OXYGEN ON MOUNT EVEREST, 1938

By PETER LLOYD

THERE were two types of oxygen apparatus available to the Mount Everest Expedition of 1938. One was the open type, used by the 1922 and 1924 expeditions, in which the climber breathes a mixture of oxygen and air. The other was a closed circuit apparatus in which pure oxygen is breathed. Now the essence of the oxygen problem is the fact that the apparatus cannot be effectively tested except actually at very high altitudes. Serious oxygen lack does not make itself felt below about 23,000 ft., so that a test in the Alps is not conclusive even with the closed apparatus, and with the open apparatus it would be entirely useless. Similarly a test in a pressure chamber is of little value since it cannot include the vitally important acclimatisation factor. There was therefore no possibility of making a comparison of the two units in Europe, and it was decided by the leader of the expedition that both must be taken.

The open apparatus was similar in principle to that devised for the 1922 expedition by Professor Finch. The oxygen was contained in two Vibrax steel cylinders of 500 litres capacity at 120 atmospheres pressure, and was fed through an adjustable spring-loaded governing valve to a small canvas bag acting as a reservoir, and thence to the mouthpiece. It is calculated that with a delivery rate of 2 litres of oxygen a minute (as measured at normal atmospheric temperature and pressure) a climber doing vigorous work at 29,000 ft. above sea level would be in an effective oxygen pressure corresponding to about 20,000 ft. Since at this altitude an acclimatised man can move almost as fast as in the Alps it is considered that this is a reasonable partial pressure to aim at, and at this rating the apparatus with its charge of 1000 litres would last for over 8 hours. The total weight was 25 lb., the charged oxygen cylinders accounting for 19 lb.

The closed unit was similar to that taken by the 1936 expedition,[1] and was of the type which has been successfully used for rescue work in mines. It had been improved as a result of tests carried out by Dr. Warren in 1937, in the course of which he used the apparatus on the Matterhorn and the Wellenkuppe. The oxygen was contained in a single cylinder of 750 litres capacity, and from the cylinder the gas passed through reducing valves into a low pressure reservoir. The user drew oxygen from this reservoir through his face mask, covering nose and mouth, and the expired gases passed back into the reservoir through a canister packed with soda-lime in which the carbon dioxide

[1] See *The Medical and Physiological Aspects of the Mount Everest Expeditions*, C. B. M. Warren, *Geographical Journal*, xc, August 1937.

was absorbed. There were, in effect, three separate automatic valve systems—the pressure-reducing valve which lowers the pressure to about 2 atmospheres and from which a weep of half a litre a minute is fed into the reservoir; the breathing valve which opens when the flexible reservoir begins to collapse under external atmospheric pressure; and the lightly spring-loaded mica valves on the flexible connections to the face-piece which control the direction of flow through the circuit—all of these had to work correctly if the apparatus was to succeed. In addition there were two hand-operated valves, one the screw-down valve on the main supply and the other a by-pass by means of which the supply of fresh oxygen to the reservoir could be supplemented. As on the open apparatus, a pressure gauge was fitted to indicate the residual pressure in the cylinder. Every effort was made to lighten the construction, even at some sacrifice of rigidity, but the apparatus weighed 35 lb. for a supply which was calculated to last $5\frac{1}{2}$ hours.

Of this 35 lb. weight only $14\frac{1}{2}$ lb. was in the charged oxygen cylinder, 10 lb. was in soda-lime and the remaining $10\frac{1}{2}$ lb. was in the frame, the canister and the valve gear. But although the quantity of oxygen was small, virtually all could be effectively used, while with the open apparatus most of the oxygen would go to waste in the expired air.

A preliminary test on the closed apparatus was done on the journey out to Tibet, at Thangu in Sikkim (12,800 ft.). In the main the results were satisfactory, but it was found that in still air the oxygen may get overheated to such an extent by the heat evolved in the soda-lime that conditions become thoroughly unpleasant for the wearer of the apparatus. This effect was obtained when climbing up a sheltered snow slope in bright sunshine shortly before midday, and the apparatus became suffocatingly hot. It cooled down rapidly when a ridge was reached which was exposed to the wind, and conditions then became normal. It was not anticipated at the time that similar conditions would be experienced above the North Col on Everest, but later results suggest that this is not impossible.

Our equipment consisted of two complete units of each type, and these, together with the stock of cylinders and the tins of soda-lime, survived the hazards of the journey and arrived safely at Rongbuk. On one occasion, a frisky yak bucked off the two boxes containing the rather flimsy closed units and careered round the camp with this precious load clattering behind it. But the damage proved to be slight and the necessary adjustment and overhaul of the units was successfully completed at this stage.

Nothing further was done with the oxygen until a month later when we occupied Camp 3 for the second time (May 18). The flow of oxygen through the valves was checked, and it was found that one of the closed units was radically out of order with a leak through the main reducing valve. The repair of this defect took two days and went some way to undermine our confidence.

Shortly after this, Warren was able to carry out the first high altitude test on the closed apparatus. He tried it on the snow slopes above the North Col (23,000 ft.), and found that although the unit seemed to be in perfect mechanical order, it tended not to stimulate but rather to suffocate him. He was actually moving more slowly than the other climbers, and was forced to stop after every dozen steps to recover his breath. The camp was evacuated on the following day and there was no opportunity of continuing this test.

When the camp was reoccupied about ten days later by a party of four Europeans and sixteen porters, this gave another chance for a comparative trial of the two forms of apparatus between Camps 4 and 5 (23,000–25,700 ft.). As Warren was not a member of this party it fell to me to carry out this trial, and having heard, at second-hand, of his ill success with the closed unit, I decided to try the other first. Starting after the rest of the party on the day that Camp 5 was to be occupied, I found that it took me the first half-hour to master the simple breathing technique and to learn the tricks of the apparatus. The oxygen was drawn into the lungs through a rubber mouthpiece which was held between the teeth. The technique consisted in biting the rubber to prevent an outflow of gas when breathing out and releasing it when breathing in. When the flow of oxygen was stopped by biting the mouthpiece the oxygen accumulated in the small canvas bag mounted above the cylinders. The only trouble with the outfit was that the rubber mouthpiece was much too stiff, but this was easily overcome by discarding it and biting straight on to the softer rubber of the connecting tube.

As we trudged up the snow slope I soon began to feel at home in the apparatus. The only thing that seemed to disturb the slow breathing rhythm was the rapid movement of step-cutting; when I was climbing over easy rock or kicking steps in snow the action was almost automatic. As to speed, I found that I was moving as fast as the fastest member of the party and therefore much better than without the help of the oxygen. But the main difference was the absence of strain or fatigue. The day before, climbing from about 21,000 ft. to 23,000 ft. I had felt really tired, whereas on this day climbing from 23,000 to 25,700 ft. and down again left me comparatively fresh.

Partly to economize oxygen, and partly to test the effect of suddenly removing its stimulus, I turned off the supply at every halt, and this did not seem to produce any reaction whatever. On the other hand, when my first cylinder was running out and I was climbing with a rapidly decreasing supply the effect was immediately noticeable. The oxygen flow had been set the previous night to a rate corresponding to 2.2 litres a minute (at normal atmospheric temperature and pressure) and at this setting the first cylinder lasted until ten minutes below Camp 5. The oxygen supply was turned off half way down the snow slope before the second cylinder was empty.

The following day it was the turn of the closed apparatus, so, rather begrudging the loss of an off day, I took the better of the two units and

charged it with oxygen and absorbent. In company with a Sherpa' Gyalgen Mieckche, I started off towards Camp 5 intending to go as far as the top of the snow slope and to compare my times and sensations with those of the previous day. But it soon became evident that there was something very wrong and that it was going to be an off day after all. Mechanically everything was perfect, and the valves were opening and closing like clockwork, but inside the mask I was nearly suffocating and I had to stop frequently to take a dose of fresh air. If the whole of the system was filled with fresh oxygen, then for a time conditions were pleasant enough, but very quick deterioration followed. In effect I was climbing far slower than Gyalgen Mieckche, who was openly scornful of the performance of the 'Oxy' as the Sherpas now call it, for the picturesque term 'English Air' is no longer used. I was at a loss to account for this complete failure, for on the two previous occasions when I had tested the apparatus, once at home on Kinder-scout and once at Thangu, all had gone well. The absorption seemed to be satisfactory, for the soda-lime canister was warm, uncomfortably warm in fact, but the effects of the overheating were much more serious this time than they had been under similar conditions at Thangu. Nothing that I could do improved the results in any way, and after a bare half-hour I was forced to return to Camp 4. When I got back and the apparatus had cooled down Tilman put it on and did half a minute's physical jerks in it with apparent enjoyment, but this short test failed to impress me and he showed no inclination to do a longer one.

The next step might have been to arrange for an oxygen attempt on the summit with the open apparatus, but for this our supply of cylinders was not really adequate. Alternatively we could have abandoned the oxygen, but it was felt that the results of the first test on the open unit had been sufficiently promising to justify the formation of a rather unorthodox mixed party in which only one member would be using oxygen. This arrangement is hardly to be recommended for the future, but on this occasion it served our purpose well enough.

The open apparatus again worked perfectly for the second ascent to Camp 5, and just over one cylinder was used. On the following day we set off with two Sherpas for Camp 6, which Shipton and Smythe had pitched at 27,200 ft. The rocks were heavily snowed up and we could well understand the difficulty which the first party must have had in breaking the trail two days before. Tilman took on the thankless task of shepherding the porters and left me free to forge ahead on my own. Thanks to the oxygen apparatus, which was working perfectly, I was feeling very fit and reached Camp 6 half an hour or an hour ahead of the others. Even at this height (27,200 ft.) I felt absolutely no ill effect on turning off the oxygen supply when I stopped climbing.

The story of our attempt to reach the main ridge of the mountain on the following day has already been told. We were forced to retreat after advancing only a short distance above the camp. In spite of oxygen, I seemed to feel the early morning cold as much as Tilman,

and I made no more impression than he did on the rocks we were trying to climb. On easy ground, however, it did increase climbing speed, as was very evident when we were roped together.

It is not an easy matter to do scientific work above 23,000 ft., for Everest has a way of sapping one's energy and leaving little inclination for detailed work. As a result the tests which were done on the oxygen apparatus are neither as complete nor as precise as one would like them to have been, and our conclusions cannot have the force of proofs. The failure of the closed apparatus on two independent tests on the North Col has yet to be satisfactorily explained, but the fact of its failure, coupled with the mechanical troubles which were experienced with it, give powerful backing to the arguments which have already been advanced against it. The open apparatus, on the other hand, behaved excellently, and it suffers from none of the disadvantages inevitably associated with the closed unit. Mechanical complication is minimized, the apparatus is robust, there is no irksome face mask to be worn, and the reaction in the event of sudden failure of the supply is bound to be much less. Perhaps the hardest thing of all is to estimate the advantage conferred by the use of oxygen. Comparison of climbing speeds is difficult and dangerous, but from this year's trials it would seem that from 23,000 to 26,000 ft. the use of oxygen in the open apparatus at 2 litres a minute has only a slight effect on natural climbing speed. The reduction of strain and fatigue, however, provides ample justification for its use at this height. Above 26,000 ft. the increase in climbing speed becomes more and more apparent. The maximum advantage is obtained, as one might expect, on easy ground where the climber moves with steady rhythm. More difficult climbing requiring greater exertion results in an increase in the rate of breathing, and with the open apparatus this implies a fall in the partial pressure of oxygen entering the lungs.

There are some who say that Everest will not be fairly climbed until it is done without oxygen, and most climbers have a certain sympathy for this point of view. But Everest is a very big proposition, so big that one can ill afford to ignore any possible aid, and oxygen may be needed after all. We suffered this year from the necessity of taking two different forms of apparatus, each with its different-sized cylinders. It is hoped that a future expedition will be able to make a definite choice.

OXYGEN AND MOUNT EVEREST

A Note by G. I. FINCH, F.R.S.

THE task of climbing Mt. Everest is at last being generally recognised as one lying very close to the limit of human endeavour. As such it calls for the exercise of every advantage that the wit of man can devise. We cannot afford to give anything away. The question of the possibility of the summit being reached without oxygen should be relegated to the mental lumber-room with any futile 'ethical' searchings. The

question of the additional risks which the use of oxygen may or may not involve is immaterial; such risks must just be accepted. The only material question is simple—namely, do the advantages of oxygen counterbalance the disadvantages of the extra weight and equipment? This was clearly and indisputably answered in 1922 when a weak party using oxygen went further on the mountain than a much stronger party meeting with distinctly less adverse weather conditions.

In 1922, the oxygen equipment, though sound in principle, was cumbersome and heavy. With the resources now available, a compact apparatus supplying oxygen at a rate sufficient to increase the total oxygen partial pressure to the equivalent of a height of 15,000 ft. and containing 10 hours' supply need weigh no more than 20 lb. Thus, two felt-jacketed Vibrax steel cylinders charged to 180 atmospheres and each containing 750 litres of oxygen at N.T.P. weigh about 14 lb. A robust combined pressure gauge, flowmeter, reducing valve and flow valve of the type used in flying weighs less than 2 lb. The only additional requirement is half a pound of rubber tubing and bag. A complete apparatus, therefore, holding sufficient oxygen for at least 10 hours at altitudes above 25,000 ft., need weigh only 16–17 lb. These figures should suffice to show that the open type of oxygen apparatus has become an indispensable part of the Everest climber's equipment. Of the so-called closed type of apparatus there is little to be said. It is, indeed, at fault fundamentally, in that it makes no use of the always available supply of oxygen from the atmosphere. Thus, foredoomed to failure on *a priori* grounds, it also failed on the mountainside.

If oxygen is to be the key to success on Everest, the use of oxygen supplies on the mountainside must be properly organized. In future, there must be no weakening of an expedition by splitting it into two parties on the question of oxygen. There is no room for divided opinion. The whole expedition must be organized with a view to pushing the attacking party up to a starting-point as high up the mountain as is practicable and properly equipped with all requisite supplies. Between the high starting-point and the summit small depots of a few cylinders each should be established, the furthest being laid, if possible, at say 28,000 ft. on the edge of the great gully. Nor is there room for two types of oxygen apparatus. The choice must be made and adhered to. In the face of facts of actual experience this should not be difficult. The finer points and details of the oxygen outfits, together with consideration of the advisability of doping the oxygen with carbon dioxide, are questions to be discussed and settled by a competent committee, long before the expedition sets out.