The Stratosphere

THE stratosphere is the name given to that layer of our atmosphere that begins about seven miles above the ground, and reaches up to about a further twenty miles.

It is still in rather the same popular position (mentally, not physically) as the north and south poles—we know that they are there, and that people still go off wandering round in their vicinity, but we feel that they really are not of much importance to us, and we do not think that it would matter very much if people kept away from them and merely let them be. That is, of course, the natural attitude towards all investigations of people not professionally concerned, until those have some practical application in their own lives.

Is it merely scientific curiosity that has caused us to probe into it with pilot balloons, unmanned, but furnished with recording instruments? To send up into its centre big gas-filled balloons dragging observers behind them in metal gondolas? To penetrate into it with our aeroplanes? One must admit that it is partially scientific curiosity and partly the human urge to do what other people have not done; it is just that spirit which has caused us to move from the middle ages to the twentieth century; and we can and will make use of the observations now being made on the position and nature and behaviour of the stratosphere.

We at the present time are living in what is called the troposphere. This familiar troposphere of winds and clouds and rain stretches up some six to ten miles, varying in its upper limit above the earth's surface with the particular surges going on at the moment, and with the position on the earth from which we measure it. We do not know certainly whether movements in the troposphere buckle up the bottom of the stratosphere, or whether undulations in the stratosphere cause perturbations in the troposphere. We will go up our six miles or so quite rapidly for the moment, through variable winds and gales and storms, with ice coating our vehicle, getting colder and colder, and moving into more and more rarefied air, until we find that the steady fall in temperature stops; the temperature has dropped to a value possibly as low as 100° Fahrenheit below zero, so it is quite cold enough; now as we continue to rise, there is no further drop in temperature, but even a small rise over big distances, and we have passed beyond the clouds and rain and ice. Where the temperature ceased to fall is looked on as the top of our lower atmosphere, or troposphere; that zone above it, free from violent storm and vertical surges, is the stratosphere; and the boundary is generally called the tropopause. It is not like the lower and upper floors of a sandwich cake with the cream between—there is no cream, and no sharp plane of separation. The air in the stratosphere is very rarefied[1]—passage through it in the future will have to be in closed vessels—and it is intensely cold, which is a further reason for having closed vessels which can be artificially heated internally. A place

[1] Captain Stevens, in his latest flight in " Discovery II ", records the air pressure as having dropped from 15 pounds weight per square inch at sea level to ½ pound weight per sq. inch when up 70,000 feet; a further rise of 5,000 feet there would mean a further pressure drop of about $\frac{1}{10}$th pound weight per sq. inch.

free from storms, free from cloud and mist, with very little air resistance, it is the obvious place to go if we want to move at three hundred miles an hour or more. We may not want to, but our children will, and I shudder to think how fast our grandchildren may go.

How do we know what is there? Mainly by the "pilot balloons", which are relatively cheap, and which do not entail the loss of life when they come down out of control. They are gas-filled balloons which carry instruments; some of the later type have been provided with radio equipment, which have automatically sent back to ground stations observations made on their journeys; others have carried messages asking the finder to return them and their recording instruments to the research station concerned. Swarms of these balloons have mapped our atmosphere up to fifteen miles. Professor Regener, of Stuttgart, got one back that had been up seventeen and a half miles, and one from Padua is reported to have risen over twenty-three miles. This last one penetrated practically to the upper limit of the stratosphere, and we may hope later to penetrate the layers beyond with our instruments, where we pass to even rarer atmospheres but high temperatures.

This article, however, concerns itself only with the stratosphere.

Humans have been up to an accepted height of 72,359 feet; this is the record obtained by the National Geographical Society's balloon on November 11th last. That is an altitude of over thirteen and a half miles, or about half way through the stratosphere. On account of the human interest, you might like to hear something of previous attempts with manned balloons: There is the now classical ascent of Monsieur Tissanidier in 1875; he rose from Paris to a height of 28,000 feet, so that he probably was still in the troposphere; his two companions died during the ascent, and he came down unconscious. Of more recent ascents we should mention that of Captain Gray in 1927. He rose to 28,510 feet, or about five and a half miles. The type of stratosphere balloon that has now proved victorious has been a later development, the gas bag dragging behind it a sealed aluminium or magnesium alloy container in which the observers and some instruments are protected against the extreme cold, and are provided with an atmosphere that in pressure and composition is suitable for human existence. Professor Picard, in 1931, thus took the record up to 51,775 feet, and with Kipfer as a companion, in 1932 attained an acknowledged 53,152 feet. This is so recent that many of you will remember that through an accident they were unable to release the gas and thus commence their descent, and were adrift in black space till nightfall resulted in cooling of gas and the contraction of the balloon, leading to their eventual safe but uncontrolled descent at night onto a glacier; *not* a nice experience.

In July of last year the National Geographic balloon, manned by Major Kepner and his two companions, Captain Stevens and Captain Anderson, ascended 60,615 feet in America; that was not the record at the time, as Major Fordney and T. G. W. Settle had been up 61,237 feet (in America again), and M. M. Prokofieff and company in Russia had exceeded that height, probably to 70,000 feet. But this particular earlier flight, sponsored by the National Geographical Society and the United States Army, a forerunner of the present record-holding flight, was exciting. Major Kepner and his assistants, Stevens and Anderson, had the exciting experience of watching,

from their sealed spherical magnesium alloy gondola, their vast gas bag ripping to pieces above their heads when up in the stratosphere and still rising. They fell eleven and a half miles to earth, fortunately falling fairly steadily for the first few miles. Their gas bag continued to break up as they descended, but it continued also to act partially as a parachute till they were a little over a mile up ; there they were falling at over a mile a minute, and had to make their escape whilst escape was possible. They managed to force open their manhole, and threw themselves out into space, all landing safely by parachutes on the highlands of Nebraska, which courteously rose up half a mile above sea-level there to meet them. Personally, after such an experience you would not have been able to lure me near a balloon, and the secrets of the stratosphere might remain untold for ever ; and yet Captain A. W. Stevens (with Captain Orvil Anderson) has just succeeded, on his third attempt, and after his earlier disturbing experiences, in completing the programme of scientific observations at the new record height, officially recognised, of 72,359 feet.

This last one is the third attempt by the National Geographical Society and United States Army conjointly ; the first one resulted in their reaching 60,615 feet and having the thrilling fall of eleven and a half miles. In the second attempt the balloon ripped before it got clear away. And yet they set off on the third and successful flight last month ! I should like to regard that purely as an example of scientific enthusiasm, but I know one scientist at least who is not sufficiently enthusiastic. In their latest flight they thought they had risen to 74,000 feet, but re-checks of their sealed instruments give the officially accepted calculated height as the 72,359 feet mentioned before. They " took off " from their Sheltered Valley at " Rapid City " at nine o'clock in the morning, and were up for eight hours, landing quite safely and quietly in a field 240 miles away that evening. The gas bag holds three and three-quarters million cubic feet of gas, and the total weight of the whole system, including the gondola, was over three tons—given as 7,000 pounds. Of course, the gas bag is only very slightly inflated when it sets off, because it has to have room to swell as the outside atmospheric pressure drops. If it were merely blown up like the observation balloons which are used for lower atmosphere work, it would burst long before it reached the stratosphere ; so that the balloon taking off appears to be a very long and skinny affair.

To go back to the stratosphere itself—and the earlier question, why go there at all ? What excuse has any one for the big expenditure of money and the risk of life ? Firstly, knowledge of stratosphere conditions is going to be of very great value in extending *scientific* weather forecasting ; it is not too much to say that the results of observations have already resulted in a far better understanding of the factors influencing the disturbances in the troposphere in which we live, and that further information will make possible much more accurate long range forecasting. Secondly, whether we *want* to move rapidly or not, we *are* going to, and the stratosphere will be the place for long distance fast travelling ; we therefore want to collect information as to conditions there. Thirdly, we can get a lot of other valuable scientific information as to external affairs by going up beyond the lower blanket of dusty, dirty, water-ridden, heavy air. But why worry about a fourthly and a fifthly ? We have a habit of making use of all knowledge, and the uses are often startlingly different from those originally postulated by the experimenters themselves.

We must not look upon the stratosphere as a place of no movement—not only is its base slowly billowing up and down, but there are strong and steady air currents throughout it. The air, being very rarefied, however, the " blowing " effect of such winds is comparatively slight. We must not forget that the stratosphere, like the lower atmosphere, consists of gases which are held in place by the gravitational pull of the earth mass below ; and that that same earth is revolving on its axis once in every twenty-four hours ; so that the atmosphere at the poles is merely being turned round with a negligible velocity, whilst the atmosphere above the equator is being whirled round at about a thousand miles an hour.

If we fired ourselves off in a rocket plane from the *vicinity* of the south pole, travelling so as to avoid air resistance, through the high altitudes of the stratosphere, then when we dropped back into the lower atmosphere on reaching the equator, we would apparently find ourselves in a terrible gale blowing at a thousand miles an hour, which would be extremely disturbing. To an observer sitting on the equator, we would be going northwards with whatever velocity our rocket aeroplane provided in that direction, but we would apparently also be going west at a thousand miles an hour. Apart from gale difficulties, the bump on landing would be disturbing. Knowing these things, of course we will be able to make the necessary correction by gradually giving ourselves the essential easterly velocity as we go north.

We have not discussed anything beyond the first twenty miles—that is, this article is limited to the stratosphere, which we reached by ascending through our familiar turbulent troposphere. In a later article we can ascend ten times that distance, penetrating the ozonosphere and the ionosphere beyond. There is still plenty of room on top. Taking the earth as a fairly round plump water-melon a foot in diameter, then the little blemishes on its skin correspond to the mountain ranges and ocean depths. To scale they would, from deepest depth to highest height, cause irregularities on our melon skin of about one-seventieth of an inch. The highest irregularity, say the Mount Everest of our melon, reaches towards the top of the troposphere, and our last balloon ascent takes us about one-eightieth of an inch above that. We ourselves would be microscopic little bacterial crawlers on the melon, not yet able to climb to the top of the tiny terrific blemishes on its skin. It is really very clever of us to think and reason and thus to devise means to carry us up relatively so high in the melon vapour. We differ from the melon bacteria in that we are not solely dependent on our physical bodies, but can, as humans, rise as high as our minds will carry us.