is more pitiful than "fear gaggles" in which no one has the courage to fly on, despite the fact that the day's lift is gradually dying. Apparently each pilot feels that nobody will come along if he moves out on course; thus, rather than increase each others' speed, those pilots in such gaggles slow each other down. Days with blue thermals are particularly good team flying days and can lead to the formation of unplanned groups — but, please, not to formidable gaggles of 20 or 40 sailplanes! Some pilots avoid being used unaware as sacrificial lambs by using a small hand mirror or rear-view mirror to see if the rest of the gang is, in fact, coming along or not.

RADIO IN COMPETITION

It is always astonishing to note how quiet the radio has become at German national championships, while some smaller contest that happens to be taking place at the same time jams a whole frequency. Not that the better teams pass along any less information; they just speak more concisely, if for no other reason than the fact that the competition can hear every word. Good teams dispense altogether with contest numbers and even names — they simply recognize each other's voices. Standard messages such as position, general condition, and so forth are abbreviated; this reduces "air time" as well as making things more difficult for eavesdroppers. It is easy to learn good radio procedures; all that is necessary is to force oneself to decide beforehand what to say, choose the best and most concise words, and only then push the microphone button. If everyone used this method the messages of many cross-country and competition pilots could be vastly shortened or even eliminated altogether. He who uses the radio too much doesn't just disturb others and reveal too much about his own position, but loses concentration as well and cannot do justice to his own flight.

Team flights in those contests that permit air-to-air radio make an increase in radio traffic unavoidable; it is just under such conditions that it is most important to make every transmission as concise and direct as possible.

TEAM FLYING

Even without air-to-air radio (which is forbidden in German competition anyway) one can fly together effectively. The first ground rule: always fly whenever possible so that your partner can see you! This is just as important while climbing, to allow more rapid centering for everyone, as it is in straight glides. During a glide no sailplane should fall too far behind, even if there are differences in altitude; waiting is usually out of the question, as it costs too much time; sailplane performance differences are so small nowadays that one simply cannot afford the luxury of waiting. Even so, it's sometimes possible on longer glides for the front runner to fly at a slightly lower speed-ring setting, allowing the last man to catch up gradually, without much speed loss. The lateral distance between sailplanes while gliding should be around 100 yards; this allows simple — and simultaneous — changes in glide direction, while larger separations tend to tear the "formation" apart. Only under narrow cloud streets should we fly closer together, or even "en echelon" (close behind one another, "stepped" to the side by one wingspan) to allow the following sailplane to benefit from the upward-moving area of the leader's wingtip vortex. Flying directly behind another sailplane is unfavorable.

If the thermals are difficult to center, the pilots should search separately to the left and right side of the course line. If in doubt, whoever is higher can deviate further, while the lower colleague sticks with whatever lift he has to mark it for the higher pilot should he find nothing and have to return. One can often advise the other pilot by hand signal in the canopy that one wants to fly on; he in turn can agree by repeating the same signal, or can indicate that he wants to stay in the lift.

Pilots with similar tactics can use this method to fly together remarkably effectively.

If one is flying in international competition, where air-to-air radio is allowed, everything becomes much easier and more effective. The Poles are masters of this technique. One still should try to stay pretty close to one's teammates, but one can advise of course corrections even without visual contact. As long as the distance between sailplanes is still small enough so that the second pilot can reach the same lift that the first pilot is working, the front-runner will advise him of the strength of any thermals used. These reports should be as realistic and accurate as possible, and should be changed at once if conditions change. Using this method, the trailing pilot has the chance either to leave the lift he's working for something stronger further on, or to stay with what he has if he knows he won't get anything that good further on course (and thus climb higher before departing with an optimal speed-ring setting). Similar pilots will soon be together once again using this method, and can continue to work together as described above. The most important use of air-to-air radio, however, is the weather information relayed back by the first pilot; any changes in the situation should be broadcast at once, without waiting to be asked. At forks in thermal or cloud streets and similar decision points, information on which way the first pilot is flying, and which way he suggests that the second fly, is especially important. This demands a great deal of concentration from the pilot, as well as an attitude free of any jealousy toward one's partner; thus, this type of team flying is not only dependent on a pilot's flying ability, but on his character as well.

INFLUENCE OF SCORING ON TACTICS

Before the beginning of a contest, one should take a good look at the formula that will be used for scoring. This gives us an idea of what counts — when differences are important, and when the point difference is so small that it's not worth taking special risks. The chance for a spectacular daily score usually goes hand in hand with the chance of landing out. Toward the end of a competition one's overall position can have some effect on flight tactics. If we are only a few points behind the leader, we will not only try to fly well, but as well as we have to, to make up the difference; in this case information about the leader's position or situation can be valuable in flight to help determine our tactics, while such information is usually only a cause for nerves and has no benefit. On the other hand, if the opposite is the case — in other words, if we are leading by only a few points — it can be correct to base our flying on that of our nearest competitor and never leave his side. Of course, this is not only enervating, but risky, since it can occur that the two leaders "ace one another out" to the point where some hitherto-unsuspected third party wins the contest. Thus, scoring can only influence our flying in special situations. During the initial two thirds of a competition it should have no effect on our flying or tactics.

TRAINING AND CONDITIONING

Sport soaring places considerable demands on the pilot. In soaring, to a greater extent than in most other sports, the intellect is just as important as the body. Thus, basic and even club training will not suffice; the conscientious soaring pilot must contribute a great deal himself to his own further training and conditioning. The following suggestions are offered as encouragement; what training programs one may set up for oneself will depend on all sorts of personal and outside factors, and will differ widely between pilots or groups of pilots.

TRAINING ON THE GROUND

SOARING THEORY

The theoretical knowledge of soaring increases constantly, as does its importance for successful cross-country flight. The "highly-talented" or "natural pilot" of past years no longer plays a significant role unless he combines his talent with appropriate knowledge. We simply have to sit down and *learn,* and will have to learn more and more in the future. We should not only own, but work through, soaring textbooks from several authors; we should also keep close watch on periodicals for new knowledge and techniques. We can always consider hypothetical flight situations and search for optimal decisions. We can practice using our final-glide calculators and wind computers, and we can examine air charts and try to imagine what the landscape represented really looks like.

Theoretical instruction in clubs should not be exhausted at the end of the basic ground school. Almost every club has pilots who can teach their comrades new cross-country techniques, if the club provides an appropriate opportunity at meetings.

CONDITIONING

Even though soaring requires little physical exertion per se, we should not be fooled: long flights, and especially contests, demand not just a healthy body, but one in definitely better-than-average condition. To fly five to eight hours a day without a break, and at the highest level of concentration, with hardly any freedom to move physically, places demands on us that can best be compared with those of manned space flight! Perhaps we should examine the astronauts' conditioning programs, since their problems are similar to ours.

In general, there's no need for the soaring pilot to cut a particularly athletic figure; his muscular strength is not all that important, at least in flight. What *is* important is good circulation, and our conditioning reflects this: endurance training. Many different sports are suitable for this; which one(s) we choose is largely a matter of personal preference. Of course, in principle we could just as well use some sort of home workout device, but few sensitive soaring pilots have the patience for such boring gadgets, at least not for the length of time that would make them effective. Appropriate sports are, for example, cross-country skiing or ski touring, swimming, rowing, cycling, and especially cross-country running. We should always put enough effort into these conditioning sports so that we really feel we've had a good workout. On the other hand, it's not only useless, but even dangerous to attempt all-out performance without a gradual training program. Moreover, conditioning should be fun: for example, a soccer game at the airfield, or a club jog through the woods. Regularity is very important: at least once or twice a week we should indulge in strenuous activity, and on the other days we shouldn't just sit at our desks all the time. We should also stick to a diet high in proteins and low in carbohydrates, try to eliminate nicotine, etc. Sufficient literature is available which covers this area much more completely than we have space for here; if in doubt, consultation with our physician is a good idea for a training program which best fits us personally.

WATCHING THE WEATHER

We should watch clouds, their forms, motion, and development, wherever and whenever we have the chance. In our minds as we fly along, pick the next cloud we'll use, and check a short time later to see whether it has really developed as we expected, or is already dissipating. Such flights of fancy train us to recognize active clouds and sources of lift, since development is usually easier to see from the ground than inflight. Moreover, it's exciting to watch the motions of these giant forces that effortlessly move thousands of tons of air and water about.

In fact, such natural dramas are sometimes played out for us at outdoor swimming pools, as mighty clouds swell, grow, and finally burst forth with rain or thunder. Most of the swimmers run about aimlessly, but why? Didn't they see the clouds developing overhead?

Weather experience, after all, is not necessarily dependent on the number of hours in the logbook. Many a venerable pilot who speaks of his years of flying experience unfortunately hasn't the slightest idea of the weather. Weather experience depends mostly on one's interest in the weather; how else could some shepherds, farmers, or sailors make such astonishingly accurate forecasts?

TRAINING IN FLIGHT

It's really not necessary for us to travel to the ends of the earth in order to fly the most expensive sailplanes at so-called "soaring paradises." After all, it even rains *there* sometimes! Such undertakings may well be worthwhile as far as experience is concerned, but are really only necessary for training in the most extreme cases. We can train effectively near home — in fact, even on local flights around the airport.

LOCAL TRAINING FLIGHTS

Here are a few examples of ways in which local flights can be made worthwhile training experiences, as well as fun . . . after all, boring holes through the sky is just that: boring.

— We can always try to climb as well as humanly possible in every thermal, to outclimb others, to change thermals frequently, perhaps even to set a height limit above which we'll only accept thermals of a given strength or better. Below the limit any lift can be accepted.

— We might try a barograph contest: During a given time period (one or two hours), we'll try to gain as much total altitude as possible. We may also rule that one may not climb in the same thermal twice in succession.

— We can fly in a two-seater with a pilot of similar abilities, taking turns at flying and observing each other's technique, criticizing and being criticized, and explaining our reasons for flying here or there and what we expect to find on arrival. We'll be astonished at how often we are wrong!

— We can set an altitude limit above which we won't climb, for practice in finding lift at low altitude.

— On really weak days, we can see who stays airborne longest. (For safety reasons, circling below 350 feet is forbidden.)

— Every landing is planned as a spot landing. Better pilots start their approach intentionally too high or too low, for practice in different outlanding situations.

Such local training flights can increase the interest of club flying operations on those days that are just too weak for cross-country flights, and are ideal for the training of new pilots who are not yet ready for cross-country. Even the normally-unloved training ships are suddenly competitive among themselves. Especially talented pilots will become evident more or less automatically; these are the ones of whom we can expect much when they start flying cross-country or in competition. Moreover, there's nothing wrong if these talented pilots don't always turn out to be the ones with the most hours in their logbooks or the flight instructors. Ambition has its place in a soaring club, but not envy or jealousy. A good instructor should be proud if his former student ends up flying better than the instructor himself — it's the greatest success an instructor can hope for, and proves how much better his instruction is than the instruction he himself received earlier in his career. A good instructor will continue to help his former fledgling toward cross-country flights and, if he is interested and ambitious, toward competition with club cooperation.

GROUP CROSS-COUNTRY TRAINING FLIGHTS

Members of a club — or of several clubs flying from the same field — who are interested in cross-country flying can agree whenever possible to fly the same tasks on the same day. On good days these can be ambitious, on bad days less so; but cross-country, away from the field, whenever weather permits! And it's astounding how often the weather does permit it! In fact, if the weather is good enough to stay aloft at the home field, it is good enough for some sort of cross-country, even if the sky is cloudless — or, for that matter, overcast. It's just these special and difficult weather situations that come up in contests; it's not rare that the bad days are the ones that determine the final standings. In order to keep things from getting out of hand as far as complexity and hassle are concerned, one plans flights with return, or — on those unsure days — short tasks that can be repeated several times. Here are a few examples:

— Flights over a common course, waiting occasionally for the slower pilots. Such flights require fairly close levels of performance and won't work for more than four or five pilots. The training effect is good for the weaker pilots, less so for the faster ones.

— Everyone departs at the same time, then flies the same course as fast as possible, like a contest. The advantage lies in the chance to compare everyone's tactics in the same weather pattern.

— Small triangle, to be rounded as many times as possible until landing out. The latter part of this task is similar to free distance.

— In case of weak thermals and strong winds: Who can make the longest out-and return flight against the wind? (The turnpoint may be chosen in flight.)

— Cross-country flight with altitude limits. A minimum height, descent below which renders the flight void, increases safety for the first cross-country flights of new pilots; a maximum which may not be exceeded trains the more experienced pilots in thermal search techniques.

— "Cat's Cradle" (Distance in a Prescribed Area or "Bikle Baseball"): This task is unfortunately not too good for actual competition due to departure-time problems, but is an excellent and interesting variant for training flights. Six to eight turnpoints are set. At any time after an agreed-upon start time, pilots are free to fly to any point (except that out-and-return flights are prohibited), as many times as desired. The total distance to landing is scored. Given turnpoints can be rounded several times, while others are not reached at all. This task is even more similar to free distance than the third example above, since the choice of courses is freer.

— Speed task with free choice of departure time; each pilot times himself, otherwise competition rules prevail.

— As above, but with pairs of pilots team-flying. Scoring is based on the slower pilot of each team.

High-performance sailplanes are not necessary for such flights, ships of the club and training classes can be used as well, as long as all the ships on one task are more or less similar in performance.

It seems likely that motorgliders will play an increasing role in cross-country training in the future, since they free us from tows and allow us to undertake long flights without the risk of landing out. Unfortunately the soaring performance of most current types is simply insufficient for good training. Motorgliders that could be used for cross-country training should have performance at least equal to that of club-class sailplanes.

Two-place fiberglass sailplanes have soaring performance at least equal to that of current Standard Class machines. They, as well as better motorgliders are entirely feasible with current technology, and are relatively affordable for clubs and individuals.

Training flights should include photo turnpoints whenever possible, so as to allow the photo procedures to be practiced at the same time. Small triangles that are rounded several times can be planned with a "final glide" and "landing" at the goal for each time around, for example by specifying that a given point on the airport must be crossed at, say, 1500 feet AGL. If the crossing is too high, the extra altitude must be eliminated with dive brakes before one sets out for the next round; if too low, it is assumed that one has miscalculated the final glide and "landed short." It goes without saying that in all these training exercises, ". to thine own self be true." No one is checking; what we're doing is training and trying to learn something.

DEBRIEFING AFTER TRAINING FLIGHTS

Training flights as described above don't attain their full effectiveness unless we can all get together in the evening after flying and compare notes. This is where such things become clear as why one pilot flew a given stretch faster or slower than all the others. This check, and this clearness and realism concerning the "rightness" of one's own decisions, is unavailable to the solo cross-country pilot, and is only seldom available — and then in much degraded form — at contests.

TRAINING AT CONTESTS

So many small and middle-sized contests take place every year — at least in Europe — that a pilot who has the time and money could fly one contest after another from May to August. Such a summer of training could certainly be effective, but who among us could realize it? We must simply make choices.

It is best to take part in contests where all the participants are at about the same level. One loses concentration and gets an inflated idea of one's own prowess at contests where one wins every task against clearly weaker competitors; on the other hand, it can be terribly disheartening to enter a contest in which one is "tail-end Charlie" every day. Contests, after all, should always be fun — especially those entered primarily for training. Some German pilots had put so much effort and energy into the Hahnweide contest that they were completely played out by the time the subsequent German championships took place. Training contests and practice days before qualifying contests are just that — practice — and we should not forget that.

As far as equipment is concerned, one should try to fly a contest with equipment that is at least up to what the competitors are using; if that's not possible, enter a different contest. Many clubs or groups of clubs put on comparison flights or "competition workshops" which are excellent for the purpose. Even if some facets of these "mini-contests" are a bit rough around the edges, they offer good training for the individual pilot, as well as flights rich in experience and enjoyment. Moreover, such gatherings usually involve much less effort, preparation, and financial outlay than the larger contests.

TRAINING FOR RECORD PILOTS

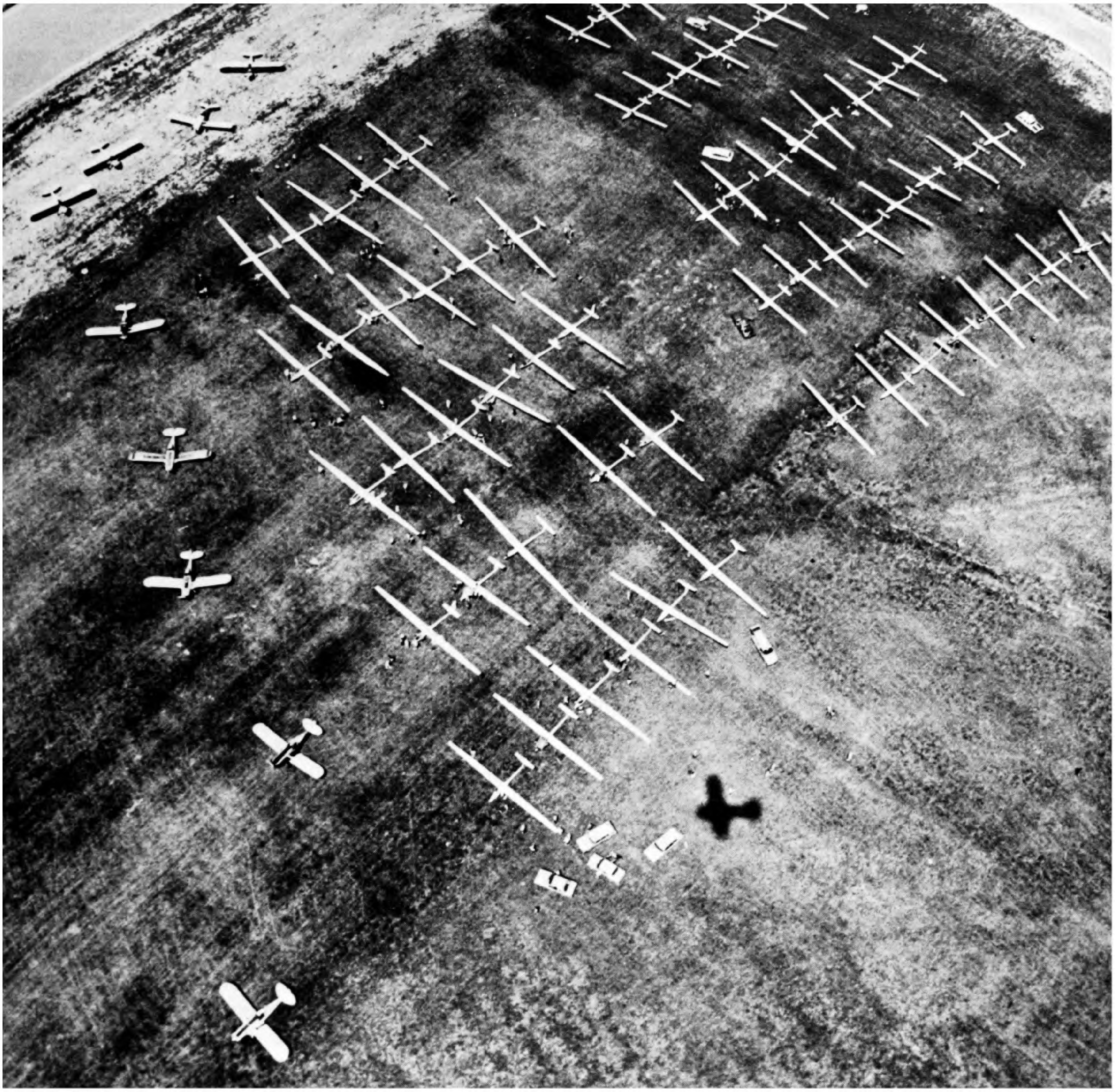
Whether one is out for long, fast individual cross-country flights or for competition shouldn't affect training procedures too much; both solo pilots and competitors train best with other pilots of similar interests; this is the only way for errors in judgement or decision-making to be brought out into the merciless light of day, rather than being passed over for want of comparison. After all, who would imagine, after completing a 300-mile triangle at over 60 mph, that the same triangle could be flown at more than 87 mph? This actually happened at the 1974 World Championships at Waikerie.

Many an ambitious record flyer might well benefit from flying a competition workshop or contest from time to time; it might aid him in getting a better record when the right weather conditions come along. Some pilots are aware of this and engage extensively in both types of flying, notably Hans-Werner Grosse. Record flights require additional exact knowledge of orographic possibilities as well as conditions on days when the weather approaches the ideal. Most records can be traced back to long hours of planning; the ideal machine for exploring record routes is a motorglider.

NATIONAL TRAINING CAMPS

The training of members of the "cadre" — that is, the top-seeded soaring pilots — occurs in regular central training camps in order to attain (or, as the case may be, maintain) a level of proficiency similar to that of the top pilots of other nations who will compete in world championships. It goes without saying that such camps include theoretical discussions as well as flying practice.

Pilots who have qualified for a world championship team position train together; their training program is based on the special rules and soaring conditions of the championship site, and should include particular attention to team flying using air-to-air radio.



EQUIPMENT

SAILPLANE TYPE

The most important factor in successful cross-country soaring flight is not the sailplane, but the pilot. Insufficient knowledge or ability cannot be replaced by a better or more expensive sailplane. I am always surprised to see how both private owners and clubs strain their financial capacities to the utmost to purchase a high-performance ship, then treat it as though it were made of gold, protect it from every and any risk, and allow only prestige-hungry so-called "experienced" pilots to fly it — but only locally, of course! Modern standard-class sailplanes, and even more so the hot open class ships, are racing aircraft specially laid out and constructed for high speeds. This is the equipment one needs when minutes or even seconds count — but for local flights or even aimless "amusement" cross-countries such sailplanes are both unnecessary and too expensive. Not only cross-country flights, but real high-performance soaring can just as well be carried out and especially practiced in older training or club-class sailplanes; the introduction of the club class in competition bears this out very clearly. Only in the stiffest competitions does it become essential to have a sailplane that is the equal of those used by others, if not better.

When considering the purchase of such a supership one should take the manufacturer's performance data with a rather large grain of salt; unbiased measurements usually reveal figures somewhat less favorable than "sales polars." The best glide angle is an important parameter, as is the speed at which it is obtained. Even more interesting is the appearance of the higher speed part of the polar, since we will almost never be flying as slowly as best L/D. The minimum sink speed is important as an indication of thermaling performance, but here, again, the speed at which it is obtained is more important than a tenth-fps either way. He who flies slower can circle tighter, and will usually climb better as a result. It's hard to understand why so few manufacturers provide circling polars together with the rest of their data; these would give a much better idea of thermaling performance. If the conventional speed polar has only a small speed range for minimum sink — that is, if it comes to a fairly sharp "point" on top — we should be prepared for a sailplane that will be difficult to thermal, since it will require very exact airspeed control to avoid higher sink rates.

Sailplanes whose best characteristics are in climb and in the lower speed ranges for glide should, if possible, be able to carry considerable water ballast so as to make their performance similar to that of faster competitive sailplanes. If so, such a glider is superior to one that was designed only for high speeds from the outset.

Factors just as important as performance include such things as good handling, well-harmonized controls, maneuverability, good visibility including downward over the nose, comfort, ventilation, short-field properties, etc.

PREPARING THE SAILPLANE FOR COMPETITION

During the process of a regular overhaul it can be worthwhile — particularly in the case of older wooden ships — to fill the surfaces with Microballoons and epoxy, which are then sanded off with a long, straight sanding block. After the surfaces have been sanded they can be covered with one thin layer of fiberglass to seal them; this method results in an excellent — and relatively impervious — surface at a total weight increase of less than five pounds per wing. Special attention should be devoted to smoothness and accuracy of contour at and near the leading edge, since this is an area where the boundary layer is very shallow.

Most modern fiberglass sailplanes are delivered by the manufacturer with an adequate surface finish. It's true that the surface can be further smoothed and the last traces of waviness removed — but at the cost of hundreds of man-hours. This arduous toil, however, only has short-term effects and at least usually no measurable performance increases. Other work, such as fillets at the wing-fuselage junction, indicate that the original design wasn't optimum and should only be undertaken after consultation with a good aerodynamicist — or, better yet, with the designer himself. There's too much risk of improving nothing but external appearance without any real effect. It might be better for the "smoothness enthusiasts" to devote more of the time they spend sanding to studying theory or keeping themselves physically fit, although I won't dispute the psychological benefits that may be gained by knowing one's sailplane is as "slick" as possible. On the other hand, proper instrumentation can really make a major difference in overall performance; this is where one must not be satisfied until everything works perfectly.

CHOICE OF INSTRUMENTATION

Up until the mid-sixties, competitive pilots felt that extensive instrumentation was an absolute necessity; it was normal to see three or four variometers of every type on an instrument panel. The (often quite large) instrument panels of the older ships were packed with gadgetry, and sometimes cost half as much as the sailplane itself. Secrecy shrouded the cockpits of famous pilots; instruments seen there in stolen glimpses were accepted as veritable philosopher's stones and immediately built into one's own sailplane. The computer boom made itself felt in soaring, too; the (frequently borrowed) devices seen in the panels of the top pilots were considered to be the key to success, and were bought by lesser pilots for impressive sums. In recent years the situation has settled down a great deal, if for no other reason than the small panels of many of today's top sailplanes. The modern tendency toward fewer instruments also makes those one finally *does* install much easier to scan and sort out.

To the astonishment of some of the visitors along the flight line at the world championships in Texas in 1970, my LS 1 sported only two inexpensive pneumatic variometers and a homebuilt electronic audio vario (cost: 150 DM) in addition to the usual airspeed indicator, altimeter, and compass. It is reassuring that this simple installation was sufficient for me. Of course, it need not be quite this spartan; there are some excellent new ideas which can result in benefits which one should not deny oneself.

Sufficient instrumentation need not be too expensive, but it must function properly. Whether it does or not is dependent not on how much money was spent, but rather on a clear understanding of the function of the individual elements and careful and competent installation; this is covered in the second part of this book.

Which instruments should be included in which sailplane is a question which I'll try to answer in the following section. Naturally, opinions may differ over some of the points I'll make, but at least this can serve as a basis for selecting a sailplane's instrumentation.

MINIMUM INSTRUMENTATION

By minimum instrumentation we don't mean the basic instruments required by regulation (airspeed, altimeter, etc.) but rather the instruments we'll need for sport soaring. This instrumentation is simple and should be in *every* sailplane, even the simplest trainer:

(1) Yaw string on the canopy. This shows whether we are slipping or skidding and simplifies any corrections that may be required. The skid ball, which is designed for the same purpose, is unsuitable because it's much too sluggish; moreover, one has to be looking at the panel to see it. The yaw string is just as helpful, if not more so, in instrument flight — especially if one is only using a turn gyro, and no attitude instrument. Unfortunately, it has a tendency to become soaked or even frozen in clouds. For such cases it's advisable to install a bubble level in the cockpit, which is still much better than the usual ball installed in the turn gyro.

(2) Airspeed indicator (pitot operated)

(3) Altimeter

(4) Total-energy compensated *speed-to-fly* variometer with a range of ± 1000 or 2000 fpm. This is basically a normal pneumatic vane variometer which has been modified by connecting its static port to a total-energy venturi and installing an appropriately calibrated capillary to allow air from the pitot to enter its capacity ("bottle") side. This idea was developed by Brückner in 1973 and has proven excellent in practice.

Since this instrument not only commands speed-to-fly in straight flight better than a regular variometer with speed ring, but also still functions fairly decently as a climb indicator, it can replace a "normal" compensated variometer. While the indicated climb rates are not 100% accurate, they're close enough so that no pilot errors will result from their use. An even better system is to install a valve in the "speed-to-fly" line, as described in the second part of this book; one can then switch in flight from a speed-to-fly instrument to a normal compensated variometer.

In desperation the speed-to-fly variometer can be replaced by a conventional total-energy compensated instrument with speed ring. On the other hand, an uncompensated rate-of-climb indicator, such as some pilots still use "to see how fast I'm really climbing," has no real purpose. It's hard to imagine a flight situation in which it would be useful to measure one's "stick thermals!"

Ultrasensitive variometers (± 200 to 400 fpm) are superfluous; while we may be impressed by their apparent greater sensitivity and large needle movements, the larger size of air bottle required could tend to increase the time lag in their indication. A good 1000-fpm or even 2000-fpm instrument can be read perfectly easily with an accuracy of ± 100 fpm and doesn't have this disadvantage (I have flown several contests with nothing but a 2000-fpm variometer and an audio unit, and didn't miss any other instruments.)

(5) Compass. If no suitable deviation-free location can be found on the instrument panel, a "ball" compass (available from auto-supply stores) will suffice and can be mounted on the canopy with a suction cup.

Sailplanes equipped as above can be used fully for one's early performance and cross-country practice. If this instrumentation is installed in all of a club's two-seaters, there will be no conversion problems later on, and one learns from the start to use the proper speed-to-fly techniques.

Moreover, adapting this instrumentation to most training and practice sailplanes shouldn't require any new instruments to be purchased, but only needs changes in the connections of those already installed. This (rather minor) effort is much more effective than any other attempts at smoothing, filleting, etc.

INSTRUMENTATION FOR PERFORMANCE AND COMPETITION FLYING

The above instrumentation can be augmented (or, as the case may be, replaced) as follows:

(1) *either:* An acoustic total-energy variometer . .

A "piep" of this sort should always be installed separately from other instruments. Its greatest advantage — very rapid response — is lost if it's integrated into the connections of a mechanical variometer.

It's vital that the acoustic signal cover the entire range of flight, not just climb. After all, in a thermal we'll be watching the vario anyway, while in a straight glide it can occur that the sink rate can increase and the pilot will continue at much too low an airspeed unless warned by the (admittedly not very melodious) wail of the audio variometer.

or: An acoustic speed-to-fly variometer . .

This permits very effective "MacCready" flight, since one can receive "speed up" or "slow down" commands without having to look at even a single instrument. The unit is connected exactly like a mechanical speed-to-fly variometer, and can be used to some extent in climb as an audio total-energy instrument. Switching it over from "speed-to-fly" to "conventional" function seems problematic, however, because it's difficult to immediately accustom oneself to the new meaning of the tone. In fact, whenever possible, the only adjustment made in flight on an audio variometer should be its volume — not its threshold.

(2) A sensitive — i.e. two- or three-pointer — altimeter is recommended for exact computation of final glides. It's also a good idea to fit it with a ring, like the speed ring on a variometer, which can be rotated and which has a zero point and 100-foot divisions.

(3) Some sort of visual display should be present for both total-energy and speed-to-fly variometers. One can either select mechanical instruments for both of these, with an independent audio unit for either total-energy or speed-to-fly, or one can use a complete electronic variometer system with its own audio unit.

This can then be used (with a pitot capillary) as a speed-to-fly variometer with the second mechanical unit the total-energy variometer, or vice versa. In any case, the total-energy instrument (a round indicator, please — no edgewise meters or suchlike!) should have a speed ring. This not only gives us two systems whose indications can be checked against one another, but leaves us covered in the event one unit malfunctions.

This instrumentation is normally completely adequate for today's contests; it's easily scanned and is not all that expensive. Those who feel they *must* spend more money can add further instruments as they see fit.

EXTENSIVE INSTRUMENTATION

(1) Taut-band total-energy variometer:

These are excellent, rapid-responding, expensive instruments. However, the rapid response is useless if the pilot considers the instrument "too nervous" and damps it to the point where it hardly differs from conventional vane instruments. If one installs a taut-band instrument, one shouldn't "damp out" its greatest advantage. Such instruments may have their own membrane-type total-energy compensator, which works fairly well and is independent of the total-energy venturi installed for other instruments.

(2) Electronic variometer with electronic total-energy compensation:

This is another way to achieve independence from the total-energy venturi, and hence freedom from failures caused by the latter (water, icing, etc.). Disadvantages include more or less complicated time-constant correction for the pitot and static connections, and the rather temperamental electronics of some units.

(3) Even more complex — and, unfortunately, more temperamental as well — are the currently-available computer systems. Some of the tricks these electronic brains can perform are quite useful, but tempt one to let the computer make all the decisions. Even the best computer can only use the "input" of *past* performance and weather conditions to decide what to do next; the pilot is vastly superior since he has eyes and can look out ahead on course! If one is not very critical of such devices they can lead one into tactical traps, even when they are working right.

(4) Universally-suspended mass-balanced compass ("Bohli" compass):

The magnet of this device aligns itself to the earth's magnetic field — that is, vertically as well as horizontally — bringing the advantage that it can be used in turns, as long as the pilot (manually) sets the compass upright, which is not always as easy as it sounds, especially in instrument flight. The Cook compass works in a similar fashion.

BLIND FLYING INSTRUMENTS

(1) Turn and Bank indicator (turn gyro):

Instruments appropriate for soaring should be set for a one-needle-width deflection at a turn rate of 6 degrees per second (one-minute turn). More sensitive instruments as used in powered aircraft will be "pegged" while thermaling.

(2) The bubble level mentioned earlier is a very helpful adjunct to the yaw string.

(3) Stopwatch for timing turns when using the turn and bank indicator and magnetic compass (turn errors!).

(4) Artificial horizon:

While not an absolute necessity, an attitude gyro or artificial horizon makes instrument flight orders of magnitude less difficult.

(5) A Cook compass or Bohli compass as mentioned above, when combined with the artificial horizon, simplifies leveling out on a desired heading in instrument flight; the stopwatch becomes superfluous.

CHECKLISTS

Soaring equipment includes so many minor items, in addition to the sailplane itself, that it's unfortunately a frequent occurrence to have one's day of soaring ruined because something important was left at home or at the airport.

Here are some checklists which can, of course, be augmented and changed according to personal preference. A copy at home and one at the airport, can save a great deal of difficulty.

SAILPLANE — TRAILER — CREW CAR

Papers:

a) Sailplane: logbook, certificate of airworthiness, registration, insurance certificate, flight manual, radio station license, landing cards, goal declaration, telephone forms.

b) Pilot: pilot's license, physical certificate, radio operator license, personal I.D. (passport if necessary), money including change for telephones.

c) Crew: personal I.D., telephone forms, driver's license, car and trailer registration, insurance papers, customs papers if necessary.

Barograph, foils + smoke material (camphor) + matches + fixative spray or, as the case may be, barograph charts + ink, seals, pliers.

Batteries for sailplane and ground radio, battery charger.

Ground radio unit.

Yaw string, camera mount, film.

Wing covers, water ballast, hoses, funnels; tape, scissors.

Grease (for main pins), grease rag, cloud mirror.

Water bucket, detergent, wax or polish, canopy cleaner, sponges, towels, chamois.

Hat, sunglasses, sunburn preventative, warm (waterproof) clothing for use after landing, tiedown kit, pocket flashlight (signal mirror or kite to help crew locate sailplane), first-aid kit.

Food inflight: sandwiches, nuts, raisins, dextrose, caramels, apples, lemons, baby food, etc., plus food for after landing.

Drinks: thermos with long drinking hose (typical mixture for a refreshing inflight drink: tea + grapefruit + lemon + dextrose).

Relief bottle, etc., toilet paper for after landing.

Trailer including all fittings, spare wheel, gas, oil.

Ignition keys for crew car — don't let the pilot fly off with them in his pocket!

For altitude flights: oxygen equipment, mask, warm hat that covers the ears, gloves (better yet, mittens), 2 sweaters, parka and warm pants (or flying suit), long underwear, knee socks, stout boots, *dark* sunglasses, sunburn cream, antifog cloth, canopy scraper (for blind flying).

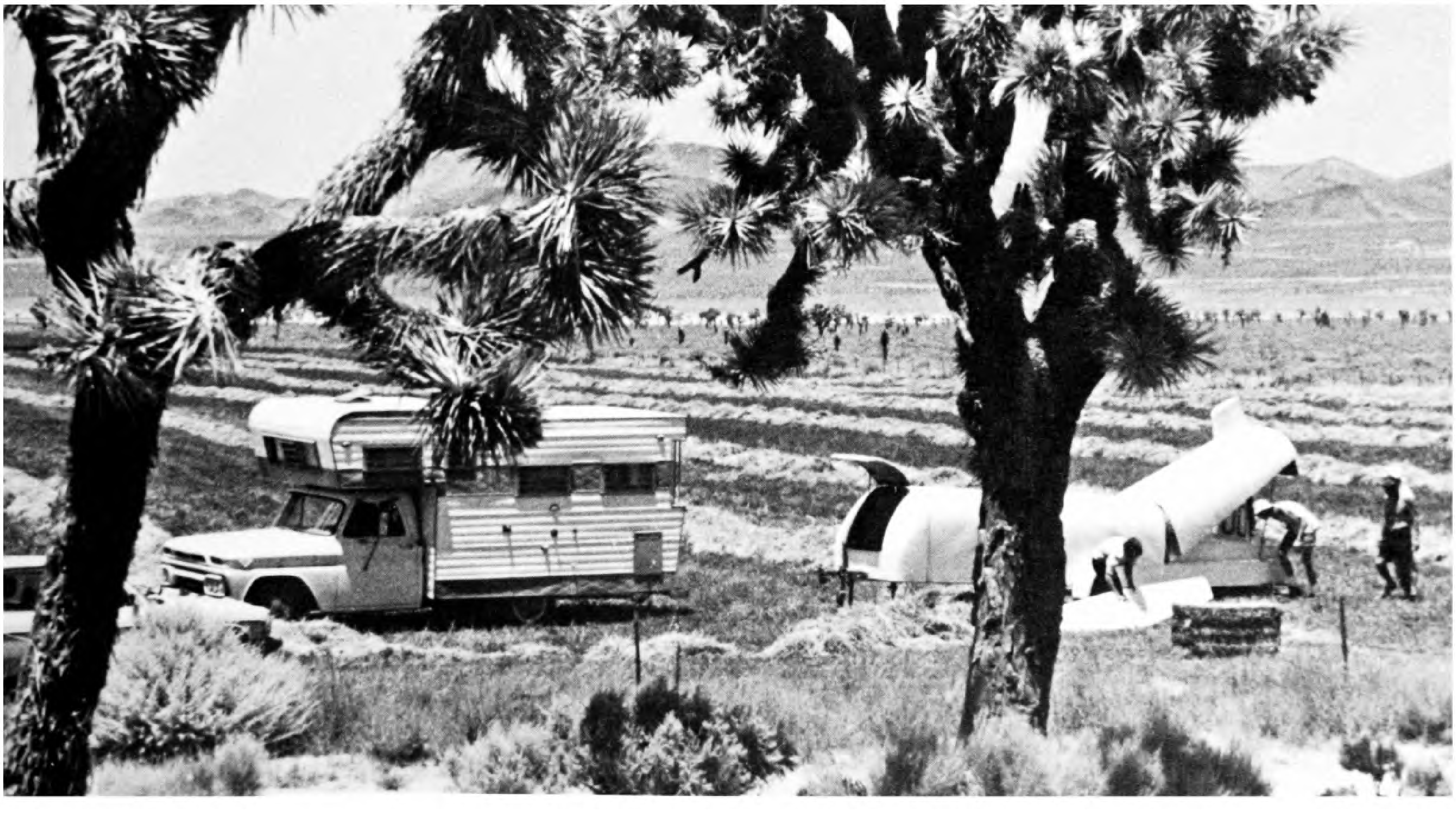
For flight preparation:

Maps: ICAO 1:500,000 map and local 1:250,000 chart.

Equipment: Ruler, protractor or plotter, deadreckoning plotter, wind computer, final glide computer, slide rule.

Writing implements: grease pencil or magic marker, cotton balls and toothpaste to remove same from plastic-covered maps, transparent tape, adhesive tape, scissors, note pad, pencils, erasers, dividers.

Photo-declaration form with wide magic marker, kneeboard with paper and ballpoint, list of competitors.



PART II: THEORETICAL SECTION

METEOROLOGY

The Temperature Sounding

The vertical temperature distribution of the air is of definitive importance for thermals. It is measured with radiosonde balloons which can ascend all the way to the stratosphere, or by means of sounding flights by powered aircraft; the humidity is measured simultaneously.

THE ADIABATIC LAPSE-RATE CHART

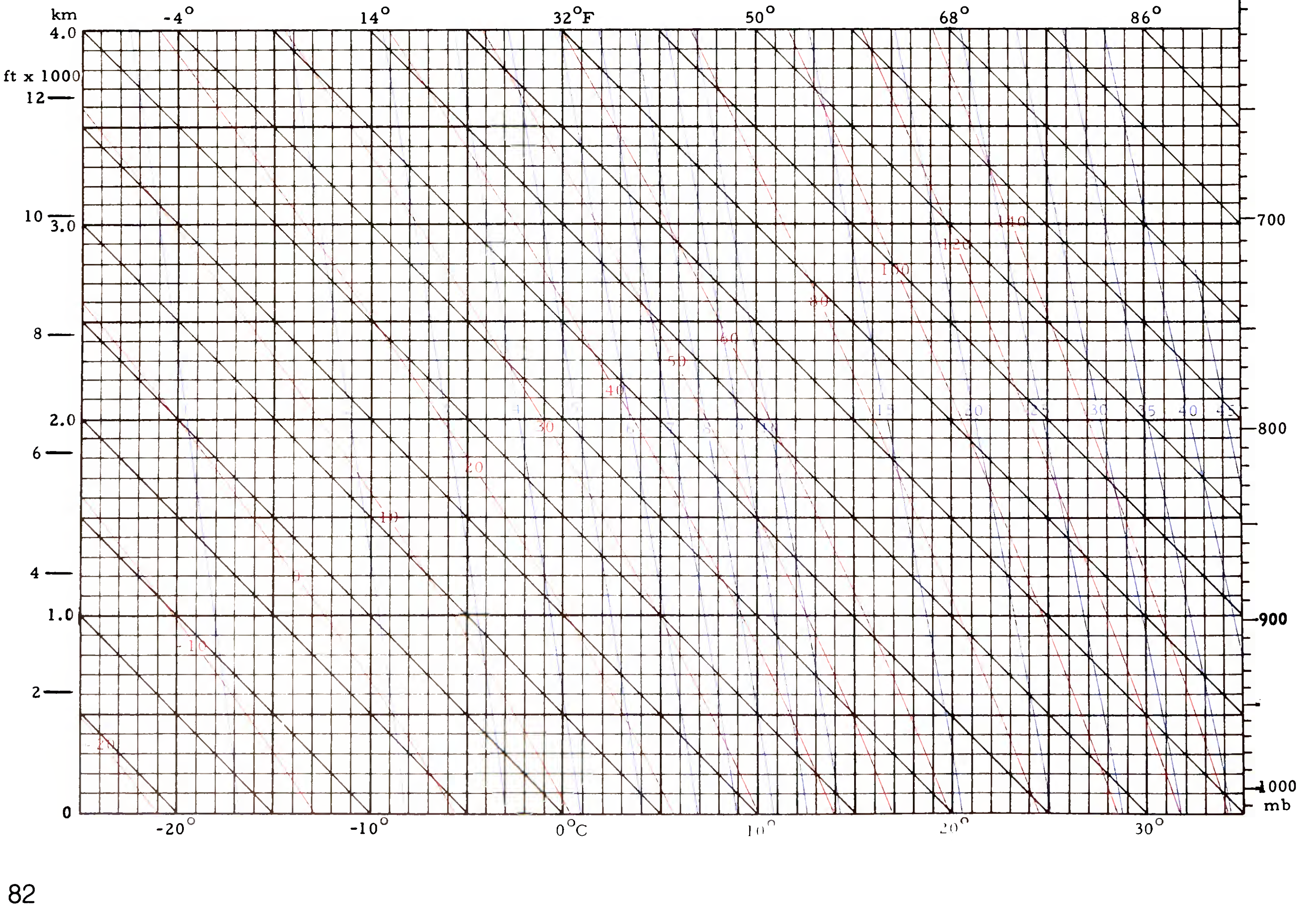
The meteorologist enters the temperature values in a preprinted chart; this diagram contains a number of lines which may appear confusing at first, but which actually simplify the analysis and evaluation of the sounding. There are various versions of such lapse rate charts; the German Weather Service usually has a "thermodynamic adiabatic chart" on which the pressure lines run horizontally and temperature lines run vertically ("Stüve-diagram paper").

The illustration shows a section from such an adiabatic chart, in which the horizontal pressure lines are presented as altitude lines above sea level. If we were to be exact, this relationship would only hold true on "standard atmosphere" days; however, since our altimeters are also calibrated for a standard atmosphere, such adiabatic paper is ideal for our specialized purposes.

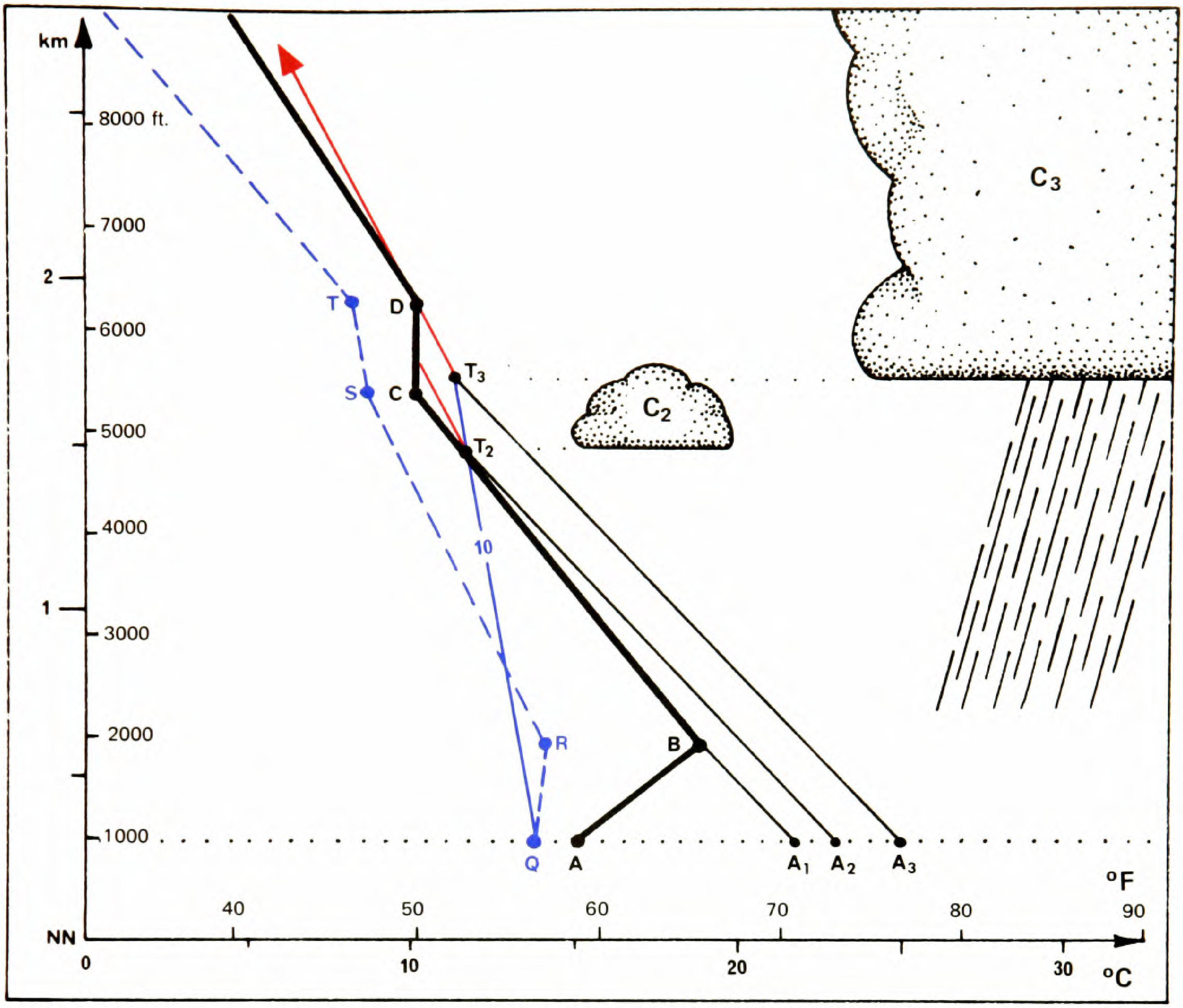
In addition to the horizontal altitude lines and vertical temperature lines, the chart has three further types of line:

— The black lines running from upper left to lower right are *dry adiabats.* They show the temperature changes in air masses that ascend or sink without either condensation or evaporation of water; this is physically defined as a process without any energy input or output.

Stüve-diagram paper



Example of Lapse Rate Chart



— The red lines are *wet adiabats*. They show the temperature changes in airmasses that ascend with continual condensation of water, or descend with continual evaporation, in either case without additional outside energy inputs. (The numbers on the adiabats indicate which dry adiabat each wet adiabat asymptotically approaches at very high altitude, and show the appropriate temperature of that dry adiabat at a pressure of 1000 mb.)

— The blue lines are *saturation lines;* their numbers indicate the ratio of water vapor (in grams) per kilogram of dry air. These lines show the relationship of temperature and altitude at which a given airmass is completely saturated; any further ascent would result in condensation and cloud formation.

Let us assume that our airport is situated at an altitude of 300 m above sea level. An early-morning sounding flight in the airmass that we expect during the day has resulted in measurement points A through D. At the surface (point A), the temperature was measured at 15° C, and increased with altitude so as to reach 19° C at an altitude of 600 m ASL (point B). Such a temperature inversion often occurs overnight due to heat losses from the surface because of radiation. From B to C the temperature decreases at a rate slightly less than the dry adiabat; thus, the airmass in this layer is weakly stable. From C to D the temperature is constant, or isothermal; above D the curve is steeper than the dry adiabats, but not as steep as the wet adiabats. Above D the airmass is conditionally unstable.

Near the surface, the temperature-dewpoint spread was determined to be 1.2° C. This means that condensation (clouds) would begin if the pressure were kept constant and the temperature lowered by 1.2° C. The dewpoint Q is marked; the number of the saturation line running through Q indicates that the surface air contains 10 g of water for each kg of dry air. The spread continues to increase up to 600 m ASL, but the water content of the air has also increased (R). At altitude S the air only contains 8.3 g of water per kg, but the small temperature-dewpoint spread (points S and C are only 1.5° C apart) shows us that the air here has a rather high relative humidity (90%). From S to T the spread increases, indicating that the air becomes drier with increasing altitude.

CHANGES IN THE TEMPERATURE PROFILE DURING THE DAY

After sunrise the surface is warmed by solar radiation (insolation). This, in turn, heats the lowest layer of the air, which expands, becomes lighter, and can ascend if triggered. For a realistic picture of what happens, we can assume this ascent to be adiabatic, even if this isn't *quite* exact because of mixing with the surrounding air. The ascent continues until the airmass is no longer warmer, and hence lighter, than the surrounding air. (The influence of inertia tends to equalize the mixing which was not taken into account.) In the diagram, such an ascent can be represented so that we start at a given surface air temperature and continue to the upper left, parallel to the dry adiabats, until intersecting the temperature profile. In our sample, nothing much will happen until a surface temperature of 22° C (A_1) is reached, since any thermals will be stopped by the 300-meter thick inversion layer. Further temperature increases, however, will very rapidly cause thermal heights to increase to a "flyable" value. At 23° C (A_2), the ascending dry adiabat intersects the 10-g saturation line at point T_2, at an altitude of 1500 m. This means that the ascending airmass, which of course has taken its water content along, is now saturated. Further ascent will cause condensation and the formation of a cloud; at this point the air will no longer cool off as quickly (due to the heat liberated by the condensing water) but will form the cumulus cloud W_2 while cooling according to the wet adiabat until the latter intersects the isothermal portion of the temperature profile at 1750 m ASL. Thus, the temperature A_2 is the triggering temperature for the formation of cumulus. Since the dewpoint at cloudbase altitude is only 1.5° C less than the air temperature, older Cu will only dissipate slowly, and lateral expansion and areas of shadow are very likely.

Let us also assume that in some areas where this shadowing has not occurred the surface air temperature reaches 25° C. Now the thermal will not reach its condensation level until 1700 m ASL; any further ascent will be along a wet adiabat.

Since, however, this thermal has "punched through" the isothermal area between C and D, there'll initially be no stopping it: a huge cloud (W_3) will form, in which temperatures at higher levels will be much less than freezing, and rain showers will occur. If the airmass' conditional instability continues to very high altitudes, thunderstorms may form.

This example serves to illustrate how useful it can be to know the temperature profile of the airmass in which one expects to fly. For example, we can use it to determine the temperature necessary for thermals to a given height — say 800 m AGL — necessary for a cross-country flight (in our example 22.5° C). Cu-triggering temperature can be directly constructed simply by starting at the intersection of the temperature profile and the surface-air saturation line (T_2 in our example) and proceeding parallel to the dry adiabat until reaching the surface (A_2). Cloudbase, the size of the expected Cu, and the probability of overdevelopment and shadows can be similarly obtained directly from the temperature profile.

The vertical temperature and moisture distribution of an airmass as presented in such a temperature profile is definitive for many meteorological processes and hence is one of the most important tools for accurate prediction of soaring conditions. Processes such as downslope winds (Foehn), instability caused by frontal action or occlusions, and more can be determined directly with adiabatic paper and the temperature profile. The soaring pilot should become sufficiently conversant with the process to be able to completely understand the meteorologists who advise him, or to make valid deductions based on simple measurements he can make himself (for example, an early-morning temperature sounding with a towplane). These points were also used as a guide to the selection of the following themes.

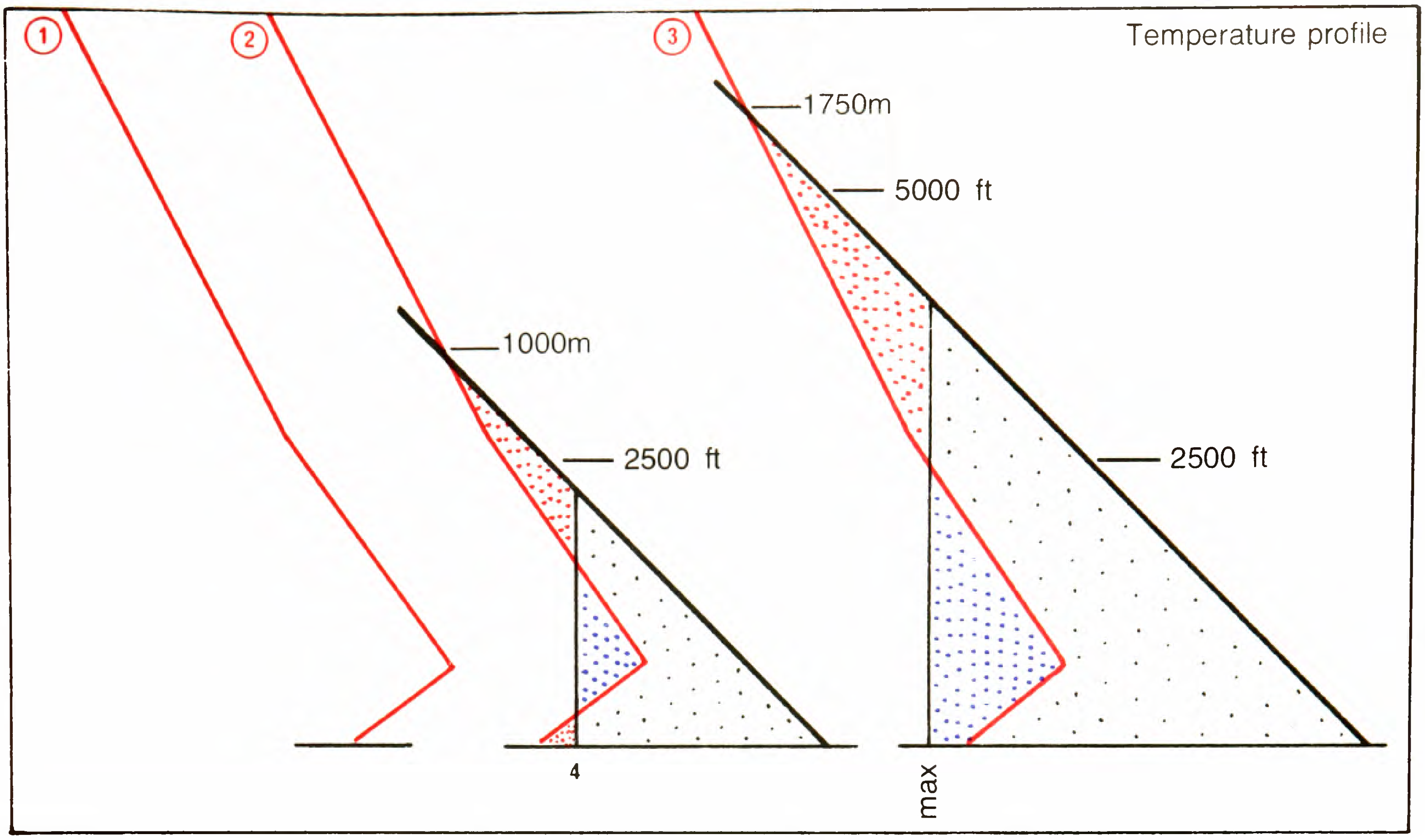
Meteorological Aids for the Soaring Pilot

DETERMINING TRIGGERING TIME FOR THERMALS OF GIVEN HEIGHT BY USE OF ENERGY-AREA OVERLAY

The upper illustration starts at the left with the midnight temperature profile (1). During the course of the morning, insolation heats the surface air, which rises along the dry adiabat and causes mixing within that portion of the airmass which is affected by convection. Thus, the temperature distribution of the lower levels of the air-mass will be nearly dry-adiabatic. The area between the old and new temperature profile is a measure of the energy absorbed by the airmass, and hence is called an energy area.

(Taken exactly this holds true only for adiabatic papers which are "area-true," such as the "Tephigram" or the "Skew-T, log-p" paper used by the German Air Force and in the U.S.A. The "Stüve" paper used by the German Weather Service is not area-true, but is still-sufficiently accurate for our purposes.)

At any given time a fixed amount of solar energy is available to heat the air, depending on the sun's angle. The energy that heats the surface in the first four hours after sunrise on a cloudless summer day is shown in part (2) of the illustration as the area between the old temperature profile and the heavy black dry adiabat. The black-dotted triangle is equal in area if the red-dotted areas are as large as the blue-dotted ones. Part (3) represents the conditions at the maximum energy for the day.



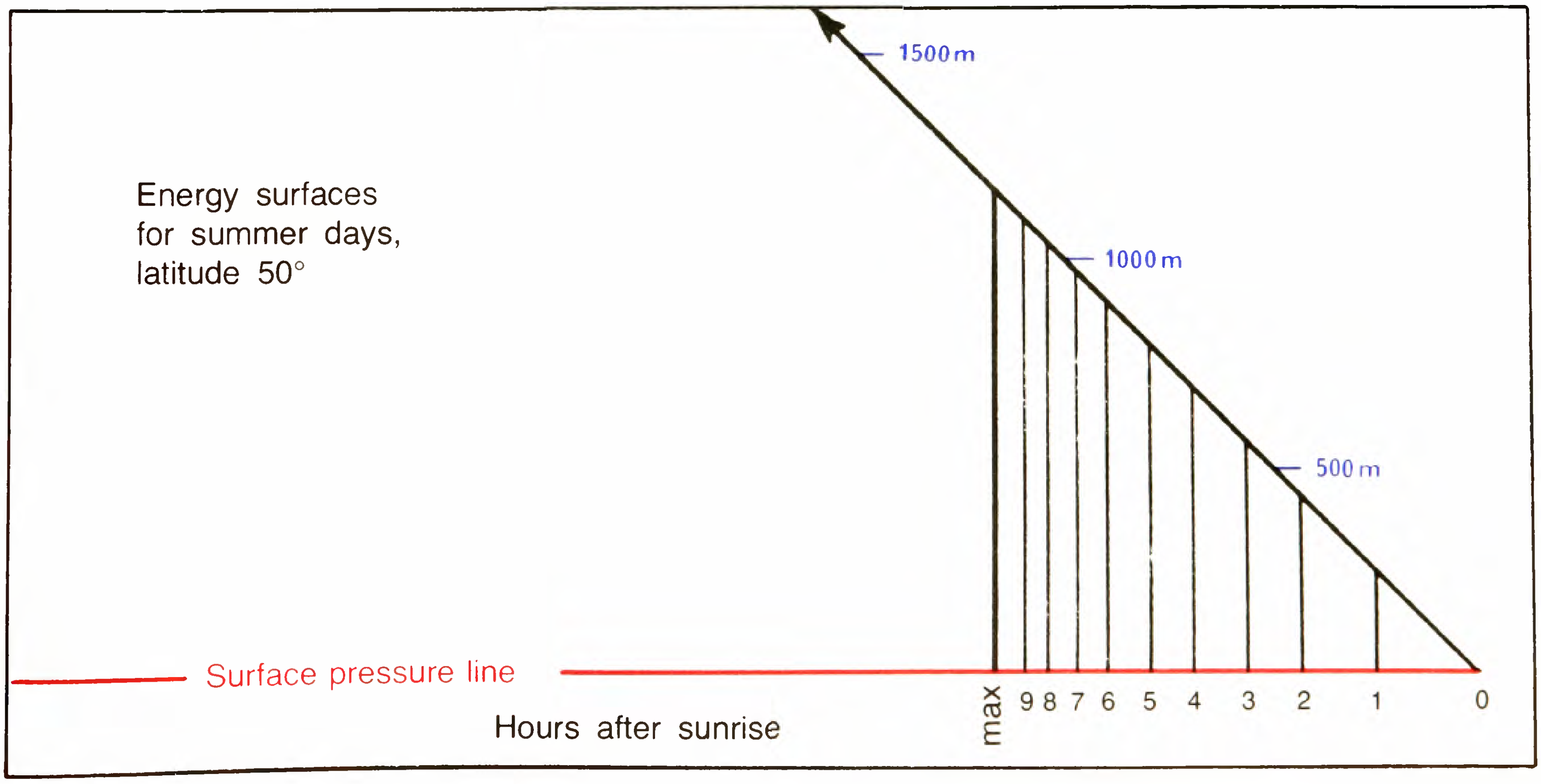
Since the amount of energy depends on the sun angle and the length of time available for heating, the temperature profile can be used to predict the time of given thermal development.

In order to rapidly compute such information from a temperature profile, one can construct an appropriate diagram on clear plastic. The second (lower) illustration shows such a diagram constructed for Stüve-type adiabatic charts. The energy areas for given time intervals are represented by the areas from the surface line to the diagonal dry adiabat. If one is counting from sunrise, as one often must, since the only sounding available in the morning may be the one from the preceding midnight, these areas are triangular.

Thermal height at a given time after sunrise can be determined as follows:

The overlay is placed on the temperature profile chart so that the surface line is at the altitude of the airport. By sliding the overlay sideways we find a position such that the (desired) energy surface on the overlay is roughly as large as the irregular surface included between the surface line and the dry adiabat.

The lowest intersection between the adiabat drawn on the overlay and the temperature profile shows the



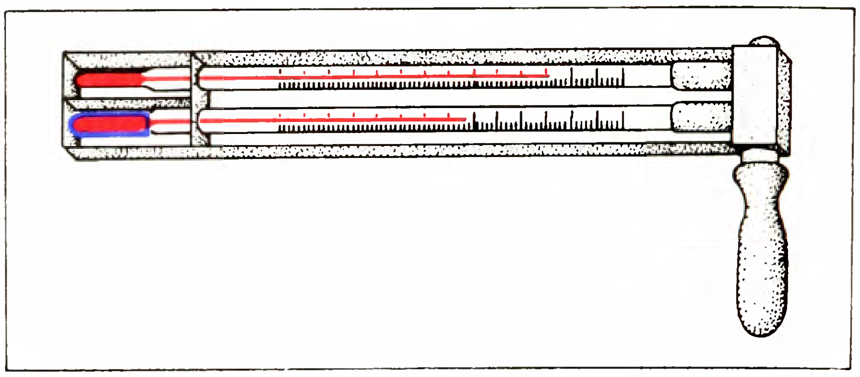
thermal height at the chosen time; this has been indicated in parts (2) and (3) of the upper illustration. Of course, one can also take the opposite approach and find the time at which one can expect thermals to a given height. About 2500 feet would be a reasonable minimum for cross-country flight in Europe, somewhat higher in less-landable countries.

The advantage of this method is that we can determine the time for thermals of given height with some accuracy without making temperature measurements at the airport — as long as the insolation is not adversely affected by cloud or heavy haze. This is as valid for the time of the first flyable blue thermal as it is for the time at which one can expect the first Cu to develop. A further advantage is that the only "inputs" necessary for calculation are the temperature profile, which can be obtained by telephone, and the energy-surface overlay. A thermometer, or even attention to the trend in temperature, is unnecessary.

THE THERMOGRAPH

The thermograph records the temperature against time of day. This "fever chart" of the air is especially useful as a means of finding out about convection if we also have a temperature profile available. Even without a profile one can see whether nighttime inversions have been dissolved or not: as long as a surface inversion works to limit the height of the convective layer to a very low value, air temperatures at the surface will increase very rapidly. If, on the other hand, the inversion has been penetrated, which means that the convective layer has suddenly become much thicker, the available solar energy will be spread throughout a much greater airmass; the surface air temperature will only increase very slowly. The thermograph will show a steep climb followed by a break in the curve; at this point thermals are often already strong enough for cross-country flights. This can occur several hours before sufficient temperature has been reached for the triggering of visible Cu. Unfortunately, the thermographs are not inexpensive, and must be installed in a white-painted louvered shelter for accurate readings. Even so, the owner or operator of a sailplane field should consider the purchase of a thermograph as an aid to better use of available soaring weather.

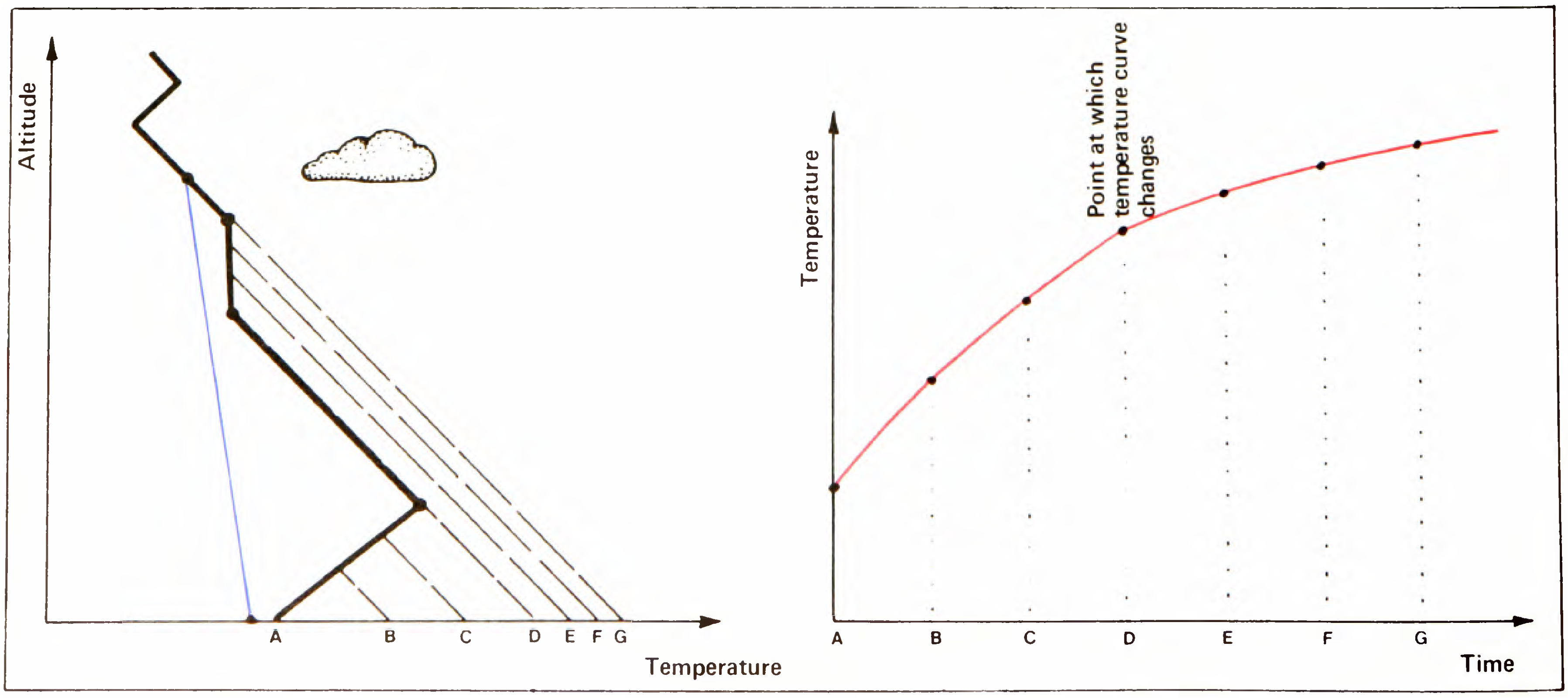
THERMOMETER AND SLING PSYCHROMETER



If no thermograph is available one can make measurements of the air temperature from time to time and enter them on a sheet of graph paper. To do this, one uses a thermometer mounted on a handgrip, allowing it to be whirled around in the air for a few minutes to eliminate radiation errors in the measured temperature. This device offers a further possibility: the measurement of moisture in the air (sling psychrometer).

In addition to the normal thermometer, a second one is installed, the bulb of which is covered with a fabric "stocking." Before taking the measurement, this stocking is wet with distilled water. At some open spot, if possible in the shade of a cloud, the device is whirled for three to six minutes, until both thermometer indications remain constant. Water will evaporate from the wet-bulb thermometer, and the resultant cooling will cause it to read lower than its dry-bulb mate. Since evaporation occurs more rapidly in dry

Temperature profile and temperature change with time



air than in wet, the temperature spread is an indication of the moisture present in the air. Since thermals are composed primarily of surface air, the results of this measurement can be used to determine the condensation level and hence the cloudbase of Cu's.

The height thus determined even gives us useful information if no Cu appear: we then know that any "blue thermals" that may exist are stopped by stable airmass layers before reaching the condensation altitude.

WIND MEASUREMENTS NEAR THE SURFACE

There are various — usually cumbersome — devices available for the measurement of wind speed and direction. While pitot-type devices respond very rapidly and are thus the ideal input for gust recorders, conventional cup anemometers provide a more useful smoothed indication. Such devices must be installed clear of any obstructions, ideally at the internationally-recognized height of ten meters above ground level. Ground crews in contests can do very well with a simple hand anemometer available at model and hobby shops; these gadgets are about flashlight-size and can be used, with a little practice, for fairly accurate wind-speed determination. Apart from their definite contribution to the safety of outlandings, their usefulness is limited. It's not unusual for the wind to double in speed and change 20° in direction (to the right in the northern hemisphere) within the first 1500 feet above ground level. If one takes this into account, one can still determine takeoff and landing directions, as well as getting a rough idea of wind for navigation or final-glide purposes.

The wind sock which is present at every sailplane field offers similar information.

If one sets up several wind socks, pilots can often spot thermals immediately after (winch) takeoff by the different angles of the socks, since the surface air flows into the bottom of the thermal from all directions.

CLOUD MIRROR FOR MEASUREMENT OF THE WIND AT CLOUDBASE ALTITUDE

The wind speed and direction at cloudbase height can be determined from the ground with a cloud mirror, if the cloudbase altitude is known. The ground crew can get this information from the pilot by radio; they should make measurements before the final glide so that the pilot can have realistic values for final-glide calculations and optimal departure height.

There is, of course, one absolute necessity: as the name implies, the cloud mirror can only work if there are clouds! In blue thermal conditions it's useless; the only solution would be a balloon, which would be cumbersome to say the least. (In fact, such balloons — together with elaborate tracking theodolites or radar sets and computer-generated calculation tables — are the method used by weather bureaus to determine winds aloft.)

A cloud mirror can be made from a round hand mirror. In addition to a compass rose around the edge, one should inscribe a small central circle (radius: 1 cm) and two further circles with radii of 4 and 7 cm. The sight or gnomon can be constructed from piano wire, small brass tubing (hobby shop, etc.) and a telescoping radio antenna (electronics store, defunct transistor radio). The sighting point should be movable anywhere in a plane that should be exactly 21.6 cm above the mirror (for especially strong or weak winds, settings of 10.8 and 43.2 cm would also be useful).

MEASUREMENT PRINCIPLE

The cloud traverses the distance S; its mirror image traverses the distance S′ on the mirror surface. The sighting point is at height h′ above the mirror, while the cloud is at height h. (To be exact, the mirror should be at height h′ above the ground, as well; in practice, however, this is unnecessary since h is so much larger than h′.)

According to the rules of reflection and of geometric projection,

$$\frac{S}{S'} = \frac{h}{h'}$$

Thus, the cloud's speed (V) is:

$$V = 3.6 \cdot \frac{S}{t}$$

(S in meters, t in seconds, and V in km/hr)

$$V = \frac{3.6 \cdot S'}{h'} \cdot \frac{h}{t}$$

if V is km/hr, S′, h′, and h are meters, and t is seconds.

The first fraction is fixed due to the construction of the cloud mirror, while h and t are measured values. If one chooses S′ and h′ such that the fraction is equal to 1, the calculation after the observation is simplified: for example, $S' = 6$ cm

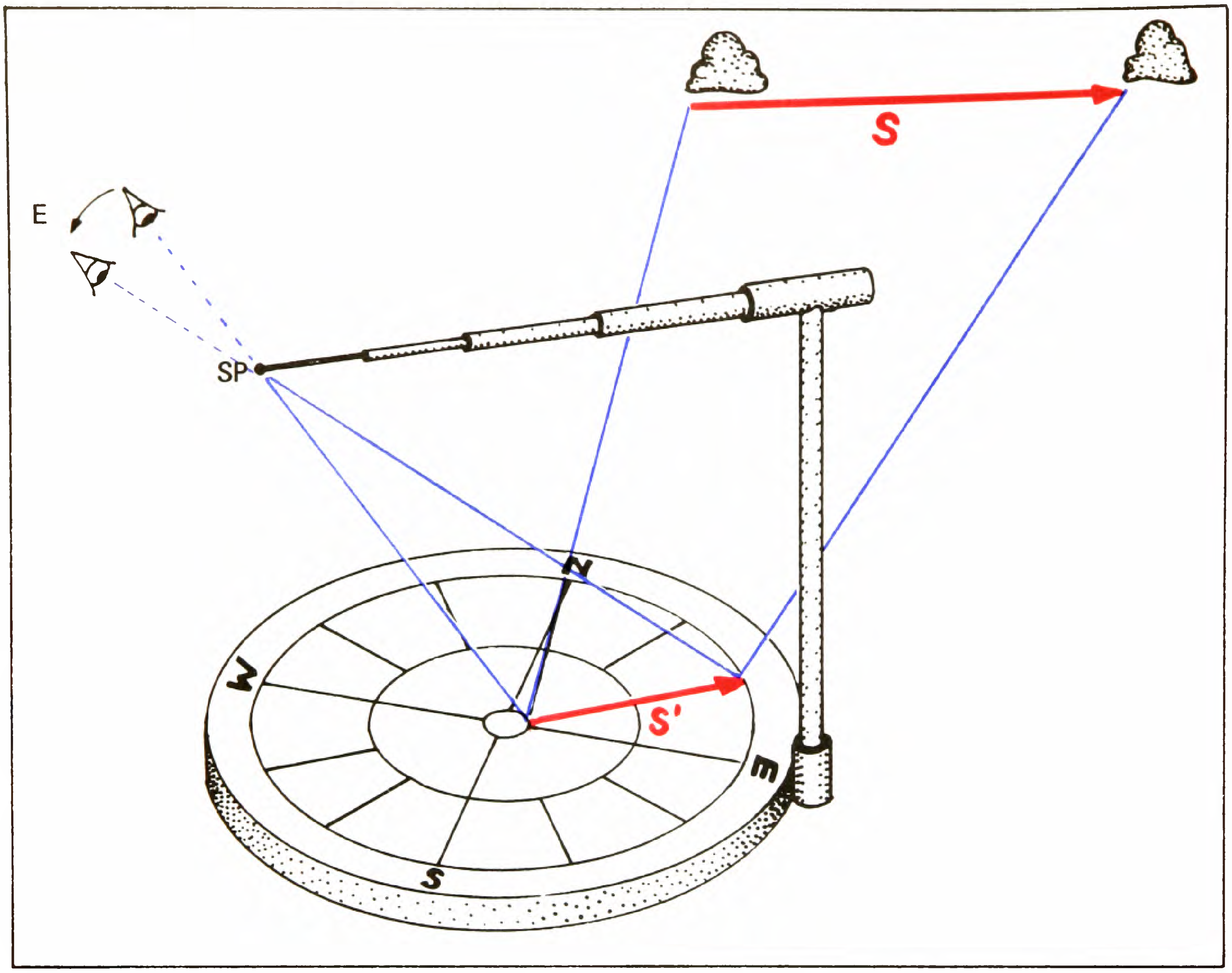
$h' = 21.6$ cm

The cloud speed will then be $V = \frac{h}{t}$

If we measure only ½ S′ this also halves V, if we double h′ we also halve V.

To be exact, the foregoing only proves that the mirror can be used if wind direction and sighting direction are the same — that is, if the chosen cloud is moving directly toward or away from us. However, the colored lines in the drawing can just as well be regarded in perspective, such that the cloud passes far behind the plane of the illustration while the distance S′ is on the plane and the sighting point is actually closer to the reader than the illustration. Even then, the relationship $\frac{S}{S'}:\frac{h}{h'}$ would still be valid as illustrated.

Cloud mirror



S	**Movement of the cloud**
S′	**Movement of its mirror image**
SP	**Sighting point**
E	**Eye**

Errors if the mirror is not horizontal:

If the mirror is not leveled, the relationships of the law of geometric projection are no longer valid; h and h′, as well as S and S′, are no longer parallel.

(High-fidelity equipment and record shops often sell small circular spirit levels with sticky backing for leveling turntables; they are ideal for cloud mirrors, as well!)

PROCEDURE FOR MEASUREMENT

(Height of sighting point: 21.6 cm)

1) The mirror is set up, leveled, and oriented (with a compass, taking the variation into account) so that the "south" mark points *north* (so that the wind direction can later be read directly).

2) The *edge* of a cloud is sighted-in so as to appear in the center of the mirror.

3) The *sighting point* is moved so as to cover the image of the cloud edge and the center of the mirror.

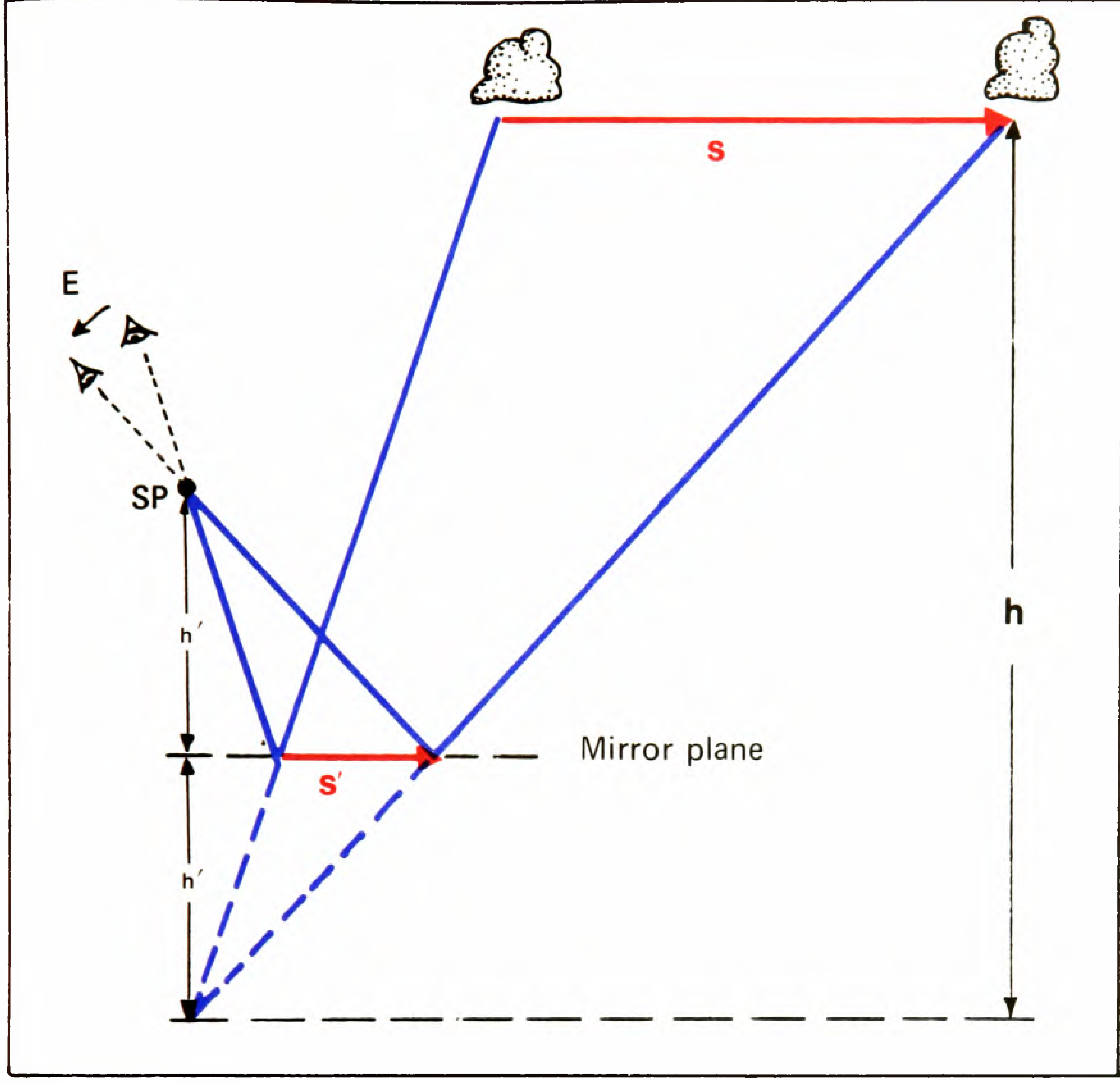
4) One continues to sight over the sighting point to the cloud edge. *The sighting point and cloud edge will both move from the center toward the edge of the mirror.* With a stopwatch, we measure the time from when the cloud edge leaves the small center circle until it crosses the outer circle.

5) The point at which the cloud edge crosses the outer circle is the *wind direction*. The wind speed in km/hr is the quotient of the cloudbase height divided by the time, with the height in meters above ground level and the time in seconds.

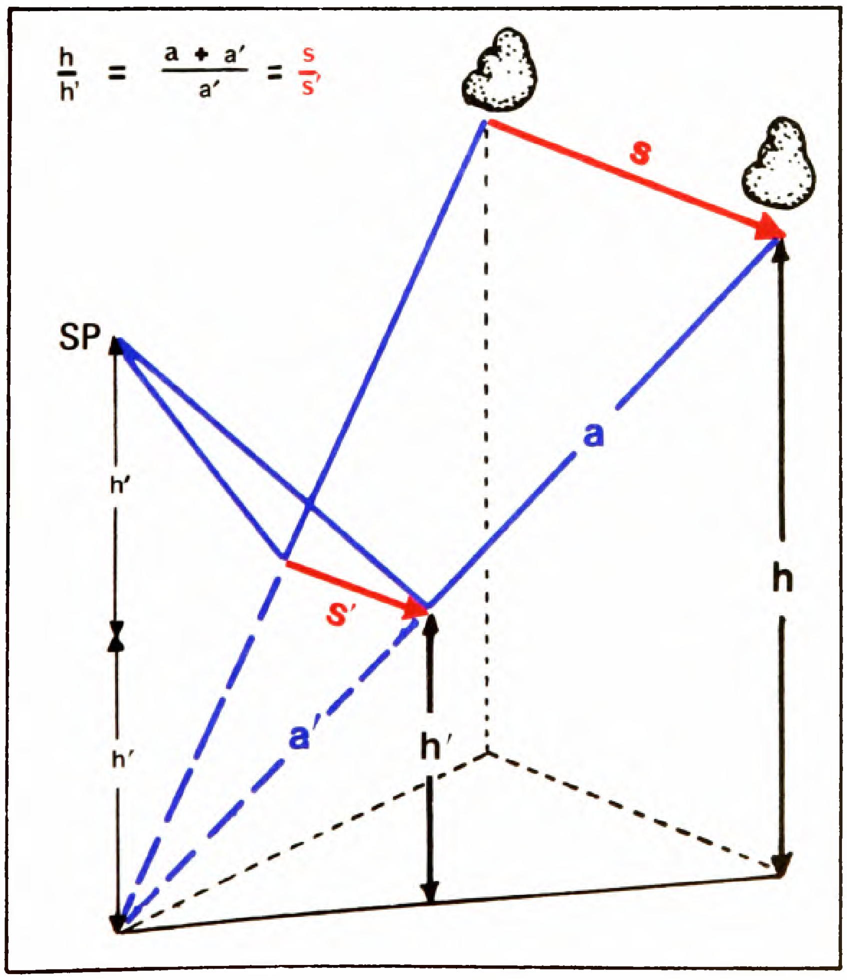
$$V_{cloud} = \frac{\text{Cloudbase (AGL)}}{\text{Time Interval}}$$

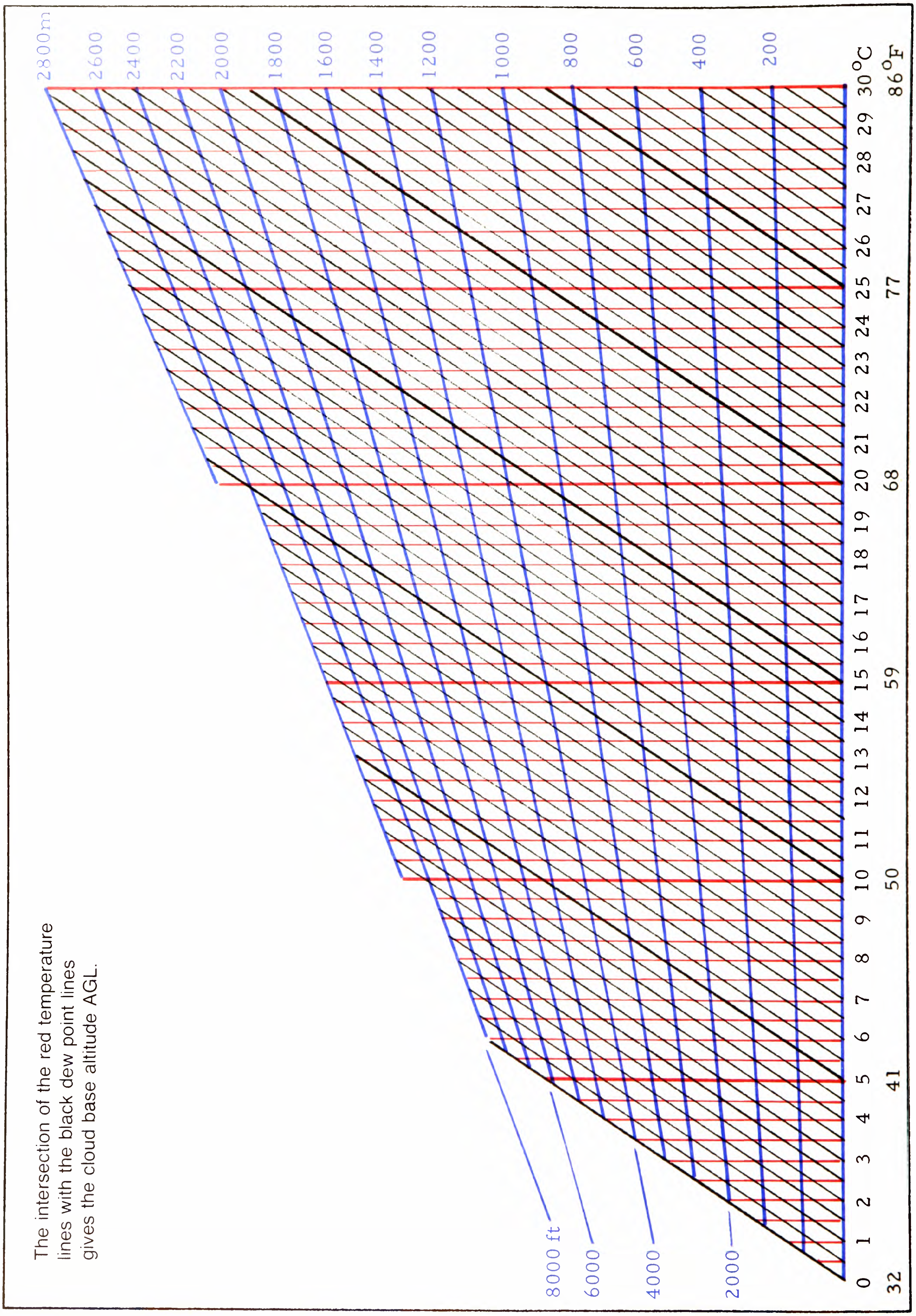
6) For accurate determination of the wind speed it is a good idea to measure twice, once on the upwind and once on the downwind edge of a cloud, to avoid errors caused by the cloud's growth or shrinkage. The speeds thus obtained should then be multiplied with a *correction factor* (for "young clouds" about 1.3) to take into account the fact that the newly-risen warm airmasses have not yet been completely accelerated to the general wind speed.

Function of the Cloud Mirror



S	Distance traversed by cloud
S′	Distance traversed by mirror image
h	Cloud height
SP	Sighting point
h′	Height of sighting point above plane of mirror (8.5 in.)
E	Eye





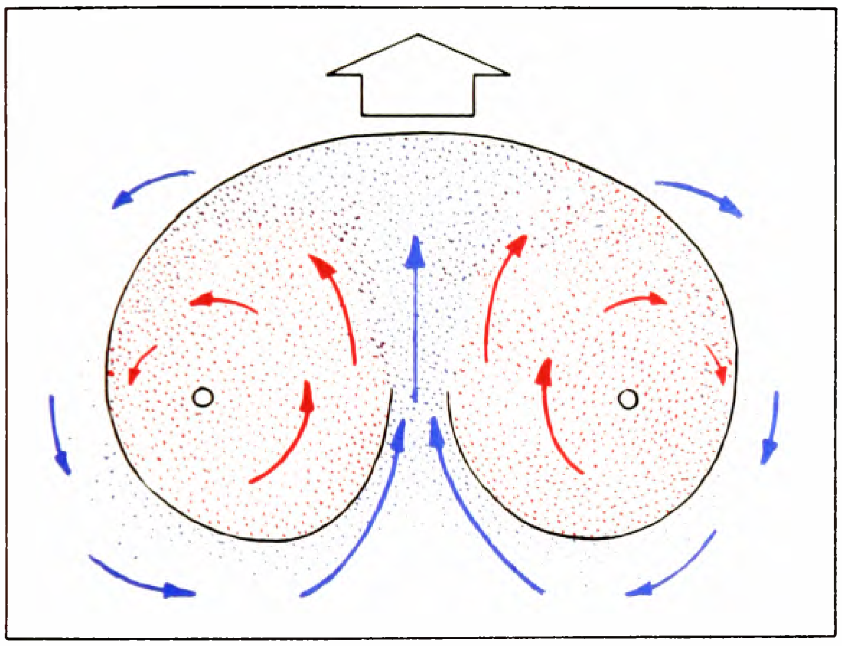
The intersection of the red temperature lines with the black dew point lines gives the cloud base altitude AGL.

Cumulus cloud base calculation

The Mechanics of Thermal Convection

It would be extremely helpful for thermal soaring if we could visualize more than just where thermals occur, but also how they ascend, what air motions occur within them, where the center(s) might be, and so forth. Unfortunately, such research soon encounters difficulties due to the great number of possible variations. The English meteorologist Richard Scorer, however, has performed some fundamental experiments. Using various differently colored liquids he was able to determine certain properties which seem to be substantiated by observations made by sailplanes — at least under certain weather conditions.

The Thermal "Bubble"



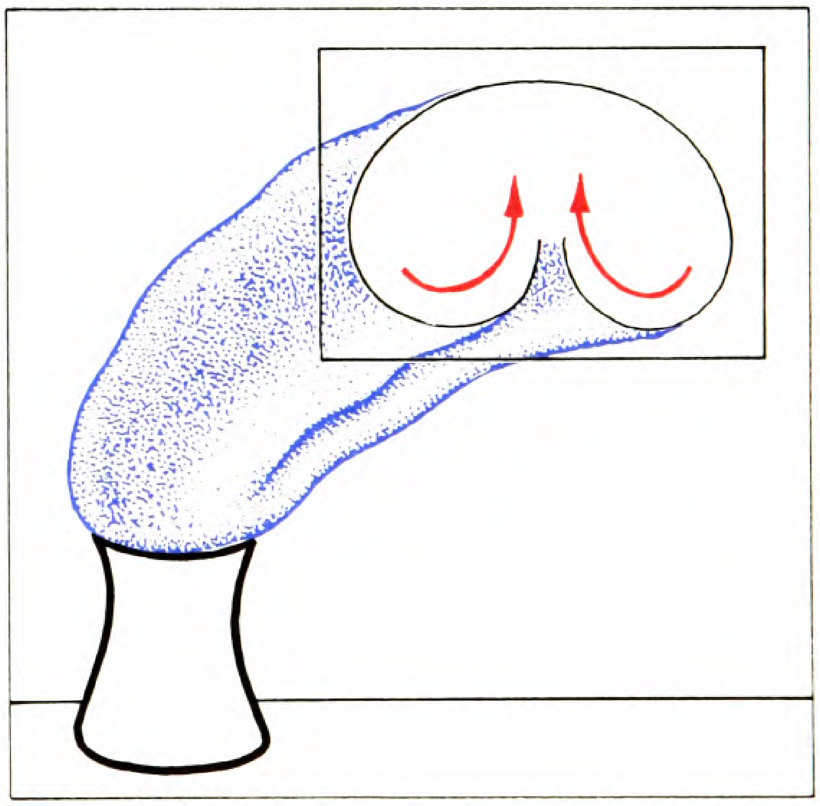
ISOLATED ASCENDING THERMAL "BUBBLES"

Let us assume that a "parcel" of air ascends adiabatically with no connection to the surface in an airmass that is free from wind shears and is adiabatic with respect to temperature profile. This simplest case results in the picture of a vortex ring similar to those generated by skilled smokers or by the first puff of an accelerating steam locomotive. The ring moves upward as a whole, and also rotates around a ring-shaped axis. The largest vertical motion is found in the center, and is larger than the vertical motion of the ring itself. As it ascends, the vortex ring becomes larger as it entrains the surrounding air and pulls it into the center, then mixes it with surrounding air — causing localized turbulence — in its upper parts. An extremely exaggerated example of this process is the whirling "caps" of the mushroom clouds which result from atom bomb tests in the atmosphere.

The flow represented in the diagram has been observed in experiments and is easy to understand; unfortunately it has the disadvantage that real thermals are hardly ever so simple. Usually, the ascending air is fed with further surface air, at least for some time, allowing sailplanes arriving far below the actual vortex area to enter the thermal and climb. Moreover, if all thermal vortices were actually round, all cumulus clouds would be perfectly circular; the area of best lift would be right in the exact center. This is — as we know — not usually the case. Wind shears, insolation on one side only, and many other factors distort the picture. None the less, the principle of the vortex ring remains an important one and explains many phenomena if one makes reasonable modifications as necessary.

For example, the schematic drawing makes it clear that the air in the lower areas of the "bubble" flows in toward the center, and this is why it is not too hard to center such a thermal — one is literally "sucked in." This is also advantageous to circling in the lower reaches of a thermal, while at altitudes both the turbulence and the outward airflow make centering more difficult. This flow schematic also explains why sailplanes entering the lower areas of the thermal are able to climb quite rapidly to the upper areas, where others may already be circling, so that soon a number of sailplanes have collected at about the same height, where they will continue to climb slowly all together as the entire bubble ascends.

Thermal "Plume" from a cooling-tower



FIXED-SOURCE THERMALS IN WIND

The warm air from industrial cooling-towers moves within the steam plumes in a fashion such that the cross-section of such plumes is similar to that of a vortex ring. If a thermal has a large reservoir of warm air and a constant triggering mechanism it will form similar "plumes," especially if the wind is not too strong.

If the vorticity within such a sloping thermal is greater than the sink speed of the sailplane, it can be advantageous for the pilot to displace his circle to the *lee* (downwind) side of the thermal, rather than to the upwind side as suggested on page 16. This technique allows one to remain longer in the area of the thermal "nucleus," which has higher vertical speeds than the thermal as a whole. Although both possibilities occur in practice, it is usually better to displace one's circle upwind.

ATMOSPHERIC MEASUREMENTS

Measurement flights for research into convective flow were made in Germany long before World War II. Extensive measurements made by the geophysical observatory at Leningrad in 1967-68 have confirmed and refined earlier results:

Konovalov published an OSTIV report on the project in 1970.

Thermals encountered were initially grouped by the relationship of their strengths to diameters in wide, normal, and narrow categories. Within each of these groups, thermal profiles were statistically derived based on diameter and maximum strength. In this process, it became evident that most thermals in all three groups could be placed in one of two categories.

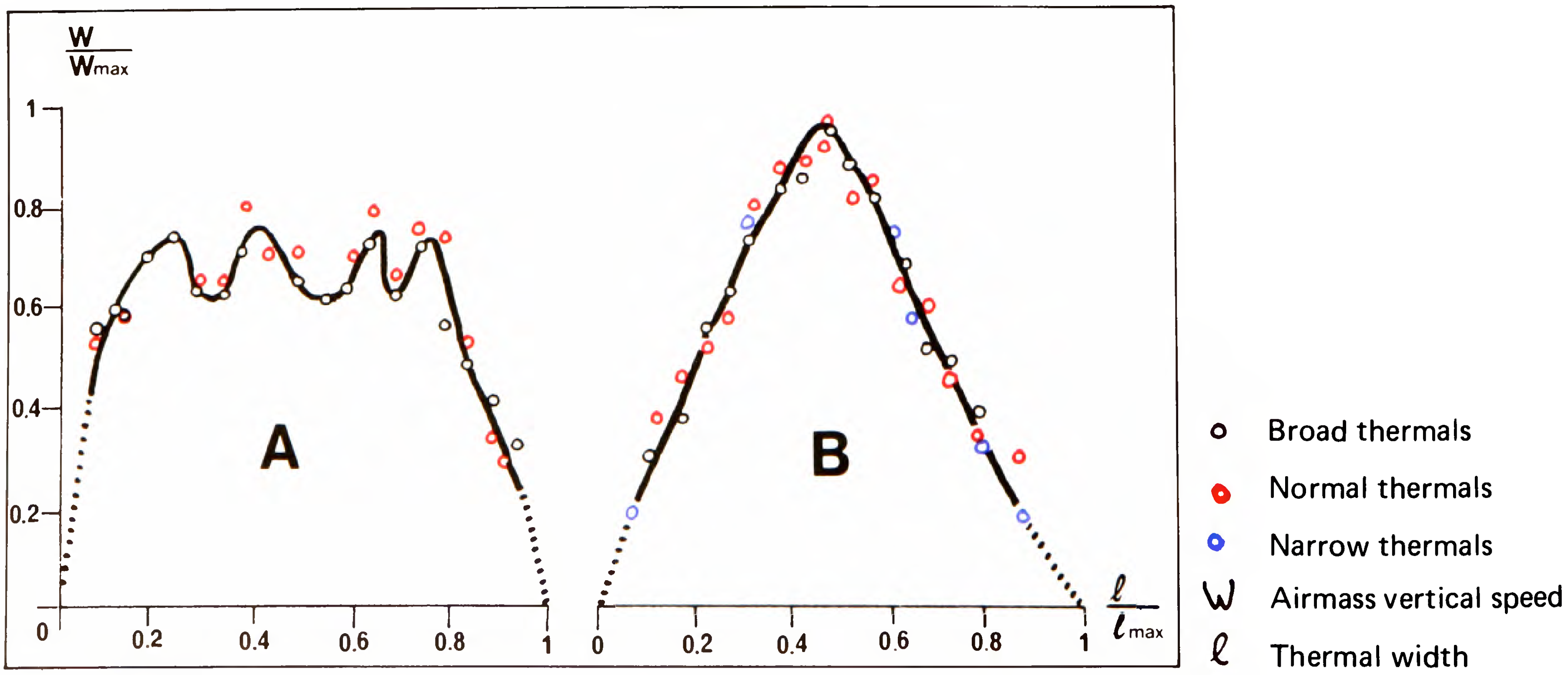
Type-A thermals have a number of maxima. They are more common with increasing instability of the surface air, and are often strong. Their diameter is larger than that of type B, and turbulence at the edges is greater than that in the center.

Type-B thermals, which tend to be more like those postulated by Scorer, are more characteristic of weak thermals. They become less common if the surface air below about 1000 feet is more unstable, have a smaller diameter, and are particularly narrow when (relatively) strong. Normally, little turbulence is associated with these thermals; what turbulence there is is often in the center.

Both types occur simultaneously. The better the conditions for thermals — i.e. the more unstable the surface air — the more the statistics are biased toward type A. This should not appear too remarkable to experienced soaring pilots; strong thermals are often quite large and can have several — although often narrow — zones of best climb.

It's almost impossible to really solve the mysteries of thermal profiles. Konovalov's experiments were carried out in almost completely still air. When such factors as wind, shear, topographic influences, and all the other conditions which affect thermals are taken into account, such experiments rapidly become extremely complex. Even so, their results should make it clear to us how unrealistic it would be to assume that any single, relatively simple shape is characteristic of all thermals. More recent experimentation on a smaller scale by the various academic flight groups has confirmed the irregularity of thermals; about all we know is that they're seldom, if ever, round. Statistical computations should be taken — at least at present — with a rather massive grain of salt. A large-scale view of actual thermal structure can best be obtained at present with time-lapse films of clouds, or by watching birds. For the sailplane designer this is, of course, highly unsatisfactory, but there's little point in designing a sailplane based on questionable statistical information about thermals, so that the pilot gets in trouble the first time he encounters a thermal that refuses to play by the published rules. The thermals that depart from the norm are most likely the norm itself!

Thermal types according to Konovalov (dimensionless diagram)



Weather Briefing for Cross-Country Flights

Cooperation between the soaring pilot and the local pilot briefers and weather forecasters cannot be too close. Usually, a visit to a weather bureau will confirm that the meteorologists enjoy our interest in their work and will be glad to coordinate their soaring forecasts with our special needs. The daily routine tasks which occupy most of the meteorologist's time and for which he has been trained actually have very little to do with our problems; thus soaring forecasts mean considerable extra work for the meteorologist. We should recognize this and reciprocate with consideration as well as our thanks. One of the most important keystones of cooperation is feedback. Only if the meteorologist is regularly informed as to whether his predictions were accurate, or how and to what extent they differed from the actual weather, can he check his prognoses and, in time, refine them and improve their accuracy. It goes without saying that such feedback should be offered by us in the friendliest possible manner. After all, we are not only asking the meteorologist to perform a considerable amount of additional work for us, but that he continue to do so in the future.

BRIEFING FORM

Based on the foregoing considerations, a preprinted weather briefing form has been developed in cooperation with the weather bureau at Saarbrücken; pads of these forms have been provided, both at the weather bureau and at each gliderport in its area. If soaring is planned the weather bureau is informed in advance, prepares the material, and can provide the data on the filled-out form by telephone anytime after 0830. This can take place very quickly, thus saving telephone charges, and is very informative. Of course, it would be better if one could get the information even earlier in the day, but this is difficult to achieve due to the schedule on which the weather bureau receives the raw data from reporting stations. It might also be handy to add a space to the briefing form in which the values of a representative temperature sounding could be entered if available (ed. note — in the United States, the temperature values from the FD-forecast can be obtained from Flight Service Stations for this purpose). After the day's flying, the data on the form are corrected or confirmed by an experienced cross-country pilot and are returned to the weather bureau as a check on the accuracy of the forecast; of course, this last can also be done by telephone. Since we've started using the form, soaring pilots ask fewer "dumb questions" and the entire cooperation has become perceptibly more intensive as well as offering better results.

WEATHER BRIEFING FORM

Compiled by ______________________________ weather bureau and valid for a ______ mile radius

Telephone# ____________ date______ 0830 hr. local time meteorologist ______________

1) GENERAL SYNOPSIS

2) INDIVIDUAL DATA at forecast time — later development (time)

a) WIND

altitude, ft	surface	3000	5000	7000
direction				
speed, kt				

b) INVERSIONS altitude, ft

c) CLOUDS altitude, ft, MSL
amount
type

d) VISIBILITY

e) TRIGGERING TEMPERATURE _____ °C, expected at _____ hr. local time
MAXIMUM TEMPERATURE _____°C, expected at _____ hr. local time
CLOUDBASE, altitude ft. MSL °C, expected at _____ hr. local time
TOP OF CONVECTION, altitude °C, expected at _____ hr. local time
THERMALS: — none — fair — good — varying — fragmented

3) SPECIAL FACTORS

4) OUTLOOK FOR TOMORROW

— the form is filled out by the weather bureau only to the extent permitted by existing data —

1) **General Synopsis** — the overall picture (locations of highs and lows, fronts if expected to have any effect) is given as concisely as possible.

2) **Individual Data** at forecast time: these are actual measurements and observations, hence entirely dependable values.

Later development, on the other hand, can be more or less difficult to predict depending on weather conditions. In sunny weather it is easier; moving cloud areas, fronts, etc. make the prognosis much more difficult and reduce its accuracy.

b) **Inversions:** surface inversions are dissipated at varying rates by surface features and/or insolation; thus, predictions here should be considered as general.

e) **Triggering Temperature** is determined from the temperature profile. **When** it will be reached is somewhat unsure depending on clouds or other barriers to radiation, as is the value for **maximum temperature. Cloudbase** is obtained, like triggering temperature, from the temperature profile; **time** of cloud formation depends once again on insolation.

Top of Convection can be predicted more or less accurately, depending on the temperature profile and how closely the intensity of incoming sunlight agrees with the forecast. These values are also used as bases for the forecast of *thermal* conditions, although complete accuracy is difficult to obtain.

3) **Special Factors:** this section can be used to advise of such things as thunderstorms or conditional instability, confidence factor of the other predictions (possibly with alternative weather development), tendency toward overdevelopment, cloud or thermal streets, wind shears, etc.

4) **Outlook For Tomorrow:** This is only possible in the form of generalized tendencies.

SPEED-TO-FLY

By "speed-to-fly" we mean the optimum airspeed for cross-country flight. It can be obtained graphically or mathematically, starting from more or less simplified mathematical models of cross-country soaring flight.

Flying at the "correct" speed-to-fly can mean either *flying farthest from a given altitude* or *flying between thermals or other sources of lift such that the average speed (cruise speed) is maximized.*

This basic difference is reflected in the division of the following material. In the case of individual calculations and illustrations we have used typical Standard Class sailplanes. The ASW 15 is often used as an example simply because extensive performance calculations and measurements already existed for this type at the time of writing. The preponderance of the results can be transferred directly to similar types (e.g. Libelles, Std. Cirrus, etc.).

The problem — or rather problems — of speed-to-fly has a long history. In 1938 Wolfgang Späte used tables which he had developed during the previous year to increase cruise speed by correct choice of airspeed between thermals. He recognized the influence of climb speeds in the thermals themselves, but neglected to include the influence of vertical movement of the airmass between them. (Ingo Renner uses very similar tables at present.) In the same year he not only published his results, but was joined by Polish pilots who wrote about "best speeds" (L. Szwarc and W. Kasprzyk) and who had expanded the calculation to reflect airmass vertical movement between thermals.

It appeared that these various articles were completely "lost" due to the intervention of the war years. However, inspired by an article by the Swiss record pilot Maurer (1948), Karl Nickel published in 1949 an extremely comprehensive article on the problem of the "most efficient speed," which had been in a desk drawer since 1946, and which included the now-common tangential construction method. For practical use he recommended a "thermal slide rule." This article in turn inspired Paul MacCready to publish his theories — developed independently in the USA during 1947-48 — in an article of only one and one half pages. The innovation: the speed-to-fly ring ("speed ring" or "MacCready ring"). This invention was the first really practical method. MacCready's inflight successes (U.S.Champion, World Champion in 1956) assured wide acceptance of the theory, which became known — not entirely deservedly — as the "MacCready Theory."

More recently, these basic theories have been further developed and expanded by various authors, particularly with an eye toward "dolphin-style" flight. The Swiss coach René Comte expanded the theory in 1972 to the extent of recognizing that climb speed in thermals could differ, and arrived — without any calculation — at some definitive conclusions (see page 59). In 1975 the Munich Academic Flight Group (W. Gorisch) proved the effects — already suspected by top pilots — of dynamic gain during speed changes. During the same year calculations at the Institute for Sport Science in Saarbrücken (the author) led toward an optimization of climb speed in irregular thermals.

The speed-to-fly theory is still very much in a state of change today and far from being completely defined.

SUMMARY OF ABBREVIATIONS

geometric quantities:
e = entire distance of a flight segment
  a, b = partial distances
h = height, gain of height
  $-h$ = height loss
  h_{25} = height required for 25-km glide
E = glide ratio (distance:height)
  E_g = glide ratio over ground
A = scale relationship for changed wing loading
FP = flight path
SP = climb path
  α = climb path angle
time:
t = flight time
  t_1, t_2 = partial times
horizontal speeds:
V = horizontal speed (airspeed) of sailplane, speed-to-fly
  V_g = ground speed
  V_1, V_2 = speeds for partial distances a, b
V_{cruise} = average speed, cruise speed (also V_{cr})
  V_{crm} = cruise speed for "classic" (MacCready) method
  V_{crd} = cruise speed for "dolphin" flight
  V_{cro} = optimum (best possible) cruise speed
  V_{crz} = increase in cruise speed
  W_c = horizontal wind component in direction of flight
vertical speeds:
Wm = meteorological air mass movements
  Wma, Wmb; W_1, W_2 = air mass movement over partial distances
Ws = sailplane sink rate with respect to airmass (always a negative expression)
Si = sink rate = Ws + Wm (in negative sense)
Cl = climb = Ws + Wm (in positive sense)
  CL = strong climb
  cl = weak climb
  W_{1f} = sailplane climb for airmass vertical speed W_1

Translator's note: Although an effort has been made to use English units, some sections of the following text have been left in metric units to correspond with the appropriate illustrations.

The Speed Polar

The basis for the calculation of efficient flying speeds is always the aircraft's polar. This characteristic performance curve is usually available either from the (often rather optimistic) sales literature of the sailplane manufacturer, or (better) as the result of impartial flight tests. It depicts the gliding performance of the sailplane in a diagram in which the airspeed V is measured horizontally with the corresponding sink rate Ws measured vertically. This is only valid, however, for one particular gross weight and hence one particular wing loading which is indicated on the polar (as well as a particular altitude, usually sea level).

Wing loading is defined for this purpose as total aircraft weight (airframe + pilot, parachute, water ballast, etc.) divided by the area of the wing, (W/S). This value is usually expressed as pounds per square foot (psf) or as kiloponds per square meter (kp/m²). In order to avoid large errors at the outset, we should compare the available polar's weight and wing loading figures to those at which we'll actually be flying. In the case of sailplanes with water ballast it is inevitable that we'll have to make separate calculations for different conditions — with tanks full, empty, and perhaps half full — since the effect of wing loading on the polar is significant.

If we expect to fly at very high altitudes, it may be necessary to change the polar to reflect the lesser air density.

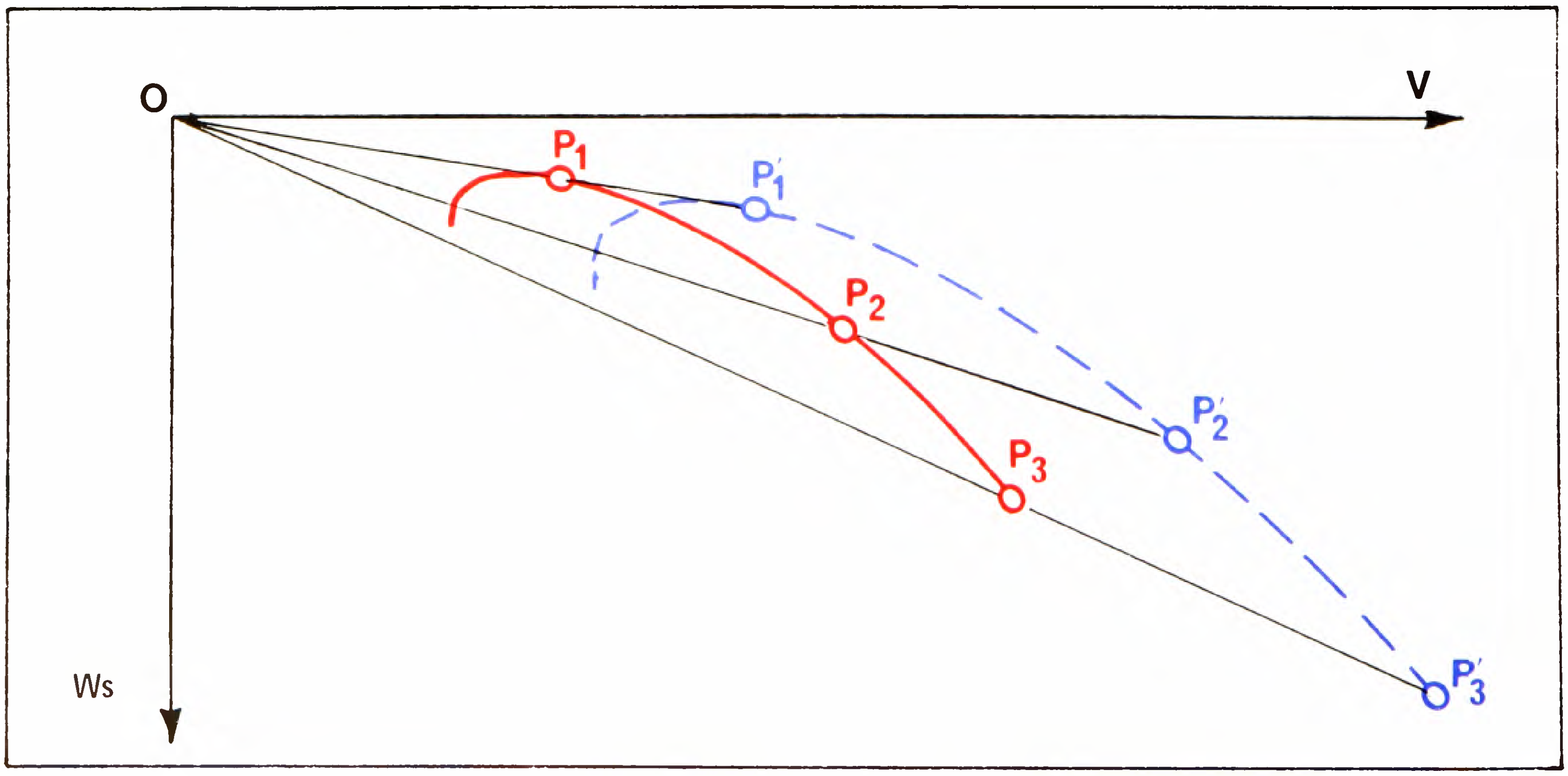
CHANGING THE SPEED POLAR FOR NEW WING LOADINGS

If the wing loading is changed, one can obtain a new polar of sufficient accuracy by the expedient of expanding or contracting the entire polar linearly from the origin. The scaling factor for this expansion or contraction is the ratio of square roots of the new weight vs. the old weight. (The influence of the change in Reynolds number is not included.)

CHANGING THE SPEED POLAR FOR DIFFERENT ALTITUDES

At very high altitudes both the air pressure and the air density are less. In order to generate the same aerodynamic forces, the sailplane must fly faster — and, of course, sink faster as well. The coordinates of each point on the polar are changed in the ratio of standard air density to actual air density or similar (but reversed) to the effect of a change in gross weight. It should also be noted, in the interest of completeness, that the airspeed indicator is subject to the same changes. Thus, one is flying aerodynamically correctly at high altitudes if one continues to use the airspeed indicator as at lower altitudes. One should be aware, however, that one is actually flying more rapidly than the indicated value suggests.

Polar changes for different wing loadings



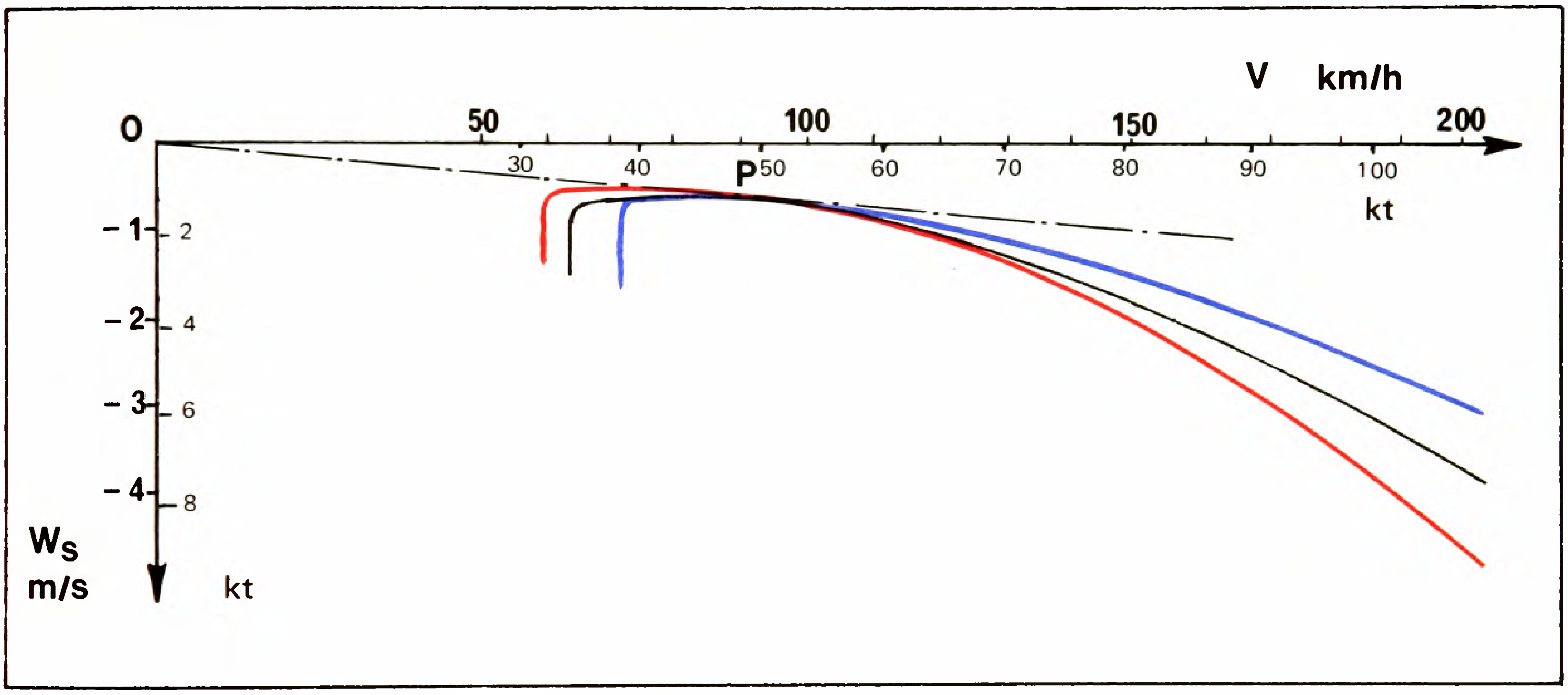
$$\frac{\overline{OP_1'}}{\overline{OP_1}} = \frac{\overline{OP_2'}}{\overline{OP_2}} = \frac{\overline{OP_3'}}{\overline{OP_3}} = \sqrt{\frac{W'}{S}} \div \sqrt{\frac{W}{S}}$$

1. Speed-To-Fly — Glide Distance

A) OPTIMUM GLIDE IN STILL AIR

It is immediately apparent that one can determine the best gliding speed by locating the point at which the relationship of airspeed (which closely approximates horizontal speed) and sink rate is most favorable. Graphically, this is the point at which a tangent drawn from the origin touches the polar. In the example, three different polars have been drawn for different wind loadings. The tangent as such is the same for all three, although there are three separate points of tangency; only that on the 28 kp/m² (5.75 psf) curve has been marked.

Speed polars for various wing loadings for the ASW 15



— 4.90 psf

— 5.75 psf

— 7.35 psf

– – – Tangent

P Point where tangent touches 5.75 psf polar

The angle of this tangent determines the best glide ratio of the sailplane — in this case an ASW 15 — to be 38 : 1 (distance : height). Thus, an altitude of 6,080 feet above ground (1 nm) would allow a glide of 38 nm. The best glide angle is the same regardless of wing loading; however, the lighter sailplane would have to fly somewhat slower, and the heavier somewhat faster, to achieve the best glide, and with it the furthest distance.

B) BEST GLIDE IN (HORIZONTAL) WIND WITH NO VERTICAL AIR MOTION

The original polar remains valid at all times with respect to the airmass. However, airmass motion can act to slow the sailplane (headwind) or accelerate it (tailwind) by the wind velocity with respect to the ground. Thus, in our graphic optimization the polar must be displaced by the wind velocity in the appropriate direction.

The example shows the relationship for an ASW 15 flown at 5.75 psf wing loading:

The black coordinate system is the original one used for still-air calculations. The red coordinate system shows the conditions for a tailwind of 50 km/h, the blue one those for a headwind of like speed. For simplicity the polar curve itself hasn't been moved, but rather the coordinate system; the end result is identical. We will continue to use this method throughout, moving the reference system rather than the polar whenever required.

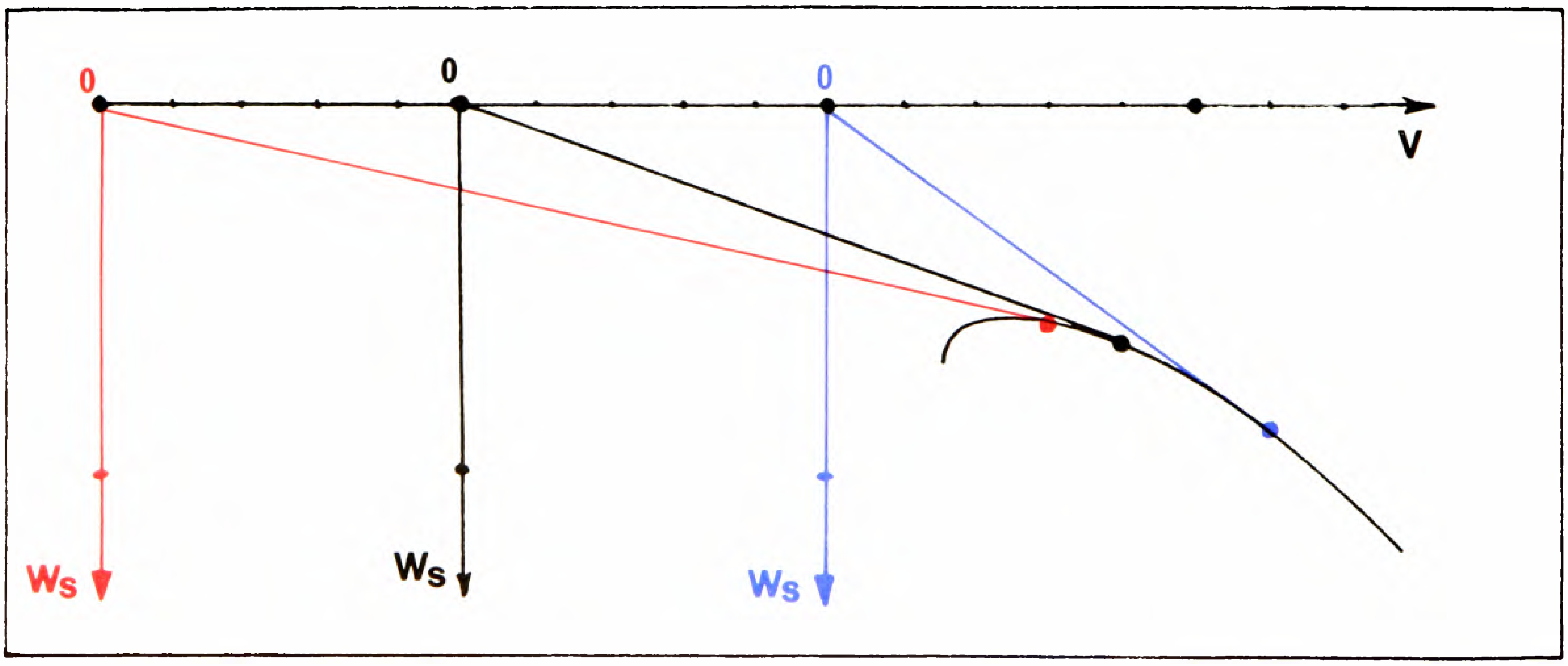
With a 50-km/h tailwind the optimum glide ratio over ground is 60 : 1. The airplane must be flown more slowly than in still air.

In the case of a 50-km/h headwind, on the other hand, the airspeed must be increased to obtain the best glide ratio of 18: 1.

Thus, we can see that one should fly slower in the case of strong tailwinds, and faster for headwinds, than the speed for best glide in still air.

In headwinds, optimum distance can be obtained by setting the speed ring to the value whose average cruise speed corresponds with the headwind velocity (or maintaining this indication on a speed-to-fly variometer). Taken exactly, this technique is only valid if there is no vertical air movement; the explanation can be found in the classic speed-to-fly theory on optimization of cruise speed.

Best glide speed for tailwind, no wind, headwind



— Coordinate system and tangent for tailwind

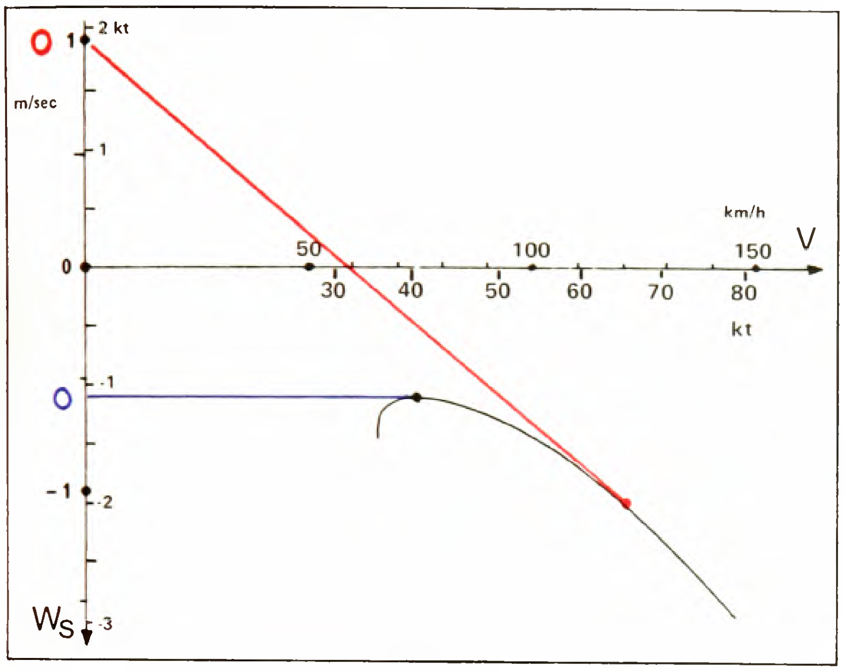
— Coordinate system and tangent for no wind

— Coordinate system and tangent for headwind

C) BEST GLIDE IN STILL AIR (or, based solely on airspeed with no wind correction) WHILE FLYING THROUGH ZONES OF LIFT AND SINK

If the airmass through which we are gliding is sinking, its sink rate must be added to the polar sink rate of the sailplane. It follows that the sailplane polar must be displaced downward by the amount of airmass sink. Of course, the opposite is the case if the airmass is rising.

Best glide speeds for rising or sinking airmasses



In the graphic example for the ASW 15 (5.75 psf) the new, displaced axis systems have not been drawn; only the tangents which would be drawn from the respective new origins (shown by appropriately colored zeros) are shown.

In our example, we find that the best glide speed is 120 km/h if the airmass is sinking at 1 m/s. The steepness of the tangent drawn in red indicates that the glide ratio is only 16:1. In this case our variometer would indicate the total sink rate, consisting of the airmass sink plus the sailplane's polar sink rate of 2.05 m/s.

The blue tangent, on the other hand, indicates the relationships if the airmass is rising at 0.58 m/s. If we fly at the correct speed-to-fly of 73 km/h, the horizontal tangent shows that the airmass motion just equals the sailplane sink rate, such that we could glide on and on with no altitude loss at all (infinite glide ratio). The variometer will indicate zero. If the airmass were to rise even faster, we should actually fly a bit slower than our minimum sink speed of 73 km/h, so as to climb as steeply as possible in straight flight.

We can see from this example that every vertical airmass movement has its appropriate speed-to-fly. Since airspeed in turn influences the sailplane sink rate, speed-to-fly is determined by the *total* sink rate of the sailplane, the combination of airmass vertical movement and the sailplane polar sink rate. Thus, we can determine a speed-to-fly for any variometer indication which will achieve the farthest glide.

In order to fly at the correct speed-to-fly, it is simplest to display the appropriate speed-to-fly values on a moveable ring fixed about the variometer. This will show the desired airspeed opposite the vertical speed displayed by the instrument.

The technique of setting up such a ring ourselves is shown on page 102. Although such rings are available in pre-calculated form, it is often necessary to do it oneself — partly because such ready-made rings are often based on the optimistic "sales polar" figures, but particularly because of differences in wing loading, which can lead to large changes in the ring values.

2. Speed-To-Fly — Cruise Speed

This problem is definitely a different one from that of greatest *distance* described above. Then, we were optimizing for distance; now we are optimizing for cruise speed: how fast should we fly from thermal to thermal to realize the best average speed. Since the best cruise airspeed will result in the best groundspeed as well, there is no need to calculate the effects of wind. In the following sections we will begin by assuming that altitude gained in thermals is achieved by circling — in other words, altitude gains are made with no distance travelled ("classic" cross-country flight).

GRAPHIC DEPICTION OF SPEED-TO-FLY

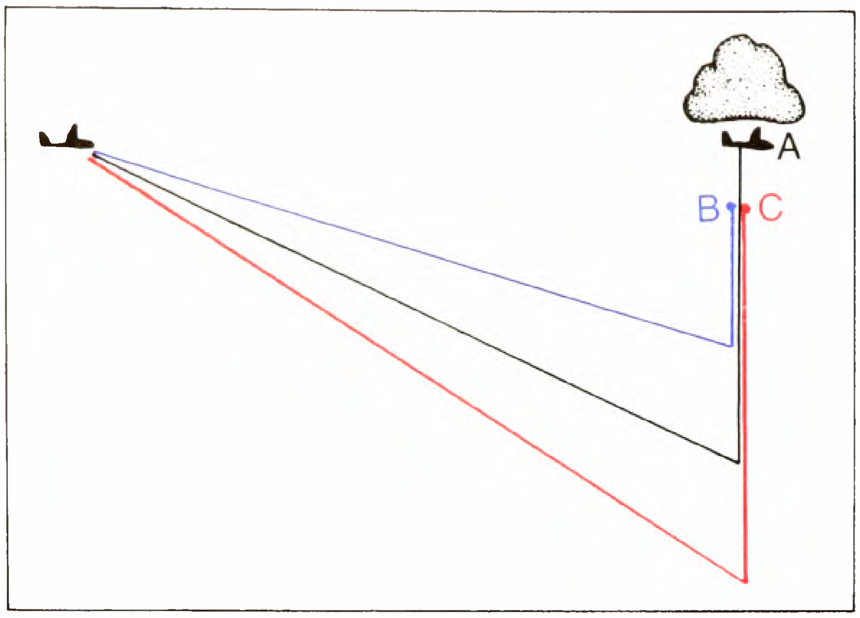
GLIDING FLIGHT FROM THERMAL TO THERMAL IN STILL AIR

Further assumption: the climb in the expected thermal is known and remains constant with altitude change.

In simpler terms, what we're trying to find out is the best speed to use when flying toward a thermal of known strength in order to achieve the best cruise speed, assuming that the airmass between thermals is neither rising nor sinking.

It becomes intuitively clear that it's worthwhile to fly faster if stronger lift is expected ahead. True, one loses more altitude enroute, but if the thermal is strong enough the altitude loss can be quickly made up. On the other hand, if one flies too quickly, the altitude loss is so great one will lose more time regaining altitude than one has saved by the high speed. Here, as before when calculating for best distance, there is an optimum speed-to-fly for each thermal strength that will result in the best cruise speed.

Principle of optimization



PRINCIPLE OF OPTIMIZATION

The illustration shows that pilot A flies most efficiently, while pilot B loses too much time during his slower glide. Pilot C arrives earlier than A in the thermal, but is so low that he cannot make up the altitude loss in time. But how can we figure the optimum airspeed? This is where the calculated, generally derived cruise speed is handy, as its projective drawing can be transferred directly onto a polar graph. The equation: (#1)

$$\frac{V_{\text{cruise}}}{V} = \frac{\text{Cl}}{\text{Cl} - \text{Si}}$$

in which V = horizontal speed in glide (airspeed is sufficiently accurate)

Cl = climb rate while circling

and, in this case,

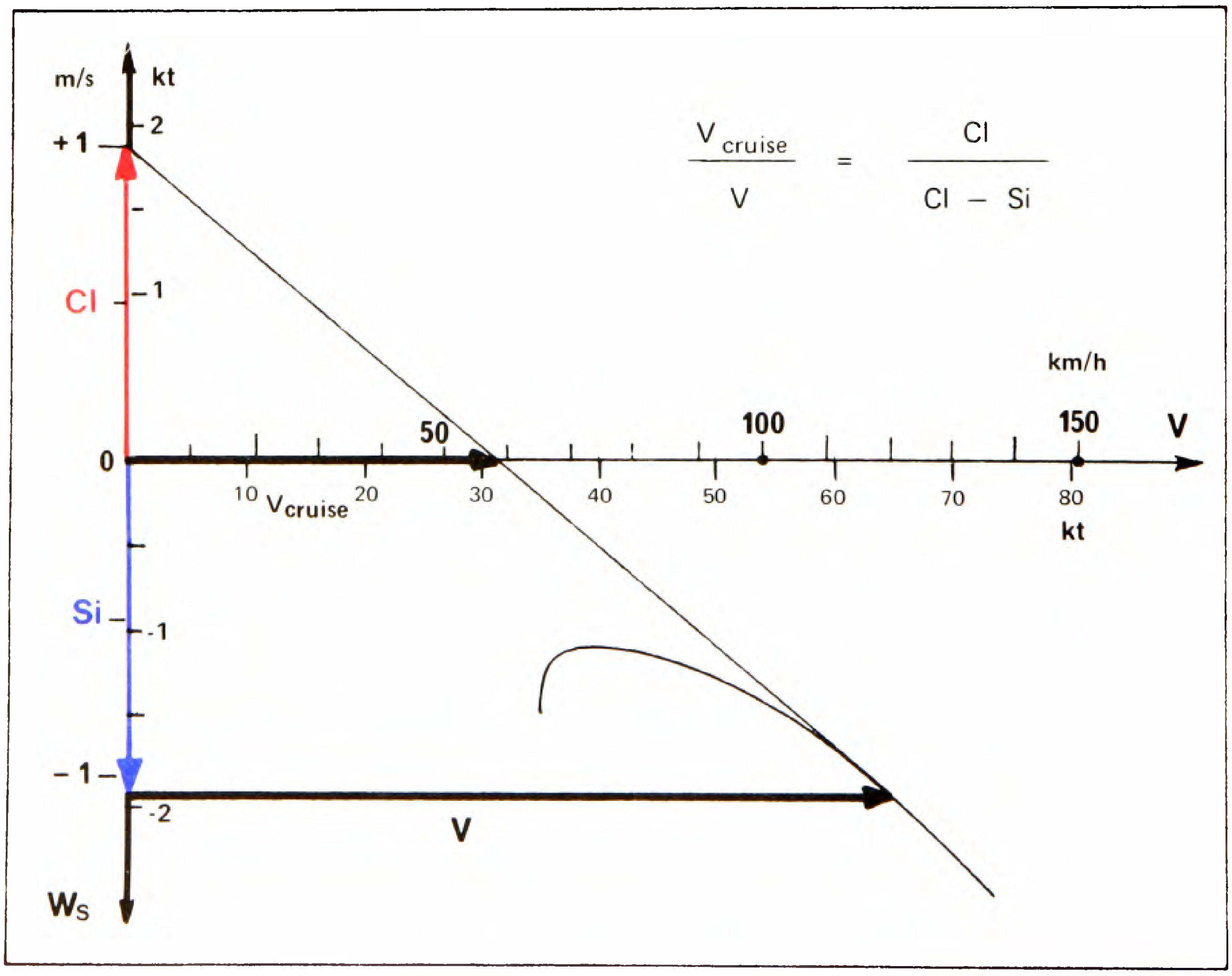
Si = Ws = sailplane polar sink rate, since we have assumed that the air between thermals is still.

Ws is always negative — a sailplane can never sink upwards, after all!

GRAPHIC CONSTRUCTION OF SPEED-TO-FLY IN STILL AIR

If we enter the expected climb rate into the speed polar upward from the origin, the optimum cruise speed will be depicted on the X-axis if we draw a tangent from the expected climb to the polar. The point at which this tangent touches the polar shows us how rapidly we must fly between thermals, as well as our sink rate during such glides.

Graphic Construction of Speed-to-Fly in Still Air



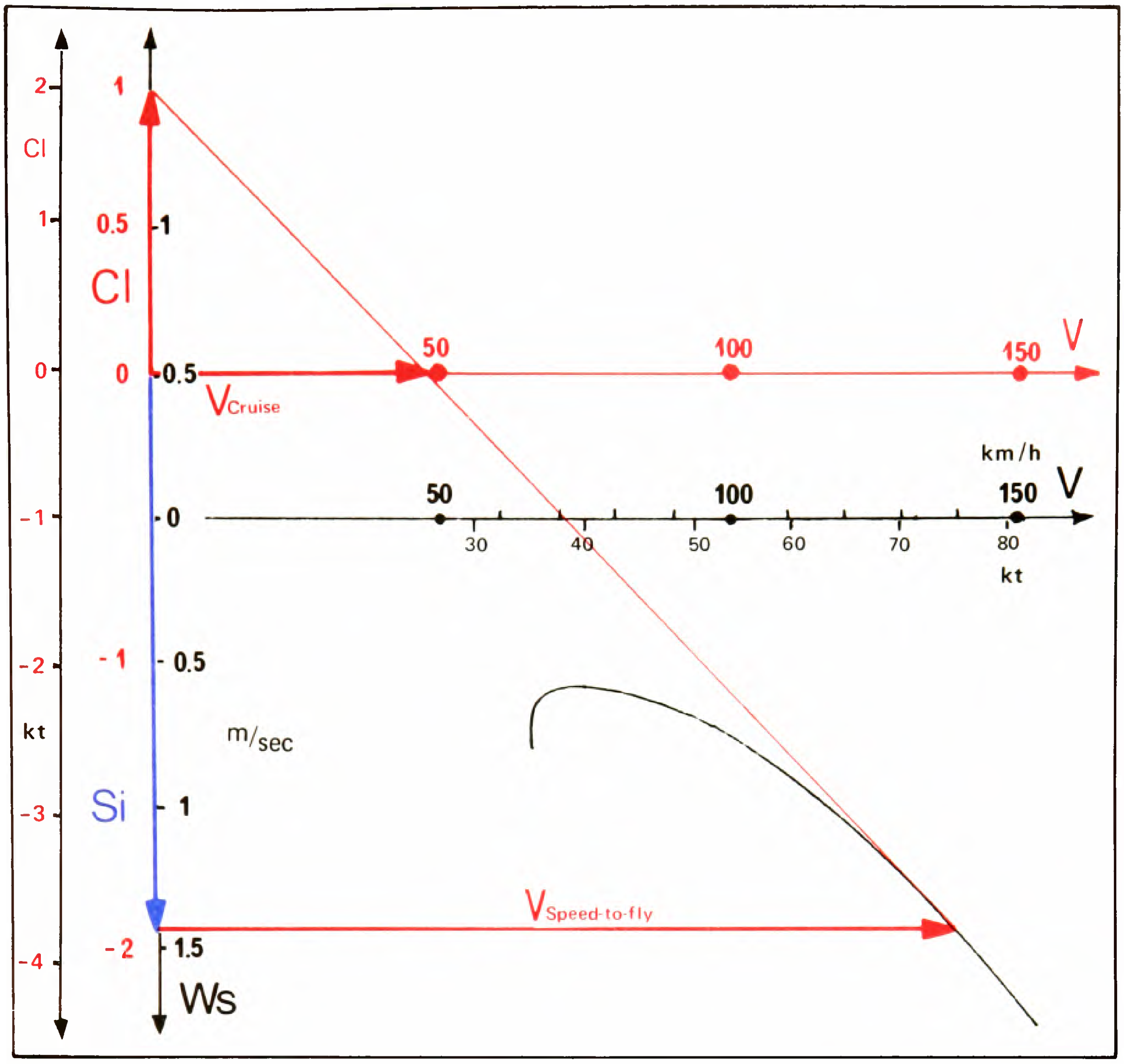
Cl = expected climb (1 m/s)

Si = sink, here = W_S = polar sink rate of the sailplane (-1.05 m/s)

V = speed-to-fly (120 km/h)

V_{cruise} = cruising speed (58 km/h)

Speed-to-fly for glides in sinking airmasses (sink = ½ m/sec or 0.97 kt)



Cl = expected climb (1 m/s; 1.94 kt)
Si = sailplane sink (-1.9 m/s; -3.7 kt)
including airmass vertical sink and (-0.5 m/s; -0.97 kt)
+ sailplane's polar sink rate (-1.4 m/s; -2.75 kt)

V_{stf} = speed - to - fly (140 km/h; 75.5 kt)
V_{cruise} = cruise speed (48 km/h; 25.9 kt)

In our example, an expected climb of 1 m/s results in an interthermal glide speed of 120 km/h; during the glide the variometer will read −1.05 m/s.

The cruise speed will be 58 km/h.

This constructed figure is similar to that on page 99, which was drawn for a completely different purpose: best glide distance in sinking air.

Thus, we find that the same speed-to-fly results whether we want to fly as *far* as possible in an airmass sinking at 1 m/s, or as *fast* as possible in still air with 1 m/s thermals. The variometer indication, however, will differ by 1 m/s — that is, the amount of the expected climb.

Thus, for a speed-to-fly ring to be useful for speed optimization as well as glide optimization, it must be installed so that it can be rotated about the variometer. *If the 0-mark is set at the expected lift, the variometer needle will indicate the speed-to-fly for optimum cruise speed.*

GLIDE FROM THERMAL TO THERMAL IN MOVING AIRMASS

Further assumption: the climb in expected thermals is known and remains constant with altitude.

If the airmass moves downward during the glide, we must add the sink rate of the air to the sailplane polar sink rate to obtain the actual sink rate. Thus, the polar in our diagram must be displaced downward by an amount equal to the airmass sink rate. Of course, rather than moving the polar, we displace the coordinate system upward.

In the depicted example we see that we'll have to fly at 140 km/h if the airmass between thermals is sinking at 0.5 m/s and the next thermal is expected to yield a climb of 1 m/s. If the entire airmass between thermals were sinking at 0.5 m/s, the cruise speed of the ASW 15 would decrease to 48 km/h; the variometer will indicate −1.9 m/s.

If the airmass sinks 1.5 m/s and the anticipated next climb rate is zero, then the best glide distance appears at 140 km/h with a variometer indication of

−2.9 m/s — again, exactly 1 m/s difference, which corresponds to the expected climb. Thus: *A speed ring set at the expected climb commands the correct speed-to-fly even in vertically-moving airmasses, whether rising or sinking.*

The movable speed ring was developed by Paul MacCready, who published his ideas in 1949 and became World Champion at St. Yan in 1956.

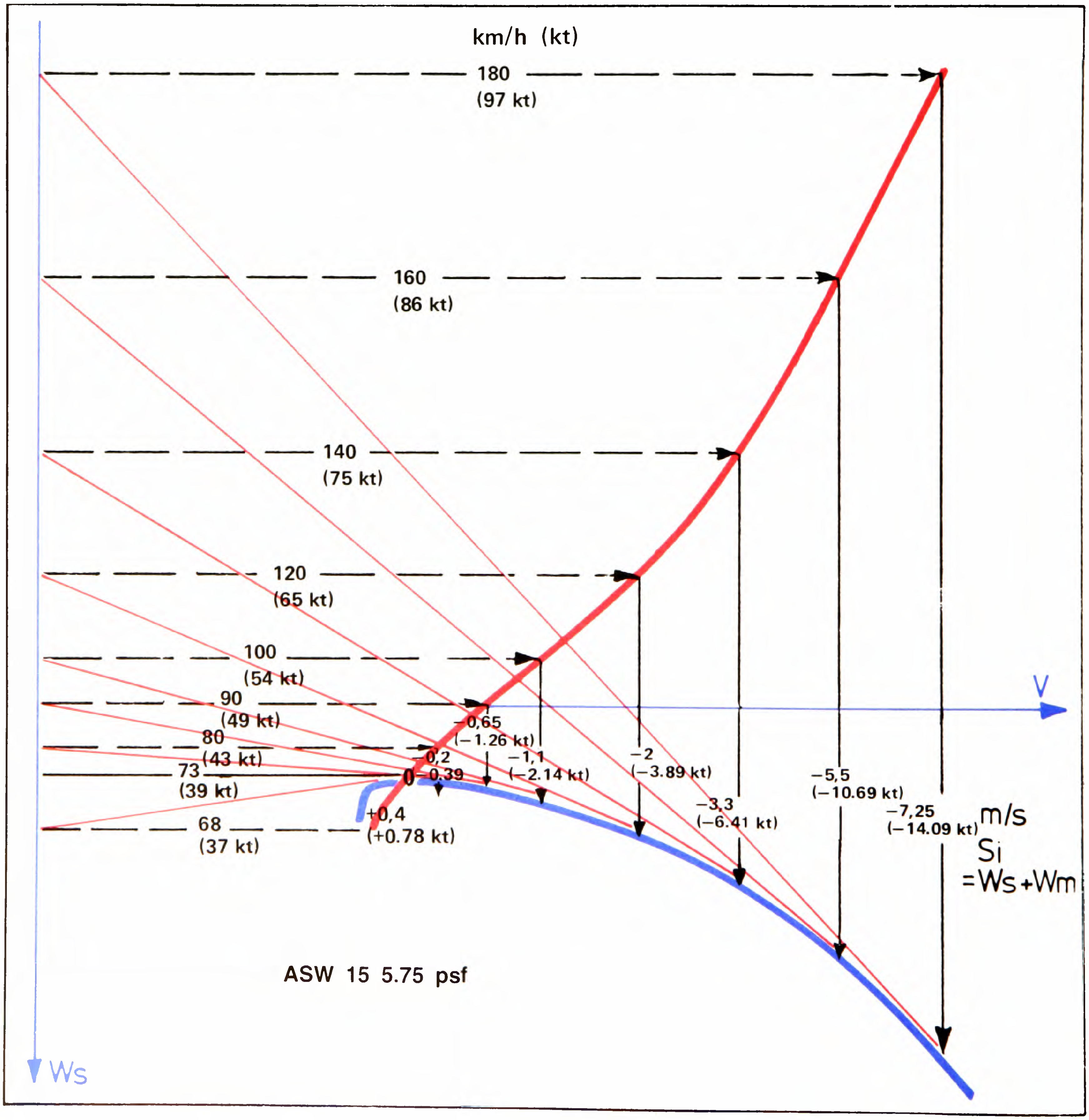
— If this graphic explanation does not appear sufficiently exact or logically rigorous, the mathematic derivation of the speed-to-fly equation can be found on page 104.

GRAPHIC CONSTRUCTION OF VALUE PAIRS FOR SPEED-TO-FLY RING

We will commence with the assumption that the expected climb rate will be zero, but that the airmass during the glide will have areas of lift and sink.

In the diagram, the coordinate system and polar for still air are shown in blue. The tangent from the origin to the polar yields the value pair V = 90 km/h, Si = -0.65 m/s. All the dashed black lines show the V-axis for variously moving airmasses; tangents (straight red lines) are drawn from each of their zero points to the polar. Each point of contact with the polar provides one value pair (V, Si). By constructing these tangents many times for different airmass vertical speeds one can obtain the "Speed-to-fly-curve" (thick red line) for all the value pairs of V and Si.

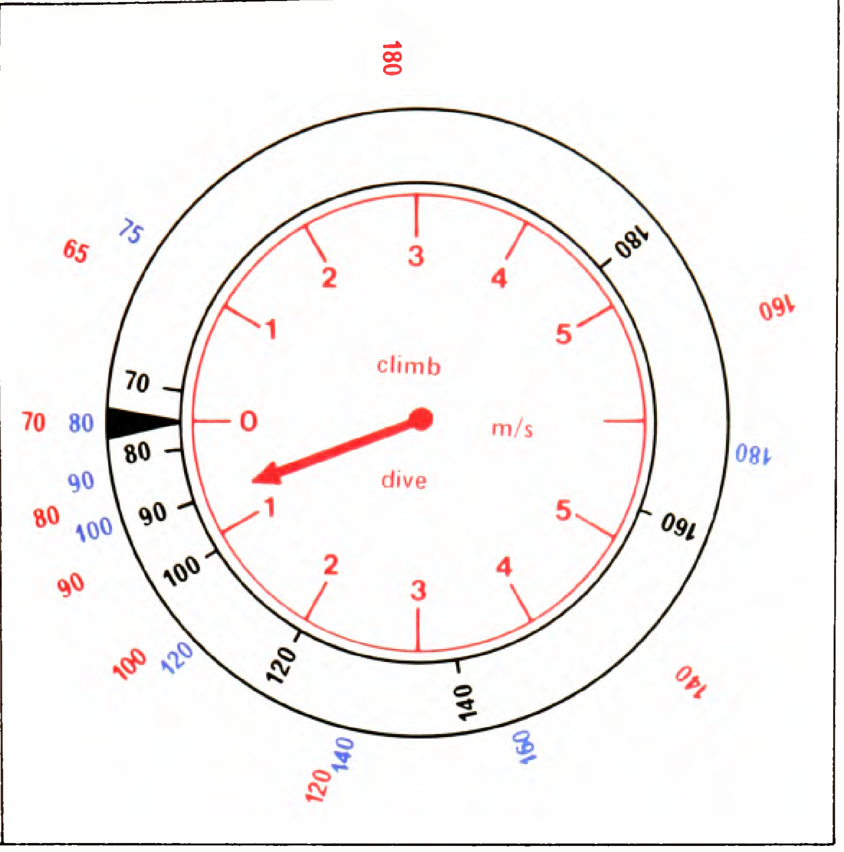
Graphic construction of values for speed-to-fly ring (MacCready ring)



Speed-to-fly ring

ASW 15, 5.75 psf
Speed-to-fly table
expected climb of zero

Speed-to-fly V in km/h (kt)	Sink Si in m/s (kt)
180 (97)	–7.25 (–14.09)
160 (86)	–5.3 (–10.30)
140 (75)	–3.3 (–6.41)
120 (65)	–2 (–3.89)
100 (54)	–1.1 (–2.14)
90 (49)	–0.65 (–1.26)
80 (43)	–0.2 (–0.39)
70 (37)	+0.25 (+0.49)



Black ring: speed-to-fly for wing loading of 5.75 psf

Blue ring: speed-to-fly for wing loading of 7.35 psf

Red ring: speed-to-fly for wing loading of 4.90 psf

Thus, for example, the tangent construction for V = 180 km/h, Si = –7.25 m/s has been shown (assuming airmass sink of –5 m/s); the value pairs for V of 100, 120, 140, 160, and 180 km/h are attained for sinking airmasses. V = 90 km/h obtains for still air.

The speed-to-fly of 73 km/h (minimum sink speed) results from an airmass *rising* at 0.58 m/s. The aircraft will then fly with no loss of altitude (Si = 0).

The speed-to-fly of 68 km/h results from an airmass rising at 1 m/s, resulting in a sailplane *climb* ("Si") of +0.4 m/s. This last case is, in a sense, a contradiction of the original assumption, since the construction was to have been made for a sailplane climb of zero; however, as we will see later, it has special significance for dolphin flight.

Changes in wing loading do not only result in a change in the polar, but require a change in the speed ring as well. The illustration shows a variometer and speed ring; the black triangle is the setting mark. The black speed-ring figures are those for a wing loading of 5.75 psf, while the blue and red figures are those for 7.35 and 4.90 psf respectively.

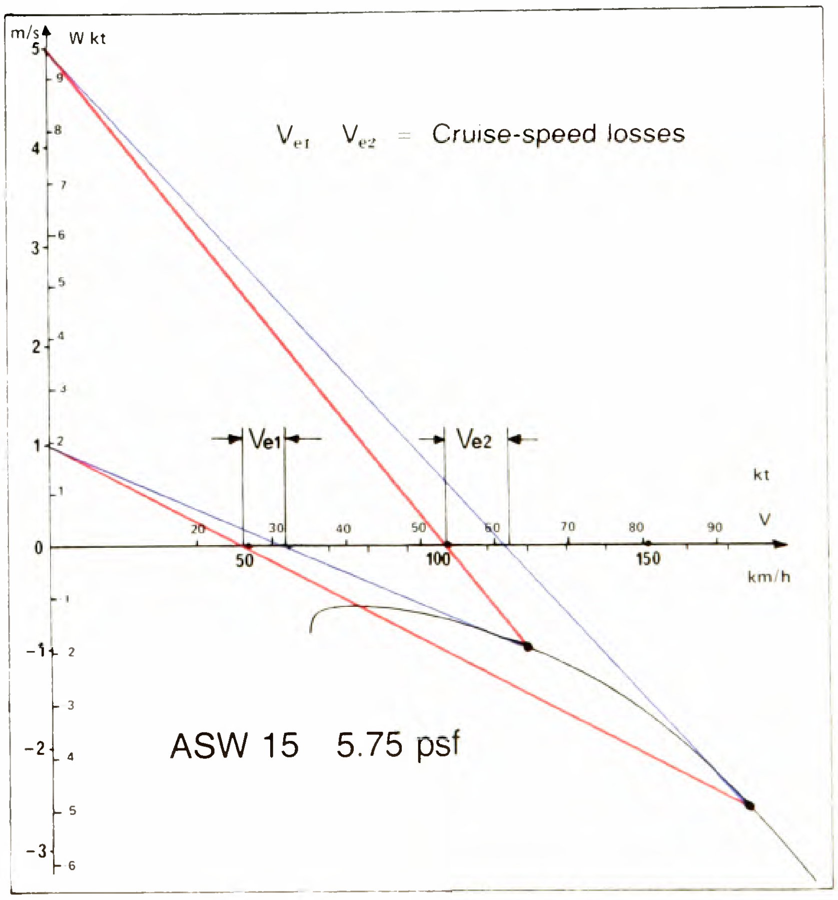
LOSSES DUE TO INCORRECT CHOICE OF AIRSPEED

Based on the general formula for cruising speed (equation #1), the loss of speed due to the choice of a non-optimal speed-to-fly can be represented graphically.

The illustration shows two examples in which the speed ring setting is extremely wrong. In the first case, an expected climb of 1 m/s would have required a speed of 120 km/h; however the pilot has completely misinterpreted the situation and has zipped off at 174 km/h, having set his speed ring at 5 m/s. Even so, his speed loss V_e is only about 10 km/h of cruise speed. In the second example, a setting of 5 m/s would have been proper, but the (overcautious) pilot has set the speed ring for 1 m/s and flown at 120 km/h; the loss of cruise speed is 15 km/h. Had he set the ring at zero, the loss would have been 37 km/h.

These extreme examples show that the cruise speed will not be significantly affected until rather large speed-ring errors are made. However, the zero setting is particularly unfortunate and should be avoided whenever possible.

Losses from incorrect speed-to-fly selection



THE "CLASSIC" CROSS-COUNTRY THEORY

DISCUSSED MATHEMATICALLY

Basic quantities:

V = airspeed

Si = sailplane sink speed in straight flight; always negative

Cl = sailplane climb in circling flight

To determine the average cruise speed V_{cruise} we base our computations on a given flight segment including glide and climb and ending at the same altitude as that at which it began.

During the glide the sailplane loses altitude h and covers distance e. Equations:

(1) average cruise speed:
$$V_{\text{cruise}} = \frac{e}{t}$$

(2) total flight time t:
$t = t_1 + t_2$ (t_1 = glide time, t_2 = climb time)

(3) altitude lost:
$-h = t_1 \cdot Si$ (Si = sink speed in glide)

(4) altitude gained while climbing:
$h = t_2 \cdot Cl$

(3/4) $t_2 = t_1 \cdot \frac{-Si}{Cl}$

(5) gliding time $t_1 = \frac{e}{V}$

used in equation (3/4):

(6) $t_2 = \frac{e}{V} \cdot \frac{-Si}{Cl}$

partial times used in equation (2):
$$t = \frac{e}{v}\left(1 + \frac{-Si}{Cl}\right) \rightarrow V_{\text{cruise}} = \frac{V \cdot Cl}{Cl - Si}$$

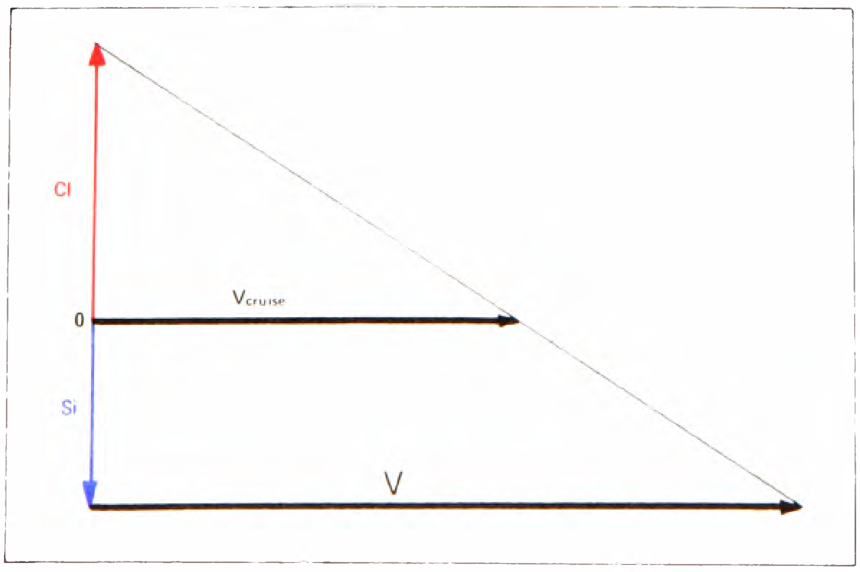
This condition holds true for any flown speed V and for any sailplane sink Si (which is the sum of sailplane polar sink Ws and the meteorological airmass movement Wm, either positive or negative).

The equation can also be converted to a ratio equation

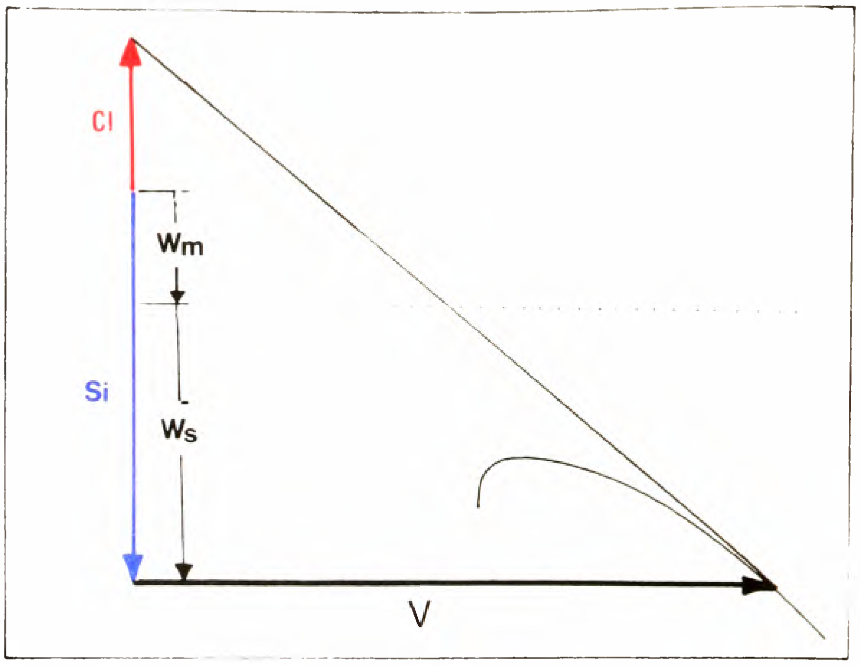
$$\frac{V_{\text{cruise}}}{V} = \frac{Cl}{Cl - Si} \qquad \text{equation \#I}$$

and can be depicted graphically according to the second rule of projection.

Mean cruise speed — rule of projection



Graphic representation of MacCready relationship



MATHEMATICAL DERIVATION OF SPEED-TO-FLY EQUATION

This is based on the same model of cross-country flight as that used for determination of cruise speed. Total time for the flight segment is;

(1) $t = t_1 + t_2$

or (2) $t = \frac{e}{V} + \frac{h}{Cl}$

t_1 = gliding time

t_2 = climbing time

e = glide distance

V = glide speed

h = altitude difference

Cl = climb rate

height lost in the glide is:

(3) $-h = \frac{Ws + Wm}{V} \cdot e$

Ws = sailplane polar sink rate

Wm = airmass motion

The use of the appropriate sign takes into consideration the fact that Ws is always less than 0 and that Wm can be either greater or less than zero. The sum (Ws + Wm) is the total sink rate Si.

By inserting the values of equation (3) into equation (2) we obtain:

(4) $$t = e \cdot \left(\frac{-(Ws + Wm)}{V \cdot Cl} + \frac{1}{V} \right)$$

The total time should tend to a minimum; we differentiate and set the derivative = 0:

$$\frac{dt}{dV} = e \cdot \left(\frac{-\frac{dWs}{dV} \cdot V \cdot Cl + (Ws + Wm) \cdot Cl}{(V \cdot Cl)^2} - \frac{1}{V^2} \right) = 0$$

since e > 0, the following obtains:

$$-\frac{dWs}{dV} \cdot V \cdot Cl + (Ws + Wm) \cdot Cl = Cl^2$$

$$\frac{dws}{dV} V = (Ws + Wm) - Cl \qquad \text{equation \# II}$$

This is the relationship which is the basis for the speed-to-fly ring.

The right side of the equation means:

$(Ws + Wm) - Cl$ = sailplane sink during glide (usually less than 0) minus expected climb; in its entirety, a negative expression.

The left side of the equation means:

$V \cdot \frac{dWs}{dV}$ = glide speed times slope of polar at point of airspeed V (since the slope of the polar in the gliding range is always negative, this is also a negative expression).

A graphic depiction of this purely mathematical derivation would be the well-known construction of tangents to the polar.

MATHEMATICAL EQUATIONS FOR SPEED POLARS

The ability to express the sailplane polar as an equation is necessary for optimization calculations as well as for the design and construction of cruise-control and similar computers. Such polars can be expressed fairly well through use of the quadratic equation:

$$Ws = aV^2 + bV + c \qquad \text{equation \# III}$$

This approximation is achieved by insertion of three value pairs (V/W) of the polar into the equation system:

$$W_1 = aV_1^2 + bV_1 + c$$
$$W_2 = aV_2^2 + bV_2 + c$$
$$W_3 = aV_3^2 + bV_3 + c$$

In order to achieve a good correspondence between the polar and the equation in the gliding area — that is, at speeds starting with that for best glide — Kauer recommends setting point 1 (W_1/V_1) at the best glide, point 2 (W_2/V_2) at redline speed, and point 3 (W_3/V_3) about halfway between. Solution of the equation system results in values for the polar equation

$$Ws = aV^2 + bV + c$$

$$a = \frac{(V_2 - V_3)(W_1 - W_3) + (V_3 - V_1)(W_2 - W_3)}{V_1^2 (V_2 - V_3) + V_2^2 (V_3 - V_1) + V_3^2 (V_1 - V_2)}$$

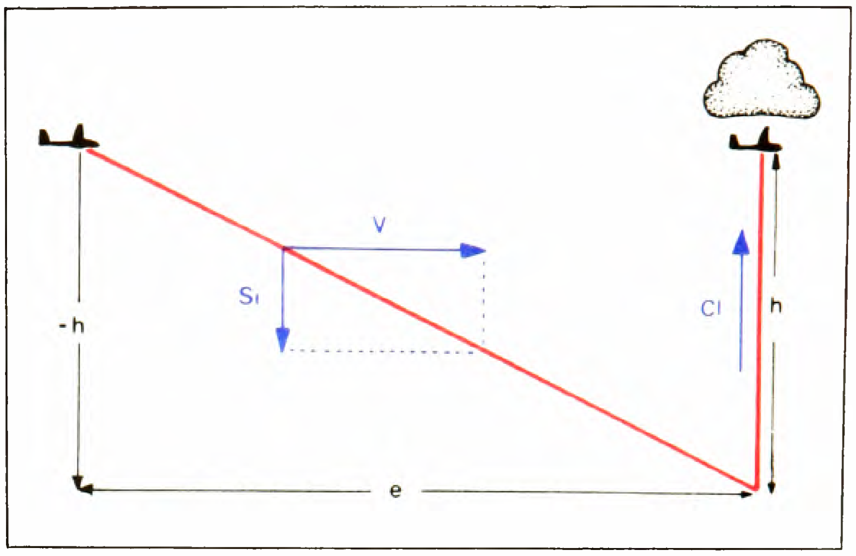
$$b = \frac{W_2 - W_3 - a(V_2^2 - V_3^2)}{V_2 - V_3}$$

$$c = W_3 - a V_3^2 - bV_3$$

The example of a polar calculated in this fashion, that of the ASW 15, shows how well the resultant parabola corresponds with the actual polar.

Since sailplanes in the Standard Class seldom use speed-to-fly values of more than about 180 km/h, it is worthwhile for speed-to-fly calculations to set the three points mentioned above at best glide, at 180 km/h, and about halfway between. This improves the accuracy of the calculation even further.

“Classic” model for cross-country flights



The above approximation of a polar by a quadratic equation is not based on physical quantities, but has the advantage of being easy to work with in instrumentation (onboard computers, etc.).

A physically-based polar equation would have the form $Ws = a \quad + bV^3$; this is based on the formulas for profile and induced drag. This would actually result in an even closer approximation, even though the equation has only two coefficients.

CALCULATION OF THE POLAR FOR NEW WING LOADINGS

If the wing loading is changed, each polar point P will be extended from the origin based on the following relationship:

$$\sqrt{\text{new wing loading}} \; : \; \sqrt{\text{old wing loading}}$$

CHANGE OF POSITION OF POLAR POINT “P” WITH CHANGES IN WING LOADING

$\frac{G}{F}$ = original wing loading

$\frac{G'}{F}$ = new wing loading

$$\sqrt{\frac{G'}{F}} \cdot \sqrt{\frac{G}{F}} = \sqrt{\frac{G'}{G}} = A = \text{scale factor}$$

based on requirements for the graph:

$$\frac{\overline{OP'}}{\overline{OP}} = A$$

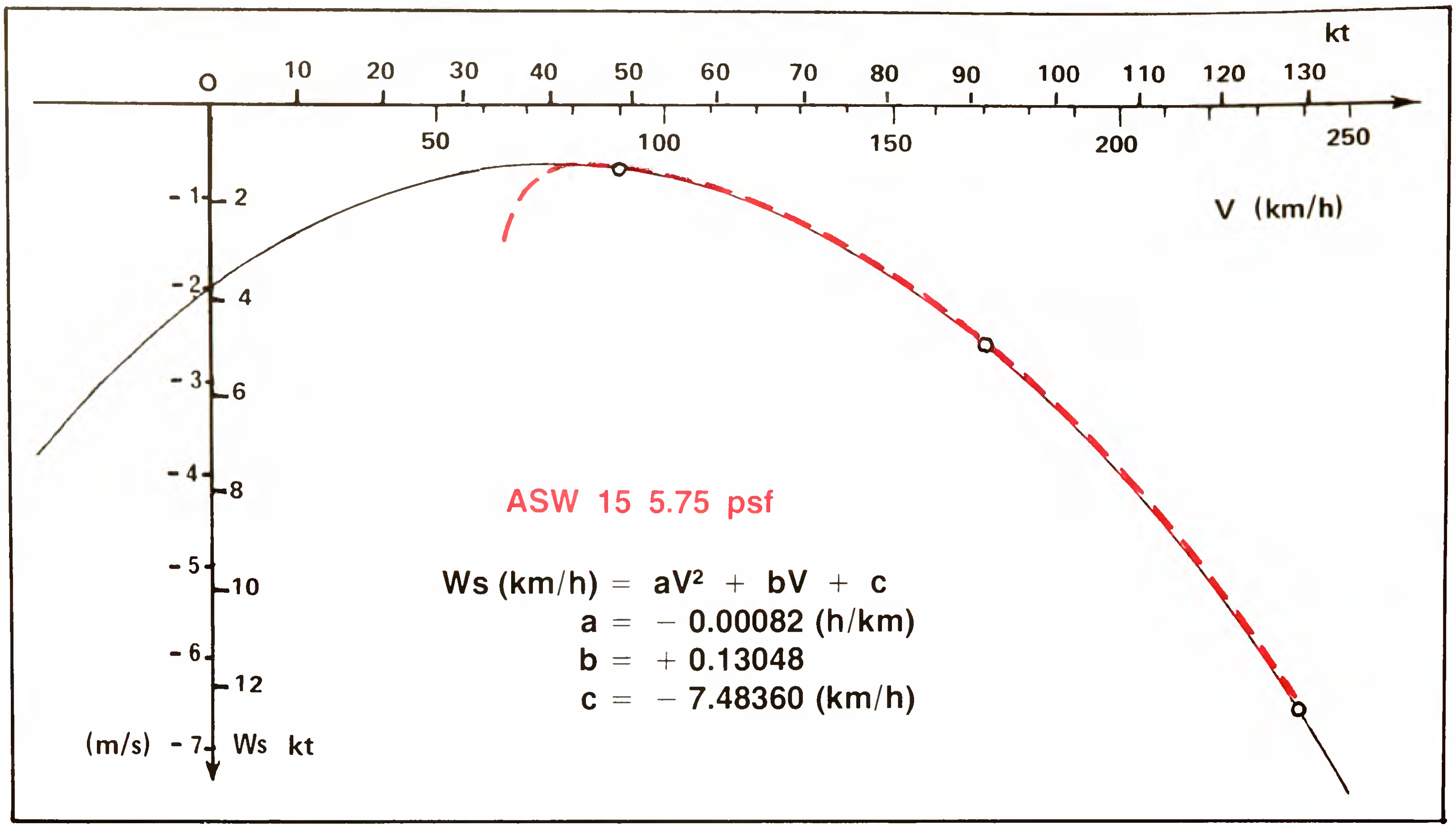
rule of projection:

$$\frac{V'}{V} = \frac{\overline{OP'}}{OP} = A$$

$$V = \frac{V'}{A}$$

rule of projection:

$$\frac{Ws^1}{Ws} = \frac{\overline{OP'}}{\overline{OP}} = A$$



Speed polars — polar equation

$$Ws = \frac{Ws'}{A}$$

These values are inserted into the general polar equation # III:

$$\frac{Ws^1}{A} = a\left(\frac{V'}{A}\right)^2 + b\,\frac{V'}{A} + c$$

$$Ws' = \frac{a}{A}\,V'^2 + bV' + Ac$$

thus:

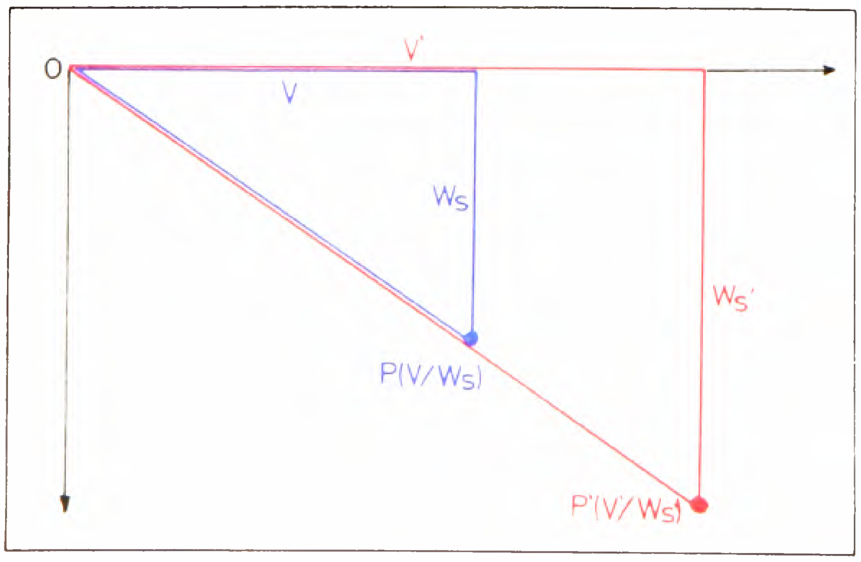
$$a' = \frac{a}{A}$$

$$b' = b$$

$$c' = Ac$$

With these conversion factors a polar can be recalculated for a new wing loading or sailplane weight.

Change of position of polar point P with changed wing loading



CALCULATION OF SPEED-TO-FLY RING MARKINGS

Kauer shows how the speed-to-fly scale can be calculated from the polar equation, if one inserts the latter into the MacCready equation (47):

$Ws = aV^2 + bV + c$

inserted into the speed-to-fly equation (II):

$(2aV + b)\,V = (Ws + Wm) - Cl$

The right-hand expression gives the distance to mark off on the variometer ring for the speed mark V. For the case in which expected climb is equal to zero, the mark for V is defined as

$$\text{Marking location} = 2aV^2 + bV \qquad \text{equation IV}$$

CALCULATION OF OPTIMUM GLIDE SPEED

Assuming an expected climb Cl and airmass movement Wm, Ws is taken from the polar equation and inserted in the speed-to-fly equation (II) and solved for V:

$$V_{stf} = \sqrt{\frac{c + Wm - Cl}{a}} \qquad \text{equation V}$$

(speed-to-fly)

Since Cl is always positive, but c and a are negative, increased sink — in other words, negative values of Wm — increases the speed-to-fly. If Wm goes positive, speed-to-fly decreases; if Wm = Cl, V_{stf} becomes $\sqrt{\frac{c}{a}}$, which represents best glide speed.

If $Wm = Cl - Ws_{min}$ (Ws is always negative), V_{stf} becomes $\frac{-b}{2a}$, the same as the airspeed for minimum sink.

OPTIMUM AVERAGE CRUISE SPEED

In the case of flight based on speed-to-fly in still air, based on equation V the following is valid:

$$V = \sqrt{\frac{c - Cl}{a}}$$

Inserted in polar equation III, this results in

$$Ws = 2c - Cl + b\sqrt{\frac{c - Cl}{a}}$$

From this, the optimum cruise speed can be calculated by equation I:

$$V_{cruise_{opt}} = \frac{Cl \cdot \sqrt{\frac{c - Cl}{a}}}{2\,Cl - 2c - b\sqrt{\frac{c - Cl}{a}}}$$

equation VI

Dolphin Flight

Dolphin flight is the straight-flight segment of cross-country flight based on speed-to-fly theory.

DOLPHIN FLIGHT IN MINIMUM CONDITIONS

(Not optimum flight; "forced dolphin flight")

If the weather conditions are barely good enough to allow us to fly straight ahead with no loss of altitude, we shouldn't really do it, since we'll actually achieve a lower cruising speed than we would using the "classic" method. None the less, we should run through the theoretical possibilities of such flight, since that will serve to facilitate introduction to dolphin flight theory.

In order to glide with minimum loss of altitude, we'll set our speed ring at zero (the same as for maximum distance in still air). This will achieve the flattest glide path.

In order to gain the most height in straight flight, we must fly the steepest possible climb path.

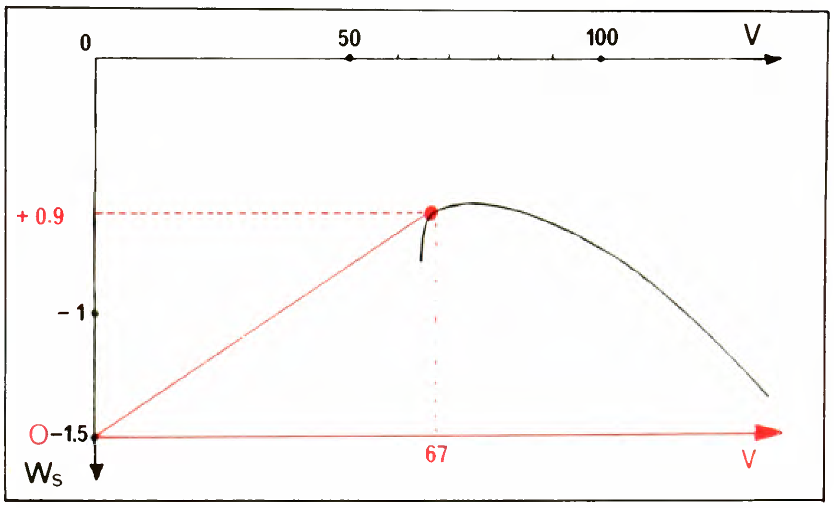
This can be calculated with polars: the polars must be displaced upward (for this purpose) by the amount of airmass movement (in our example 1.5 m/s). One can, of course, displace the coordinate system downward instead. The tangent representing the steepest climb path indicates a speed-to-fly that is actually lower than the sailplane minimum sink speed.

In the ASW 15 polar used here, this would result in a speed-to-fly of 67 km/h (compared to a minimum sink speed of 73 km/h). The sailplane would climb at 0.9 m/sec.

For dolphin flight the MacCready ring must be extended upward; above the O-mark, the speed-to-fly values are continued down to the stalling speed.

In practice, of course, one will try to avoid flight too close to the stall, so that in the case of the ASW 15 one would hardly recommend flight slower than 70 km/h.

Path of steepest climb



DOLPHIN FLIGHT MODELS

In order to at least partly understand the complex problems of dolphin flight on a mathematical basis, one starts out from simplified, more or less typical, meteorological lift-distribution models. Conclusions drawn from these models must be taken with caution, since if one is to be rigorous one must bear in mind that any such conclusions can be proved only with regard to the particular model used.

1st MODEL (ANTWEILER, JONAS)

P. Antweiler based his thoughts on a rectangular distribution of lift and sink (see graph), calculated the dolphin-flight cruise speed and drew the appropriate projective figure.

K. Jonas worked with the same model and calculated the possible cruise speeds for both "classic" and dolphin flight for various climb rates, lift/sink distributions, and aircraft performance figures.

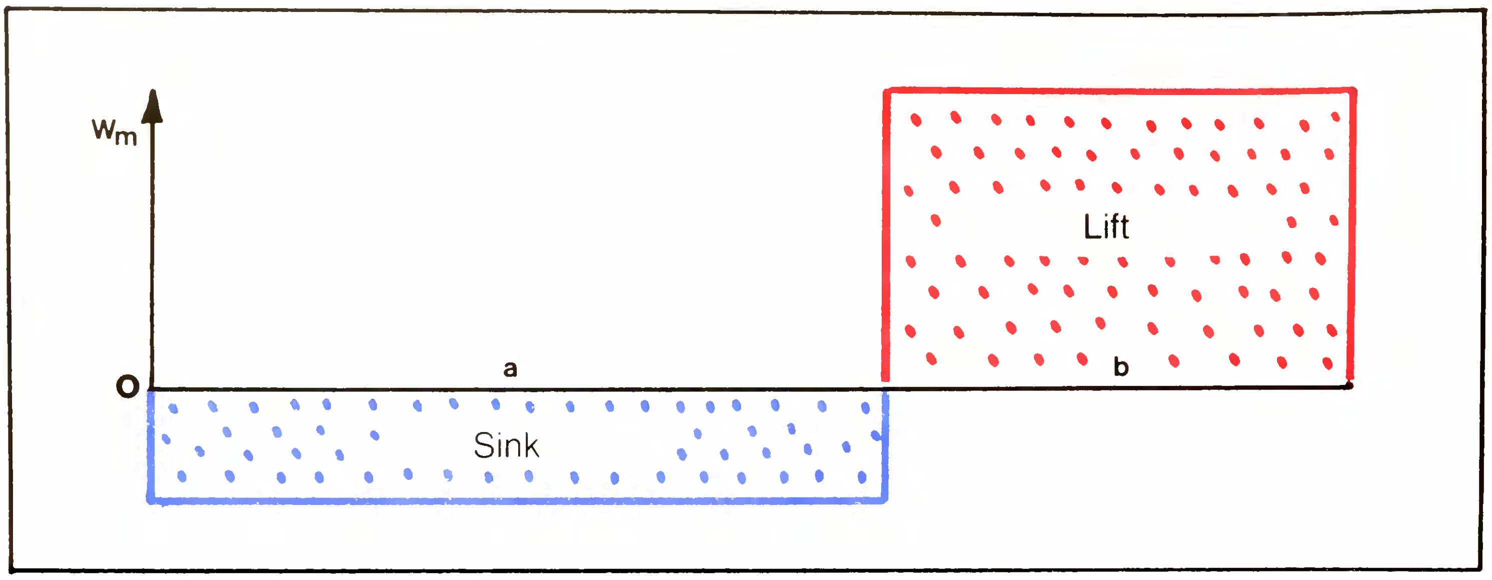
Dolphin cruise speed can be generally calculated from the partial times t_1, t_2, and the partial distances a and b. (Si is negative, since it is directed downward.)

$$t = t_1 + t_2 = \frac{-h}{Si} + \frac{h}{Cl}$$

$$V_{crd} = \frac{a + b}{t} = \frac{a + b}{h} \cdot \frac{-Si \cdot Cl}{Cl - Si}$$

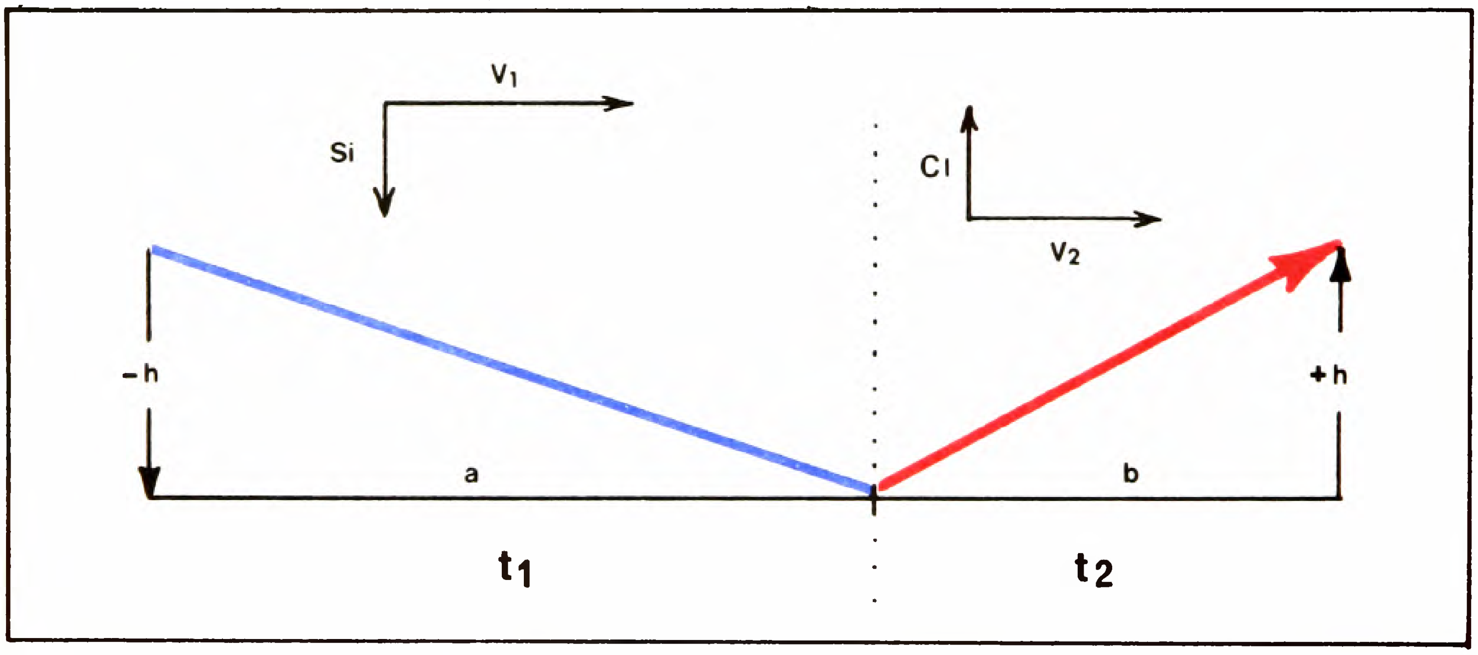
with $\frac{a}{-h} = \frac{V_1}{Si}$ and $\frac{b}{h} = \frac{V_2}{Cl}$ the result is:

$$V_{crd} = \frac{Cl}{Cl - Si} \cdot V_1 + \frac{-Si}{Cl - Si} \cdot V_2$$



1st Model (Antweiler, Jonas)

Flight path for 1st Dolphin flight model



Wm = vertical speed of airmass motion

a = segment flown in sink

b = segment flown in lift

V_1 = airspeed for segment a

Si = sink speed for segment a

V_2 = airspeed for segment b

Cl = climb speed for segment b

if we insert

$$V_{crm} = \frac{Cl}{Cl - Si} \cdot V_1$$

$$V_{crz} = \frac{-Si}{Cl - Si} \cdot V_2$$

Thus, we can depict V_{crd} as the sum of V_{crm} and V_{crz} according to the rule of projections.

Let us assume that the area of lift is just long enough compared to the total distance so that with a speed ring setting equal to the straight-ahead climb rate Cl, the resultant dolphin flight ends up horizontal overall. We can then depict dolphin flight with the aid of polars.

When we compare this with the previous illustration it becomes clear that the dolphin-flight cruise speed V_{crd} is greater by the amount V_{crz} than the "conventional" MacCready or "classic" cruise speed V_{crm} (compare with page 104).

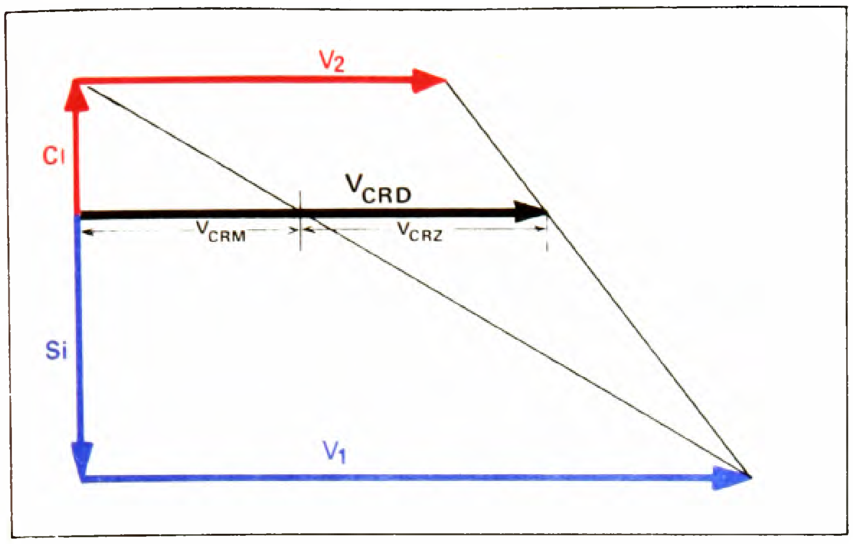
V_{crz} represents the increase which occurs if the airmass climb rate Wmb is not restricted to small areas, but rather sufficiently spread-out so as to allow horizontal dolphin flight with the speed ring set at Cl.

This construction of dolphin cruising flight shows how the construction of cruise speed on the MacCready method is actually a special case of a more general speed-to-fly theory, a case in which V_2 — cruise speed during climb — is set at zero (circling climb).

If the area of lift, compared to the entire distance, is not sufficient for pure dolphin flight at speed-ring setting Cl, a "forced" dolphin flight may still be possible at a lower ring setting. However, Jonas has proved mathematically that the highest cruise speed will still be obtained with the speed ring set at Cl, resulting in a dolphin flight with overall altitude deficit that is made up by circling from time to time.

(The difference between climb rate in straight flight and while circling is not included in the calculation, nor are centering times and similar difficult-to-measure quantities.)

Cruise speed for Dolphin-style flight



2nd MODEL (KAUER, JUNGINGER)

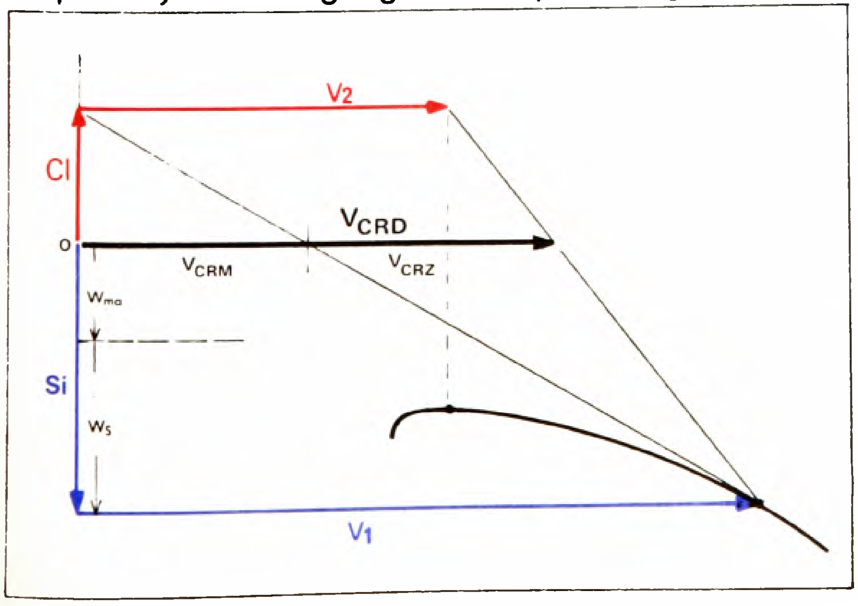
Sinusoidal distribution of Lift and Sink

E. Kauer and H. J. Junginger examined which flying "style" would achieve the best cruise speeds from a given weather setting, making extensive use of computer simulation. They showed that the speed ring retains its validity. In the case of sinusoidal areas of lift and sink that just barely allow "forced" dolphin flight by means of a very low ring setting, they proved the definite superiority of the conventional MacCready method (ring set at the full climb rate, height deficits made up by circling in lift centers).

For example: with a maximum sinusoidal meteorological climb rate of 4 m/s, a cruise speed of 110 km/h can be achieved in a Standard Cirrus if the speed ring is set at the maximum sailplane climb rate of 3.4 m/s. Using this figure, somewhat too much altitude is lost overall and must be regained by circling in lift.

Under the same weather conditions, pure dolphin flight (no circling at all) is possible at a speed ring setting of 0.5 m/sec; the cruise speed, however, is only 100 km/h!

Dolphin-style cruising flight with speed-ring setting St



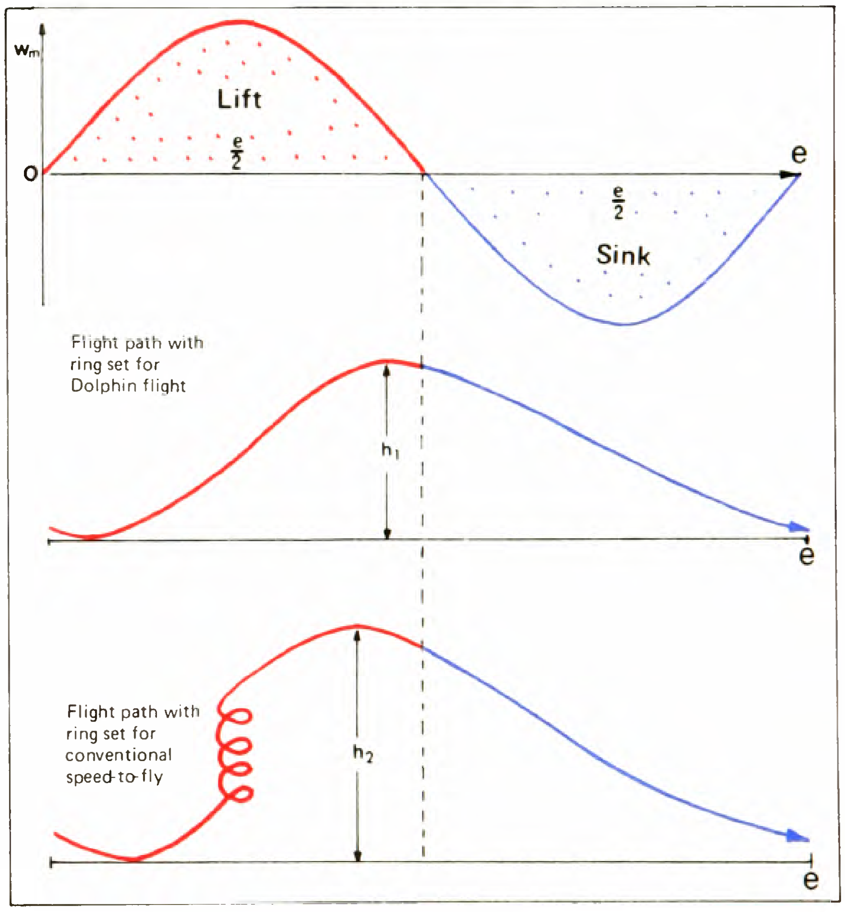
This superiority of the "classic" technique decreases as airmass vertical speeds increase, and is less than 1% when the lift reaches 6 m/s.

Thus, the superiority of "classic" techniques has been proven for sinusoidal distribution of lift and sink; further models tend to confirm this. The point at which a speed ring setting equal to the actual climb results in an almost loss-free dolphin flight is fairly high, but only for sinusoidal lift-sink distribution. The values that Kauer obtained for the Standard Cirrus can be found on page 110.

For example, with a meteorological (airmass) climb rate of 6 m/s, 91% of the flight time is spent cruising straight ahead, and 9% circling in lift.

COMPARISON OF TRADITIONAL SPEED-TO-FLY TECHNIQUES WITH DOLPHIN FLIGHT

The sinusoidal distribution of lift and sink satisfies the requirement of continuity — that is, as much air as is carried aloft comes back down somewhere else. In other words, this represents a situation where the pilot's choice of course has not allowed him to achieve a better balance of lift to sink than the overall atmospheric average.



Hans-Werner Grosse has reported (page 61) cruise speeds of 90 km/h in an ASW 17 with a sailplane climb rate of 1 m/s. This fact tends to contradict Kauer's calculated results, even when one considers the influence of higher aircraft performance. Obviously it is possible in practice — particularly in weather conditions that offer some visible sign of thermals such as clouds — to pick a course that will result in a considerably better lift/sink balance than that required to fulfill the requirements of continuity. The result of this is that pure dolphin flight is actually possible at lower atmospheric climb rates than Kauer's figures indicate. Moreover, the assumption used in the model — that the *areas* of lift and sink are equally large — seldom seems the case.

Since further performance losses occur in circling flight because of centering inaccuracy and the increased circling sink rate, the picture becomes even more favorable for dolphin flight — as Kauer admits himself.

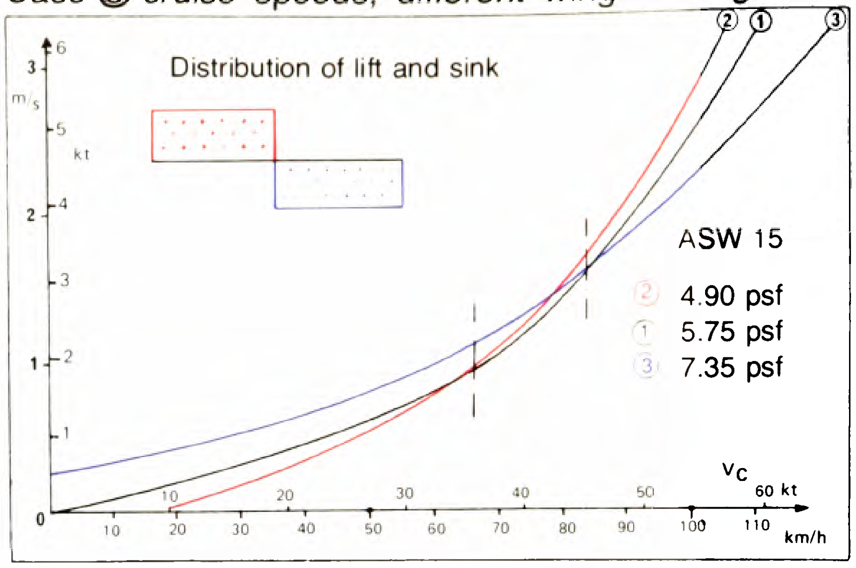
Thus, although the superiority of "classic" flight has been mathematically proven for sinusoidal lift/sink distribution, the fact that in practice we can pick our course so as to improve the lift/sink ratio displaces the moving border where classic flight automatically becomes dolphin flight. The change to dolphin flight can be explained in that the advantage of airspeed changes allows straight flight with no altitude loss in favorable atmospheric conditions.

Since in "classic" flight the circling climb rate, which—according to Kauer's results — is set into the speed ring, is always less than that of a sailplane flying straight through the same area of lift, dolphin-speeds-to-fly result that are actually less than the sailplane minimum sink speed. Theoretically, the speed ring should be extended above the zero mark for these figures (see also page 103).

Comparison: Pure Dolphin Flight vs. "Classic" Flight

Maximum Meteorological Climb Rate (m/s)	Dolphin Flight in Sinusoidal Lift Distribution			"Classic" Flight in Sinusoidal Lift Distribution			
	Cruising Speed (km/h)	Speed Ring Setting	Straight Flight (%)	Cruising Speed (km/h)	Speed Ring Setting	Straight Flight (%)	Circling Flight (%)
1	Pure Dolphin Flight Not Possible			37	0.4	40	60
2				74	1.4	68	32
3				95	2.4	78	22
4	100	0.5	100	110	3.4	83	17
5	119	2.5	100	122	4.4	87	13
6	130	4.1	100	131	5.4	91	9
7	138	5.5	100	139	6.4	93	7
8	145	6.8	100	145	7.4	96	4
9	151	7.9	100	151	8.4	97	3
10	156	9.0	100	156	9.4	99	1
11	160	10.1	100	160	10.4	100	-0

Case ③ cruise speeds, different wing loadings



3rd MODEL (WAIBEL)

G. Waibel's model is similar to that of Antweiler (rectilinear distribution of lift and sink). However, it adds the requirement of continuity: that is, exactly as much air must be transported upward as downward.

His calculations are based on three different relationships between lift and sink distances:

Case 1	1 : infinity
Case 2	1 : 3
Case 3	1 : 1

Due to the continuity requirement, the sink in case 1 is nil, in case 2, ⅓ as strong, and in case 3, equally as strong as the lift.

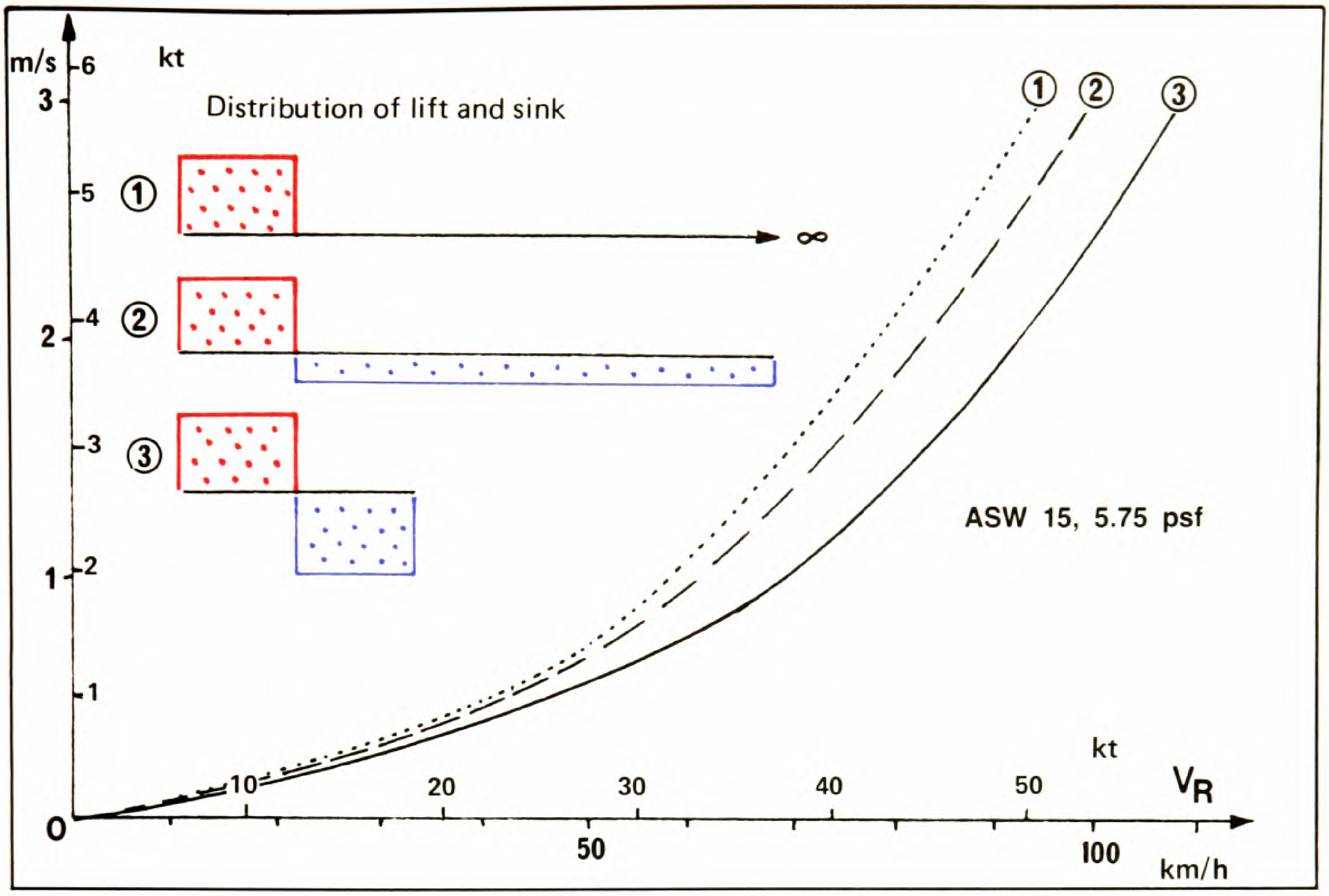
He goes on to calculate the optimum cruise speeds for different lift (and hence sink) strengths, including both "classic" flight with circles flown at 40° bank angle as well as "pure" dolphin flight.

The illustration shows the calculated optimum cruise speeds for case 3. Let us examine first the black 5.75 psf curve. As soon as the sailplane is able to climb at all, cruising is possible; this is the reason why this curve goes through the zero point. The lighter sailplane 2 is already climbing when sailplane 1 is just at the zero point, and attains a cruise speed of 20 km/h. The heavier sailplane 3 doesn't even begin until sailplane 1 is making good 27 km/h and sailplane 2 is cruising at 37 km/h. If the soaring conditions are even slightly worse, sailplane 3 will have to land. This shows very clearly the superiority of light wing loadings in weak conditions.

In the areas of cruise speeds between 67 and 84 km/h the cruise-speed curves cross such that now the heavy sailplane cruises faster than the lighter ones. This superiority of the heavier sailplane increases further if the lift is stronger than 2 m/s.

The higher the cruise speeds, and hence the higher the lift and sink rates, the more efficient is dolphin flying, since circling becomes a smaller and smaller proportion of the total flight.

The graphs for cases 1 and 3 are not depicted. However, they are quite similar, although for case 1 a high proportion of circling, and in case 2 a lesser amount (but still greater than that of case 3) are



noted. In both cases the cruise curves intersect in the area between 1.5 and 2 m/s lift.

The next illustration shows the optimum cruise speeds for constant wing loading (5.75 psf). Curves 1, 2 and 3 represent the three cases of lift/sink distribution mentioned above; thus curve 3 is the same as in the preceding graph's curve 1.

We see that the lift-sink relationship of case 3 produces the highest cruise speeds. This is due to the equality of the lift and sink areas which lead to a greater difference of the vertical air movement and allow a more effective dolphin flight, with greater airspeed changes. Thus, less circling is necessary than in case 2 and especially case 1. Waibel has calculated that this tendency also obtains for other wing loadings.

Furthermore, Waibel's calculations suggest that it will be worthwhile to load a sailplane as heavily as possible for lift in excess of 2 m/s, and as lightly as possible for lift less than 1.5 m/s (note case 3). This last, however, must be considered only in connection with Waibel's thermal model (continuity requirement and circling bank 40°).

4th MODEL (REICHMANN)

This model *does not* satisfy the continuity requirement. Rather, it is based on a situation typical for flight under cloud streets: lift is available over the entire distance, but its strength varies. In the model very small centers of strong lift, in which a sailplane could climb effectively while circling, alternate with large areas of weaker lift. In order to simplify airspeed optimization, we will further assume that the areas of strong lift compared to weak lift are so small that their effect on pure dolphin flight can be disregarded.

While one of the basic conditions of the previous models has been that the altitude at the end of each flight segment had to be the same as that at the beginning (horizontal flight path), the following model will be expanded to include climbing and descending flight paths.

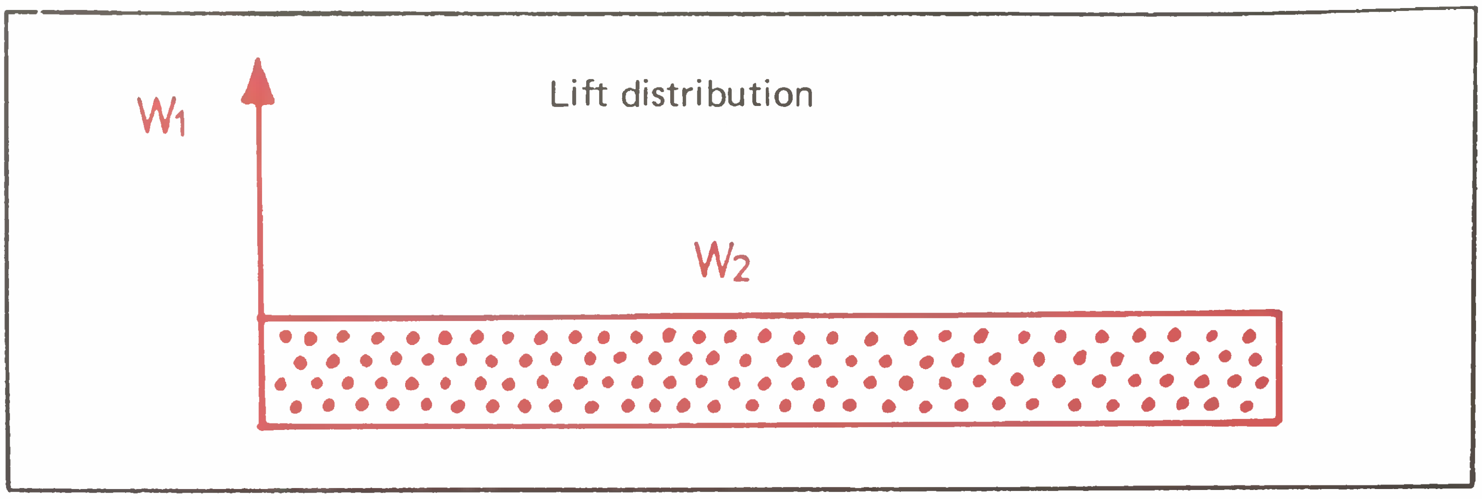
All results can easily be modified for models in which it is assumed that the air between the areas of lift either sinks or is completely at rest.

Case (1) Overall altitude remains constant (as in case 1 on page 24)

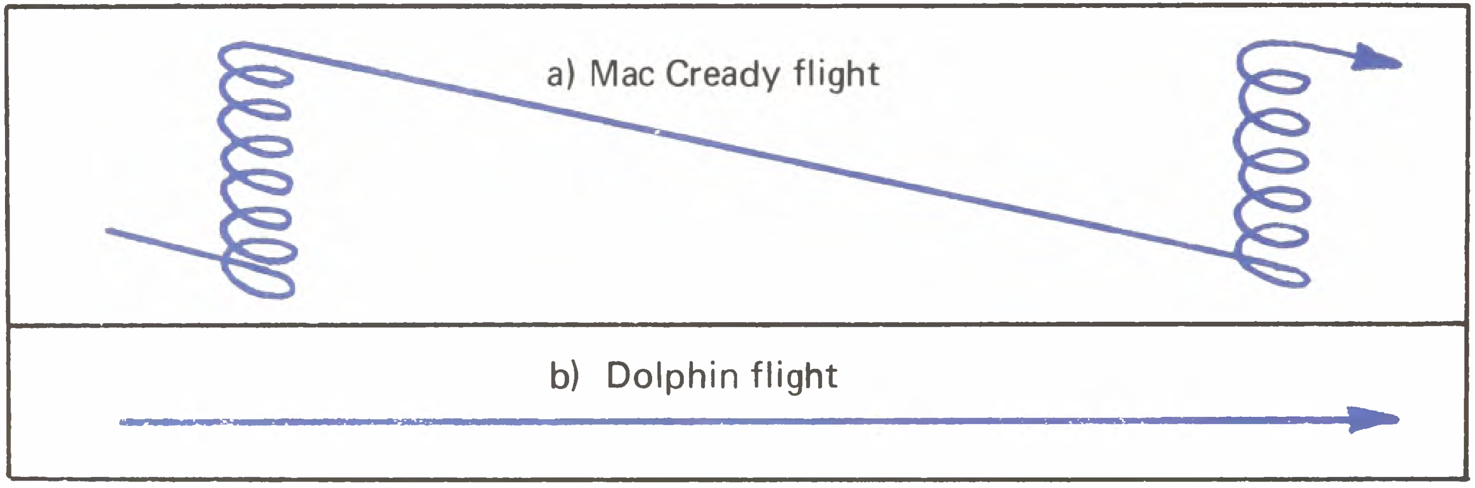
It will be proved, or rather substantiated by this model system, that the highest cruise speeds are obtained by setting the speed ring at the climb rate achieved in circling flight.

Whether or not pure dolphin flight will be possible depends on the initial values W_1 and W_2, as do the questions of whether dolphin flight will achieve optimum cruise speeds, or even if the speed ring should be set at a value higher than actual. For example, let's take a "point source" meteorological climb of 3.6 m/s, in which a circling ASW 15 can achieve the sailplane climb rate W_{1F} of 3 m/s. The values for the weaker large-area climb W_2 have been assumed differently for the various cases (a) through (d) (in-

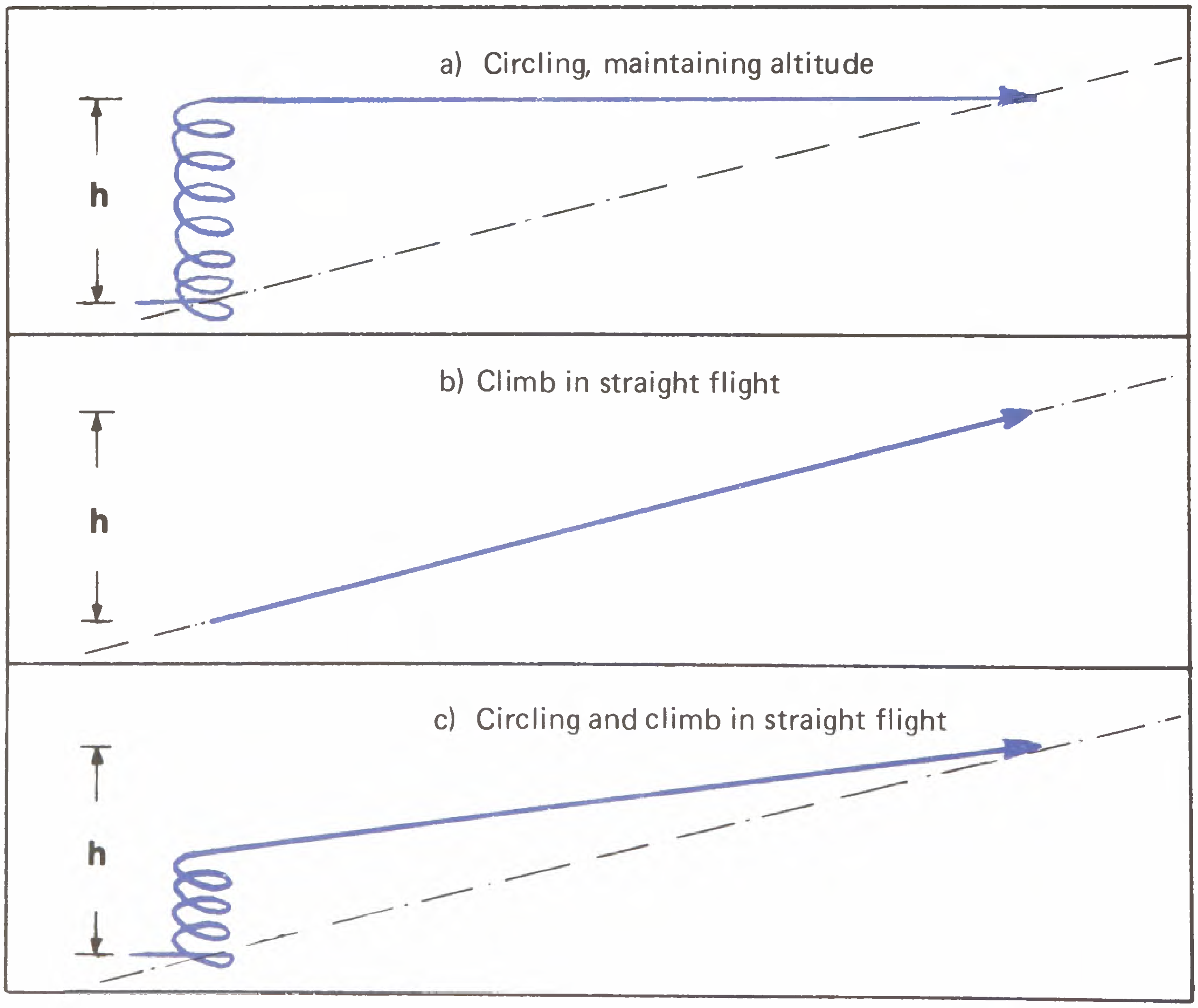
4th Model



Case ① height constant overall



Case ② height gain



creasing from one to the next) in order to depict all of the typical possibilities.

(a) The extended airmass climb W_2 is less than the sailplane's minimum sink rate:

In this case a climb of 0.4 m/s was assumed. The original zero polar (black dashed line) is moved upward by 0.4 m/s and is reproduced in red as the W_2 polar The optimum classic cruise speed V_{cro} is the section of the V-axis cut by the tangent from W_{1F} to the new polar. Pure dolphin flight is not possible.

(b) W_2 is equal to the polar minimum sink (0.58 m/s) :

The optimum classic cruise is obtained as in case (a). Pure dolphin flight with no altitude loss is possible using airspeed V_{crd} of 73 km/h; however, the classic cruise speed is considerably higher, at 108 km/h.

(c) W_2 is just strong enough to allow straight flight with no altitude loss with speed ring set at W_{1F}:

With an airmass climb of 1.2 m/s the sailplane's sink at a cruise speed corresponding to a speed-ring setting of W_{1F} (3 m/s) will just be compensated, so that despite the high ring setting no altitude will be lost in the areas of weaker lift. Circling becomes unnecessary and pure dolphin flight results "automatically" as a special case of the classic technique.

(d) The airmass climb W_2 is greater than the polar sink resulting from a ring setting of W_{1F} :

If one flies in this case based on speed-ring or speed-to-fly variometer, the result will be an ascending flight path at cruise speed $V_{rs.}$ If one were to fly at a very high airspeed (200 km/h drawn in this example) one would attain a new cruise speed V_{cr2} such that the altitude loss would be compensated by the sailplane climb rate W_{2F}.

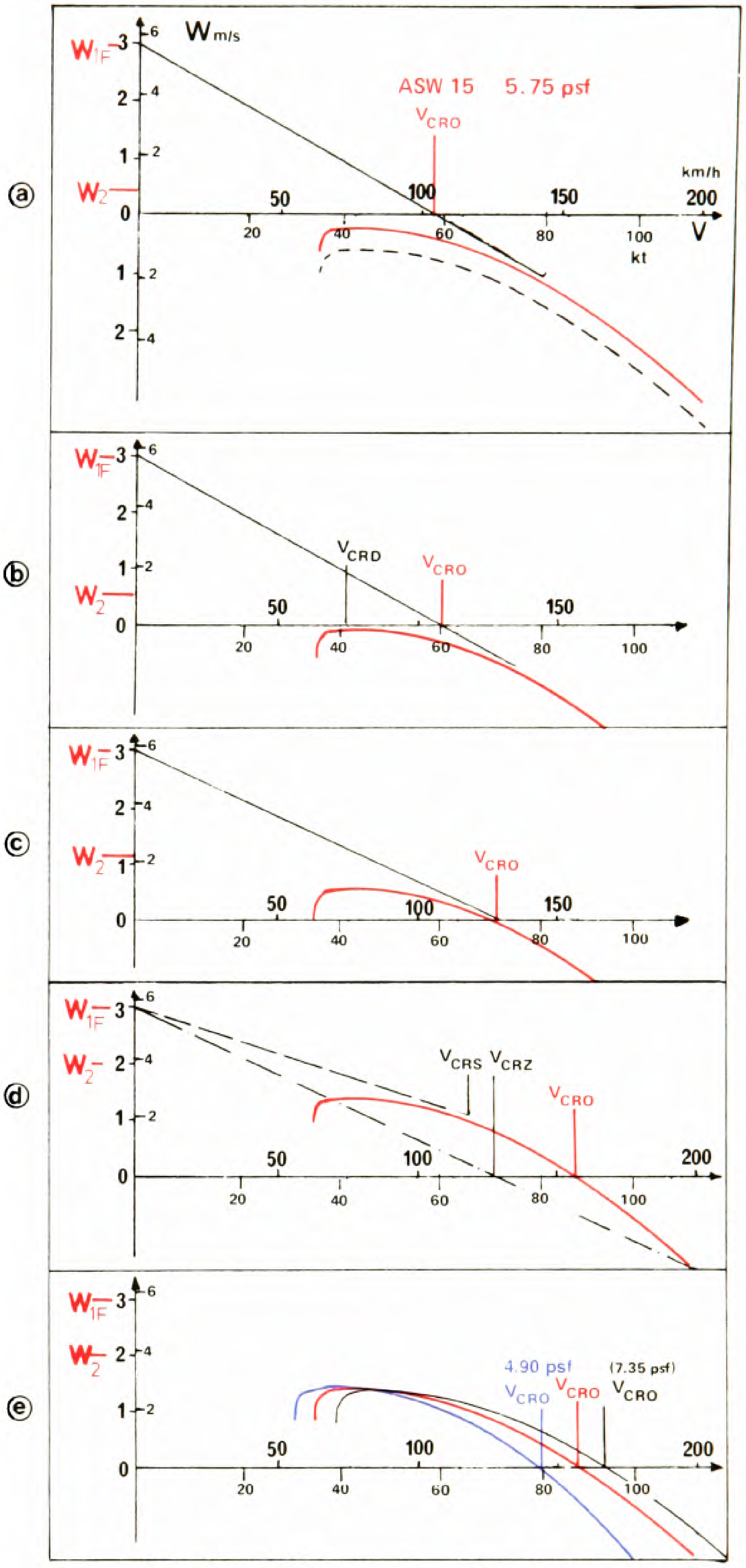
Since sailplane polars are normally positively curved, the optimum cruise speed V_{cro} for these cases is basically the intersection of the polar with the V-axis. In other words, one should fly such that the variometer indicates zero, even though this may cause the speed-to-fly variometer to indicate some value higher than W_{1F} (in this case 5 m/s rather than 3 m/s).

(e) Influence of wing loading on dolphin flight:

The higher the wing loading, the higher the cruise speed in dolphin flight will be (in general).

Only in an extreme borderline case might this last not hold true: If the airmass climb W_2 just equals the minimum sink of a light sailplane (as in case (b) above), and at the same time W_1 is so weak as to allow the heavier sailplane to climb only very slowly, the heavier sailplane — which would have to fly by the "classic" method — would be at a disadvantage. In general, though, higher weight is an advantage in cloud or lift streets as assumed for this model.

Case ① height constant overall



Case (2) : Ascending flight (as in case (2) on page 24).

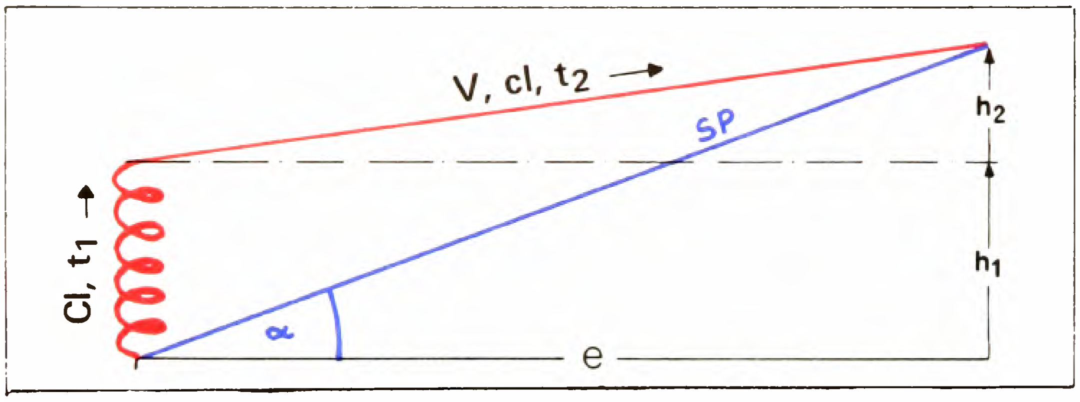
Let us assume that we have flown under a good-looking cloud street, are currently a thousand feet or so below cloudbase, and wish to depart from the end of the street at maximum altitude.

The question is whether to circle in the strongest lift, as well as what airspeed should be used for straight flight in order to achieve the desired cruise-climb objective.

Thus, we are given the distance, the necessary gain in altitude, and the weather conditions. Distance and altitude gain can also be defined in terms of desired flight path. The slope of this path is the relationship of altitude gain to distance (equal to the ratio of integrated climb speed to flight path cruise speed) or, as the case may be, the tangent of the flight path angle α.

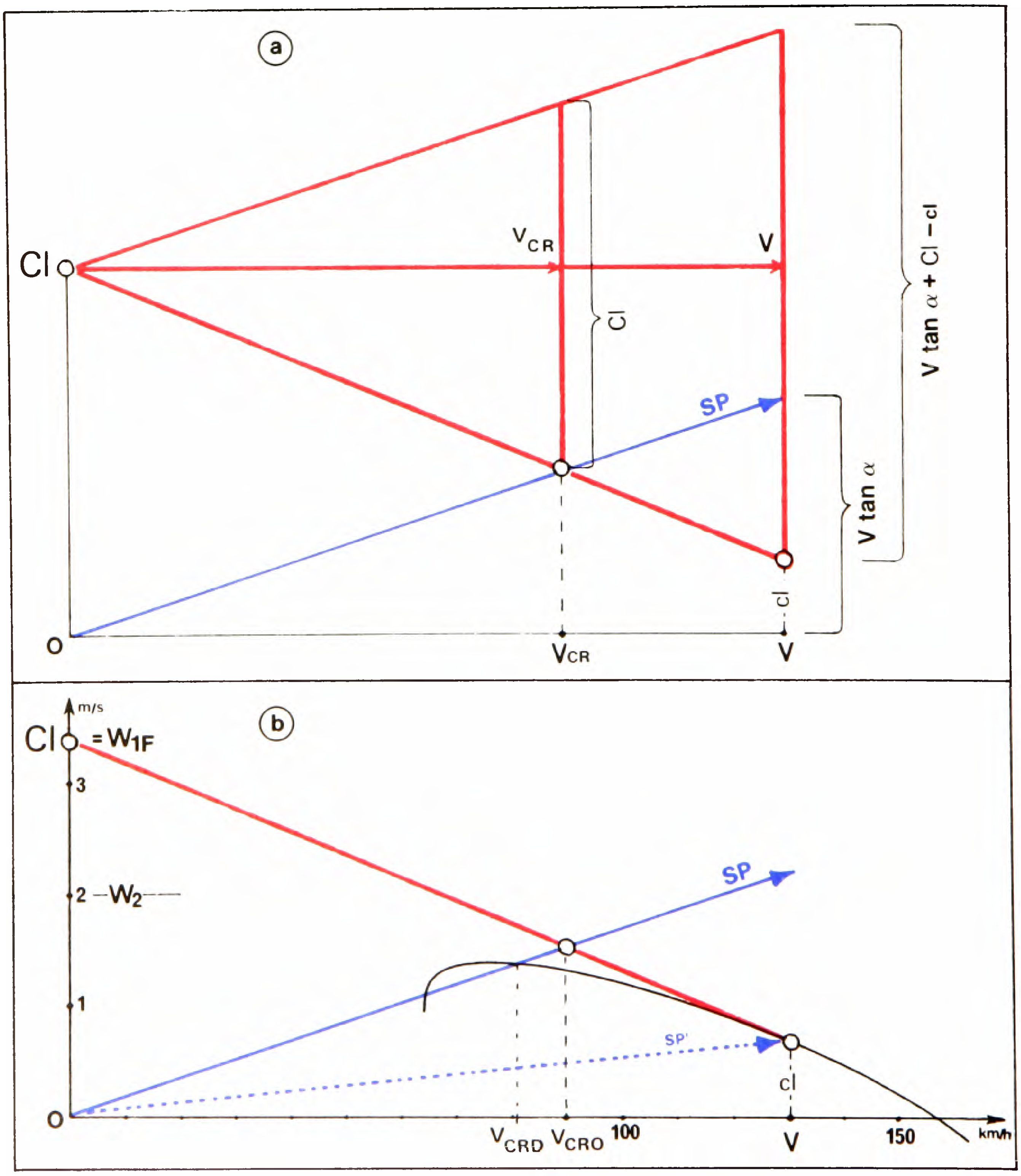
It is now necessary to determine the optimum climbing cruise; here is how it is done.

Case ② flight with altitude gain



ST = Real climb rate while circling
h_1 = Circling altitude gain
t_1 = Circling time
st = Rate of climb in straight flight
V = Speed of straight flight
h_2 = Altitude gain in straight flight
t_2 = Straight flight time
e = Distance
h_1+h_2 = Total altitude gain
α = Angle of climb path
SP = Climb cruise path

Flight with altitude gain: illustration of rule of projection



CALCULATION OF A CLIMBING CRUISE IN GENERAL

The expression "climbing cruise" is taken to mean the cruise speed based on the ascending flight path; we base our calculations on a rapid circling climb in strong lift, followed by a slower climb straight ahead in weaker lift.

For circling time:

$$(1) \quad t_1 = \frac{h_1}{Cl}$$

and for straight-flight time:

$$(2) \quad t_2 = \frac{e}{V} \quad \text{as well as}$$

$$(3) \quad t_2 = \frac{h_2}{cl}$$

Slope of the climb path is:

$$(4) \quad \frac{h_1 + h_2}{e} = \tan \alpha$$

Climb cruise is:

$$(5) \quad V_{cr} = \frac{e}{t_1 + t_2}$$

$$2/3: \frac{e}{V} = \frac{h_2}{cl}$$

$$h_2 = \frac{e \cdot cl}{V}$$

$$4: \quad h_1 = e \cdot \tan \alpha - h_2$$

$$2/3/4: \quad h_1 = e \cdot \tan \alpha - \frac{e \cdot cl}{V} = e\left(\tan \alpha - \frac{cl}{V}\right)$$

$$1/2/3/4: \; t_1 = e \, \frac{\tan \alpha - \frac{cl}{V}}{cl} = e \, \frac{\tan \alpha \cdot V - cl}{V \cdot cl}$$

From this equation and equation (5) we obtain the climb cruise:

$$V_{cr} = \frac{e}{e\left(\frac{1}{V} + \frac{V \cdot \tan \alpha - cl}{V \cdot Cl}\right)}$$

$$V_{cr} = \frac{V \cdot Cl}{Cl - cl + V \cdot \tan \alpha}$$

This equation can be converted to a ratio equation:

$$\frac{V_{cr}}{V} = \frac{Cl}{Cl - cl + V \cdot \tan \alpha} \qquad \text{equation VII.}$$

For the case in which $W_2 = 0$, cl becomes negative (= Si). If at the same time α is assumed to be 0 the result of equation VII is equation I (page 104) as a special case. Equation VII is depicted in the accompanying projective figure.

This figure itself is drawn in red in the illustration. All the other lines are additions to show how the figure fits into the polar diagram. The blue line SP indicates the climb path.

Illustration (b) shows an example of how one can obtain the optimum values graphically from the speed polar: the optimum straight-flight speed V is the point at which the tangent from W_{1F} meets the W_2 polar. The intersection of this tangent with the climb path shows the optimum climb cruise speed V_{cro}. If V_{cro} and V correspond — for example for flatter climb paths or weaker values of W_{1F} — it means that straight flight at V will achieve the climb path and that no further circling will be necessary. In the illustrated optimum case a climb was in fact made in straight flight (along climb path SP'), but not steeply enough. The remaining height has to be gained by circling in the strong part of the lift centers. If the polar point of the straight-flight speed V lies below the zero-climb axis, it means that altitude is lost during the straight-flight portion. In our example straight climbing flight along climb path SP would still be possible by flying at the dolphin flight speed V_{crd}, but "classic" flight at ring setting W_{1F} would result in a significantly higher average speed.

Case (3): Flight with loss of altitude (as in case (3), page 24):

If one chooses a negative slope of the "climb" path, the "sink path" intersects the polar (except for very shallow descents and/or very weak W_2). The optimum dolphin flight speed is the projection of this intersection onto the V-axis. This would be used, for example, in special cases such as a final glide below a cloud street.

If we set $W_2 = 0$ or negative, the calculation and its graphic depiction remain valid, and the results are usable.

Based on this overview, the "classic" theory appears as a special case of this extended theory, based on a slope of 0 for the flight path.

5TH MODEL (REICHMANN)

This last model is the most comprehensive. It can be developed by a step-by-step generalization of the 4th model (compare with page 111).

1) If one imagines an arbitary number of "4th models" strung end-to-end, one can achieve a representation of a continuous series of W_2 areas. The strongest value of W_1 (or several equally strong maximum values) determine(s) the "circling thermal(s)" and the speed-ring setting. All other W_1 areas can be ignored. All the results developed on pages 111 to 115 can be proven to apply to such a model, with dolphin flight models 1 through 4 taken as special cases.

2) This (intermediate) model can be further developed along René Comte's guidelines if one assumes that areas of lift are present in the (strongest) W_1 areas in which the lift is at a maximum and decreases at higher and at lower altitudes. René Comte's results can be proven to apply to this (final) version of model 5. This last model includes all other cruise speed models described thus far as special cases.

For this model, the general speed-to-fly rule applies:

Fly at the highest speed-ring setting that allows the desired flight path, either in straight flight or based on the rule of "final climb in the last thermal = ring setting = initial climb in the next thermal." Any eventual excess energy is transformed into speed by using a higher ring setting.

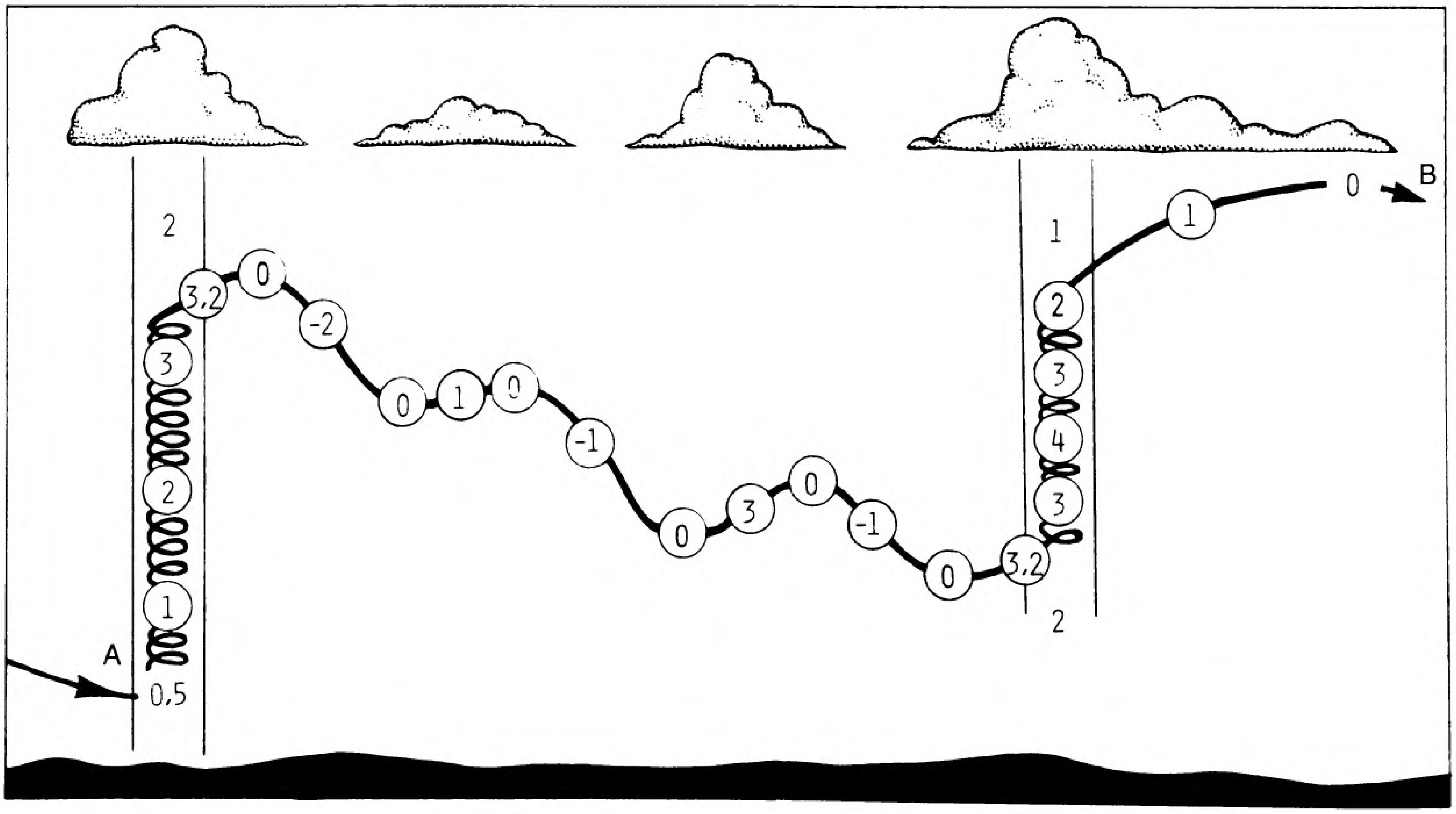
The illustration shows a series of thermals which are indicated by clouds. The circled figures show the indication of the total energy variometer of an optimally-flown sailplane. The other figures show the possible climb rates. The pilot has reached the initial thermal at point A after flying at a speed-ring setting of 0.5, and finds lift of 0.5 m/s. His tactical goal is to reach the end of the cloudstreet at maximum altitude (point B). Thus, the flight path AB has been fixed.

To optimize cruise speed along the flight path, the pilot must climb in the first thermal until the speed-to-fly rule has been satisfied. The pilot leaves the thermal (which will increase, then decrease as he continues to gain altitude) when he can use the final-climb speed-ring setting to reach the next thermal at an altitude where he can make a circling climb at the same rate. After he straightens out to leave the first thermal, he will notice a brief variometer surge above the circling climb rate (about 3.2 m/s vs. 3 m/s) due to the reduced sailplane sink in straight flight. This would suggest a speed-to-fly of less than the minimum-sink speed of the sailplane.

If a sailplane climb rate of 3 m/s is noted in straight flight, the pilot should fly straight through, since he knows that only about 2.8 m/s would be possible in a circling climb. The second thermal in which the pilot climbs is indicated by the variometer showing *more than* the desired climb rate while in straight flight. The pilot begins to circle and initially climbs at 3 m/s. The lift increases, then decreases; the pilot leaves the thermal when the climb rate has decreased to the value of the new ring setting (2 m/s) which will allow flight to point B.

RESULTS OF DOLPHIN FLIGHT MODELS

For dolphin flight, a new theory results, which contains the "classic" theory as a special case. The speed ring and similar speed-to-fly devices retain their validity. Thus, according to the theory, the ring is set exactly the same as for "classic" flight (apart from possible tactical considerations, of course). It has been proven that "forced" dolphin flight causes cruise-speed losses.



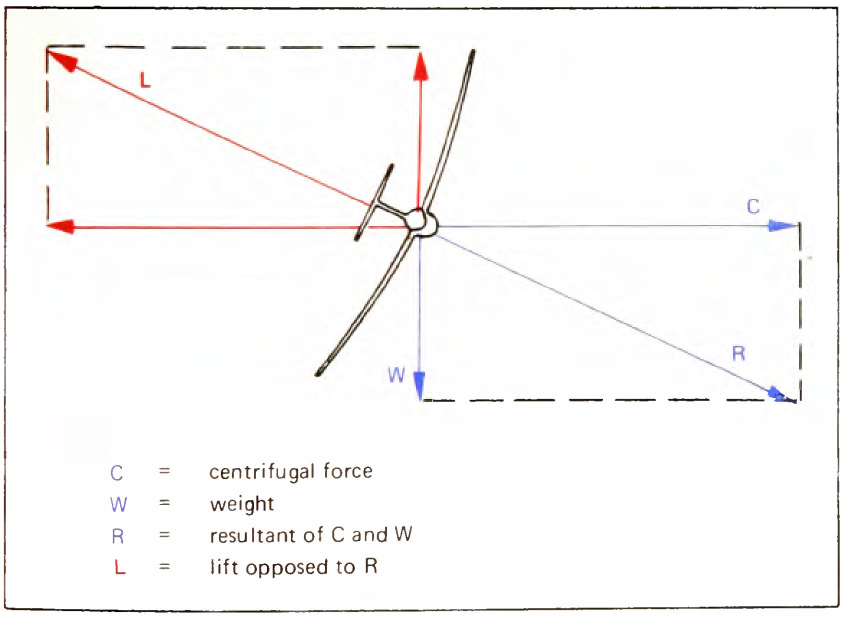
Circling and Cruising With Water Ballast

FORCES IN TURNING FLIGHT

In circling flight, higher wing loadings occur than in straight flight due to centrifugal force. This force depends on both sailplane speed and circle radius: the higher the airspeed and/or the tighter the circle, the higher the centrifugal forces. Since centrifugal force works horizontally outward, while the sailplane's weight works vertically downward, the final result is an oblique resultant force R.

The aerodynamic lift L must be opposed to this resultant, and exactly as strong; this requires a bank angle that is exactly 90° to the direction of the resultant. Thus, bank angle serves as an indirect measure of centrifugal force, and also of the additional acceleration placed on the sailplane (in our example 2.3 g). In order to counter this acceleration, more aerodynamic lift must be produced than would be necessary for straight flight; this is only possible with an increase in induced drag, which in turn causes an increase in sink rate. Therefore, normal speeds are meaningless for circling flight, and special circling polars must be calculated.

Forces in turning flight

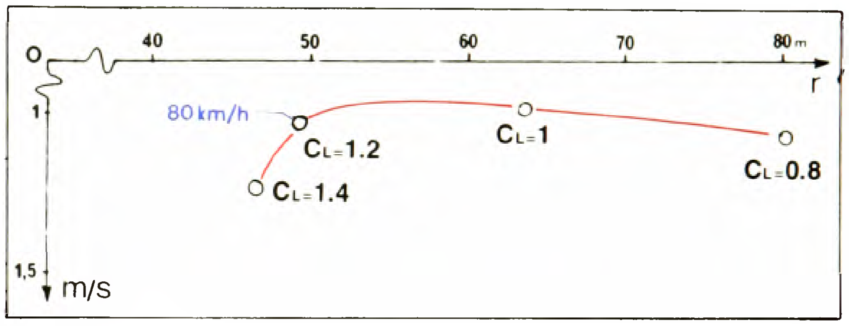


BANK ANGLE POLARS

A given bank angle — for example 45° — and the appropriate higher g-load (in this case 1.4 g) can be flown in regular circling flight in various ways: either by circling tightly at low airspeeds or by making larger circles at higher airspeeds. If one plots sailplane sink rate against circle radius one gets the following picture:

As the circle radius decreases, lift coefficients (C_L) must increase, until the C_L max is reached (for this example, at r = 47 m). Overall sink speeds result which are higher than those for straight flight.

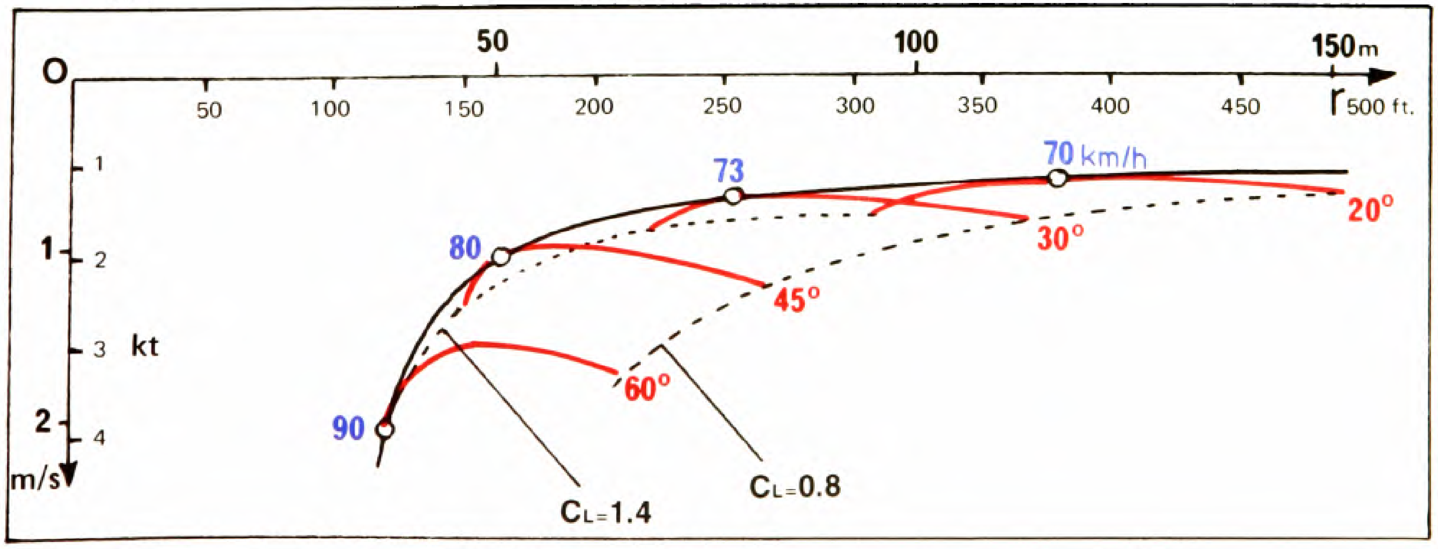
45° polar of ASW 15, 5.75 psf



CIRCLING POLARS

If one constructs several polars for different bank angles and fairs an overall curve, the result is a "circling polar" which contains the most favorable sink speeds together with the appropriate bank angles and airspeed for given circle radii. Thus, the circling polar is an optimum curve for the most efficient possible circling flight. It is clear from the example that narrower circles require higher airspeeds as well as higher values of C_L (and hence higher angles of attack).

Circling polars for ASW 15 at wing loading at 5.75 psf



THE INFLUENCE OF BALLAST

Although increased weight only causes losses at low speeds in straight flight, and is an advantage at higher speeds, increased weight always impairs circling performance. If very large circles are flown the losses are relatively small, but increase rapidly as the circle radius decreases. The heavier the airplane, the sooner C_L max will be reached as circle radius decreases.

After this point has been reached it is simply not possible to circle any more tightly. The next illustration has the circling polars of the ASW 15 added below the r-axis to illustrate this fact.

THERMAL PROFILE — CLIMB — CRUISE

If one always knew how the lift was distributed in the cross-section of a thermal, one could reduce the thermal's climb curve by the sink curve of the circling polar (addition of ordinate values) and thus determine the maximum possible climb as well as the appropriate bank angle, airspeed, and circle diameter. Unfortunately (or, perhaps, fortunately) thermals are not quite so cut and dried, seldom really circular, and certainly not laid out along regular profiles. None the less, sailplane design factors are often based on standardized thermal profiles; these design factors in turn determine cruise speed with respect to climb rates for different weather conditions and thermal profiles. There is no doubt that this is only the roughest possible approximation of true conditions but — or so it is claimed — one has to start somewhere.

Depending on how typical and realistic such assumptions have been, we've seen sailplanes that had extremely good weak thermal performance but fell a bit short on high-speed performance, or vice versa. To find the happy medium is the very difficult task of the designer.

In the construction of the D 36 (Darmstadt Academic Flight Group) an attempt was made to approach the dilemma differently: a survey was organized among the top competition pilots in an effort to determine how steeply they banked when thermaling. The result was fairly unequivocal: around 40°. "Very well," they thought, "the average thermal must have a climb gradient — that is, the amount the climb rate increases as one approaches the center — of $0.015\ m/s/_{meter}$ (assuming, of course, that the respected competition pilots are flying optimally!)". As a matter of fact, many of the current generation of fiberglass sailplanes were designed based on these thoughts. The results have certainly been good, even if other factors such as dolphin flight seem to have been neglected in design concepts.

Although the practical value of sum curves composed of thermal profiles and circling polars remains questionable, the following graph makes it easier to understand how climb performance figures are arrived at:

Let us assume three thermal profiles:

(1) "strong thermal"
(2) "wide thermal"
(3) "weak thermal"

as described by Carmichael and used by F. Thomas in cooperation with the Braunschweig Academic Flight Group. We will assume that 3 Standard Class sailplanes (ASW 15) are circling in these thermals with wing loadings of (a) 4.90, (b) 5.75, and (c) 7.35 psf, and define optimum climb and achievable classic cruising speed for each.

The marked points on each of the sum curves (of the given thermal profile and the sailplane circling polar) show the best attainable climb rate. If one uses these climb rates and draws tangents to the appropriate straight-flight polar in the next diagram the cruise speeds can be read from the V-axis in the usual fashion.

For our example, the results are:

	(a) 4.90 psf	(b) 5.75 psf	(c) 7.35 psf
strong lift	95 km/h	98 km/h	95 km/h
wide lift	93 km/h	94 km/h	100 km/h
weak lift	65 km/h	58 km/h	50 km/h

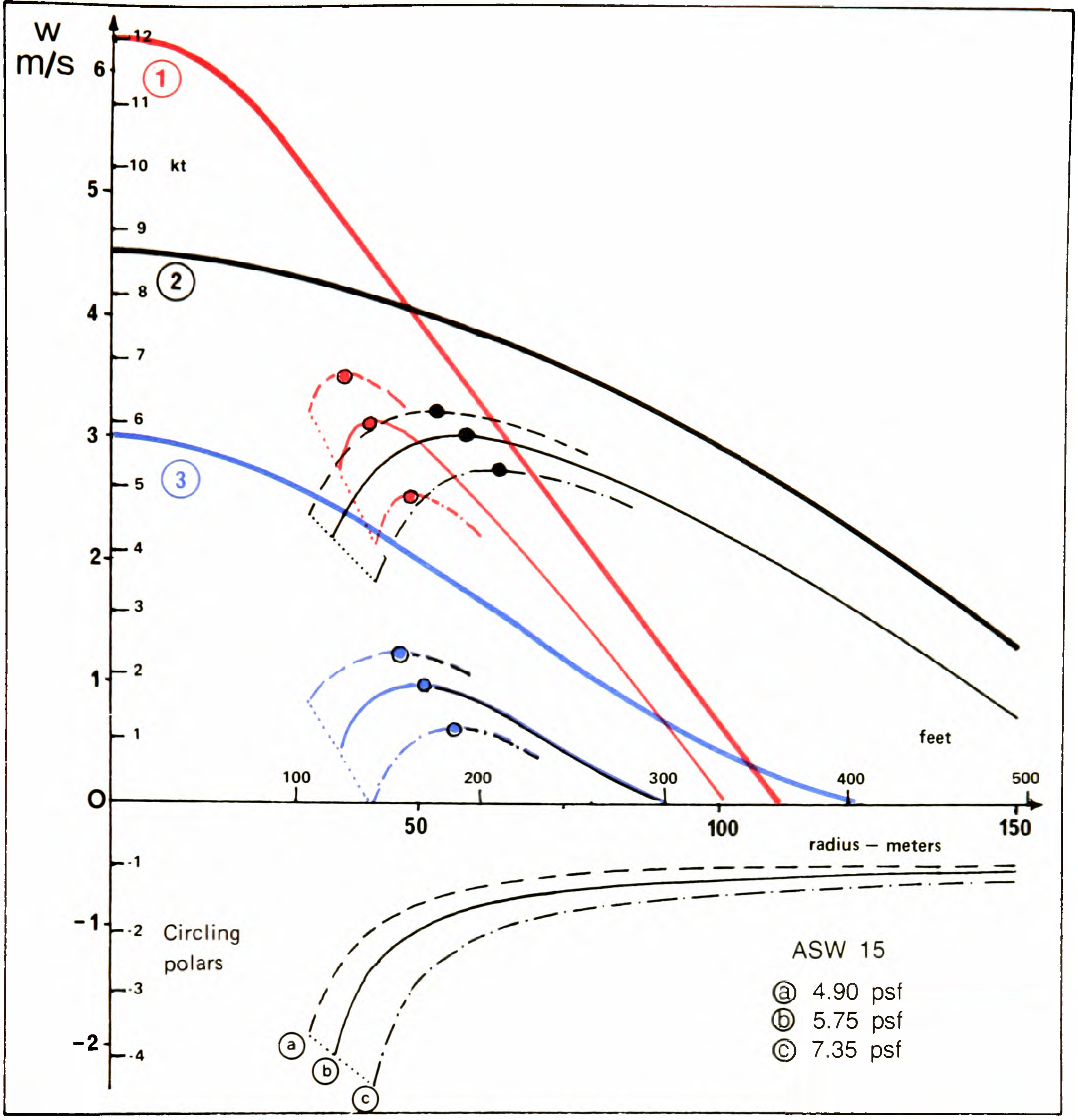
Comparison of the result indicates firstly, that although the "wide" thermal was not only wide, but also fairly strong, it yields almost the same sailplane climb rates as the "strong" thermal: about 3 m/s! Even so, it is shown that the "strong" thermal does not allow the heavy sailplane to cruise fastest. It is so narrow that the heavy sailplane (c) does no better than the light one (a), which cannot glide as fast but which climbs faster in the narrow thermal. The median sailplane (b) here obviously offers the best compromise. Since the wide thermal is fairly strong, it offers the advantage to the heavier sailplane.

The weak thermal has been set fairly narrow and therefore leads to marked differences in climb rate. The heavy sailplane (c) climbs at 0.6 m/s, which is only half as fast as the light sailplane (a). The differences in cruise speed are similarly large.

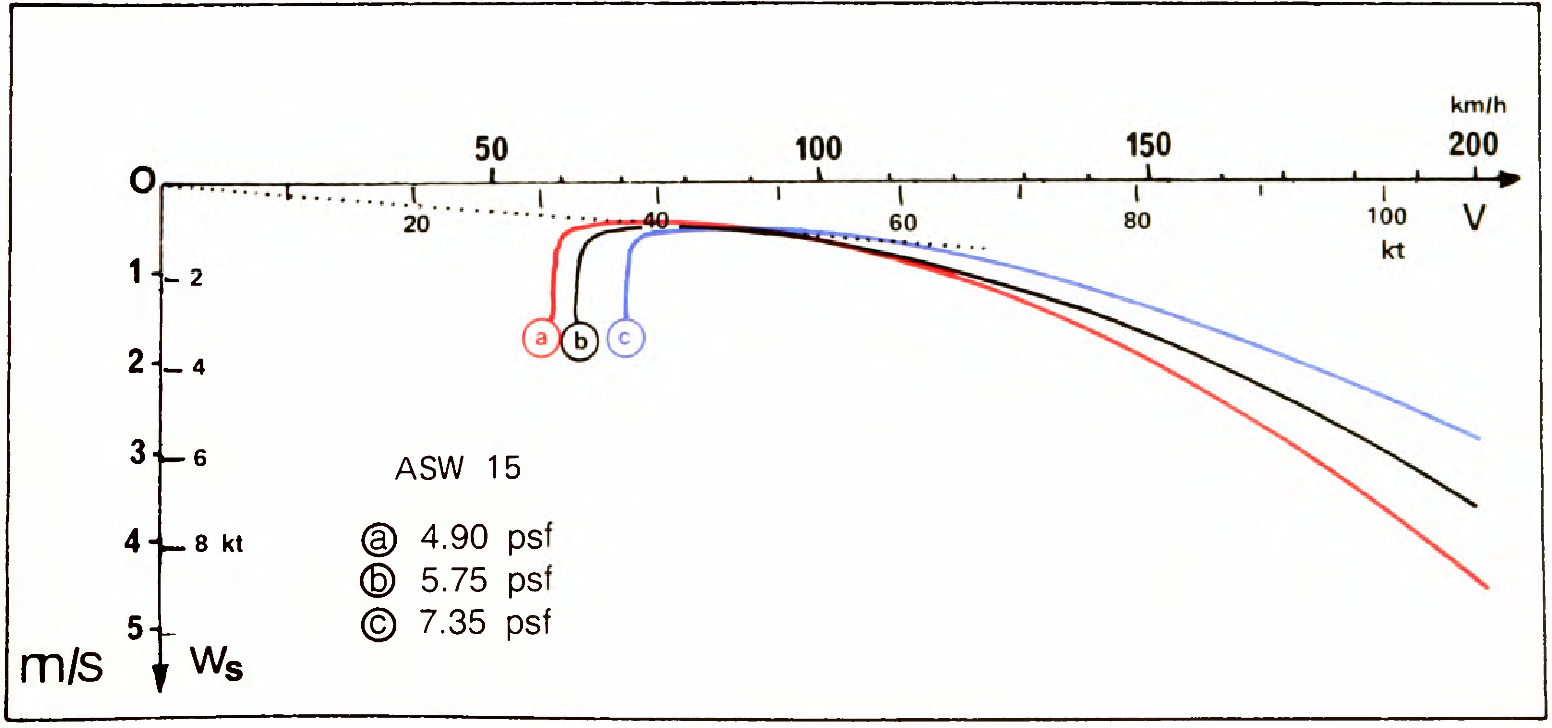
Even if these examples are not necessarily typical, they show one fact clearly:

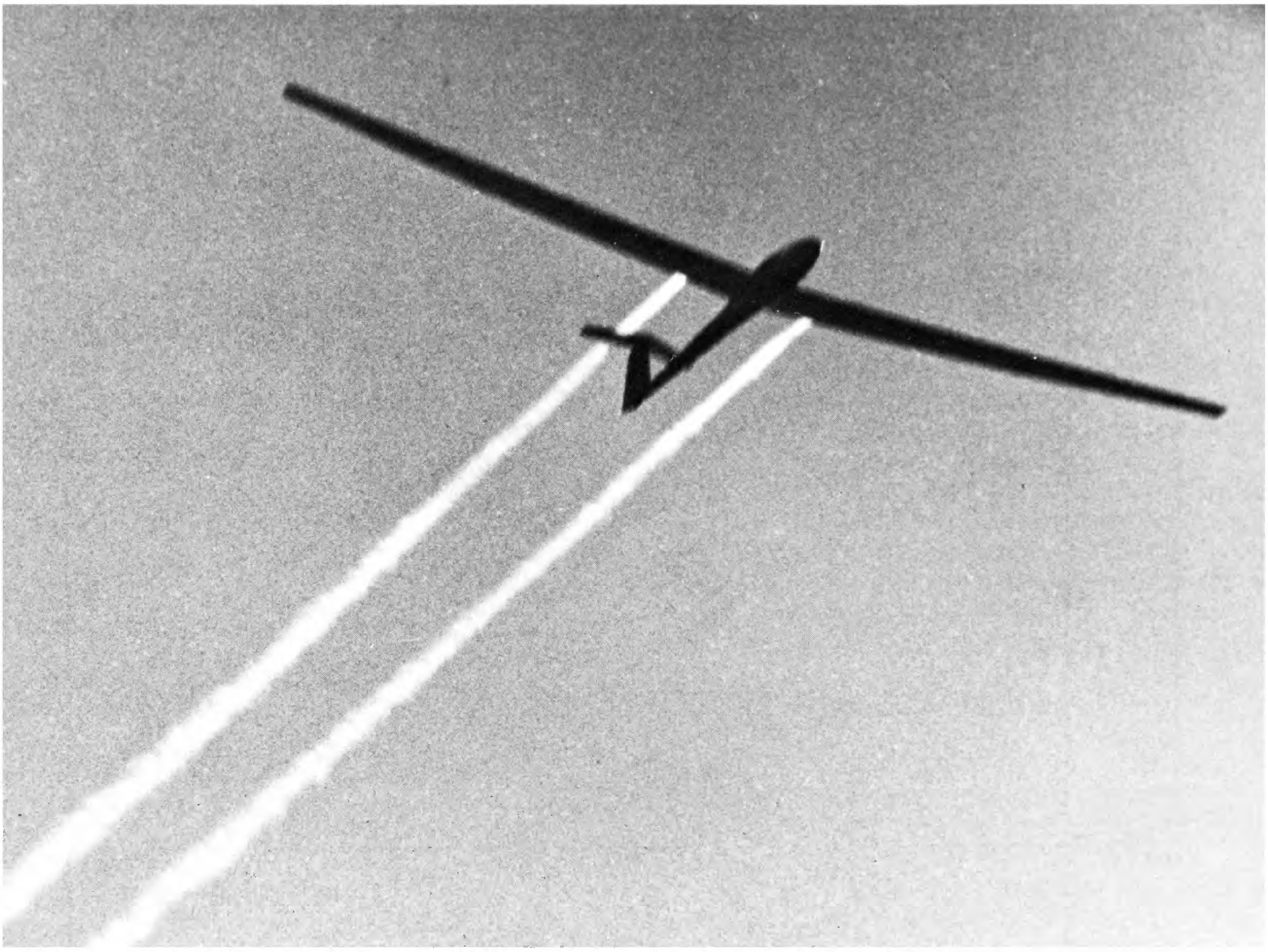
When deciding the optimum wing loading (water ballast), it is not sufficient to consider thermal strength only; the horizontal size of the thermals plays an important role as well. If it is necessary to circle very steeply, the water ballast will hurt the climb considerably more than for wider circles. Thus, the question of whether one should fly with ballast must be answered based on thermal strength, thermal distribution, and thermal size.

Thermal profiles, sum curves for circling flight



Straight-flight polars





The Final Glide

CALCULATION OF INITIAL VALUES

In order to construct a final glide calculator — no matter what type — we have to know the glide ratio over ground of our sailplane for various ring settings and wind components. We will assume that upward and downward airmass movement during the final glide will balance out overall, and take our values for speed-to-fly and sailplane sink from the still-air polar. The polars that we use for this purpose should be as realistic as possible and should be accurate for the wing loading and altitude at which we usually fly! The necessary initial values are obtained by tangent construction, as usual.

For the construction of final-glide calculators it is best to draw up a value table containing the various glide ratios over ground (E_g). For some calculators, such as the Stöcker calculator whose description follows, it is advantageous to calculate the needed altitude for a given distance (here 25 km) at the same time.

We copy off the table and fill out the left side with the values that we've taken from the polar. The values for the columns "$1 \cdot (Si \cdot 3.6)$" and "90,000 Si" are worked out and entered as well, as this will simplify the further calculations. Based on the V-values the right-hand columns for V_g are filled in. The rest can then be done very quickly with a slide rule or small calculator.

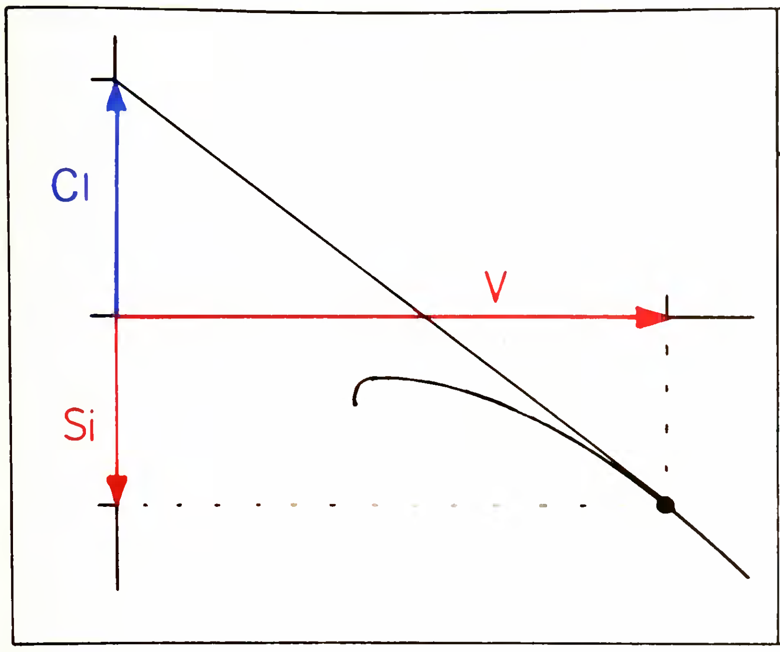
Depending on what type of calculator we want to make we will calculate either "E_g" or "h_{25}" and fill them in.

CONSTRUCTION OF THE STÖCKER FINAL-GLIDE CALCULATOR (BACK SIDE: WIND COMPUTER)

For the construction of the Stöcker final-glide calculator we'll need a "base plate" of any appropriate material 22 cm (8½ in) across; we'll put a compass rose on the outer edge of both sides.

Next, we'll make a plexiglass disc with a diameter of 21 cm (8 in), onto which we can scratch the spirals

Final glide table



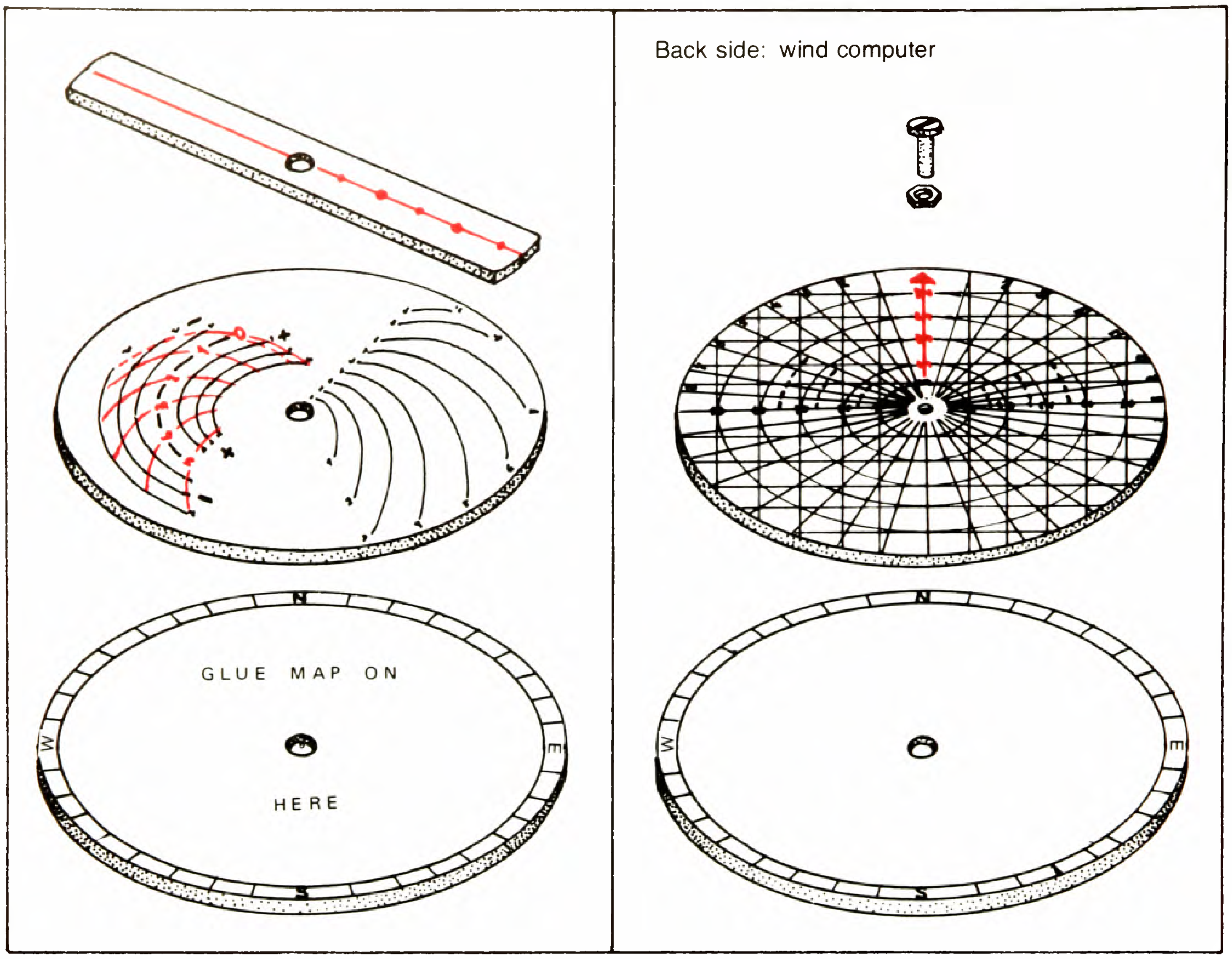
$$E_g = \frac{V + W_k}{Si \cdot 3.6}$$

$$h_{25} = \frac{25000}{E_g} = \frac{90000\ Si}{V + W_K}$$

Cl = climb in last thermal (m/s)
E_g = glide ratio over ground
V = speed-to-fly (km/h)
V_g = ground speed (km/h)
W_k = wind component (km/h)
S_i = sailplane sink rate (m/s)
h_{25} = height needed for 25 km final glide (m)

Cl	V	Si	1:(Si·3,6)	90000·Si			Head			Wind component			Tail	
						-40	-30	-20	-10	0	+10	+20	+30	+40
0					V_g									
					E_g									
					h_{25}									
0.5					V_g									
					E_g									
					h_{25}									
1					V_g									
					E_g									
					h_{25}									
2					V_g									
					E_g									
					h_{25}									
3					V_g									
					E_g									
					h_{25}									
4					V_g									
					E_g									
					h_{25}									
5					V_g									
					E_g									
					h_{25}									
6					V_g									
					E_g									
					h_{25}									

"Stöcker" final-glide calculator



and color them by filling with ink. (These, by the way, are not arithmetic spirals, as Stöcker originally suggested.) The spirals are arranged such that they divide any radius into equal parts; the numbers indicate altitude in hundreds of meters. Thus, 12 is 1200 meters, etc. Further, we'll make a rotatable cursor; on one side we'll make a mark every 2 cm, equal to 5 km on the map. Thus, the farthest point indicates a distance of 25 km from the goal.

The grid lying across from the spirals differs from sailplane to sailplane. Hence, we do not transfer it directly to the plexiglass, but rather draw it on paper which we'll later glue to the underside of the plexiglass at the right point. Thus, we retain the option of later converting the calculator for other sailplane types. The wind components are circle segments; the climb and sink values are entered from the prepared table as follows:

For each climb Cl in the last thermal, the table value h_{25} is determined for each wind component. We then rotate the cursor so that the 25-km point lies on the appropriate height spiral for the h_{25} value.

At the other end of the cursor we mark the climb (or sink) rate on the appropriate wind component circle segment. We glue a 1:250,000 map to the base plate with the goal airport in the center and the directions aligned with the compass rose.

It is practical to make the wind-drift computer described in the first part of the book the back of the final-glide calculator. A sheet of graph paper is used, and after the radials and concentric circles have been drawn, it is cut to a diameter of 20 cm and glued to the back of another movable plexiglass disc.

DIRECTIONS FOR USE OF STÖCKER FINAL GLIDE CALCULATOR

I. Given: position, climb speed, wind component.
Desired:
    a) distance to goal
    b) course to goal
    c) height needed for final glide
    d) glide ratio over ground

1) We set the cursor so that the line crosses the point on the grid where the climb rate and wind component are indicated.

2) Next, we turn the plexiglass disc *with* the cursor so that the other end of the cursor lies over our location.
    a) distance to goal is read from the cursor
    b) course to goal is read from the compass rose
    c) height needed for final glide is read from the spiral running through our location
    d) glide ratio over ground is read at the point where the 1000-m spiral intersects the cursor.

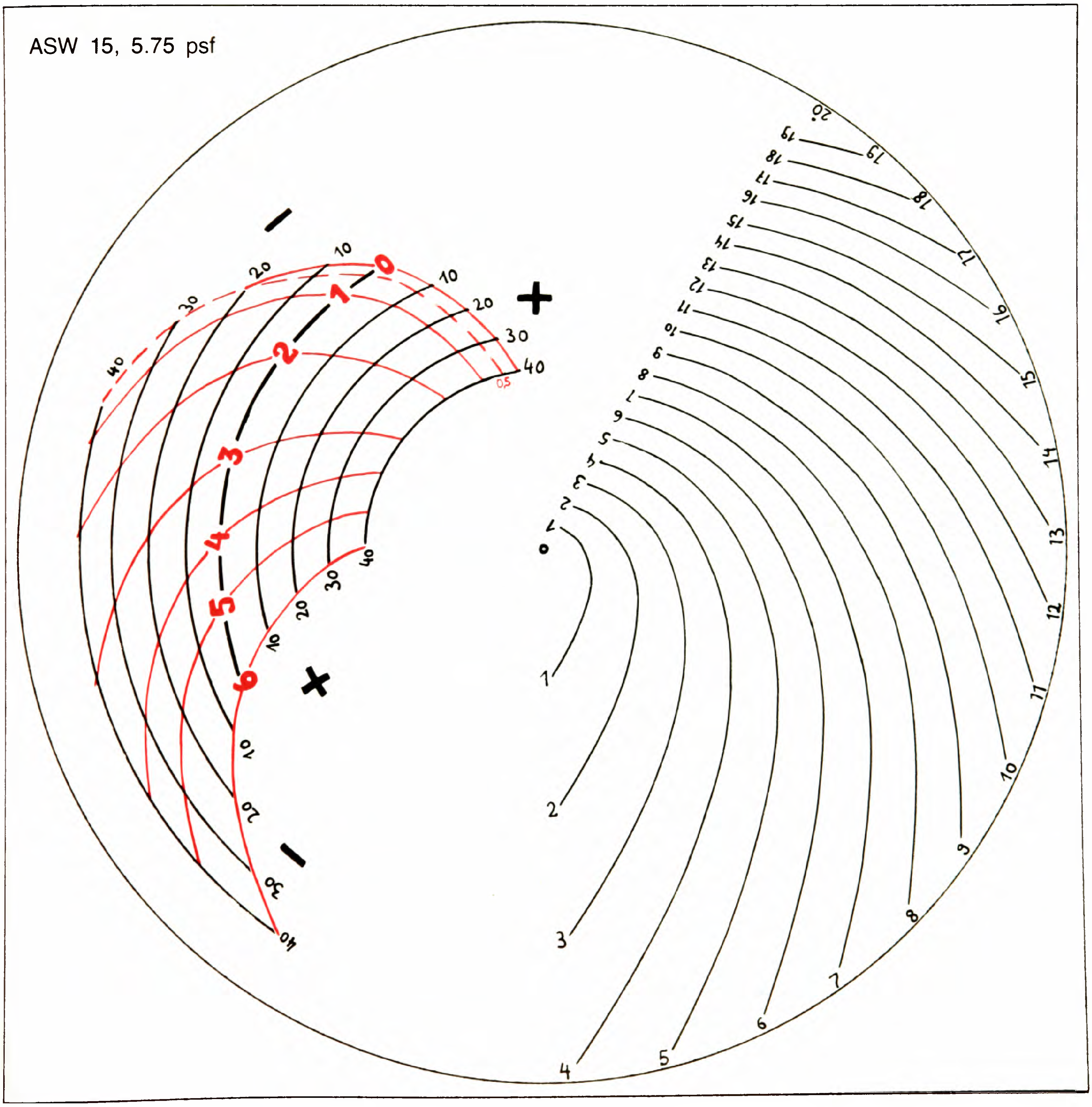
II. Given: position, altitude, wind component
Desired: optimum speed-to-fly setting (speed-ring setting)

1) We rotate the plexiglass disc so that the appropriate altitude spiral is over our position.
2) We rotate the cursor so as to cover our position.

The desired optimum ring setting is read at the point where the cursor intersects the actual wind component on the grid.

III. Positions farther than 25 km from the goal require either a 1:500,000 map (the altitude figures, of course, must be doubled) or measurement of the distance from a separate map. Since the distances are marked on the cursor the calculator can still be used to find the desired values. It has the further advantage of allowing us to stow other maps once within range of the goal, using the calculator only; this allows much more concentration on other factors. Once the calculator has been properly set the needed height in the final glide can constantly be cross-checked without the need for resetting the calculator (for use in final glide, see pages 49 and 64).

Disc for Stöcker final-glide calculator



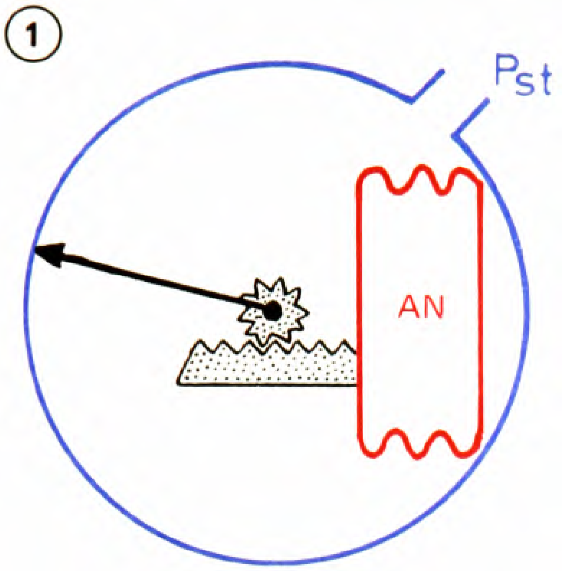
EQUIPMENT

Instrumentation

The schematic overview drawings should allow a brief overall look at the function of various instruments and their similarities. Questions concerned with variometers are discussed extensively in the following section because of their particular importance.

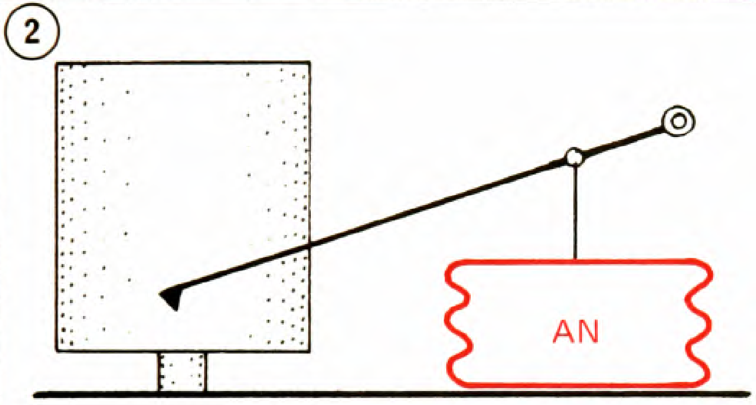
The representation of other instruments is restricted to the bare essentials.

SCHEMATIC OVERVIEW



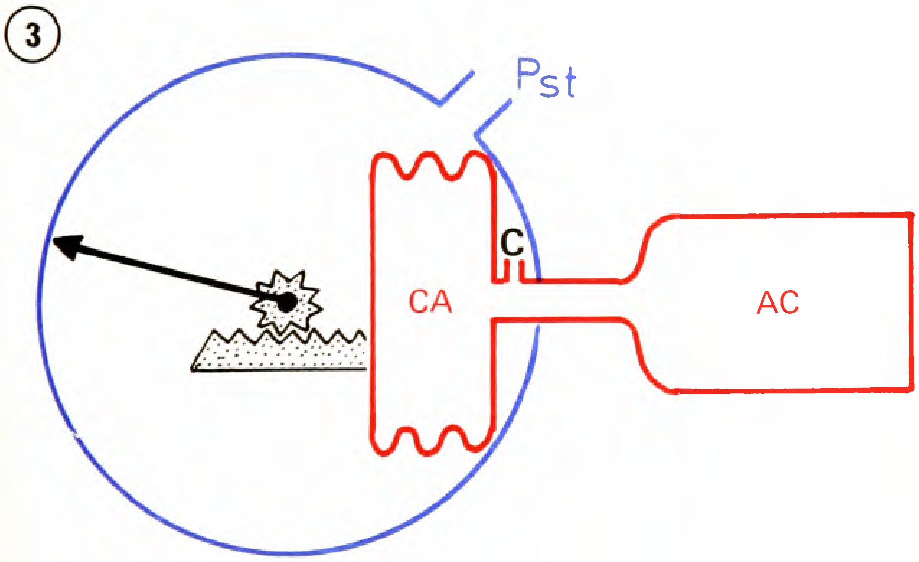
Altimeter

Pst : Static pressure
AN : Aneroid capsule



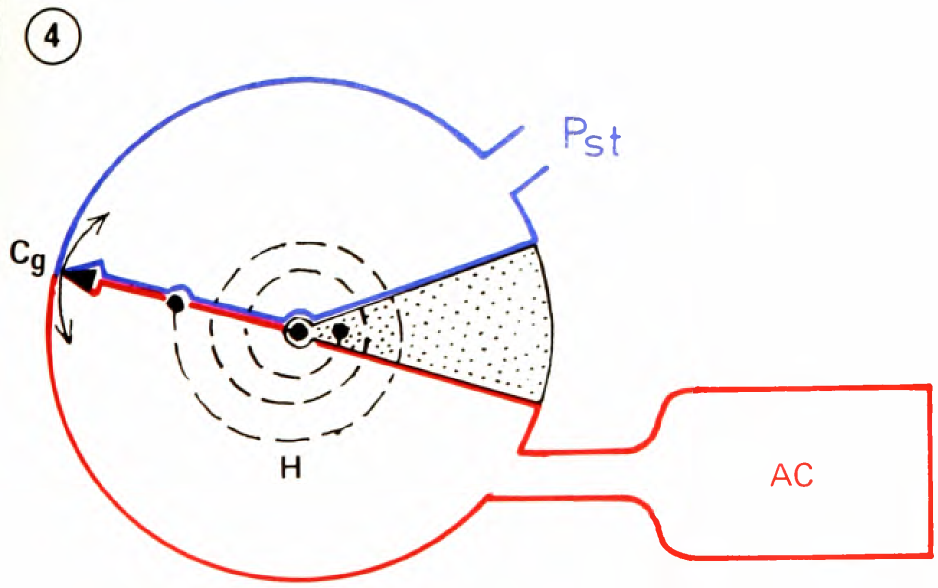
Barograph

AN : Aneroid capsule



Diaphragm Variometer
(Rate of climb indicator)

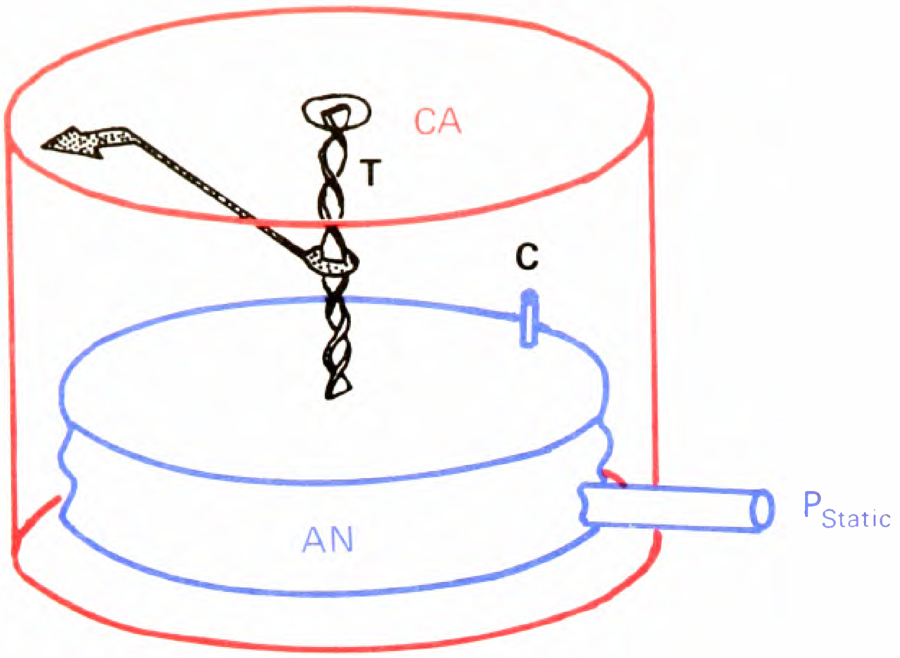
CA : Diaphragm
AC : Air capacity
C : Capillary



Vane (Horn) Variometer

H : Hairspring
C_g : Capillary gap

⑤

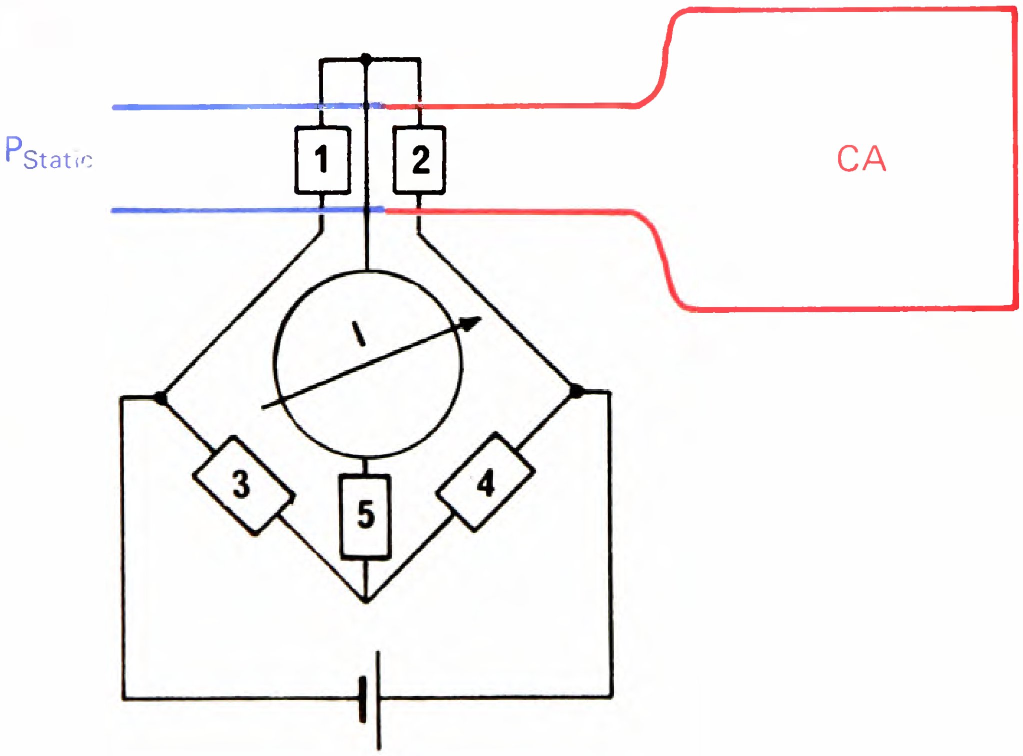


Taut Band Variometer

C : Capillary

T : Taut band

⑥



Electric Variometer

1, 2 : Matched pair of thermistors

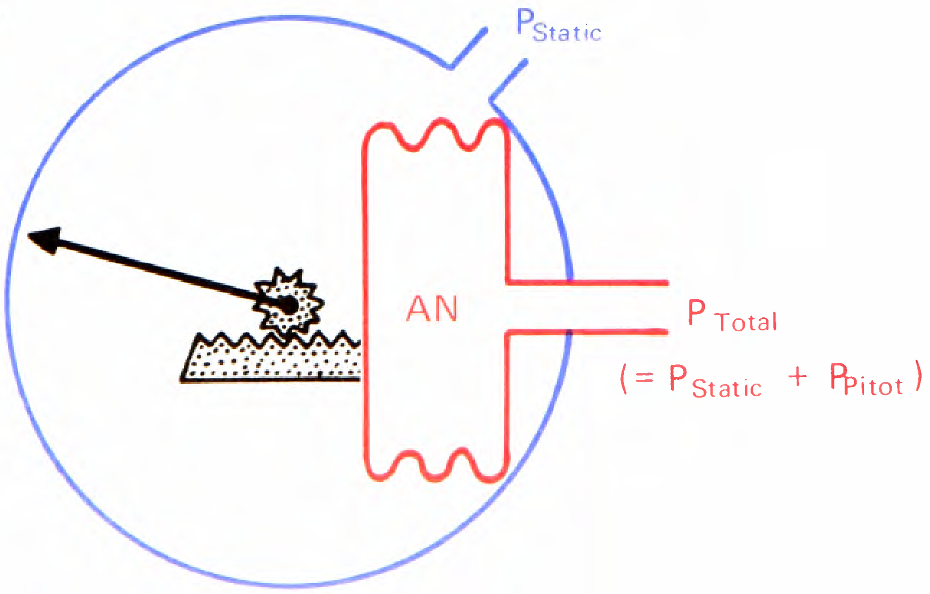
3 : Fixed resistor

4 : Variable resistor to set zero point

5 : Switchable fixed resistor to select measuring range

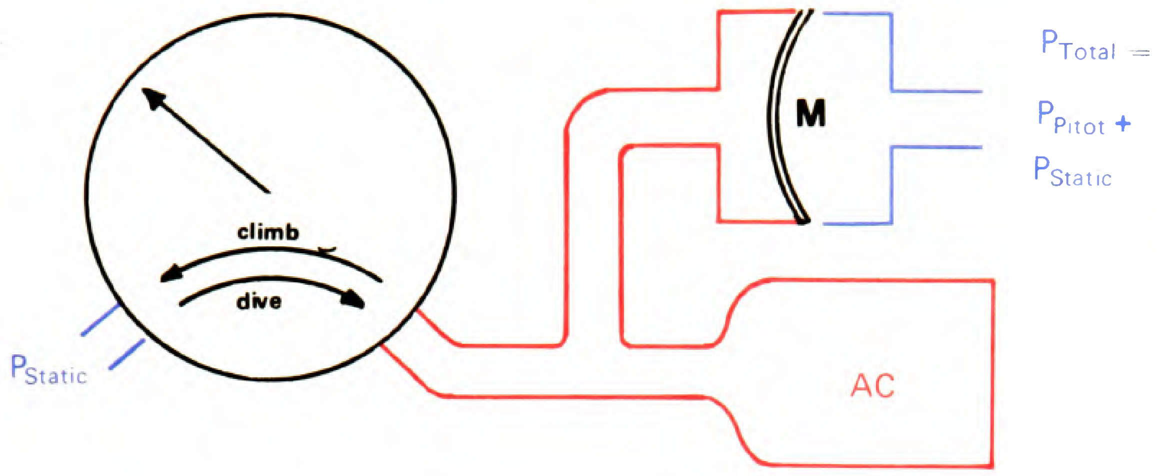
I : Indicator

⑦



Airspeed indicator

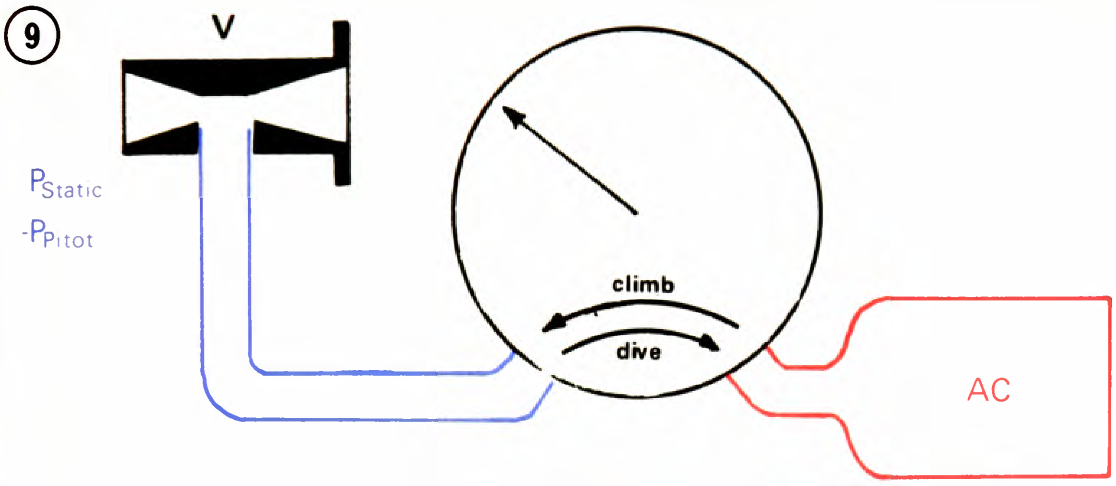
⑧



Membrane
Compensated
Total Energy
Variometer

M : Elastic membrane

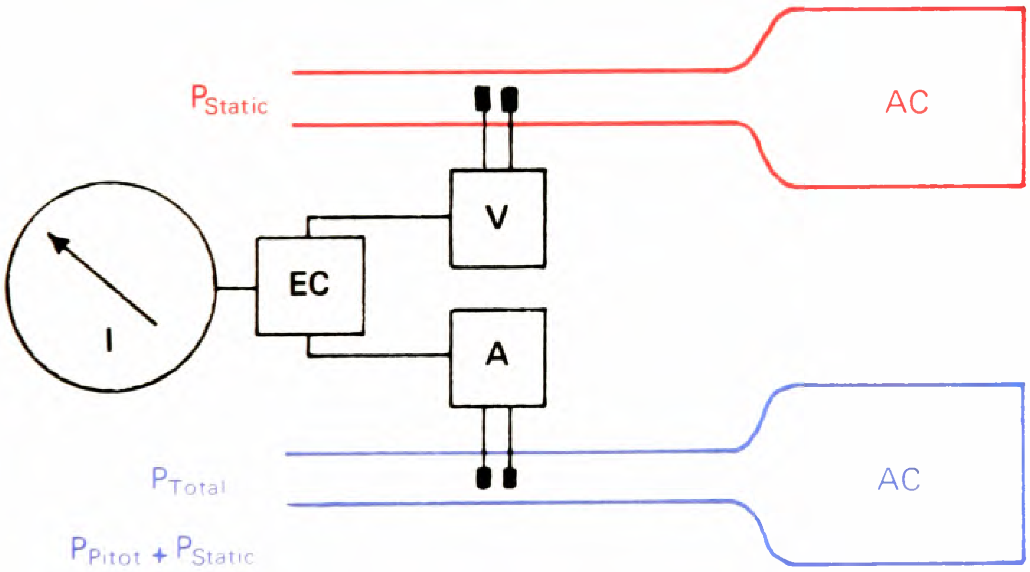
⑨



Venturi
Compensated
Total-Energy
Variometer

V : Venturi with value of — (P_{pitot})

⑩



Electronically
Compensated
Total-Energy
Variometer

V : Electronic rate of climb sensor

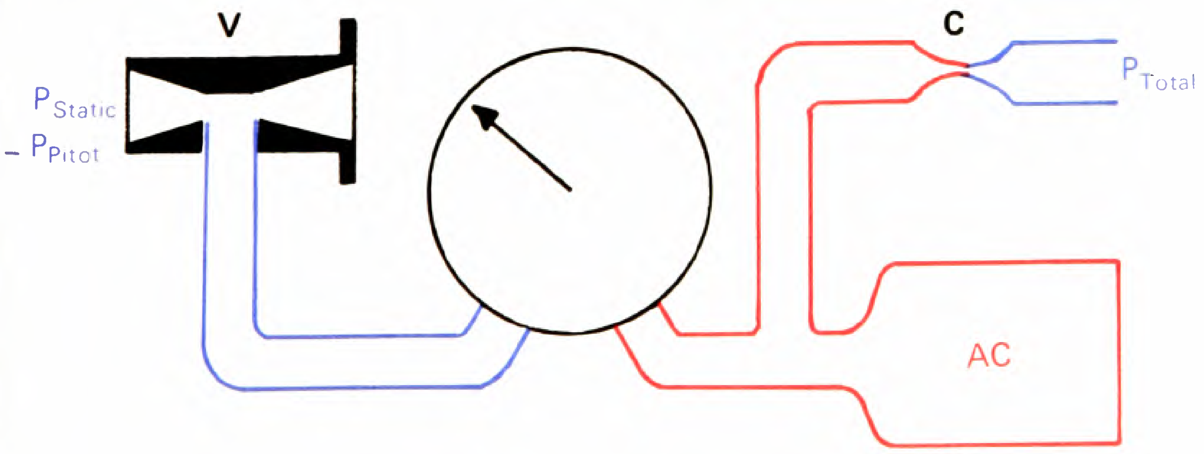
A : Electronic airspeed sensor

EC : Electronic compensator

I : Indicator

(This drawing could also represent a speed director, etc.)

⑪



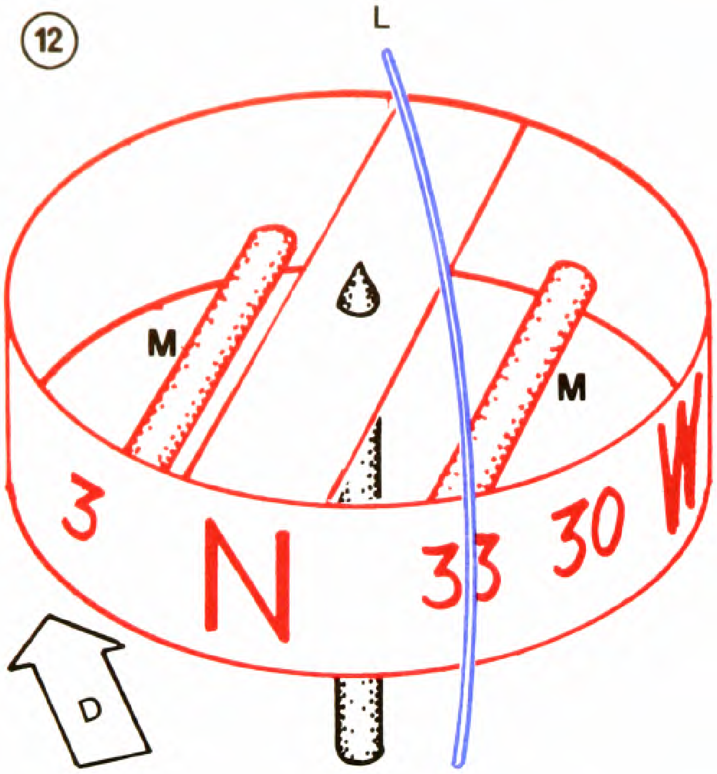
Speed-To-Fly
Variometer

V : Venturi with value of — P_{pitot}

C : Capillary

(With different calibration at the capillary, this could be a Netto Variometer)

⑫

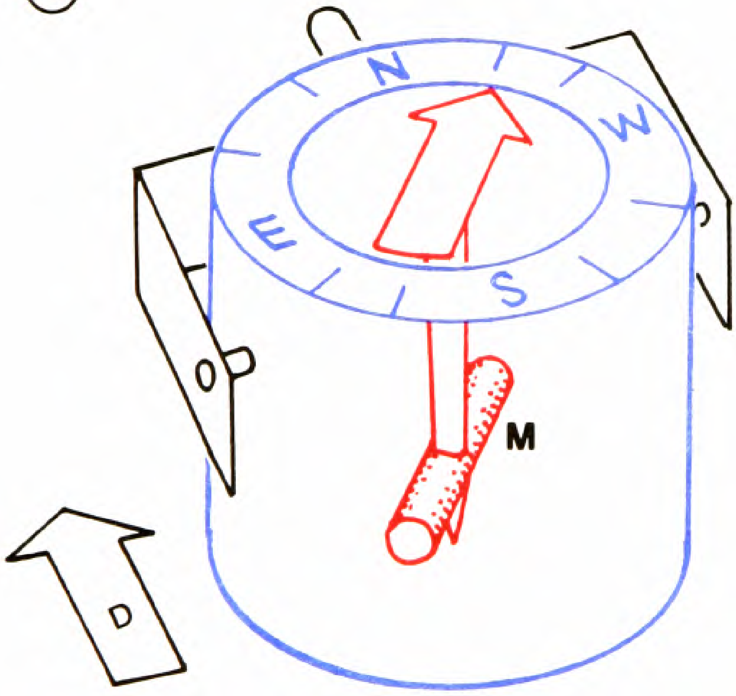


M : Magnets (everything rigidly attached to the magnets is shown in red)

D : Direction of flight

L : Lubber line

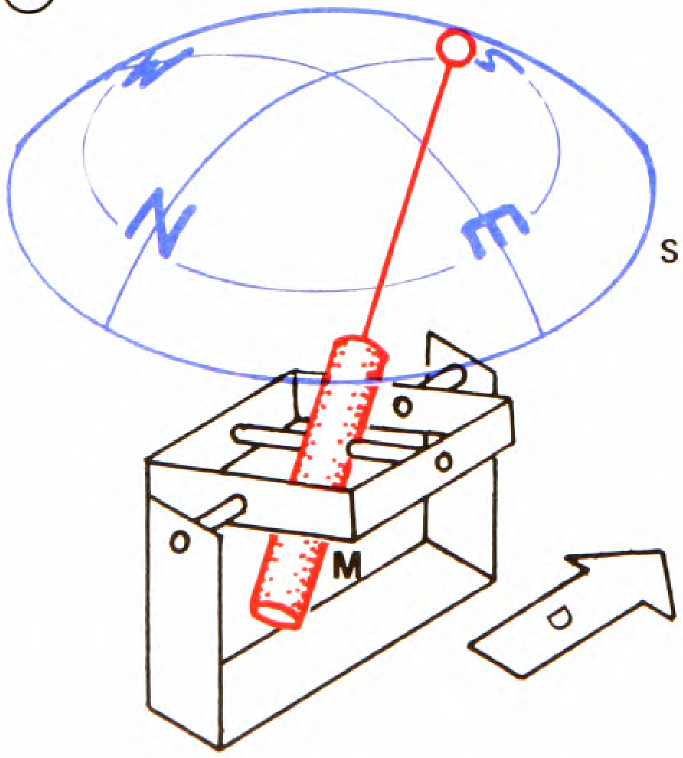
⑬



Cook Compass

Compasses 12 and 13 are seen from the same direction and indicate the same direction of flight

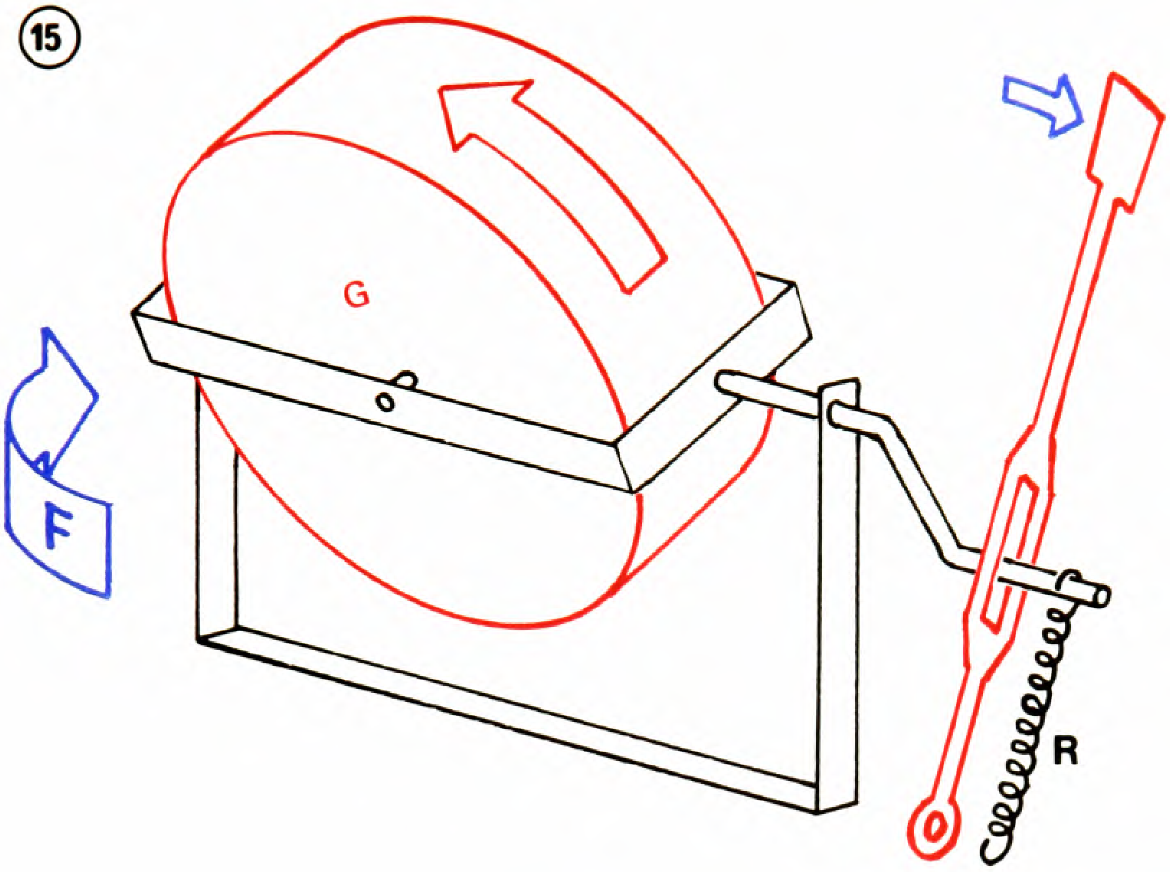
⑭



Bohli Compass
universally-mounted
mass-balanced movement

S : Transparent compass rose

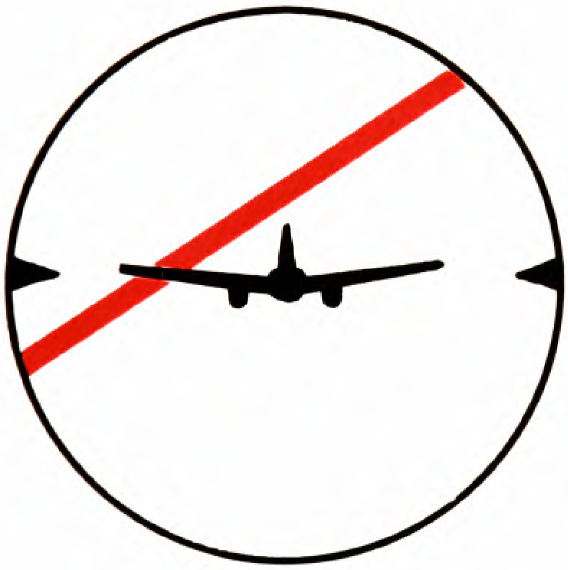
⑮



Turn Indicator

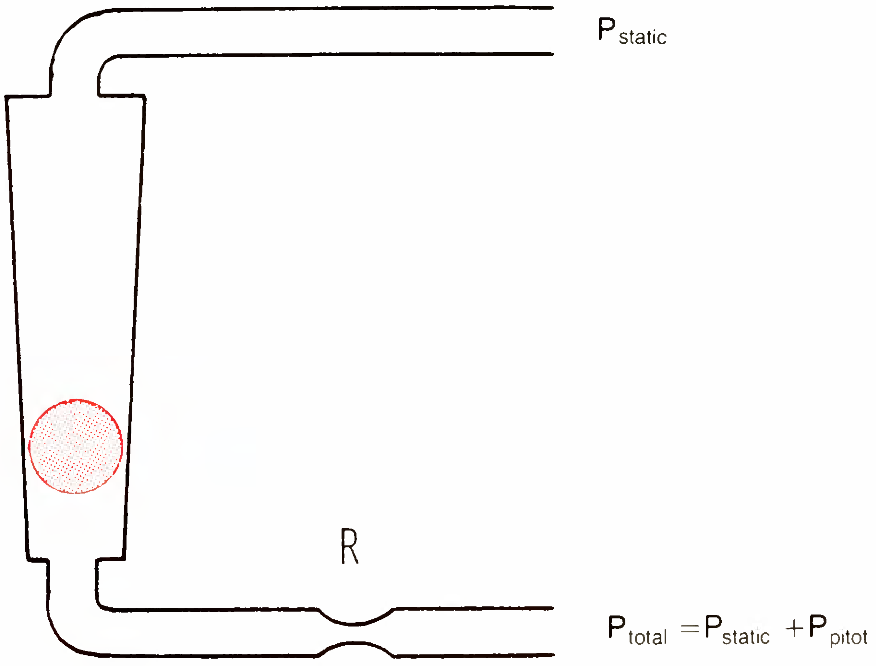
G : Gyroscope
R : Return spring
F : Flight path
(right turn)

⑯



Artificial Horizon
(contains universally-mounted gyro)
This illustration shows
a right diving turn

⑰



Lift Coefficient Indicator

R : Restrictor

INDIVIDUAL INSTRUMENTS

(The number in parentheses after certain instrument names indicates the number of the appropriate diagram in the schematic overview.)

Yaw String:

The yaw string is installed on a relatively flat section of the canopy where it is easily visible. The center position should be marked by a bit of tape or a Magic Marker line. The string shows — with almost no delay — whether the sailplane is in coordinated flight, is skidding, or is slipping. The angle at which the string is blown to the side is generally larger than the real sideslip angle. Correction for crooked yaw string: rudder against the string and/or aileron toward the string. In a spin the string always points to the inside. Every sailplane should have a yaw string.

Ball (skid ball; often part of turn-and-slip indicator):

The ball shows the direction of total force (weight plus centrifugal force) relative to the airplane. In a spin it is usually — but not always — deflected outward. It reacts sluggishly and is almost useless for sailplanes.

Spirit Level:

— shows the direction of total force in the opposite sense compared to the skid ball, reacts much faster, and is a good aid for blind flying, if filled with freezeproof liquid. Corrections for a skid: rudder against bubble, aileron toward bubble or both — in other words, just like the yaw string.

Altimeter (1) :

This is basically an air-pressure gauge, based on an elastic vacuum container (Aneroid). The altitude scale is calibrated for standard-atmosphere conditions. A setting knob adjusts for changes in local barometric pressure by displacing the measuring mechanism relative to the scale.

Altimeter with height scale:

Attached like a MacCready ring, the additional scale can be set to a different altitude to simplify turnpoint and final-glide calculations.

Barograph (2):

— records air pressure against time.

"Smoke" barographs record on a smoked aluminum foil and are more reliable than the ink type. Peravia-type barographs punch a tiny hole in special strips of graph paper every 6 seconds and provide a barogram that is particularly easy to read and evaluate, but they are very expensive and somewhat sensitive to rough handling.

Pitot airspeed indicator (7):

— measures the difference between total pressure, taken from the pitot tube, and static pressure:

$P_{total} - P_{static} = P_{dynamic}$

The scale is calibrated for km/h, mph, or knots and for standard atmosphere at sea level.

VARIOMETER SYSTEMS (3, 4, 5, 6, 8, 9, 10, 11)

The word "variometer" means literally "change meter," and this is how it should be understood. Without further information it remains unclear *what* changes are being measured. To clarify this we must differentiate between:

a) Rate of climb indicator (3, 4, 5, 6) (uncompensated variometer)	*measures change in aircraft altitude over time period*
b) Total-energy variometer (8, 9, 10) (TE-compensated variometer)	*measures changes in the aircraft's total energy over time period*
c) Netto-variometer (11) (TE-compensated variometer)	*measures lift and sink of airmass rather than sailplane*
d) Speed-to-fly variometer (11) ("Speed Director" designed by Bruckner)	*measures for which expected climb rate the current airspeed is optimum*

Each of these four instruments displays something entirely different, although their main component — the indicator itself — is always similar.

How it is connected and how it is used make the difference in what is measured. Variometers work on the following principle: a given air volume ("capacity") is used for the measurement of pressure changes. For this purpose the air volume has one capillary opening. Either the pressure difference between the capacity and the pressure to be measured is measured directly (diaphragm variometer, taut-band variometer) or the flow between the capacity and the pressure to be measured is used for indirect measurement by deflecting a vane (vane variometer) or, for example, by cooling an electrically-heated wire (electric variometer).

a) RATE OF CLIMB INDICATORS

The simple variometers which were once in general use, and were connected to a capacity and a static pressure, are rate of climb indicators. They display the climb or sink of the sailplane in m/s, fpm, or kt. Since the sailplane sink is affected by its polar sink rate (Ws) as well as by vertical air movement (Wm), such variometers could also be called "gross" variometers. Since the actual sailplane climb and sink displayed on these instruments depends not only on airmass movement and sailplane performance, but also in large part on angle-of-attack changes (elevator movements), the needle in a modern sailplane using current soaring techniques, which involve large airspeed changes, would execute remarkable excursions. This makes it virtually impossible to extract useful information, such as — for instance — the location of thermals.

Rate of climb indicators are creatures of the past. The only reason they are even discussed here is a twofold one: first of all, they are unfortunately still to be found in some 80% of training and "fun" sailplanes, and secondly they allow the clearest explanation of the actual measuring instrument, which can be constructed in various ways:

Diaphragm variometer (3):

— Operates with an elastic diaphragm and is very sluggish in response.

If the operation is especially sluggish, which can be achieved by means of restrictors in the connections, it is useful as an indicator of "average" rate of climb in thermals over a certain length of time, and it is simpler than electronic integrators and similar gadgets. Otherwise it has no further use for soaring.

Taut-band variometer (5):

This unit is based on the same principle as the diaphragm variometer, but the transfer of movement to the needle makes use of a frictionless taut band and a very light pointer. This allows a particularly rapid and accurate indication.

Vane variometer (4):

A movable metal vane attached to a fine return spring is deflected by the flow from the capacity. This is the most common type in current use.

Electric variometer (6):

Here one finds quite a few different principles; the most common makes use of two electric resistances (heated wires or thermistors) arranged behind one another in the flow path from the capacity. The airflow cools them at different rates, since one is always in the warmer air "downwind" of the other. This causes a difference in resistance which is indicated by means of a bridge circuit and meter. The advantages are very fast reaction and the possibility of using the changing electric current to drive a tone generator (audio variometer). Such variometers are found under the descriptions of "thermistor variometer," "heated-wire variometer," "metal-probe variometer," etc.

Other electric variometers operate on the diaphragm principle, in which the deformation of the elastic capsule is measured electrically; others make use of an electronic altimeter and electronic differentiation over time, so that the unit actually "calculates" climb or sink.

Since all of these units provide climb/sink information in electrical form they lend themselves (in conjunction with an electric airspeed indicator) as sensors for various automatic calculators.

b) TOTAL-ENERGY VARIOMETERS

While rate of climb indicators show altitude changes and hence changes in the potential energy of the sailplane, total-energy variometers indicate changes in the total energy of the sailplane, that is, both its potential energy (due to altitude) and its kinetic energy (due to airspeed).

$$E_{total} = E_{kin} + E_{pot}$$

The great advantage of the total-energy variometer is that airspeed changes, which are basically exchanges between E_{kin}, and E_{pot}, are no longer displayed. Thus, we can read if we gain or lose energy even if we are slowing or accelerating. This makes it much simpler to locate lift as "energy-increase areas." Due to its insensitivity to airspeed changes, the total-energy variometer is suitable for use with a MacCready speed ring.

There are various types of total-energy compensators which can be used to construct total-energy variometer systems:

MEMBRANE COMPENSATOR

The airspeed "signal" is fed into the system across an elastic membrane.

A connection is branched off the pitot tube (total-pressure pickup) upstream from the airspeed indicator, allowing total pressure to "bulge" the membrane to a greater or lesser extent. Thus, with increased airspeed air will be forced from the capacity side of the membrane into the variometer system, while the opposite is the case as the airspeed decreases.

Since the non-pitot side of the membrane is connected to the capacity side of the variometer system, increasing airspeed has the effect of causing a "climb" indication on the variometer, while decreasing airspeed will cause a "sink" indication. If the membrane has been calibrated exactly for the variometer, these airspeed effects are just large enough to cancel out the increase in sink due to acceleration (or, as the case may be, the decrease in sink due to speed reduction) of the sailplane. Thus, the variometer will show only changes in total energy

It is apparent that such a system will only work properly if the membrane meets rather precise specifications of size and elasticity, which in turn must be matched to the size of the capacity.

Most commercially-available compensators do not meet these requirements and are also subject to aging effects. Moreover, any membrane compensator will actually work properly only at one altitude, that for which it was calibrated or adjusted. Difficulties can also crop up due to the fact that the total-pressure signal is taken from a different point than the altitude-change static pressure (total pressure → compensator → capacity → instrument vs. static pressure → instrument). If one of the signals works more rapidly on the instrument than the other, gross distortions of the indication will occur, requiring further "fine tuning" with restrictors. Only one variometer at a time can be connected to a membrane compensator.

VENTURI COMPENSATOR

Instead of being connected to static pressure, the instrument is connected to a venturi in the free air stream which provides a pressure of $P_{static} - P_{dynamic}$, in other words a "negative" pressure. This venturi has a value of -1 and causes a static pressure reduction exactly equal to the increase caused by pitot pressure.

Function: in horizontal flight at constant airspeed (possible only in lift in sailplanes, of course), the entire variometer system is under pressure $P_{static} - P_{dynamic}$ which comes from the venturi. The variometer indicates 0 since both sides of the instrument see the same (lower than atmospheric) pressure.

Altitude loss at constant airspeed increases P_{static}. Since the measured pressure $P_{static} - P_{dynamic}$ also increases, the variometer shows sink.

Airspeed increase at constant altitude (only possible in lift) increases $P_{dynamic}$. This reduces the measured pressure $P_{static} - P_{dynamic}$; air flows from the capacity through the variometer, which indicates an increase in total energy ("climb").

If this "climb" indication is equal to the increased sink caused by increased speed (in still air) we have a total-energy indication which shows total-energy changes independent of airspeed changes. This is the case if the value of the venturi is exactly -1 and it is installed at a point on the aircraft where the airstream is exactly equal to the airspeed (free air stream).

Since this compensation method takes its airspeed and altitude signals from the same point there is no need for time compensation. The size of capacity is not critical and the venturi operates error-free at all altitudes. Moreover, this system has the advantage that a single venturi can be used with several variometer systems.

Since the installation of a speed-to-fly variometer requires such compensation, it is attractive to compensate the "normal" variometer with it as well.

These advantages have led to the fact that currently almost all competition sailplanes are equipped with such a venturi, even though it causes some slight drag and is not a particularly elegant addition to the lines of a high-performance ship.

Venturi compensators are reliable, operate with no aging problems no matter how long they are used, are inexpensive and easy to install once the proper spot on the sailplanes has been found.

The soaring world owes this practical means of compensation to Frank Irving (England), who published his ideas as early as 1948.

Types of venturi: the Cosim venturi (= Irving venturi) with endplate looks rather clumsy and certainly has more drag than modern venturis, but has the advantage of being fairly independent of yaw errors (up to 20°). The Althaus venturi, which has been measured in wind tunnels, is considerably more elegant, but unfortunately no longer so insensitive to yaw (about 10°), so that small corrections while thermaling can cause significant error signals — especially if the venturi is mounted on the fuselage. The Braunschweig Academic Flight Group developed an extremely yaw-insensitive (about 40°) and very small venturi on the same principle as the Cosim unit. Gerhard Waibel used a simple vertical tube with two holes in the sides. From Hanover comes a similar arrangement with slots, instead, developed by H. Bardowicks and known in English-speaking countries as a "Braunschweig Tube" even though it has nothing whatsoever to do with the city of Braunschweig. Nicks (USA) designed one with a single hole in the middle of a small tube. Actually, whatever one chooses to use to obtain a measurable pressure of $P_{static} - P_{dynamic}$ is fine, as long as it has a value of -1 (a simple way for testing this can be found on page 145). The measured pressure should be as independent as possible of yaw errors . . . after all, nobody's perfect!

ELECTRONIC COMPENSATOR

Two electric variometers, based on the construction principle of drawing (6), are connected differently:

Vario 1 is connected to static pressure (P_{static}) and hence operates as a height variometer. It has a double calibration, that is, it measures the variation over time of $2 \times P_{static}$.

Vario 2 is connected to P_{total} ($P_{static} + P_{dynamic}$) and is thus an "altitude/airspeed variometer." It has negative calibration, that is, it measures changes in $-(P_{static} + P_{dynamic})$.

Both values combined will measure the variation over time of $P_{static} - P_{dynamic}$ (since $2 \times P_{static} - P_{static}$

$-P_{dynamic} = P_{static} - P_{dynamic}$), as in a venturi-compensated variometer.

c) NETTO VARIOMETERS

1) NETTO VARIOMETER WITHOUT TOTAL ENERGY COMPENSATION

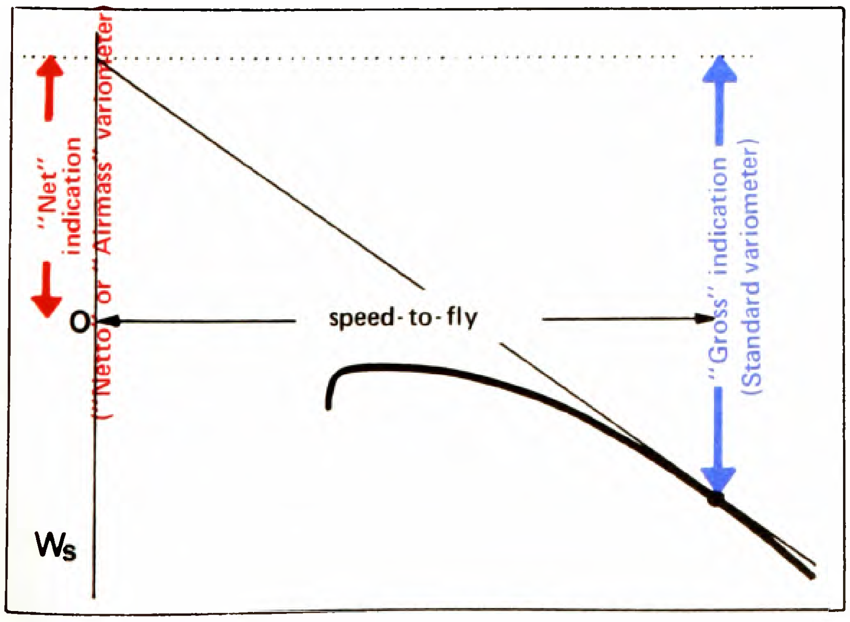
— shows the climb and sink of airmass (not of the sailplane!), as long as airspeed remains constant.

In order to achieve a "net" indication, the always-present polar sink of the sailplane (Ws) must be "compensated out" of the indication. To do this, one makes use of the fact that above the speed for best glide the polar sink speed of the sailplane increases roughly with the square of the airspeed. Since pitot pressure also increases with the square of the speed, one can use it to "compensate away" the effect of sailplane polar sink over virtually the entire speed range.

In order to clarify the principle, let us assume a sailplane flying in still air. Due to its polar sink Ws, the external pressure (P_{static}) will constantly increase. In a "normal" variometer, then, this pressure would cause a continuous flow of air from the atmosphere through the variometer into the capacity, causing a "sink" indication.

If we now arrange a capillary which will "bleed" just enough air from the total-pressure pickup (P_{static} + $P_{dynamic}$) into the capacity as would normally flow in through the variometer, the pressure in the capacity will increase at the same rate as the pressure of the outside air. No air would move through the variometer itself, and the indication would remain at "0", corresponding to the fact that the airmass was not in vertical motion. The "gross" variometer has become a "net" or "netto" variometer.

If the airmass is in vertical motion, the "netto" indication will still always differ from the "gross" indication by the amount of sailplane polar sink; that is, it will always indicate exactly the *airmass* vertical speed.



Different variometer indications

2) NETTO VARIOMETER WITH TOTAL ENERGY COMPENSATION

— *The TE-compensated netto variometer shows climb and sink of the airmass even during airspeed changes of the sailplane.*

Naturally, a netto variometer is only really usable if it continues to accurately show airmass climb and sink even if the airspeed changes. This can be achieved quite simply if the variometer is connected to the compensating venturi rather than to static pressure. However, since this venturi provides pressure $P_{static} - P_{pitot}$, while the capillary still "sees" total pressure, the pressure difference across the capillary has now doubled. The capillary must now be calibrated differently: if the calibration setup has not been changed, the calibration line is now the dot-dash line in the graph, which is obtained by simply halving the Ws-values of the previous calibration line.

INDICATION ERROR OF THE NETTO VARIOMETER CAUSED BY THE CALIBRATION CURVE

The difference between the speed polar and the calibration curve shows the indication errors which are unavoidable in the netto variometer system. In the ASW 15, this causes lower indications than the actual airmass movement at airspeeds less than 88 km/h, since the polar is not completely "compensated out." From 90 to 160 km/h the indications of the netto vario will be "skewed" toward a climb; above 160 km/h the error changes sign once again. In the ASW 15, these errors are on the order of 0.015 m/sec, and are not so large as to significantly impair the usefulness of the variometer system.

CALIBRATION VALUE FOR THE CAPILLARY

It is obvious that the amount of air flowing from the total-pressure source through the capillary into the capacity must be very accurately controlled for the system to function properly. The longer and narrower the capillary, the less its compensating function; thus, it must be exactly calibrated. It will be different for sailplanes with different polars and is also dependent on the size of the capacity.

Since the pitot pressure increases with the square of the speed, the compensative effect of the capillary also increases with the square, and can be graphed as a parabola. That particular parabola which most nearly approximates the speed polar is the basis for calibration of the capillary.

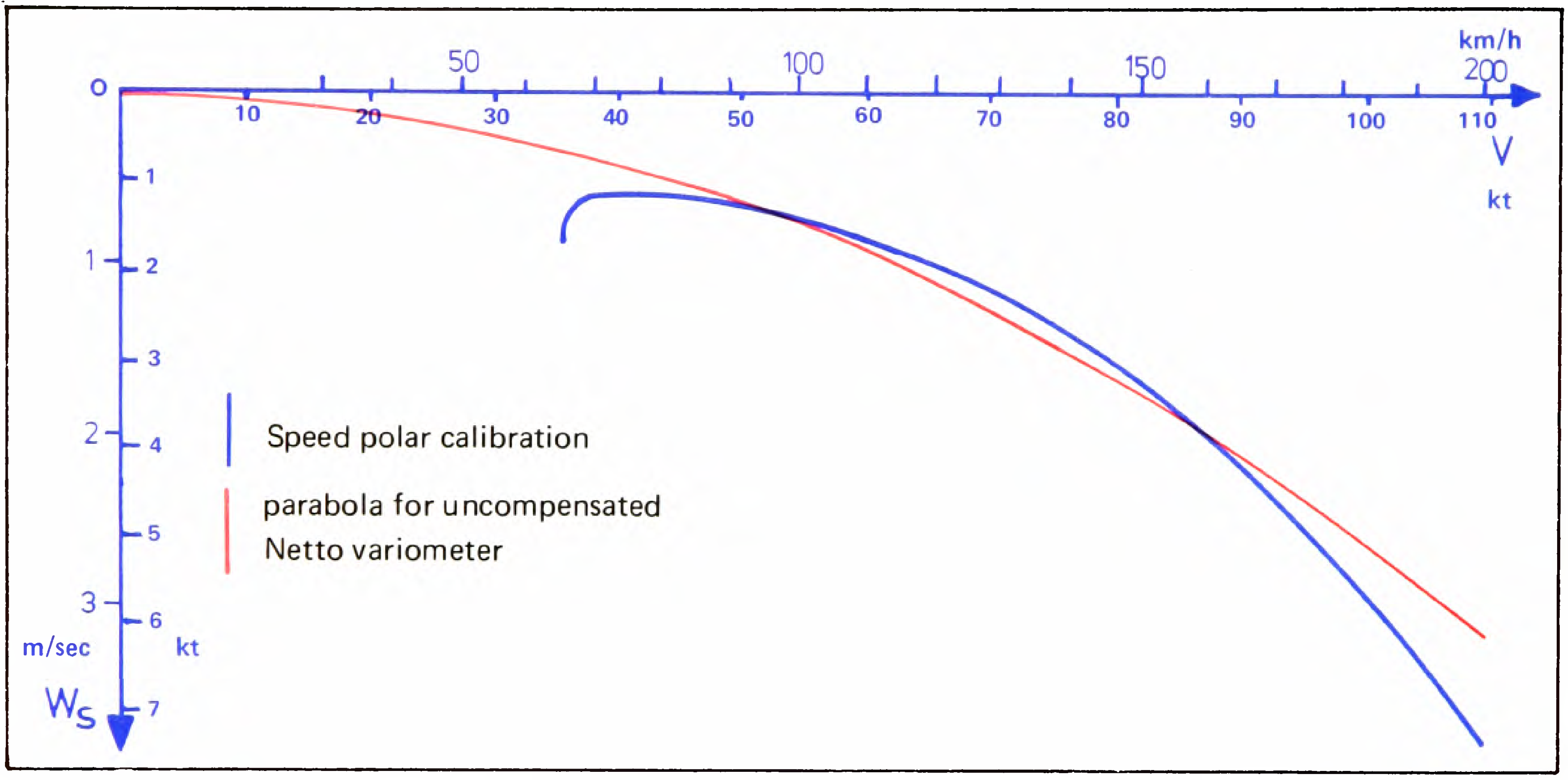
In order to avoid time-consuming construction of parabolas in the speed-polar diagram, we make use of a trick: if one graduates the V-axis according to the square of the speed rather than the speed itself, the speed polar will become an almost straight line, and any calibration parabola will be a truly straight line passing through the origin. The second graph shows the V^2 axis and above it the now-quadratically-divided values of V. The polar of the ASW 15 (kp/m^2) has become an almost-straight line. A freely-chosen, close-fitting calibration line (drawn in red) passing through the origin shows the values for calibration of the capillary (e.g. 160 km/h and −2 m/s).

CAPILLARY CALIBRATION PROCEDURE

We simulate flight with no loss of altitude (since the sailplane remains on the ground):

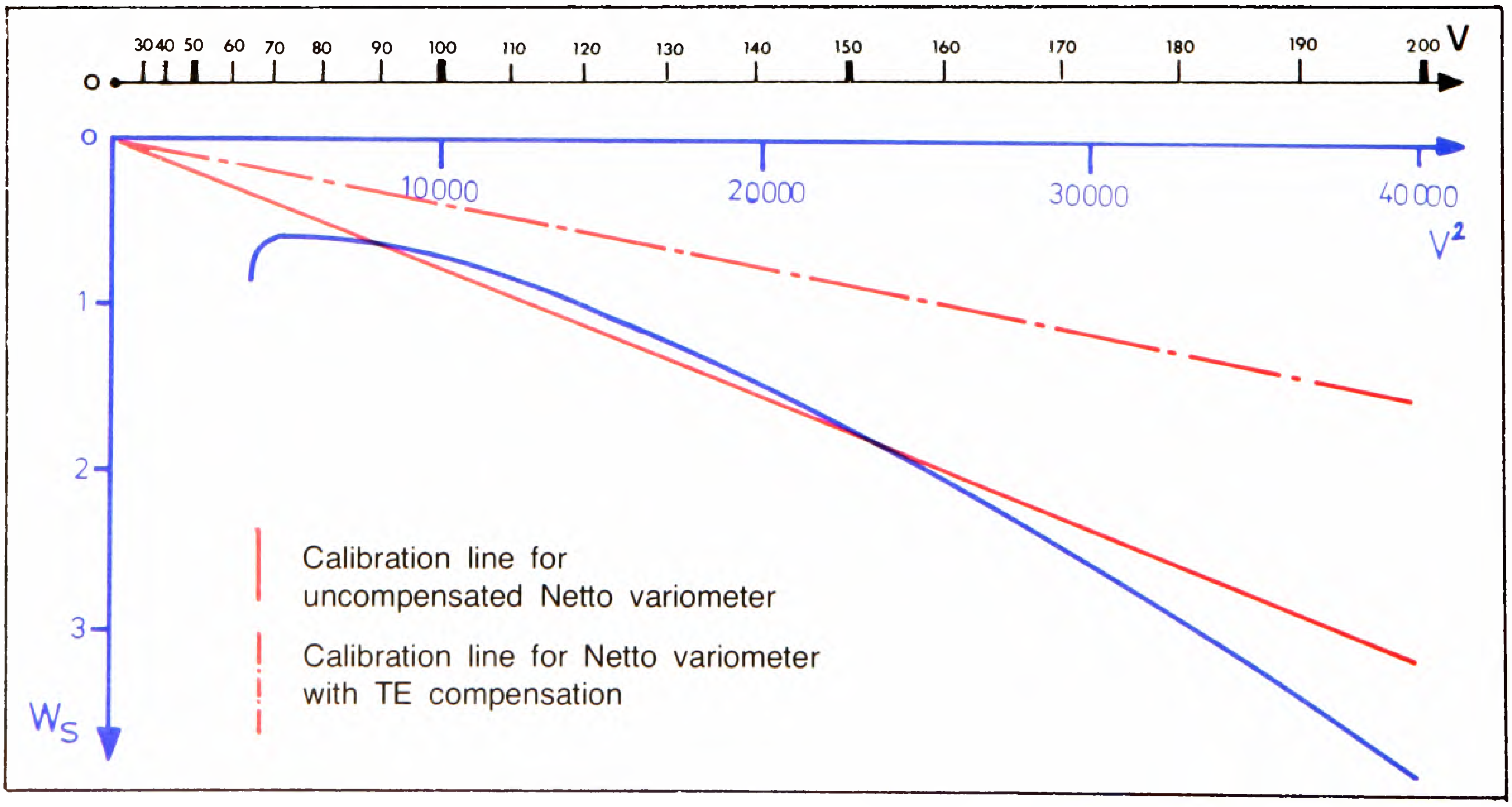
Such a flight is actually possible only if the airmass is rising exactly as fast as the polar sink rate of the sailplane; thus, the netto variometer must now show this value as a climb. All that is necessary is to fix a hose to the pitot tube and blow gently into it until the airspeed indicator shows the desired value.

Once the variometer indication has settled down and the airspeed indicator is steadily showing the desired value, the variometer should indicate a climb corresponding to the datum from the calibration line at the point of the simulated airspeed. For the ASW 15, for instance, this would mean a variometer indication of +2 m/s at an indicated airspeed of 160 km/h. If total-energy compensation is employed, half the variometer indication (1 m/s) would be correct, since



Calibration for Netto Capillary

ASW 15, 5.75 psf

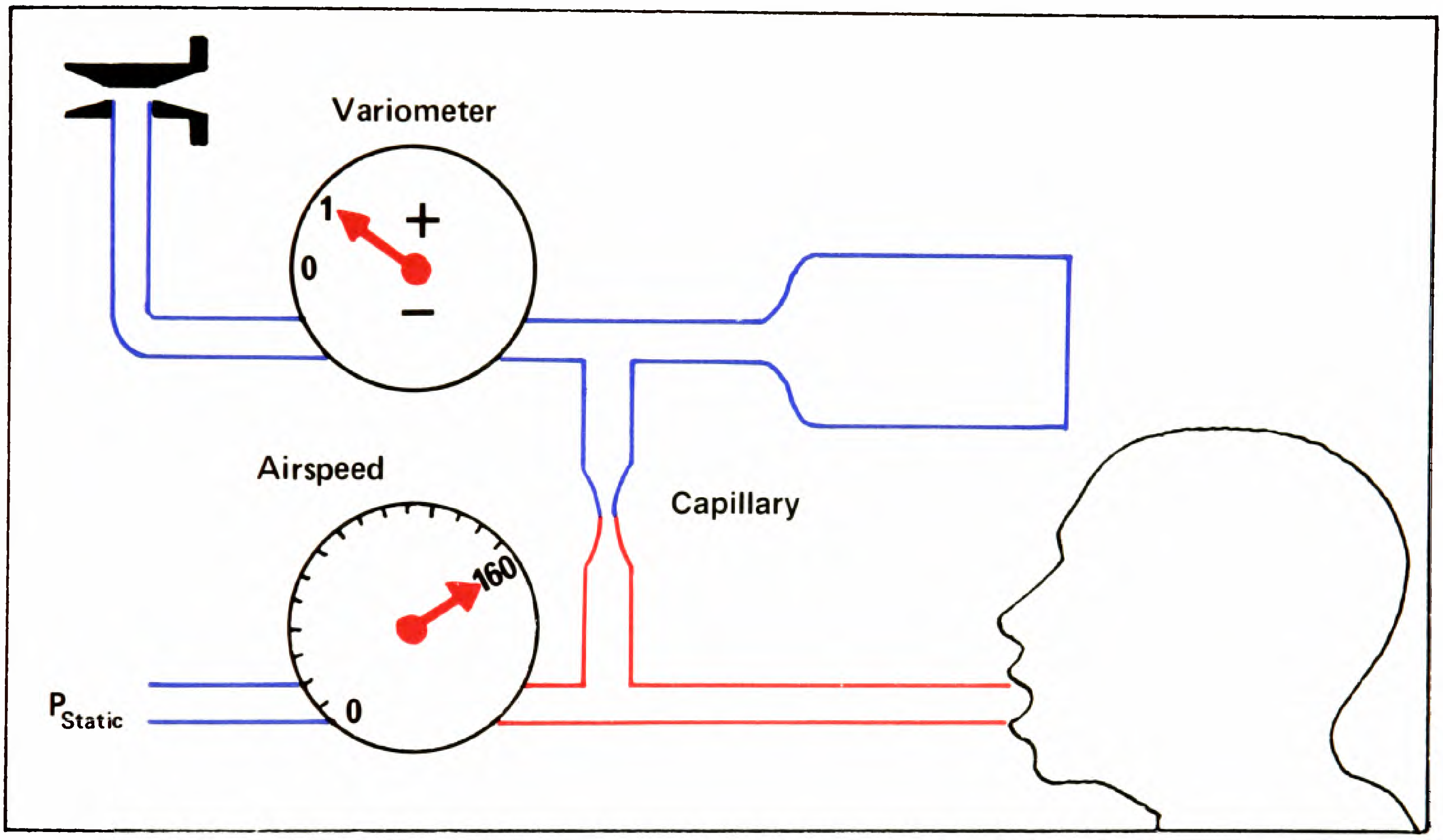


Calibration values in quadratic diagram

we are not simulating the lowered pressure at the total-energy venturi. A good material for capillaries is medical capillary tubes or glass thermometer tubing with an interior diameter of about 0.3 mm. If the climb indication is too small, the capillary must be shortened until it is accurate. For compensated netto variometers with a 0.45-liter capacity, the length of the capillary will be somewhere between 8 and 15 cm. If the capacity is larger, the capillary will prove to be shorter. Once the capillary has been set for one value pair, the calibration is automatically correct for all other values. Thus, the actual procedure is as simple as can be imagined.

SPEED RING FOR NETTO VARIOMETER

Value pairs for speed-to-fly/netto sink are constructed from the speed polar as on page 104. The netto sink (or climb) speeds are the Wm values, that is, measurements are made from the origin of the initial coordinate system and not from the polar. The value for a netto sink of 0 (speed of best glide) is the mark on the speed ring that should be set in flight opposite the expected *sailplane* (i.e. "gross") climb rate.



Calibration of TE — compensated netto variometer

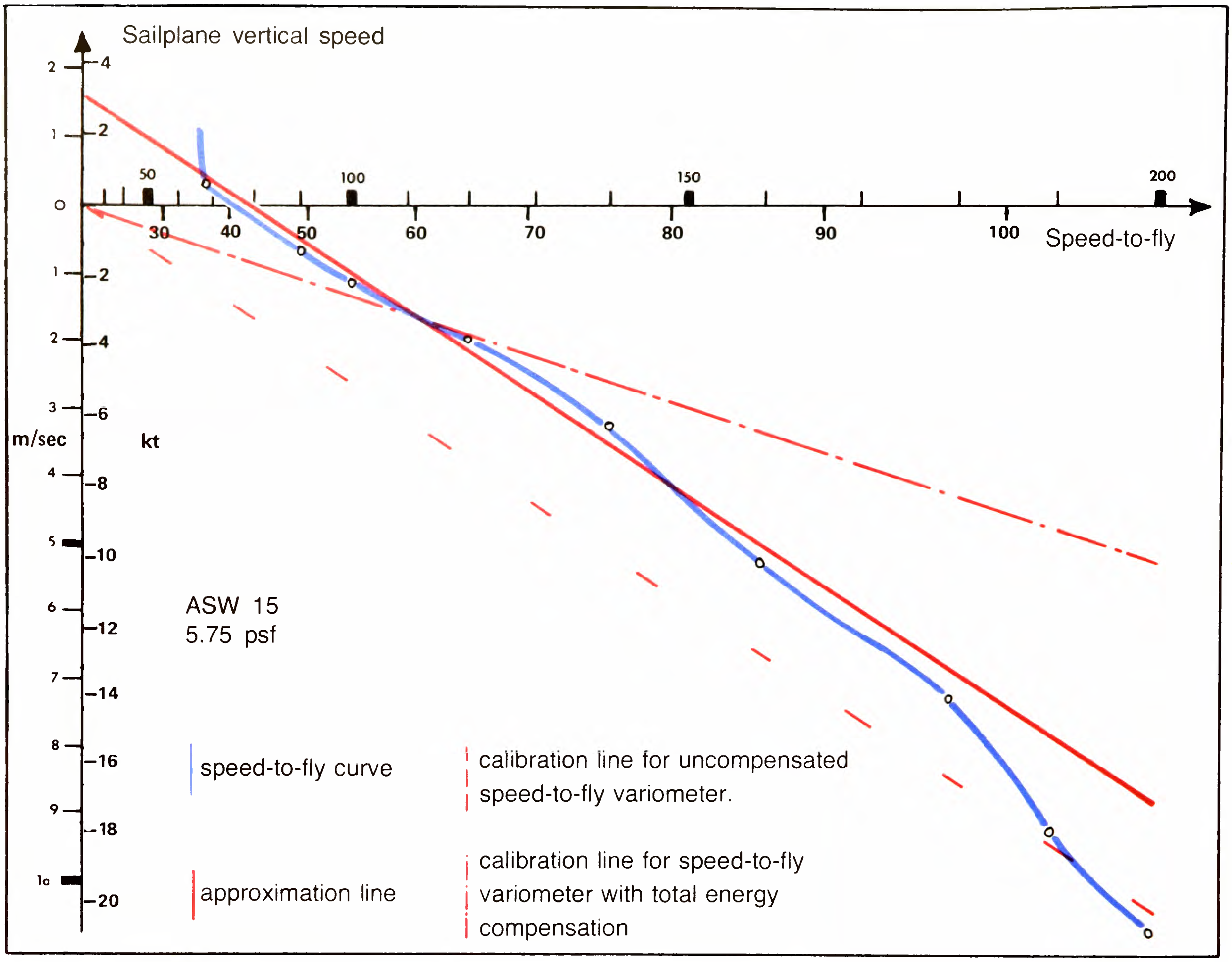
ADVANTAGES AND DISADVANTAGES OF THE TOTAL-ENERGY NETTO VARIOMETER

Since the calibration of the netto variometer is based on the straight flight polar, it is inaccurate for any flight condition in which the straight-flight polar no longer obtains, including sloppy flying, dirty or wet wing surfaces, changed wing loading, *or circling.* Since the increased polar sink is no longer completely compensated by the capillary, the netto variometer indicates values that are displaced to a greater or lesser extent toward "sink." Thus, the netto variometer can really be used only in yaw-free straight flight — a definite disadvantage.

Perhaps the netto variometer makes it easier to understand weather processes. A further advantage is that the speed-to-fly indication can immediately be read at its full value upon entering an area of sink, while increases in speed cause a "gross" total-energy variometer to indicate greater sink and hence call for a higher speed-to-fly. The same is true on entering lift. Overall, though, it remains questionable whether it is worthwhile to change a regular instrument into a netto variometer.

On the other hand, it is definitely more than worthwhile to use the same principle — and the same minimal amount of work— for the construction of a speed-to-fly variometer.

Speed-to-fly curve and calibration points for speed-to-fly variometer (quadratic diagram)



d) SPEED-TO-FLY VARIOMETERS (11)

("Cruise Control" designed by Brückner)

The total-energy compensated speed-to-fly variometer shows the climb speed for which the current airspeed is the proper speed-to-fly. (To be exact, it would have to be called a "total-energy compensated expected climb variometer.")

In order to understand the workings of the speed-to-fly variometer it would be a good idea to run through the preceding discussion of the netto variometer.

While the meaning of a netto variometer is quite different from that of a speed-to-fly variometer, the actual construction and connection of the instrument is the same, although its capillary must be calibrated differently.

FUNCTION AND CALIBRATION

For an optimum glide, any sailplane has a certain speed-to-fly. The blue speed-to-fly curve in the graph (note that the speed-to-fly axis is quadratically divided) shows the values for an expected climb of 0; they are the same as the values for division of the speed ring on page 103.

Based on the already-stated definition of the speed-to-fly variometer the gadget should indicate 0 no matter "where on the speed-to-fly curve" we are flying. Somehow we have to figure out a way of calibrating the variometer so that the blue speed-to-fly curve results in a zero indication.

The speed-to-fly curve itself is first "replaced" by a linear approximation, which unfortunately does not pass through the origin. How can we compensate this to zero? By proceeding in two separate steps:

1) We'll physically readjust the zero point of the variometer by the same amount toward "sink" that the approximation line intersects the climb axis positively — in this case, 1.6 m/s. This can be done on most common vane variometers by carefully removing the glass and adjusting the central adjusting wheel; those who do not feel sanguine about rushing in where others fear to tread could have it done by the manufacturer. Variometers that cannot easily be reset must be provided with an external "expected climb

scale." This zero-point readjustment has the effect of moving the approximation line down until it intercepts the origin of the coordinate system.

2) This red dashed line can now be compensated to 0 by an appropriate capillary, just like that of the netto variometer. However, since we want our speed-to-fly indication to remain valid in flight even if the airspeed changes, we'll connect the instrument to the total-energy venturi and calibrate for half the original value, just as before for the total-energy netto variometer. Calibration procedures and hookup are exactly the same.

For those to whom this calibration procedure doesn't appear sufficiently logical or rigorous, let us work through the following explanation. We simulate once again flight with no loss of altitude and "blow up" a given speed-to-fly, which in the real world would only occur for an appropriate expected climb. For the ASW 15, for example, level flight at 167 km/h would require lift of +5.6 m/s (red solid approximation line). By adjustment of the variometer zero point alone the instrument is now showing −1.6 m/s; thus, the capillary must achieve a total compensation of 5.6 + 1.6 = 7.2 m/s toward "climb." This requires calibration for half of the desired amount (3.6 m/s) since we are not simulating the lowered pressure at the total-energy venturi. Since the zero point has been set down by 1.6 m/s, the variometer should read +2 m/s.

The best instruments to use as speed-to-fly variometers have ranges of 8 – 10 m/s, although 5-meter instruments can also be used. Older ultrasensitive variometers with large capacities can be used by connecting them to capacities with ¼ the volume. Thus, for example, a not-very-useful 2 m/s variometer can be converted to a splendid 8 m/s speed-to-fly variometer.

Errors of the speed-to-fly variometer due to calibration:

Since the approximation line does not correspond exactly to the speed-to-fly curve, indication errors occur. In the case of the ASW 15, the errors in the speed-to-fly range of 68 to 180 km/h are less than 4 km/h! This is so little that it does not affect cruise speed measurably.

The error of up to 15 km/h in the 200 km/h range is also not particularly critical.

USE OF THE SPEED-TO-FLY VARIOMETER IN FLIGHT

1) STRAIGHT FLIGHT

If one flies at optimum speeds, the needle of the indicator will always show the ("expected") climb (speed ring setting), regardless of "MacCready" airspeed changes.

If the indication sinks below this value, we are flying too slowly; if it rises above it, we are flying too fast.

If the indication remains above the expected climb value despite flight at minimum-sink speed, it is worthwhile to circle.

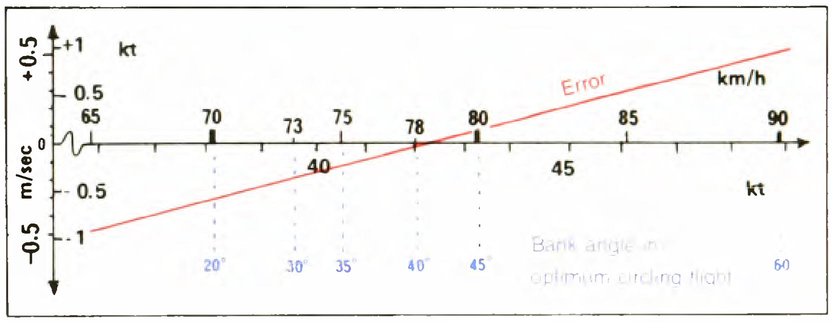
If the speed-to-fly variometer incorporates an audio unit, we attempt to keep the pitch of the tone as constant as possible in straight flight. If the tone falls, speed up; if it rises, slow down; if it remains too high even at minimum sink, circle.

If one has a double-tone audio with constant and "chopped" tones, it is recommended that the threshold between "constant" and "chopped" be set right at the expected climb.

2) CIRCLING

In circling flight the speed-to-fly variometer loses its original meaning; what we need now is actually a total-energy indication of climb and sink, as provided by a TE- "gross" variometer, both for centering the lift and for determining its strength. How does the indication of a speed-to-fly variometer differ from that of a "conventional" TE-instrument?

There are, of course, two differences: first of all, there is the changed zero point of the speed-to-fly instrument, and secondly the changed indication due to the air flowing through the capillary. Both cause an "error" just opposite to the way it is depicted by the approximation line in the speed-to-fly variometer calibration graph. For clarity, the area around the usual thermaling speeds has been extracted and enlarged below.



Errors caused by using a speed-to-fly variometer as a total energy variometer while circling (ASW 15)

We can see that at 78 km/h the properly calibrated speed-to-fly variometer will indicate the same as the "gross" variometer. From 78 to 90 km/h the speed-to-fly variometer will show an increasing excess (up to 0.5 m/s too high); from 78 km/h to the stall speed the indication will be too low (again, by up to 0.5 m/s). This speed range covers optimum circling for the ASW 15 at all bank angles up to 60°.

Thus, if one plans to use the speed-to-fly variometer for circling it is recommended that the calibration curve be laid out (if possible) so as to cut the speed-to-fly axis at or near the area of usual circling speeds.

We can see that the speed-to-fly variometer is usable for circling in a pinch, but is accurate for only one particular airspeed which is set by the calibration. A better solution would be the inclusion of a valve by which one could shut off the capillary, thus changing the instrument into a TE-gross variometer (a separate scale would be required due to the changed zero point).

In sailplanes of the open and 15-m classes, one can arrange this capillary value so as to be operated automatically when the flaps are moved into climbing position. Such "automation" ensures correct display at all times and prevents the pilot's forgetting to change the mode.

ADVANTAGES AND DISADVANTAGES OF THE SPEED-TO-FLY VARIOMETER

Other than the rather problematic area of use as a circling variometer (which would require the addition of a shutoff valve for the capillary), the only disadvantages of the speed-to-fly variometer are those which it shares with other instruments such as TE-gross variometer, speed ring, and airspeed indicator: altitude errors, acceleration errors, and errors due to changed wing loading.

The speed-to-fly vario can be elegantly adapted to various wing loadings by the addition of a selector valve and several appropriately-calibrated capillaries, disregarding the small zero-point readjustments.

The great advantage of the instrument is, of course, that it takes over the function of two instruments at once: TE-variometer with speed-to-fly ring and airspeed indicator. *One* glance at the panel is all it takes to be sure of flying at the correct speed-to-fly.

The airspeed indicator can be installed out of the pilot's direct field of vision if necessary, since it will only be used for takeoffs, landings, and other special conditions of flight.

The excellent idea behind the speed-to-fly variometer comes from the physicist Egon Brückner. He also developed the netto variometer, without realizing that Paul MacCready had already suggested the principles behind its operation at an earlier date.

The speed-to-fly variometer has made possible such increases in flight performance that it will certainly revolutionize the instrumentation of our sailplanes, just as the MacCready ring did years ago. Once its function is understood, its construction is extremely simple.

By now, hardly any top competition pilot flies without this device; it has become as "mandatory" as good total-energy compensation.

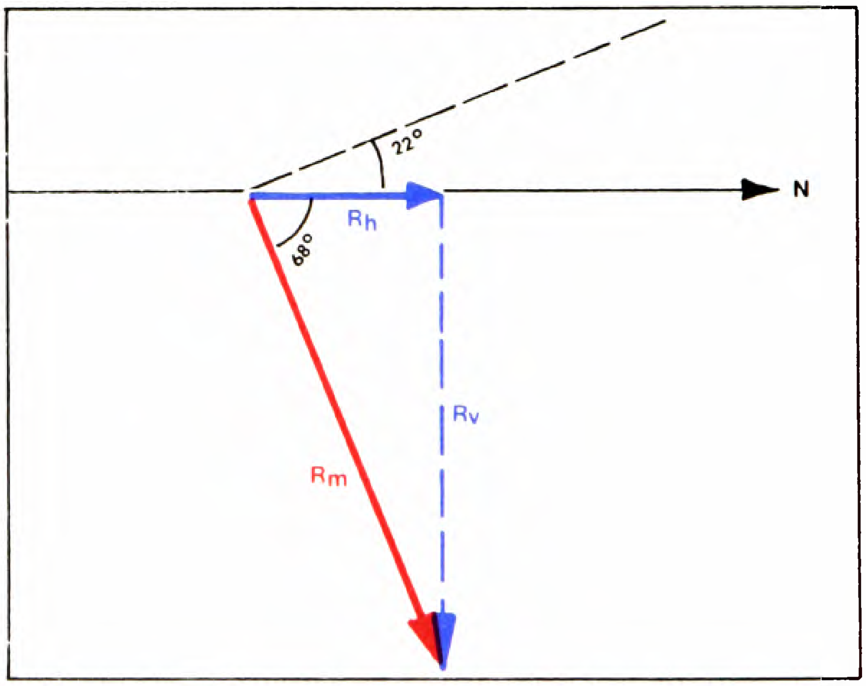
CAPILLARY CONNECTION TO STATIC PRESSURE INSTEAD OF TOTAL PRESSURE

Both the TE-netto variometer and the speed-to-fly variometer can also be connected differently. If one connects P_{static} to the capillary, rather than P_{total}, the pressure difference across the capillary in flight is only $1 \times P_{pitot}$. A variometer connected in this fashion will be calibrated in the same fashion as described on page 134, with the difference that the full value, rather than half value, of the approximation line will be calibrated. Variometers connected in this fashion have shorter capillaries but are twice as sensitive to inaccuracies of the compensating venturi.

8) COMPASS — (12, 13, 14)
COMPASS ERRORS

The magnetic lines of force of the earth's magnetic field are only roughly parallel to the geographic north/south direction. The local *variation* is different from place to place and is available on air charts in order to allow correction in course calculation. The *inclination* is the slope of the lines of force in a downward direction (in northern Europe about 68°) and can, depending on aircraft attitude and compass type, cause "turning errors." The *deviation* is the compass error caused by its installation near metal parts of the sailplane, and can be minimized by choice of compass position and, if necessary, be compensated at the compass itself. If this is not possible, a deviation table must be provided.

Magnetic forces (for Central Europe)



N	Geographic north
R_m	Direction of earth's magnetic field
R_h	Horizontal component of Rm
R_v	Vertical component

COMPASS TURNING ERRORS

In the following examples, local variation and installation deviation will be disregarded, that is, assumed to be zero. In order to minimize turning errors, the

Cook compass and the universally mounted mass-balanced compass ("Bohli" compass) have been developed.

The Cook compass (13)
— is fixed, but can be manually turned, along the sailplane roll axis and is freely gimballed in pitch. The magnet itself is not freely gimballed, but rigidly attached to a vertical axis. If one takes the trouble in flight to constantly set the compass upright (by observing the horizon or artificial horizon as necessary), the magnet needle can only rotate in a horizontal plane; in constant circling flight, no turn errors will appear.

The universally-mounted mass-balanced compass (14)
— has the advantage that the magnet can always align itself with the magnetic lines of force. To read the compass correctly, though, one must still manually position a transparent compass rose horizontally over the needle. As in the Cook compass, the compass rose can be manually rotated about the sailplane's roll axis. This compass has the further advantage that the needle provides attitude information for blind flying, even if the housing has not been set to the horizontal.

Any other compasses (12)
— in which the magnet can only be kept level in straight-and-level flight (since its center of gravity lies below the point from which it is suspended) will show turning errors depending on aircraft attitude and direction.

1) STRAIGHT FLIGHT

We will assume that we are flying due North:

—level flight
the horizontal compass needle is directed by the horizontal directing component R_h, which is much smaller than the total force R_m.

—during pitchover (acceleration)
the compass rose initially tilts in the same direction, the horizontal force is enhanced.

—during pull-up (deceleration)
the compass rose tilts in the opposite direction, the horizontal force becomes smaller (unstable indication) until it reaches a critical angle of 22° and becomes = 0. Further deceleration causes the compass to reverse to an S indication.

—roll to the left
as long as the compass rose also rolls (coordinated turn) the vertical component R_v has the opportunity to act on the needle and pull it downward and to the left. Result: the compass moves to the right and indicates too great a course (error — 30°).

— roll to the right
causes a false westward indication.

Flights to the South, West, East:
— cause similar errors for the same reasons. In order to avoid irritation due to the various different kinds of false indication, it is important to remember that the needle is always pulled *northward* and *downward* in the northern hemisphere. For greater clarity, see the following table:

flight direction	N	S	E	W
acceleration indication	St	U	left to N	right to N
deceleration indication	U	St	right to S	left to S
roll left	right to E	left to E	U	St
roll right	left to W	right to W	St	U

>St = stable U = unstable

For courses such as NE, NW, etc. the errors of the neighboring cardinal points are in effect but weaker.

In order to avoid these errors, one should get into the habit of waiting at least five seconds after maneuvers involving bank or pitch to allow the compass to settle down before reading.

2) TURNING FLIGHT

In constant circling flight the compass rose will be vertical to the combination of weight and centrifugal force. The strength of the "north-seeking" horizontal force is dependent on the size of the angle between the magnetic lines of force and the plane of rotation of the compass rose. At a bank angle of 22°, therefore, in a left turn the E indication is overly stable and remains visible for too long.

North appears too late.
West is completely unstable.
South appears too early.

If one wants to get more or less reasonable indications for all directions one cannot circle very steeply. At 80 km/h, a one-minute turn (6°/sec.; one needle width on standard sailplane turn indicator) requires only 13° bank angle, which is less than the critical angle.

ONE NEEDLE-WIDTH TURN

— results in following compass indications:

left turn:				
direction	E	N	W	S
indication	stable	30° late	unstable	30° early
right turn				
direction	W	S	E	N
indication	stable	30° early	unstable	30° late

Thus, for normal visual flight one can remember:

1) *North is always indicated too late, South always too early*
2) *In a left turn, East will be stable; in a right turn, West*
3) *Rolling out on course:*
   Lead North by about 30°
   Overshoot South by about 30°

For corrections, when cloud flying, depending on the desired course change:

1 second of rudder only (1 needle-width) results in about 10° change

5 seconds of coordinated turn (count aloud) = about 30° change

TWO-NEEDLE-WIDTH TURN (12°/sec)

— at 80 km/h, 12°/sec requires about 26° bank = more than the critical bank angle.

left turn:				
direction	E	N	W	S
indication	E →	N →	E → S	→ E
	stable	rapid	reversal	

right turn:				
direction	W	N	E	S
indication	W →	N →	W → S	→ W
	stable	rapid	reversal	

left turn: the E appearing after S is correct
right turn: the W appearing after S is correct

The compass rose must turn left in a left turn, right in a right turn.

Rolling out on course:
either:

time rate of turn from a known accurate heading (E or W)

at 12°/sec:	start	7½ sec	15 sec	22½ sec
left turn:	E	N	W	S
right turn:	W	N	E	S

or: reduce turn rate to one needle width, then recover.

9) TURN AND SLIP INDICATOR (15)

The precession of the rotating gyro causes a needle deflection as long as the sailplane is turning about the yaw axis. If one allows a sailplane to gradually turn more and more steeply, the turn indicator will initially show a faster and faster turn, then later a lower rate. In the extreme case of a circle with bank = 90° the turn indicator would remain at zero since there would be no rotation about the yaw axis. This fact can allow novice cloud flyers attempting steep turns to make control errors by which a modern high-performance sailplane will very rapidly approach its limit load.

10) LIFT COEFFICIENT METER (17)

In 1975 an American pilot published the details of an extremely simple device he had developed to measure the coefficient of lift (C_L).

PRINCIPLE OF MEASUREMENT

Given that the angle of attack and thus the coefficient of lift are kept constant in flight, then the relationship of lift to total pressure (pitot plus static) will be linear, since

$$F = q \cdot C_L \cdot A$$

Lift then determines, for example, how hard the pilot will be pressed into his seat in turning flight. If one were to allow an airstream derived from total pressure to play from below on a sphere in a funnel-shaped tube, this sphere would "float" upward. As long as C_L remains unchanged, the position of the sphere would remain constant even during changes in airspeed and acceleration. Thus, the position of the sphere is an indication of the instantaneous value of C_L and thus also an indication of angle of attack.

CONSTRUCTION AND CALIBRATION

This device is very easy to construct: we will obtain (from a laboratory supply house) a flowmeter, a tapered glass tube with a choice of spheres of varying weight, like the old Cosim variometer (pellet variometer). The upper end is connected to a *separate* static connection, the lower to a *separate* pitot connection. These connections *must* be separate from those for the other instruments, or the flow through the lift coefficient meter will affect them.

For an initial rough calibration, temporarily connect an airspeed indicator to the lift coefficient meter's pitot connection and blow gently to simulate a speed equal to the stall speed of the sailplane. Install an appropriate restrictor upstream of the lift coefficient meter so that the sphere floats in the lower section of the tube.

Exact calibration is carried out in flight, by marking the tube for minimum speed (just above "mushing") minimum-sink speed, and best-glide speed. (V_{min}, Ws_{min}, L/D_{max}).

USE IN FLIGHT

Apart from the very small errors caused by changes in Reynolds number and asymmetric airflow over the wings in circling flight, the indicator always shows exactly the current value of the coefficient of lift.

Such direct aerodynamic information is very valuable in flight. As soon as one flies into lift, the sinking of the sphere, as well as the increased seat pressure, provide immediate recognition, well before the variometer can react. The indicator is particularly useful for steep and/or irregular circling flight, since keeping the value of C_L constant and near maximum helps avoid aerodynamically unfavorable control movements; the airspeed indicator is not a good aid to this task. When flying speed-to-fly, the unit can help avoid very low — and hence unfavorable — C_L values, as well as avoiding high-speed stalls during sudden pullups.

In training, the lift coefficient meter is a useful safety aid. Stalling, falling through, spins, and so forth can be avoided without unnecessarily high airspeeds, as long as the sphere is kept over the maximum-lift mark. An acoustic warning of some sort would be particularly valuable.

The real value of this instrument is probably its tendency to reveal mercilessly even the slightest aerodynamically unfavorable control inputs, thus helping the pilot to avoid them in the future. Even if the indication tends to be dismissed after sufficient practice in flight, the possibilities of the lift coefficient meter remain very interesting for student pilots and for competition training.

INDICATION ERRORS OF PNEUMATIC INSTRUMENTS

1) ALTIMETER AND BAROGRAPH

Since these instruments measure atmospheric pressure, they are influenced by atmospheric factors. For example, if the air pressure drops due to the approach of a weather low (or flight toward one) lower pressures will occur at unchanged altitudes, with the result that the altimeter indicates that we are higher than we really are ("from high to low, look out below").

Warm air has a greater volume than cold air; thus, for the same surface air pressure, the warm summer atmosphere is thicker than in winter, and its air pressure decreases more slowly with increasing altitude. On hot days we fly higher than our altimeter indicates since it is calibrated for 15° C/59° F at sea level.

A rule of thumb for the temperature error is:

$$h = hi + \frac{hi}{100} \cdot 0.36 \cdot (t - t_s)$$

in which

h = actual height
hi = indicated height
t = average temperature between surface and h in °C
t_s = standard average temperature between surface and h in °C

Therefore, for each degree C difference between the average temperature for the layer between the surface and the flight altitude and the standard temperature for that layer, the altitude error is 3.6%.

For conditions of 35° C and soaring weather with a lapse rate of about 1° C per 100 m altitude, 1000 m actual altitude (start altitude for competitions) would only be indicated as 920 m! One should bear this in mind in competitions for both starts and final glides.

2) AIRSPEED INDICATOR

At higher altitudes, pitot-type airspeed indicators will measure less dynamic pressure for the same airspeed than at lower altitudes, and will read low; the actual airspeed is higher than the indication.

Since, for a given altitude, warmer air is also less dense than cold air, temperature also plays a role. The formula for true airspeed is:

$$V = Vi \sqrt{\frac{\delta.}{\delta}}$$

in which
V = true airspeed
Vi = indicated airspeed
δ = actual air density
$\delta.$ = standard air density

The diagram of indicated vs. true airspeed on the back of the dead-reckoning plotter on page 148 shows the difference graphically.

For completeness' sake we should add here that the behavior of the sailplane with respect to the air is the same as that of the instruments. In other words, we should always fly according to the instrument indications, even at high altitudes; the actual speed remains a theoretical quantity. This holds true for stall speed, redline, best glide, etc.

3) VARIOMETERS

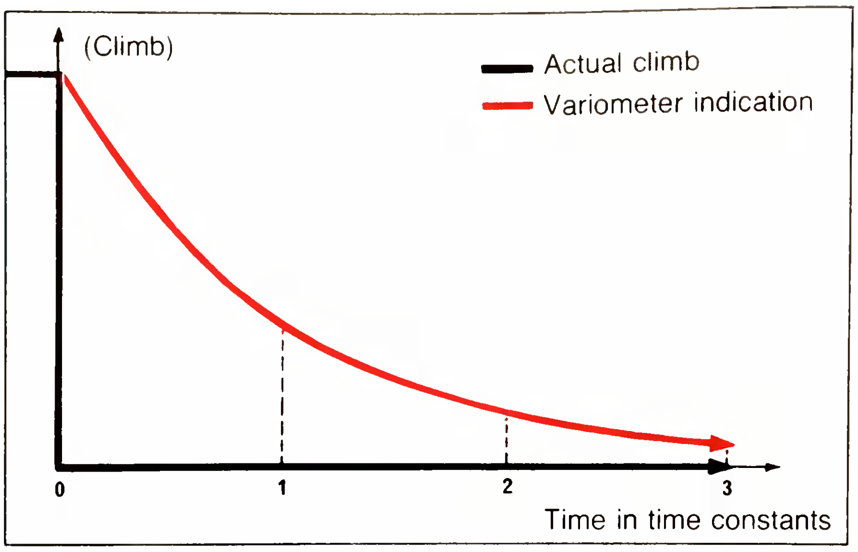
ERRORS DUE TO TEMPERATURE CHANGES OF AMBIENT AIR

The climb indication of a variometer is caused mainly by the expansion of the air in the capacity compared to the decreasing outside pressure. This expansion causes the air in the capacity to cool almost adiabatically (especially since the capacity is usually a thermos flask and allows only minimum temperature losses). This then causes the capacity air to expand a bit too little (since it is now cooler), causing a slightly low variometer indication. When the actual climb stops, the indication does not reach 0 at once, since the walls of the capacity remain warmer and gradually heat the air, causing further expansion. This process lasts more than 20 seconds and causes considerable hysteresis.

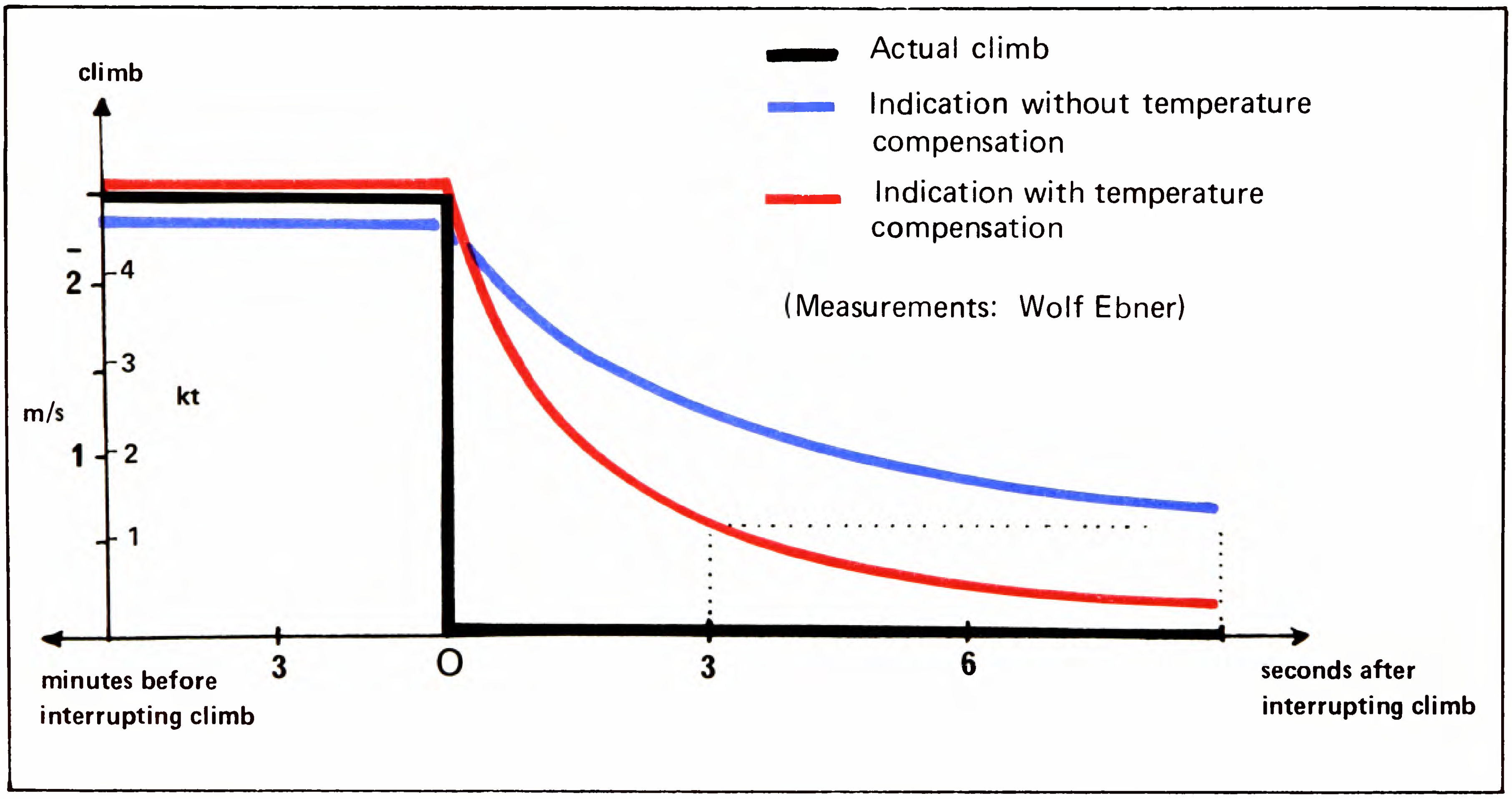
Luckily, the problem can be dealt with in a really sophisticated and elegant fashion:

For each individual capacity bottle, take 3-5 copper "chore girl" pot scrubbers and stuff them in — that's all it takes! This causes the temperature of the air from the capacity to remain essentially constant and effectively ends all temperature problems. The rapidity of indication is increased, often several times over, and becomes more exact. Those who eschew this technique should not try to buy a "fast" variometer, particularly an electric one — it would be money wasted. The graph shows typical test results with and without temperature compensation. The vario without pot scrubbers takes 9 seconds to settle down to the value that the one with scrubbers reaches after only 3 seconds; that is, it takes three times as long. In the case of naturally fast variometers the difference is even more impressive.

Time Constant



Variometer indications with and without temperature compensation



THE TIME CONSTANT

Even if the temperature compensation is installed, no variometer can react instantaneously to changes in rate of climb. In measurement techniques one uses the term "time constant" to express the time that an instrument requires to display the result, except for a remainder of ($\frac{1}{e}$ = 0.368), for an instantaneous change. Expressed the other way, about 63% of the change must be displayed. Actually, the instrument will never quite display the entire change, since after the passage of one time constant it will require another to reduce the remainder by 63%, and so forth. The typical measurement for variometers is illustrated in the graph.

The faster a variometer responds, the shorter its time constant. The time constant for diaphragm variometers is usually distinctly more than that for vane instruments. Instruments of the same type but differing in scale and size of air capacity have different time constants.

ALTITUDE ERRORS OF VARIOMETERS

Depending on what a variometer actually measures it can be considered a mass-measuring or a volume-measuring instrument.

Volume-measuring variometers:

such as diaphragm variometers, taut-band instruments, vane variometers, and electric variometers based on the diaphragm principle, have no altitude error. At any altitude, a given climb rate will cause a given volume of air to flow through the capillary; thus, the geometrically-measurable climb is displayed.

This is not that reassuring for speed-to-fly purposes, however, since at high altitudes these instruments, as we will soon see, have other high-altitude speed-to-fly errors.

Mass-measuring variometers:

measure (usually indirectly by measuring the cooling of the capacity airflow) the mass of the escaping air. However, for the same volume this mass is smaller if the air pressure is lower. Most electric variometers work on this principle, and at high altitudes indicate less than the actual lift or sink. The same is true for high air temperatures, since they reduce air density. True vertical speed is calculated from indicated vertical speed as:

$$W = Wi \cdot \frac{\delta}{\delta.}$$

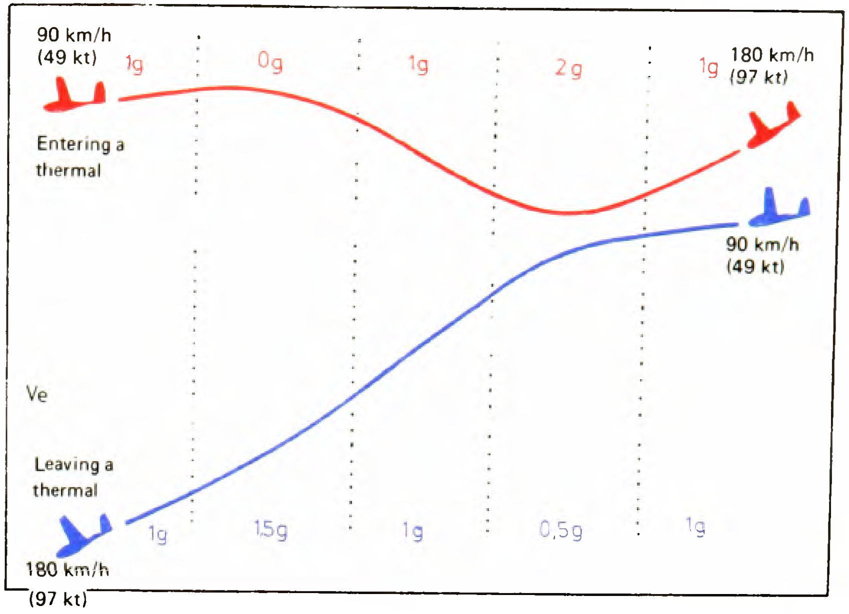
in which W = actual vertical speed
Wi = indicated vertical speed
δ = air density for which vario was calibrated
$\delta.$ = actual air density

The comparison with the formula for true airspeed is obvious; unfortunately the formulas differ by the square root sign, so that these variometers, too, lead to speed-to-fly errors.

If one disregards the effects of temperature, the errors for variometers and the airspeed indicator appear in the graph below.

Altitude errors of the speed-to-fly variometer are discussed on page 146.

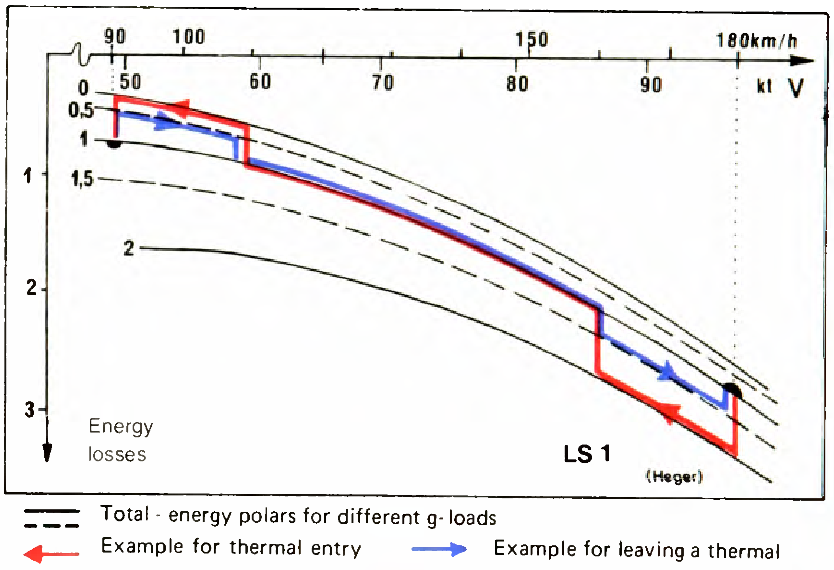
g – loads while flying at correct speed-to-fly (example)



TOTAL ENERGY ERRORS DUE TO G-LOADINGS

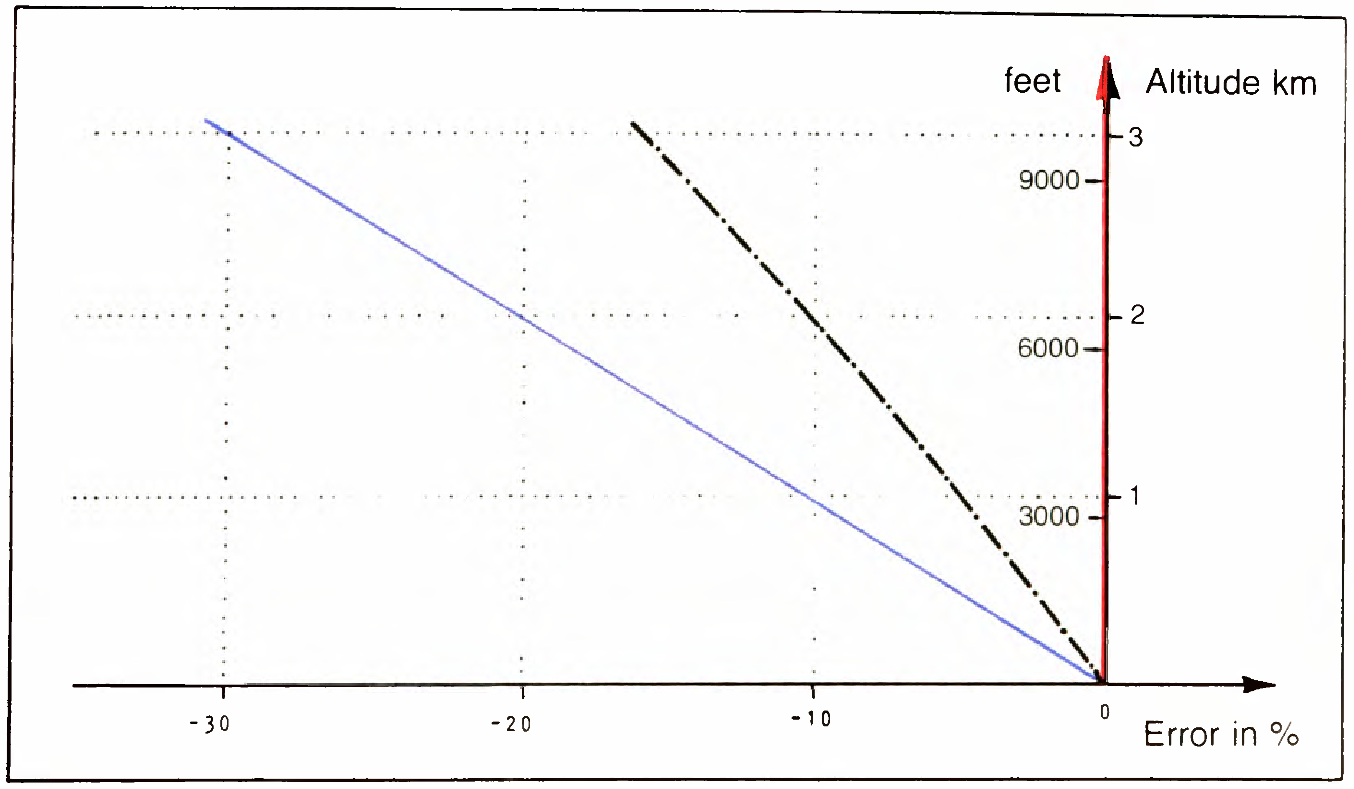
If we pull briskly on the stick in flight, we increase the g-load on the airplane. Where the wings formerly only

Total - energy indications while flying at correct speed-to-fly (example)



Total - energy polars for different g-loads
Example for thermal entry
Example for leaving a thermal

Error in %



Airspeed indicator error
Volume based variometer (no error)
Mass-based variometer

had to support the weight of the sailplane, they must now generate more lift, in proportion to the increased load. This, of course, causes losses, since increasing the lift also increases the drag.

At any constant airspeed the sailplane is subject to a given energy loss over time, defined as aircraft weight times sink speed. If we assume the normal gross weight to be = 1, we can consider the speed polar to be a total energy polar. For the increased losses of higher g-loads, a new total-energy polar must be obtained.

The indication of the total-energy variometer, which of course measures changes in total energy, is dependent on the g-load. Here are two examples of what can occur if one is flying the proper speed-to-fly upon entering or leaving a thermal.

We can see that the changes in g-load are more pronounced on entering a thermal than on leaving one. The next graph shows what a properly-functioning total-energy variometer would indicate in each case.

As one pulls up (2 g), the indication will drop, only to return to normal as one climbs at 1 g, decreasing as airspeed decreases. As one pushes over (0 g) the indication will pop up before dropping back to normal for 1 g flight.

These jumps in the indication are not really errors if taken exactly, but are still a nuisance; for example, upon entering a thermal one can not really measure its strength unless the g-load is around 1.

As long as the climb or glide angle remains constant, even if the airspeed changes, the indication will remain the same since the g-load is about constant at 1 g.

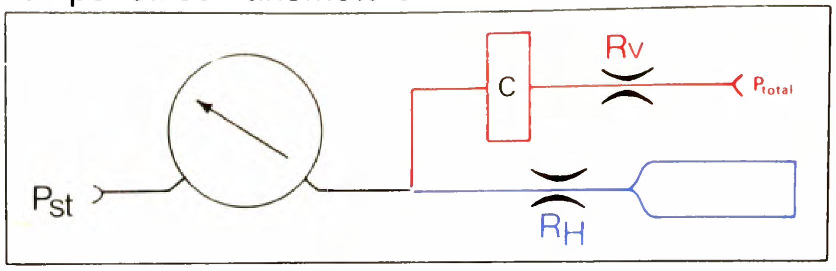
TIME COMPENSATION OF TOTAL-ENERGY VARIOMETERS

— types other than venturi-compensated

Any type of compensation that does not obtain height and airspeed change signals from the same source must be time-compensated so that the increased airspeed doesn't affect the indication either before or after the corresponding increase in sink. This is done by means of restrictors (e.g. 1-mm diameter tubes of different length) inserted into the appropriate hose connections.

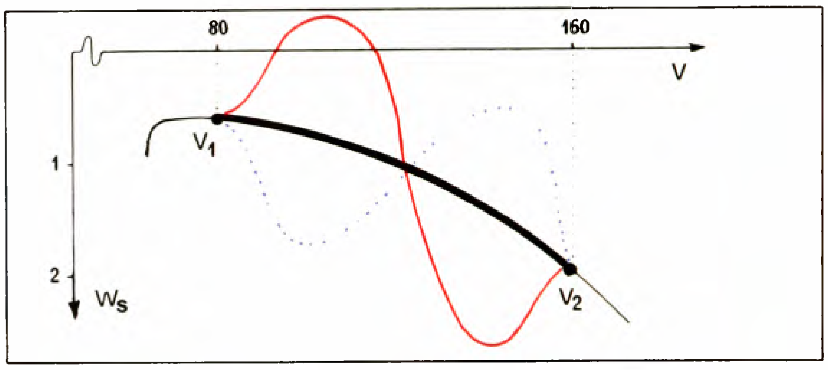
Unfortunately such time compensation can only be tested in flight. We accelerate in still air with the gentlest possible stick movements. During acceleration an ideal variometer would indicate increasing sink according to the sailplane polar. An ASW 15, for example, accelerating from 80 to 160 km/h should show a slow increase in sink from 0.6 to 2.4 m/s. If the airspeed increase affects the variometer too early, the instrument would first indicate a climb, then too much sink. Airspeed decrease could cause the same errors in the reverse order; insertion of a restrictor Rv would be the cure. The opposite, of course, would be the case if the altitude change appeared at the instrument too early (blue dotted line). Compensation would be achieved by restrictor Rh.

Response adjustment for membrane-compensated variometers



C: compensator
R_V: restrictor for compensation (airspeed signal)
R_H: restrictor for air capacity (height signal)

Indications if response rate is improperly set



▬ ideal indication for increasing or decreasing airspeed
— airspeed signal (compensation) effective too early:
→ increase restriction at R_V
····· altitude change (static pressure) effective too early:
→ increase restrictions at R_H

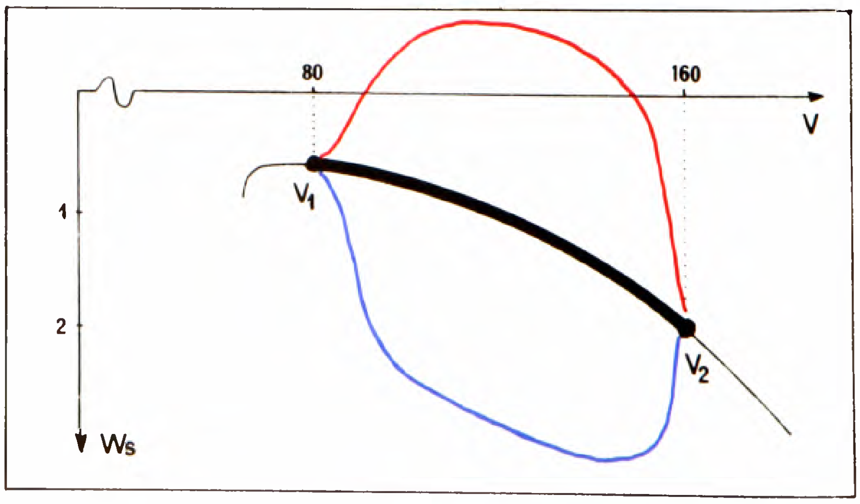
To determine whether the proper restriction has been installed, further test flights are necessary.

ADJUSTMENT OF VARIABLE TOTAL-ENERGY COMPENSATORS

The diagram shows the indications for over- and under-compensation. An undercompensated variometer (compensation too weak) will behave similarly to an uncompensated altitude variometer.

During the period of airspeed increase it will show too much sink; airspeed decrease will show too much climb. The opposite is true of over-compensation; a climb will be shown during airspeed increase, and sink during airspeed decrease.

Variometer indication with inaccurate total-energy compensation

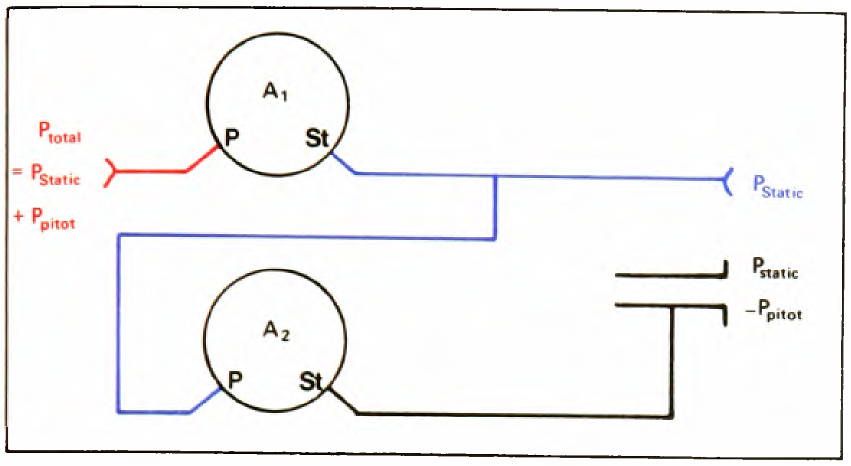


TESTING VENTURI-TYPE TOTAL-ENERGY COMPENSATORS

A rough test of venturi compensators can be performed simply in any weather conditions:

If we connect an extra test airspeed indicator (A_2) between static pressure and the venturi such that the pitot connection of the indicator goes to static air, and the static air goes to the venturi, this indicator should register exactly the same value in flight as the standard indicator.

Testing Venturi-type compensators



A_1, A_2 Airspeed indicators **P** Pitot connection **St** Static connection

This test can also be carried out in a wind tunnel, or from an automobile, etc., as long as an exact static source is available. It will also be accurate in flight only so long as the sailplane has an exact static source, which is unfortunately not always the case.

If the indication of the test instrument is too low, the compensation is insufficient; if too high, the compensation is excessive.

(Indication of the test instrument should first be compared with that of the regular indicator by connecting both in parallel and applying a series of test pressures.) After such a test, exact tests should still be made by flying in still air at varying airspeeds and 1 g.

INSTRUMENT INSTALLATION

Many sources of instrument error which will later cause false indications can be avoided or reduced by proper installation practice. Extra effort initially will save a lot of trouble later on. Here are a few tips:

— Don't forget the pot scrubbers (or steel wool) in the capacities for variometer temperature compensation.

— For rapid and precise indications, keep all hose connections as short as possible.

— Colored instrument hoses are available (aquarium shops, etc.) which can simplify the "hose salad" behind the panel.

— If several instruments are to be connected to the same static source, a "distributor" (a small can with soldered-on hose connections) will cause less interference between instruments than the usual T or X connections.

— Sensitive electronic variometers may require their own static source to isolate them from errors caused by interference from other instruments.

— If the pitot line can't be installed right from the start so as to prevent rainwater from getting to the instruments, a water trap — a can at the lowest point in the line — should be installed. This goes for other hoses, too.

— If prevalent weather conditions are damp, it is a good idea to arrange some sort of dessicator upstream of the capacity bottles to avoid condensation and evaporation in them — but only if such dessicators don't significantly increase the capacity's volume.

— Venturi compensators should generally be installed some two feet ahead of the vertical fin, or about a foot and a half ahead of the leading edge of the stabilizer if installed on the latter. If the venturi is installed such that it is on the lower side of the mounting tube there is little danger of rainwater getting into the works. Any other locations, such as on the fuselage between wing and tail, are more susceptible to errors and must be tested inflight since a change of only an inch or two can be critical. Since the installation should be the same for sailplanes of the same type, it is simplest to check with the manufacturer.

— The line from total pressure to the capillary of a speed-to-fly variometer should have a dust filter to prevent clogging of the capillary (e.g., a gasoline filter from an auto-parts store). Narrow restrictors used for time compensation should have similar filters.

Such filters should be installed before calibration of the capillary or the instrument, since the filters themselves have some restrictive effect.

— Gyro instruments must be installed so that in level flight attitude they are as close to horizontal as possible and exactly aligned with the flight direction; otherwise very annoying errors will appear in turning flight.

TESTING THE INSTRUMENTATION FOR LEAKS

Such a general test should be a routine part of the annual inspection or overhaul, and should also be performed after any instrumentation change or installation and before competitions and such. A particularly useful aid is a small aquarium air pump fitted with a suction connection, a capillary, and a needle valve (e.g., a model-airplane engine carburetor). One can make do with a length of hose with a restrictor, into which we can blow with great care.

The best way to test is in three steps:

Static pressure system (P_{st} connections)

This is tested together with all instruments normally connected to it, such as altimeter, airspeed indicator, uncompensated or membrane-compensated variometers, etc.:

1) Close off static pressure openings.
2) Insert a T-junction in static pressure line.
3) While observing variometers and airspeed indicator, gradually apply suction. Be careful — variometers, especially vane or taut-band instruments, are very sensitive to pressure changes!
4) When the airspeed indicator indicates about 100 mph, close off suction connection and observe whether the indication remains constant for 2 - 5 min.
5) While observing variometers, slowly let air back into system.
6) Unseal covered connections and remove T-junction.

If the airspeed indication drops while the system is sealed off, repeat tests, isolating instruments and connections until leak has been located. Prime candidates: hose connections, instrument-glass gaskets, membrane compensators, capacities. Less frequent: T-junctions, connections at backs of instruments.

Total-energy venturi system (P_{stat} - P_{dyn} connections) with capacities and speed-to-fly capillaries:

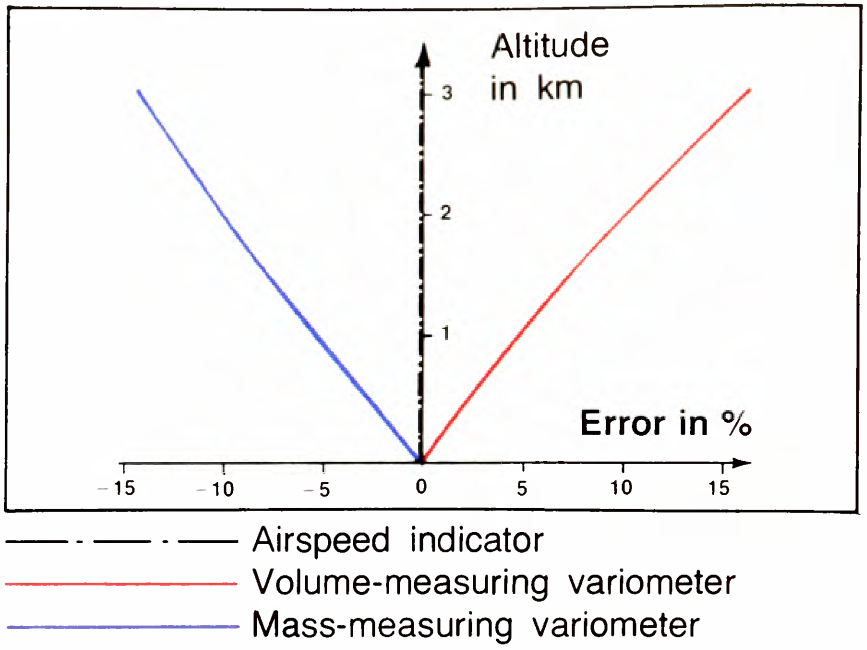
1) Seal off venturi, remove pitot end of speed-to-fly capillary and seal.
2) Insert 4-way (X) junction in line from venturi, connect one connection to pump, other to pitot side of airspeed indicator.
3) Apply pressure, proceed as in steps 3 to 6 above. — the indication of various TE-variometers can be compared while applying and/or removing pressure.

Pitot pressure system (P_{total} connections) with ASI and speed-to-fly capillary:

1) Remove variometer end of speed-to-fly capillary and seal. Seal pitot tube.
2) Insert T-junction in pitot line.
3) Apply pressure, proceed as above.

Venturi-compensated variometers are particularly sensitive to leaks, since the whole system is under slight vacuum from the venturi. The tiniest leak on the capacity side of the instrument will have immediate and catastrophic results; the same is true for the capillary of the speed-to-fly variometer. Some electronic compensators and all membrane compensators require similar care. The pitot line to the airspeed indicator is less sensitive. The altimeter is completely uncritical, and would work with acceptable accuracy if not connected at all, but merely left open to cockpit static air.

Variometer errors vs. airspeed indicator errors



SPEED-TO-FLY ERRORS AT ALTITUDE

The altitude errors of the various instruments would not be particularly important were it not for their effects in speed-to-fly indications. In order to fly more-or-less correct speeds-to-fly at higher altitudes, we must examine the problem as a whole. At altitude, the aerodynamics of the sailplane change as well as the indications of variometers and airspeed indicators.

a) Changes in sailplane performance:

If we disregard the minor inaccuracies due to changes in Reynolds numbers, both airspeed in straight flight and sink speed depend on the same factor — the square root of the inverse of air density (Greek letter "rho"); that is, the lower the density, the faster the sailplane flies and sinks.

b) Airspeed indicator:

Since this polar change is exactly the same as the airspeed-indicator error (page 141), flying by the airspeed indicator (e.g., redline, stall, etc) at high altitudes will still result in aerodynamically correct speeds, although the geometric speeds in space will be higher.

c) Variometers:

It would be nice if the variometer error were the same as that of the airspeed indicator; then everything would agree. True, the geometric values would be off, but speed-to-fly indications would be correct.

Unfortunately, this is not the case.

The graph shows the indication error of various types of variometer against the (geometrically too small) airspeed indicator error.

Thus, the geometrically-correct volume-measuring variometer leads to speed-to-fly errors, as does the mass-measuring variometer as well.

DO WE FLY TOO FAST OR TOO SLOW AT ALTITUDE?

The answer to this question depends on the instruments installed. Here is an example of a real situation: An ASW 15 flies at 2500 m altitude with a wing loading of 5.75 psf the new polar will now be the same as if we would have increased the wing loading at sea level from 5.75 to 7.35 psf. Let us assume that our pilot has 3 m/s thermals regularly. What will he see on his instruments during straight flight?

a) Instrumentation: vane variometer, speed ring, pitot airspeed indicator:

The climb of 3 m/s will be indicated exactly, the airspeed indicator will show too low a speed, so the pilot will fly too fast. In still air he flies at 162 km/h indicated airspeed. This is a true airspeed of 185 km/h. Due to the changed polar this causes 2.4 m/s sink, resulting in a speed-ring command of 162 km/h. Actually, though, the pilot should fly a true airspeed of 173 km/h, which would be indicated as 150 km/h!

Volume-measuring variometers cause us to fly too fast at high altitudes.

b) Instrumentation: thermistor electric variometer, speed ring, pitot airspeed indicator:

The 3 m/s climb would be indicated as 2.35 m/s due to the variometer error and that value would be set into the speed ring. Apparent optimum flight in still air would result at an indicated airspeed of 144 km/h, which would cause a true airspeed of 163 km/h. At this speed the true sink is 1.75 m/s, but the variometer would only indicate 1.4 m/s sink. Since the ring is set at the (incorrect) climb of 2.35 m/s, the result is a speed-to-fly indication of 144 km/h. The *actual* optimum speed would be 150 km/h indicated airspeed.

Mass measuring variometers cause us to fly too slowly at high altitudes.

In practice, if a speed ring is used, it is generally sufficient to be aware of these tendencies and fly a bit faster or slower than the speed-to-fly displayed by the instruments, depending on the instrumentation installed. Fanatics would have to develop interchangeable speed rings for different altitudes; they'd be extracted from the polars at the desired altitudes, and the V and Ws axes would have to be divided according to the *indicated* values.

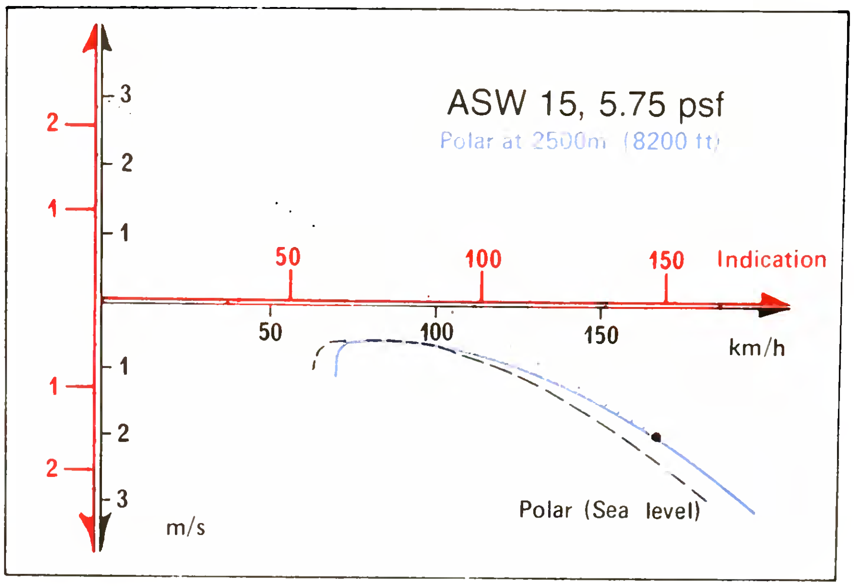
c) Instrumentation: speed-to-fly variometer:

Additional factors affect the error indications of the speed-to-fly variometer at altitude, as well as the change in polar and hence in speed-to-fly curve.

The flow through the capillary is directly dependent on indicated airspeed. During a glide in a moving airmass it will change even if the value of the speed-to-fly indication is kept constant.

The flow through the instrument itself depends on its zero-displacement as well as the chosen value of thermal strength; it will not change in flight in moving airmasses.

Construction of speed-to-fly @ 2500 m/8200 ft (ICAO)



Both flows change with altitude, so that the errors in the speed-to-fly variometer are very complex, especially when the changes in polar and speed-to-fly curve are considered.

Based on several examples that have been theoretically calculated, we can make a few recommendations for flying with speed-to-fly variometers at high altitude:

1. *Determine the climb in lift with the same type of instrument used for the speed-to-fly display; i.e., either two mass-type or two volume-type variometers; otherwise large speed-to-fly errors will result.*
2. *The more rapid the sink in straight flight, the greater the speed-to-fly indication will err toward "too fast."*
3. *It appears that errors are greater for mass-measuring instruments.*

DEAD-RECKONING PLOTTER

On the front we find km-divisions for 1 : 500,000 maps at the top (distances must be halved if 1 : 250,000 maps are used). At the right-hand side are speeds of 10 40 km/h for wind and 100 260 km/h for (true) airspeed. The oblique red lines running from lower left to upper right indicate flight time spent on a given course.

Finding current position:

Place the scale on the chart with the zero point over the last known position.

Next, find a "wind point" by turning the scale to the appropriate angle (marked on its edge) and noting the distance (based on wind speed and flight time).

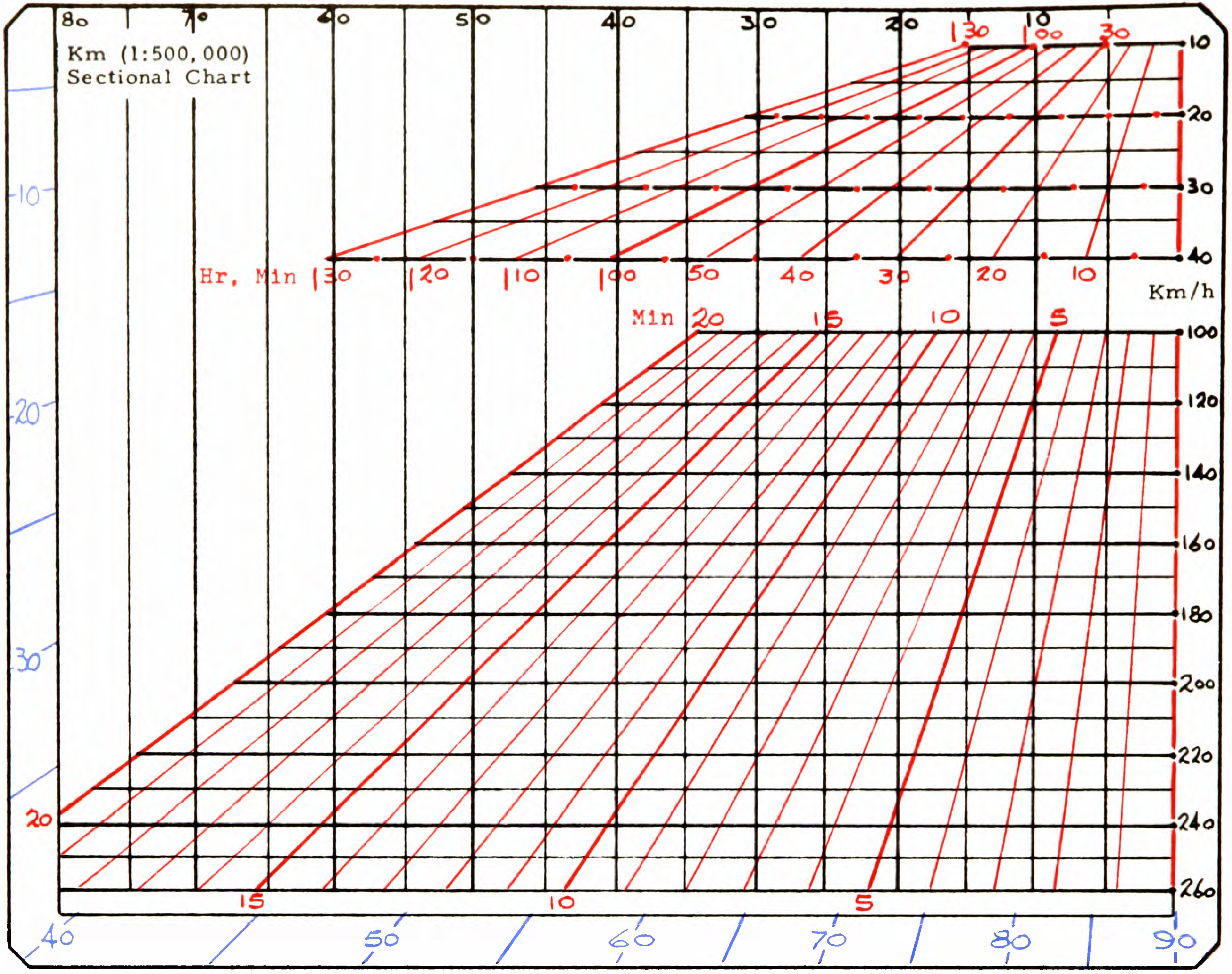
Now, place the zero point on the wind point and repeat the process for the sailplane course and true airspeed. Using flight time, locate the actual position.

Indicated airspeed can be converted to true airspeed using the graph on the back of the scale.

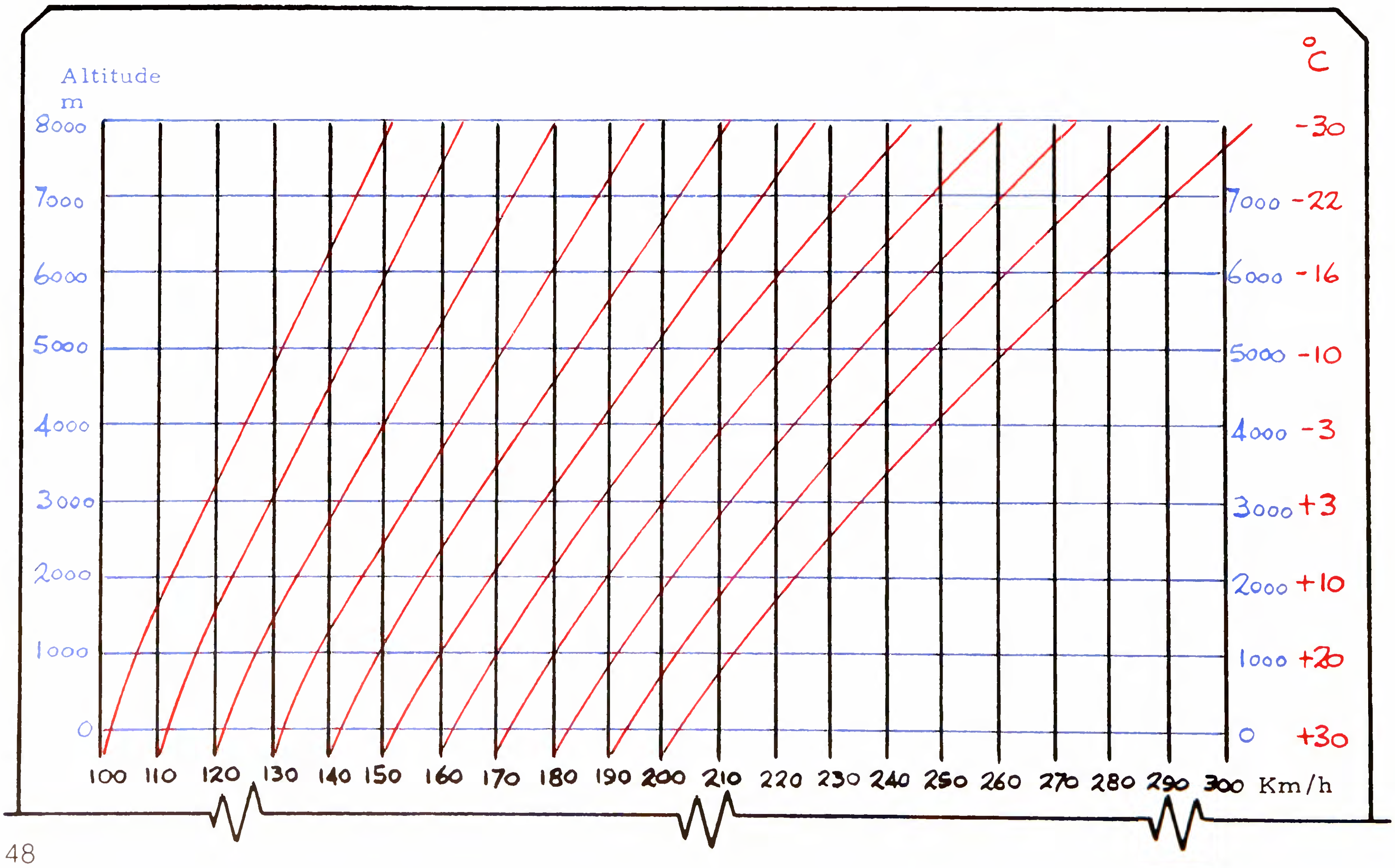
CAMERA MOUNT

The camera mount illustrated is made of 2-mm sheet aluminum. If the fiberglass mounting strips are ar-

Front Side: Dead-Reckoning Plotter

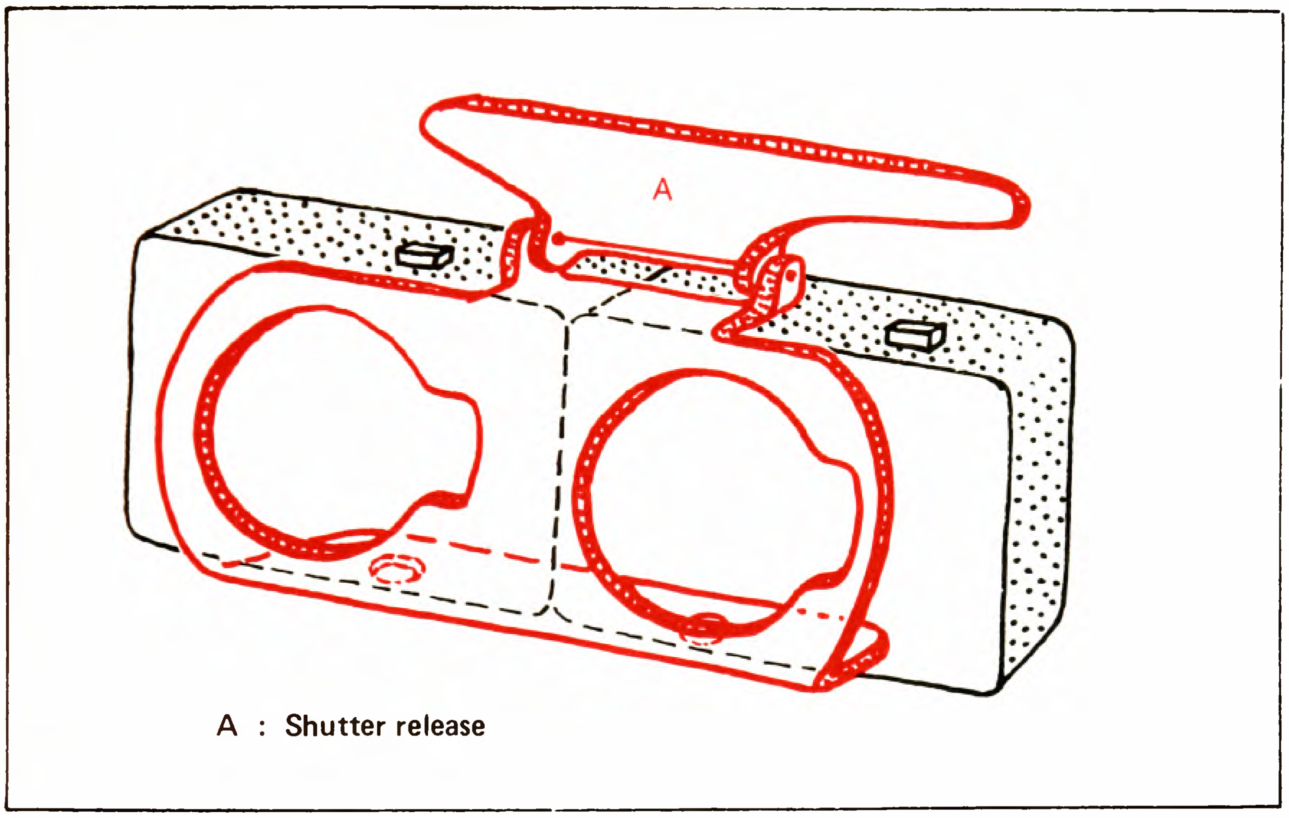


Back Side: True Airspeed

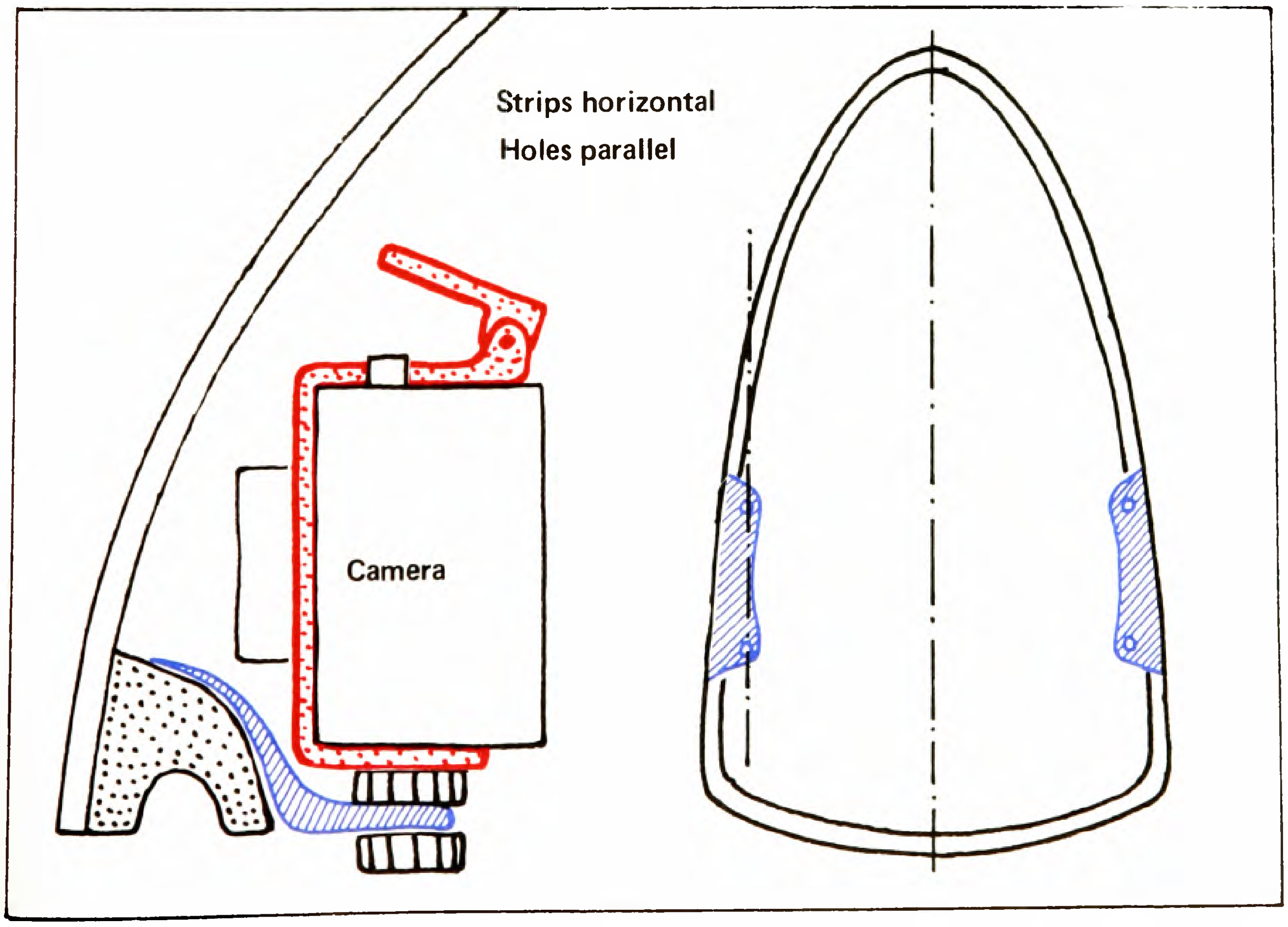


ranged so that the camera points exactly 90° to the side and is perfectly horizontal, the wingtip will appear in the upper rear corner of the picture. To take a photo, aim the wingtip at the turnpoint and release the shutter when the turnpoint is just ahead of the wing. If desired, the release handle can be bent a bit so that one camera will release a bit before the other. The cameras are attached to the mount by their tripod sockets, and similar tripod screws are used to secure the mount to the fiberglass strips.

If possible, the addition of a cable release to the mount makes turnpoint photography even simpler.



Camera mount for 2 Instamatic cameras



Attachment to canopy frame with fiberglass strips

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He started soaring in 1958; his competition career began in 1965 and includes the following first-place standings:

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1968, 1971, 1973: German champion
1970, 1974: World champion

Since 1973, he has been the honorary trainer of the German national soaring team. In addition to "Cross-country Soaring," he has published his Ph.D thesis at the University of Karlsruhe, "On the Problem of Airspeed Optimization in Cross-Country Soaring Flight."

Translated by Peter Lert