THE SOARING FLIGHT QUESTION.

Abstract of Paper read by Dr. E. H. Hankin, M.A., before the Institution at the Engineers' Club, Coventry Street, W.1, on 9th November, 1923. Mr. H. B. Molesworth in the chair.

DR. HANKIN said :—

One reason for the neglect of the question of soaring flight by contemporary scientists is psychological. Discoveries that show that existing beliefs are wrong, or that long cherished beliefs need revising, are usually accorded a very hostile reception. The facts of the case of soaring flight are of this nature.

There is another reason by which my own contribution to the subject is handicapped. My very slight acquaintance with physics, with meteorology and other sciences that may be concerned has made it difficult for me to know which facts were most worth observing or most deserving of publication. My rôle has been merely that of an animated photographic camera recording facts of whose meaning and importance I was and am ignorant.

Hitherto the subject has been treated by me as if maintenance in the air of the soaring animal was the only thing to be explained. It is possible, however, that some of the phenomena that accompany soaring flight may turn out to be scientifically more important. The following examples are worth our attention.

The humming sound made by flying-fishes when in gliding flight has been noted by others. The musical whirring sound made by vultures is well known. A few instances have come under my observation in which gliding of vultures and cheels was silent in unsoarable air, but was accompanied by whirring when, a few minutes later, the air had become soarable. When diving in soarable air vultures make a loud crackling roaring sound similar to that made by a large rocket. It is so loud that, even in the presence of wind, it may be heard from a distance of at least 300 metres.

Another peculiar phenomenon seen in soaring flight may be described as "distortion." The Bengal vulture has part of the underside of its wings of a white colour. When circling the white area appears a little larger

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than it does in the dead bird. When soaring at a higher speed than circling, the white area appears magnified to more than twice its real size. When thus gliding across the field of view and seen from the side, the white area of the near wing appears magnified and that of the far wing appears diminished.

The third peculiar phenomenon to be described is the appearance of colour on the underside of the wings of soaring birds. If one watches a scavenger vulture in soaring flight the white portion of the underside of its wing appears of a bright chrome yellow colour. If the bird is looked at through a crystal of Iceland spar two images of the bird are seen. One of these images appears yellow, while, on some occasions, the other image appears snow white. If the bird is on a curved course the inside wing has the deeper colour. This description applies to the Bengal vulture and to the scavenger vulture. In the adjutant bird the colour appears not on the wings, but on the underside of the body. If an adjutant is on a curved course a patch of deeper yellow appears on the side of the body near to the inside wing. If any of these birds ceases to take energy from the air, if, that is, by flexing its wings it begins to fall feet foremost through the air, the yellow colour instantly vanishes. If the bird then changes its mind and decides to glide on instead of landing, the yellow colour reappears as it extends its wings and begins to regain its speed ahead.

The next phenomenon to consider is the occurrence of steep upward glides without apparent loss of speed. These have been observed by me in different species of birds and also in the case of dragon-flies. In such glides the long axis of the body is tilted up in the direction in which the soaring animal is travelling. The plane of the wings, so far as observation shows, also lies in the line of flight. This is entirely the reverse of what occurs when the bird is in a known ascending current. In such a current the bird is lifted gradually as on a rising tide. Its long axis is horizontal and the plane of the wings, whenever observable, shows an apparent negative angle of incidence which, as already explained, indicates the positive angle of incidence with the bird's relative wind. The change to this apparent negative angle of incidence, which, as already explained, indicates a positive angle of of the steamer has been observed by me in the case of gulls. In the steep upward glides we are now considering there is no apparent negative angle. There is no gradual lifting as on a rising tide. The bird shoots upwards almost as if fired out of a gun. Gulls show an apparent increase of speed at the moment of commencing the upward glide. That this is a real increase of air speed is made probable by the fact that it is accompanied by an increase of flexing of the wings, which is the disposition used in high speed flight. An instance has been observed by me of two scavengers making a steep upward glide for a distance of more than 200 metres, their course while doing so making an angle of between 30 and 40 degrees with the horizon. In the case of gulls the steepness of the glide may be much more. It may amout to as much as 70 or 80 degrees with the horizon.

If maintenance in the air was the only thing accomplished by the soaring

bird, it might be justifiable to settle the matter by assumptions about its gliding angle and suppositions about ascending currents. The occurrence of these steep upward glides furnishes a clear proof that something more is required.

The most astounding fact about these upward glides is that they only occur on occasions when there are grounds for suspecting that the bird is in a descending current.

On the windward side of a steamer there is an ascending current in which gulls sometimes glide with gradual gain of height as usual in such currents. At or near the stern of the steamer and especially on its leeward side there is usually a descending current. Often, but only if wind is present, gulls can soar when enveloped in this descending current. It is in this descending current that steep upward glides occur. Gulls that have stayed behind for food may be seen overtaking the ship by flapping flight just above water level. When they reach the leeward side of the stern, still near water level, they may be seen to make a sudden turn upwards, to cease flapping, and to glide steeply upwards, usually to about the level of the stern flagstaff. When near the level of the top of the flagstaff they may be near the limit of the descending current. There may be room for arguing that they are outside of it and aided by a neighbouring ascending current. Hence this glide upwards is of interest in that it begins near water level where it is very difficult to believe that any strong upward current can be present.

In these steep upward glides in a descending current we see the mysterious force of soarability in its strongest form, and here is where one should look for some clue to the nature of the phenomenon.

The first question that arises is whether these apparently descending currents are really descending. A very interesting observation by Mr. J. D. North bears on this point. He informs me that at the stern of a steamer he has observed pieces of paper that he had thrown overboard rising continuously when enveloped in dilute descending smoke. That is to say, there was an admixture of ascending air that carried the paper with descending air that carried the smoke particles. Major Turner, in a very suggestive paper on soaring flight, quotes experiments by Dr. Betz of Gottingen, in which it was found that if an alternating up and down movement was given to the air current in a wind channel, a model wing showed negative resistance; that is, it tried to move against the wind stream. These facts suggest the theory that in descending currents in which soaring flight has been observed neighbouring masses of air may be ascending and descending relatively to each other and that, as in the experiment of Dr. Betz, such opposed movements can do more for the soaring bird than could the ascending component alone. Should soaring flight in descending currents be due to such a cause one might anticipate that a descending mass of air striking another mass of air relatively at rest would be better fitted for such flight than a " contour current " formed by a light wind flowing over a rounded surface, for in the former case there would be much more tendency

for a mixture of air curents flowing in different directions to be formed than in the latter. Further, if alternations of air direction have to do with soaring flight one might anticipate that a certain minimum speed would be necessary before soaring, as distinct from gliding, could begin. Further one might anticipate that a particular speed of the bird would be appropriate to a particular degree of alternation. Also, if a bird on entering the descending current lacked the necessary speed, one might anticipate that, or at least would not be surprised, if, at that moment, it showed some form of instability. Let us see how far the facts of the case agree with such anticipations.

In dust-storms of the kind that have been described by me as "primary dust-storms," the dust is raised by steeply descending currents that strike the earth as if coming from a gigantic hosepipe. In such descending currents cheels and scavengers make steep upward glides recalling those made by gulls at the stern of a steamer. Such glides appear always to commence at the moment when the bird is struck by a gust as shown by movements of the trees below them. A proof that it is at this moment that the bird is entering the descending current is given by the fact that at this moment the bird shows instability round the transverse axis. It has been found by me that both soaring and non-soaring birds show this form of instability when leaving but not when entering an ascending current. One would expect them therefore to show it also when leaving relatively still air for a descending current. This instability is shown or countered by the bird by a sudden upward jolt of the tail and depression of the wings. At the moment of entering a descending current of a dust-storm the bird shows tail-jolting which may be at the rate of four or five jolts per second. With gulls, on entering the descending current at the stern of a steamer, this form of instability has been seen by me, but it is very transient and difficult to observe. It may be replaced by a trembling of the wings. In the case of two scavengers gliding upwards in a dust-storm gust, already mentioned, my notes relate that they were tail-jolting all through their upward glide for at least 200 metres, and that it was so marked as to be visible with the naked eye though the tail of the scavenger is much smaller than that of the cheel. This may be regarded as a proof that all through the glide, which was at high speed, they were passing through portions of air that relatively to each other were ascending and descending. The immediate neighbourhood of dust-storm gusts contains rising currents, as shown by the movements of the dust, but in such air other forms of instability occur and no steep upward glides.

On one occasion a dust-storm was observed by me which reached the steamer while we were going through the Red Sea. When struck by gusts of this storm, gulls in the soarable area glided ahead with very great and sudden increase of speed. On one occasion, near the Straits of Bonifacio, in a gale of wind, which came from nearly ahead, some gulls were following the ship in gliding flight. Occasionally one of them turned round and glided for a long distance, at least a hundred metres, away from the ship

to leeward. It did this with its wings fully extended and flat as if to check speed. Then it turned round to glide again towards the ship. It did this with wings flexed and arched—that is, in the high-speed wing disposition. During this glide up to the ship its speed through the air must have approached thirty metres per second. The fact of a gull gliding to leeward slowly, then turning and gliding upwind at such enormous speed, yields a further proof that in soaring flight we have to do with a far greater expenditure of energy than is involved in mere maintenance of height in the air. The main mass of the air, in which these 100-metre glides from leeward were made, probably had a slight descending trend. That it was highly turbulent was proved by the instability shown by the gulls.

The air brought down in the descending currents of a dust-storm travels for long distances as a dust-laden but not dust-raising wind. This has been described by me elsewhere as the "derived dust-storm." Owing to friction with the surface of the ground, the advancing margin of this air current has a rolling movement causing a restricted descending current. An instance has been observed by me in which cheels rose into the air in gliding flight on the coming of the dust-laden air. But as soon as they were out of the probable area of the descending current, which happened within two or three seconds, they glided with loss of height and settled. This occurred near my post of observation. The dust-laden air passed on and, three miles away, reached a row of factory chimneys. The smoke of each chimney in turn was momentarily depressed to ground level as the dust reached it, thus proving the presence of the temporary descending current at the advancing margin of the dusty air.

Under some atmospheric conditions isolated gusts of wind descend, striking the earth at an angle and raising masses of dust that have been described by me as "dust-curtains." Cheels have been seen by me soaring in steady flight in a wind in which no dust-curtains were being formed. When the wind changed in character so that dust-curtains began to appear, immediately the cheels, at intervals, began to show transverse axis instability and either increase of speed ahead or upward glides. Conversely, a soarable wind in which dust-curtains were present has been seen by me to change into an unsoarable wind as soon as dust-curtains ceased to be formed.

On one occasion a dragon-fly was seen in a dust-curtain. While within the dust it glided horizontally, but after passing through the dust, when probably enveloped in the descending air, it glided upwards for about 3 metres, its course making an angle of about 40 degrees with the horizon. Such long upward glides are never made by soaring dragon-flies under ordinary conditions.

In thundery weather a gust of wind usually precedes a rain shower. Since this gust commonly has a slight power of raising dust it probably has a descending trend. In this wind cheels always rise in gliding flight. They do so even if the wind comes after sunset and in deep twilight, that is, at a time when, in the absence of this wind, the air would be completely

unsoarable. In 1917, a gust of wind of this nature was observed by me that covered an area measuring about one mile by three miles. Within it birds were soaring with steep gains of height and showing strongly-marked transverse axis instability. Soaring flight having these peculiarities had not been seen by me during the preceding three years owing to the chance that no primary dust-storms had occurred during that time in Agra.

Thus we see that steep upward glides, often at high speed, occur in descending air in cases in which there is likely to be a violent mixing of differently moving masses of air. Now let us consider instances of soaring flight in descending contour currents in a light wind.

Soaring flight in the Himalayas generally takes place in ascending currents of air. But on one occasion, at Naini Tal, a cheel was seen circling and gaining height when enveloped in thin cloud and in a current that descended at an angle of about 15 degrees with the horizon. The gain of height while in this descending current was about 150 feet. The gliding was at low speed with only a very gradual gain of height. It was recorded in my notes that " at the time the cheel was gaining height, it was in cloud sufficiently thin to let through enough sun energy to make heat eddies (my term for convection currents), judging from the amount of glare at the time, and from the results of observation of heat eddies that I had made two hours previously." Thus it is probable that the descending air was diluted with ascending convection currents.

The only other instance known to me of soaring flight by a bird in a contour current in India happened at Matheran, a hill station in the Bombay Presidency. This is situated on a flat-topped ridge rising probably about 2,000 feet above the surrounding plain. During a visit there cheels and other birds were seen by me on the windward side of the hill being lifted by the rising current. Wishing to see true soaring flight, I went to the leeward side of the hill and there found a place where vultures had made their nests in a position where for the greater part of the year they were probably exposed to a descending current of air. Near by they were circling with unusually steep gains of height. This occurred in sunshine when rising convection currents probably were being formed. It may be repeated that in the known ascending current on the windward side of the hill, where convection currents, if present, were flowing in the same direction as the ascending wind, no such steep upward glides were observed.

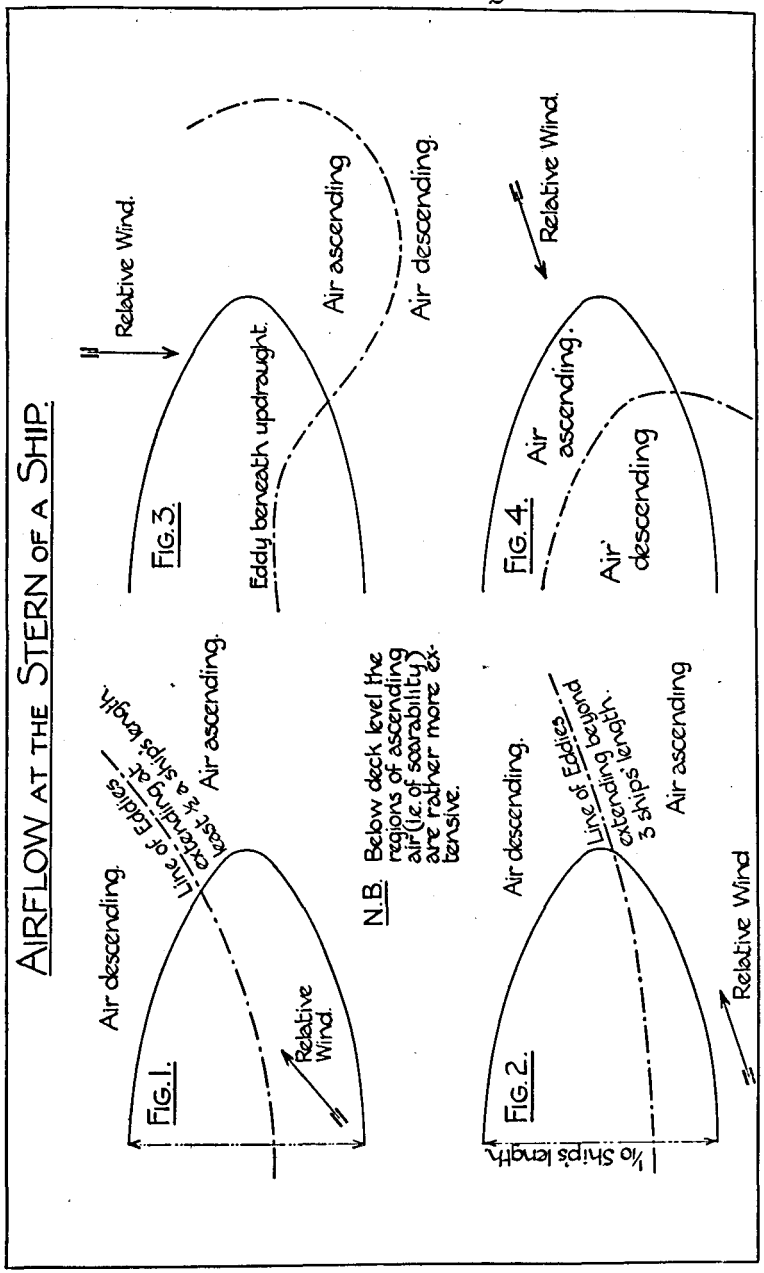
Thus far the facts seem to agree fairly well with the idea that soaring flight in descending currents is due to mixing of ascending and descending masses of air or at least to some kind of turbulent motion. Now let us consider some of many facts known to me that indicate that, even if the suggestion contains some germ of truth, much more research is necessary before we can hope to understand the phenomenon.

In the first place the presence of wind seems necessary to permit the development of a soarable area at the stern of a steamer. In the absence of wind, there is still a relative wind caused by the movement ahead of the steamer and presumably a descending current at the stern. But under

such conditions no soarable area is formed. Gulls following the steamer do so by flapping flight. On one occasion, after this had been observed, a light wind appeared coming from the port quarter. Its speed was much less than that of the ship, so that smoke was left behind over the starboard quarter. Apart from any turbulence that this wind brought with it, it must have resulted in a decrease in turbulence of and decrease in the strength of the descending current at the stern. Nevertheless, a soarable area appeared.

Further, some winds, though fitted by their force and direction to aid mixing of ascending and descending air masses in the descending current at the stern, as in Mr. North's observation, do not permit the appearance of a soarable area. On leaving Port Said last February year the behaviour of the gulls suggested that the wind was losing its power of forming a soarable area in the descending current, in that the gulls when gaining height moved as if they were being lifted one wing at a time. Also their gliding upwards was interrupted. Commonly each gain of height was only about a foot. On the following day the wind was on the quarter, and there was no soarable area. Gulls accompanying the ship were in circling flight at a height of about 400 metres. Below this level they flapped.

Perhaps something might be learned about soaring flight by means of model gliders. The lecturer proposes to discuss this question. Having now made forty-five small gliders, he hopes soon to be able to make them sufficiently well for scientific experiments, and is anxious to find someone expert in aeronautics to fly them for him.



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