LESSONS FROM HISTORY

English Air—The Story of the 1922 Mt Everest Oxygen Apparatus

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The highest of mountains is capable of severity, a severity so awful and so fatal that the wiser sorts of men do well to think and tremble even on the threshold of their high endeavour.

George Leigh Mallory¹

After a successful reconnaissance of the mountain in 1921, the first expedition with serious aspirations to climb Mt Everest left Darjeeling in the spring of 1922. Amongst the many hundreds of loads that would make the difficult journey across Sikkim and Tibet were 10 oxygen apparatus and 28 800 L of bottled oxygen.² At a cost of £400 the Mt Everest Committee had invested heavily in equipment that was both controversial and unproven. Whilst the pragmatists voiced suspicions over the weight and reliability of the system, romantics denounced the apparatus as “unsporting” and “un-British,” preferring the mountain to be climbed without “artificial aids.”³ George Ingle Finch, the Oxygen Officer appointed to the expedition, made a spirited defense: “In answer to this grave charge I would remind the accuser that, by the inhalation of a little life giving gas, the climber does not smooth away the rough rocks of the mountain or still the storm. . . . Oxygen renders available more of his store of energy and so hastens his steps, but it does not, alas, fit the wings of mercury on his feet!”⁴

Finch’s enthusiasm for supplemental oxygen stemmed from a meeting he, together with Alpine Club member PJH Unna, had with Oxford Professor George Dreyer in March 1921. On hearing their plans to climb Everest without supplemental oxygen, Dreyer expressed his concern: “I do not think you will get up without, but if you do succeed you may not get down again.”² Dreyer’s words were backed up by considerable experience and proved difficult to ignore. As a consultant to the Royal Air Force and the US Army Air Corps during the First

World War, Dreyer had been one of the first to study the effect of altitude on aviators and had designed an oxygen apparatus that had been used with considerable success.⁵ Using a small pressure chamber installed in his laboratory, Dreyer had witnessed at first hand the effects of hypobaric hypoxia as well as the improvements made by the addition of supplemental oxygen. To prove his point Dreyer invited Finch to participate in one such test and to be “pumped up to [a pressure equivalent of] 23 000 feet (6900 m).” Looking on, Unna described the effects:

The face and hands lose their red colour and become bluish, especially the fingernails. Breathing becomes faster, even without exercise. The blood turns a very dark red. The subject tends to become incapable of taking exercise. . . . The symptoms, of which the subject is unaware, of the approach of unconsciousness are mental confusion and a tendency to quarrel, while the blueness becomes more marked.²

In addition, Unna also noted that “Those taking oxygen retain the red colour in face and hands and the normal colour in their blood, nor do they exhibit the other symptoms.”²

These findings led Finch and Unna to urge Alpine Club president JP Farrar that “the question of oxygen ought to receive serious attention.”² Although convinced by their arguments, Farrar was unable to organize a meeting until the members of the reconnaissance party had returned from Tibet. Nine months later, on January 31, 1922, Dreyer together with representatives of the Alpine Club, Air Ministry, and the equipment manufacturer Siebe Gorman met in London. Within 2 months the group had designed, built, and tested the first Mt Everest Oxygen Apparatus. The forerunner of today’s high-altitude systems had been born. But would it work?

The equipment

The principles behind the apparatus used on Mt Everest in 1922 will be familiar to anyone who uses supplemental

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oxygen in clinical practice. As an “open” system, the apparatus allowed mountaineers to inspire a combination of supplemental oxygen and ambient air before venting exhaled gas directly into the atmosphere. The oxygen was supplied from 4 cylinders fitted onto a metal carrying frame and worn on the back like a rucksack (Figure 1). To ensure that it was “possible to change over from one bottle to another without interruption,” Dreyer had insisted that the system should be duplicated wherever possible.² This meant that gas from 2 cylinders was fed through 2 high-pressure copper hoses, each with its own stop valve, into a bulky arrangement housed against the mountaineer’s chest. Here, the high-pressure oxygen was attached to a pressure gauge and reducing valve before passing through a flow meter, “fine adjustment valve,” and rubber hose toward its final destination. In the event that this part of the system failed, a bypass valve was placed near the reducing valve so that oxygen under cylinder pressure could pass freely through the system. The result of these additions meant that the apparatus weighed an uncomfortable 33 pounds (15 kg), leading one mountaineer to comment “I confess that when I saw and lifted the complete outfit . . . I was aghast at the idea of anyone being saddled with such a load. But if the men who would have to be carrying it were not deterred it was not for me to raise an objection.”⁶

THE MASK

Although 2 face masks were originally chosen, it soon became clear that the “economizer” mask would cause considerable problems.⁷ This tightly fitting mask contained 2 expiratory valves and a single inspiratory valve attached to a “flexible corrugated India rubber tube” and the oxygen supply. During exhalation, the inspiratory valve was closed and supplemental oxygen would collect in the tubing, ready for the next inspiration. Unfortunately the mask had not been designed for “hard exercise,” and expiration was met with considerable resistance. On February 23 the expedition members met at the Air Ministry for equipment testing: “Each was made to run up at full speed four flights of stairs on to the roof with the apparatus in actual use, to see that everything was all right. They were thoroughly blown, and Dr Wakefield nearly got asphyxiated, as when panting hard he could not get enough air, and the mask had to be ripped off his face.”²

Although the source of the problem was unclear, the designers believed that the expiratory valves were at fault. Each valve was of a square design and secured to the mask at each corner. By freeing 2 of the corners, the designers felt that resistance would be eliminated. Unfortunately, this was not the solution, with Finch later

commenting that the “masks supplied to the expedition proved useless, partly owing to their stifling effect upon the wearer.”⁴ In order to solve this problem Finch set to work modifying the second face mask. The “standard” face mask was a much simpler affair, consisting of a flexible copper dome lined with chamois leather and pierced by 2 holes and a stiff rubber oxygen hose that inserted into the mouth. Using a “little thought and much cheerfulness,” Finch stripped away the copper dome from the “standard” mask and divided the original tubing some way from the mouthpiece.⁴ Here he inserted a glass T-piece and upon reconnecting the tubing attached a toy football bladder to the spare port.⁸ Throughout the breathing cycle the hose was held between the teeth like a smoker’s pipe and only opened during inspiration (Figure 2). According to Finch, the addition of a reservoir had 2 potential benefits: “Firstly it economizes oxygen to the greatest possible extent and secondly, the swelling and shrinking of the bladder during each exhalation and inhalation gave the climber a fair idea as to how rapidly the oxygen is flowing through the apparatus.”⁷

The reservoir was subsequently adopted by future designers and used successfully by Sir Edmund Hillary and Tenzing Norgay on the first ascent of Everest on May 29, 1953.

THE CYLINDERS

Unfortunately time restraints meant that Finch was forced to use Royal Air Force (RAF) oxygen cylinders, which weighed 5.75 pounds (2.6 kg) each. Made from stainless steel, each 2-L cylinder was filled to a pressure of 120 bar and therefore contained 240 L of oxygen when full. To illustrate the limitations of this cylinder, it is worth comparing the apparatus to the equipment that is routinely used in high-altitude mountaineering today (Table 1). Although the modern Poisk cylinder (St Petersburg, Russia) weighs more than the RAF model, it is twice as large and can be filled to a pressure of 280 bar. Using the ratio of cylinder capacity to filled weight in order to illustrate cylinder efficiency, it is possible to compare cylinders of different volumes. From Table 1 it can be seen that modern equipment is more than 3 times more efficient than the cylinders used in 1922. This had important practical implications for Finch and his colleagues. If members of the party were going to climb the mountain with supplemental oxygen, large numbers of cylinders were going to be needed at a series of different locations on the mountain. This would require the help of a large number of porters and all of the necessary logistics in place to enable this. In addition, climbers would also be required to carry a minimum of 4 cylin-

Figure 1. The 1922 Mt Everest Oxygen Apparatus.

ders on summit day, not only to make up for the small volumes of oxygen in each cylinder, but also to compensate for the higher flow rates that were needed to cope with the additional weight of the system.

Everest 1922: On the mountain

On April 30th the expedition arrived in the Rongbuk valley and soon established base camp at the snout of the glacier. As Oxygen Officer, Finch's principal task was to unpack, assemble, and test the apparatus for use higher up the mountain. It soon became clear to Finch that he was faced with a potential disaster. Not only had many of the flow meters and pressure gauges been damaged by the long journey across Tibet but somehow "The soldering on most metal joints had begun to leak and the sealing washers had shrunk so much that the screwed connections no longer formed air tight seals."⁷

Working outside in temperatures below freezing, the process of repairing the systems was painstaking and required "days of hard toil with soldiering iron, hack-saw, pliers and all the other paraphernalia of a fitters shop."⁴

Nevertheless, on May 20th the apparatus was finally ready. That afternoon, in the company of expedition members Edward Strutt and Arthur Wakefield, Finch and Geoffrey Bruce donned their apparatus and set off over the East Rongbuk glacier to the Ra-Piu La pass at the foot of Mt Everest's northeast Ridge.⁷ The gain in ele-

vation provided an ideal test for the equipment. Finch was delighted with the results, writing later that "Colonel Strutt and Dr Wakefield, unoxygenated, accompanied us on this little expedition and oxygen at once proved its value, so easily did Bruce and I outpace them."⁴ In his diary Finch was even more effusive, commenting "The effect of oxygen was remarkable—We two went like a house on fire!"⁹

Two days later Finch, Bruce, and the Gurkha soldier Corporal Tejbir Bura tried the apparatus again, but this time on the steep icy slopes from Camp 3 (6300 m) to the site of Camp 4, situated on the North Col (6900 m). On returning to Camp 3 later that evening Finch expressed his delight: "Our oxygen experiment was an unqualified success. . . . Time up was about 3 hours only. Down back to Camp 3 only 50 minutes. Going easy. Returned fit and fresh to Camp 3. Oxygen consumption exactly three bottles each."⁹

During the ascent the trio had come across the first party who, without oxygen, had reached an altitude of 26 985 feet (8096 m) on the previous day.¹⁰ Plagued by strong winds and the effects of altitude, their pace had slowed dramatically. Over the last 2000 feet (600 m) of ascent the party, containing such notable mountaineers as George Mallory and Howard Somervell, had managed just 320 feet (96 m) per hour before abandoning their attempt.¹⁰ Despite this failure, Finch was not put off and instead took encouragement from the fact that his men had climbed from Camp 3 to Camp 4 much more quickly than those in the first party (Table 2).

After a day's rest the 3 climbers, accompanied by expedition cameraman John Noel, set off for the North Col again. Using supplemental oxygen the 4 completed the journey in less than 3 hours and "bent on a determined attack camped there for the night."⁵ The following morning 12 porters were sent ahead carrying oxygen cylinders, camping equipment, and provisions for the final summit bid. Despite starting out some 90 minutes later, the 3 climbers quickly overtook their porters at a height of 24 500 feet (7350 m), with Finch explaining to them that "Our phenomenal speed was due to us imbibing 'Bottled English Air.' We certainly had the twist of them."⁷

Shortly after 1:00 PM the weather began to deteriorate and instead of continuing, an area on the crest of the North Ridge was levelled and a tent pitched. Throughout the night and much of the following day violent storms took hold: "The storm tore viciously at the tent's guy ropes; it shook and rocked the tent, then rushed in underneath the bottommost tarp like an angry monster, raising first one side then the other into the air, lifting its inhabitants with it. Like wrestlers, we threw ourselves onto the tarp whenever this happened, the three of us barely able to tame it."⁷

Figure 2. The 1922 Mt Everest Oxygen Apparatus in use on the mountain.

Table 1. A comparison between the cylinders used on Mt Everest in 1922 and 2007

	1922 Oxygen Cylinder	2007 Poisk Cylinder
Cylinder volatume (L)	2	4
Maximum filling pressure (bar)	120	280
Filled capacity (L)	240	1120
Weight when full (kg)	2.6	3.27
Ratio of filled capacity to weight	92.31	342.51

By late afternoon on May 26th the winds had begun to calm. But instead of abandoning their attempt and descending, the 3 agreed to stay for a further night and make their summit attempt the next day. Despite their enthusiasm, Finch realized that a second night at 25 500 feet (7650 m) was now beginning to take its toll:

*Something had to be done. Like an inspiration came the thought of trying the effects of oxygen. We hauled in an apparatus and cylinders into the tent, and, giving it the air of a joke we took doses all round. . . . We connected up the apparatus in such a way that we could breathe a small quantity of oxygen throughout the night. The results were marvellous. We slept well and warmly.*⁴

Finch had discovered the enormous benefits of using supplemental oxygen during periods of rest at altitude. Following his example, the majority of mountaineers today use a flow rate of between 0.5 and 1 L·min⁻¹ of oxygen prior to a summit day on Mt Everest.¹¹

At 6:30 AM the following morning the 3 climbers set off for the summit. According to Finch, “Our scheme of attack was to take Tejbir with us as far as the North East Shoulder, there to release him of his load and send him back.”⁴ The addition of an extra oxygen cylinder from Tejbir’s load meant that if the maximum flow rate of 2.5 L·min⁻¹ was used, the pair would still only have 8 hours to reach the summit and return to Camp 5. Given that the summit was more than 3000 feet (900 m) above, them the pair would need to maintain the ascent rate of

the 2 previous days (666 feet·h⁻¹; 200 m·h⁻¹) if they were to complete the round trip on supplemental oxygen. Although this is possible in theory, those who have climbed Everest will know that even with supplemental oxygen, climbing rates over the last section of the mountain slow dramatically. In the end this had no bearing on the pair’s chances. Soon after departing from Camp 5, Tejbir “showed signs of waning” and eventually broke down just a few hundred feet above camp. Still some way short of his proposed turnaround point, Tejbir was forced to hand over his cylinders and return early to camp. As the cylinders Finch and Bruce were using still contained oxygen, the 2 climbers were now burdened by an additional load. In order to compensate for this and to move more quickly, the pair unroped and continued apart up the North Ridge. Unfortunately, by this stage the winds of the previous 2 days had returned and Finch was forced to make a detour, leading his partner onto the exposed north face of the mountain. Here progress slowed yet further, as “The general angle became much steeper, and our trials were accentuated by the fact that the stratification of the rocks was such that they shelved outward and downward, making the securing of adequate footholds difficult.”⁷

As the pair reached the distinctive “Yellow Band” of broken sandstone, Bruce suddenly cried out “I’m not getting any air.”⁷ Turning around Finch saw his partner stumbling and struggling to find his balance on the steep terrain. Quickly he descended the 20 or so feet to him, hauled his partner onto a small ledge, and handed him his own oxygen apparatus from which to breathe. In order for both climbers to benefit from the oxygen in the working apparatus, Finch then set about removing the reservoir bag from the set’s T-piece and replacing it with a second piece of tubing, through which he would be able to breathe. Once accomplished,

[Finch] resumed my examination of the damaged breathing apparatus, and tried in a calmer and more careful manner to make my diagnosis. . . . I tested the individual components starting with the mouthpiece, and soon found

Table 2. The ascent times and rates of both summit attempts made on Mt Everest in 1922

Route	First attempt		Second attempt	
	Ascent time to 26 985 feet (8096 m) (h)	Ascent rate (feet·h ⁻¹)	Ascent time to 27 250 feet (8175 m) (h)	Ascent rate (feet·h ⁻¹)
Camp 3 to 4	4	500	3	666
Camp 4 to 5	4.5	444	3.75	666
Camp 5 to highpoint . . .	6.25	320	5.5	318*

*By avoiding a section of the North Ridge, Finch and Bruce added approximately 150 m to their route.³

that a glass connector-tube that had been used when constructing the improvised masks had broken. The thick rubber that had originally protected the tube had been partially pulled away, and the unprotected glass had broken while climbing on one rock or another. Fortunately, since I had a spare glass piece, I was able to repair the damage quickly and easily, and Bruce could once again use his breathing apparatus.⁷

As Finch made preparations to set off again, he realized that the damage had been done and that his partner was in no state to follow: "All at once I saw that Bruce had already worked his body to the limit, just like Tejbir before him. One more step would inevitably do him in. This realization hit me like a hammer."⁷ Finch now knew with crushing certainty that his chance of climbing Everest had vanished. But despite such a terrible disappointment, Finch and Bruce still had reasons to celebrate. Not only had the pair set a new high-altitude record (27 250 feet, 8175 m), but they had also gathered important anecdotal evidence of the benefits of oxygen during sleep, rest, and exercise in an extreme altitude environment.

Summary

Following the 1922 Mt Everest Expedition, Finch remained an enthusiastic supporter of the use of supplemental oxygen at the extremes of altitude. Even with the primitive equipment available, Finch had shown that an increase in oxygen delivery could make an important difference to performance on the mountain. Whilst pragmatists and romantics still continue to debate the role of "English Air" at altitude, generations of high-altitude mountaineers have followed Finch's example and adopted systems based on the 1922 Mt Everest Oxygen Apparatus in order to successfully climb many of the world's highest peaks.

Acknowledgment

The authors are grateful to the Trustees of the National Library of Scotland and George Ingle Finch's daughter, Anne Russell, for permission to reference Finch's 1922 Mt Everest diary. Anne Russell has also kindly permitted the reproduction of her father's photographs from 1922. The authors are also indebted to Graham Hoyland and other members of the Caudwell Xtreme Everest Medical Research Expedition (University College London, UK), who helped immeasurably in the preparation of this manuscript.

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