Ambulatory Oxygen Therapy:
Oxygen Inhalation at Home and Out-of-Doors*

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The use of oxygen at home was based on the application of respiratory physiology to clinical disorders of breathing, but its recent increased employment is the result of the development of apparatus that is now practical for the patient to handle himself. Oxygen is prescribed for relief of shortness of breath, hypoxia and coronary insufficiency; in addition, for increase of cardiorespiratory reserve by utilizing an oxygen exercise program. The technique of oxygen therapy will be presented, including its use during exercise in clinical states characterized by chronic respiratory insufficiency; reference will be made to oxygen inhalation for patients with coronary disease.

The Oxygen-Exercise Regimen

When we found that inhalation of relatively low concentrations of oxygen relieved shortness of breath during exertion, in patients with pulmonary emphysema, a standardized program of graduated walking exercises was inaugurated in our clinic with the purpose of developing the muscles of breathing, and preventing atrophy of disuse of the body musculature and increasing cardiorespiratory reserve. Since inhalation of 32 to 36 per cent oxygen was adequate for this purpose, a simple technique was readily developed which did not include the use of an uncomfortable mask.1-3

During the past 10 years in which walking regimens during the inhalation of oxygen has been employed and found to produce benefit in breathing in more than 100 patients so treated in our clinic, as well as by Cotes et al.4 in England, and W. B. Miller5 in the United States, no untoward result has ever been reported. No respiratory depression has been encountered even with inhalation of 40 to 50 per cent oxygen during exercise.

One or more of the apparatus to be described may be employed for the administration of oxygen. A conventional large oxygen cylinder containing approximately 6,000 liters may be obtained from an oxygen therapy service company and installed in the patient's home, with regulator.**

*This presentation contains excerpts from a book in preparation, a Doctor-Patient Manual for Patients with Bronchial Asthma, Pulmonary Emphysema and Bronchiectasis. (Williams and Wilkins, Baltimore.)

**There is no charge for the rental of the cylinder, but the patient is billed for the contents of oxygen in it. The oxygen regulator is purchased rather than rented from the oxygen therapy company since it is much less expensive in the long run to own it, as well as the nasal device for inhaling of oxygen, such as the double bent plastic tubes that enter about one-quarter inch inside the nares.

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The use and care of the regulator is of considerable importance. Even though an oxygen technician is employed to change the regulator from one cylinder to another, patients should be familiar with the simple rules involved. The circular wheel at the top of the large cylinder is turned counter-clockwise to blow away any dust that may have accumulated in transport. Under no circumstance should any oil or lubricant be smeared on the thread or any part of the regulator. The regulator is then connected to the tank and made tight by a wrench which is supplied with the valve. Before the oxygen is turned on from the cylinder, by turning the circular wheel at the top of the cylinder, the regulator handle is turned counter-clockwise until it is loose, i.e., in order that no oxygen is delivered when the wheel at the top is turned on. This precaution prevents the full force of oxygen from hitting the valve mechanism or diaphragm inside the regulator.

If a hissing noise is heard at the attachment on the valve, the wrench is employed again to tighten it further. The regulator handle is now turned clockwise until 1, 2, 3, 4, 15, or whatever flow of oxygen, in liters per minute is desired. An oxygen humidifying bottle may be attached to the regulator but it is a needless expense. (Some of the oxygen water bottles leak and oxygen may be lost thereby.) For periods as short as those

FIGURE 1: Light weight oxygen cylinder with double nasal plastic tubes.
involved in an oxygen-exercise program, the dry oxygen inhaled has no decipherable effect on the mucous membrane of the nose or pharynx.

A 50-foot length of rubber tubing is generally used in the oxygen-exercise program. Light rubber is preferable to gum tubing, although a good texture of plastic tubing may also be firmly attached to the regulator and to the device for inhaling. If powder is present in the tubing a thorough cleansing with water should first be used. The facial attachment to the rubber tubing consists of a double plastic cannula that is currently in use. Many years ago a metal curved nasal cannula was used; later we employed a rubber nasal tube shaped by wire in the wall, or molded to enter into the nostril about one quarter of an inch. Recently, plastic tubes have been made, like the Hudson or other make, attached either by an elastic or rubber band or by an eyeglass setting to hold the cannula in place. If the nasal tube is set correctly, so that the oxygen is delivered toward an open aperture in the nose and not so as to strike the mucous membrane above or below, the inhalation of oxygen by this method is more comfortable to most patients than by any other type of oxygen therapy apparatus. The oxygen flow from the large cylinder runs continuously, although demand type oxygen or oxygen inhaled during inspiration may also be provided, even at times with a mask. The nasal

FIGURE 2: Varieties of Oxy-Hale apparatus provide from 3 to 24 liters of pure oxygen, 21 to 168 liters of 32 per cent oxygen at sea level, or 30 to 240 liters of 100 per cent oxygen, saturated with water vapor at 37°C., at 30,000 feet altitude.
tubes and oxygen apparatus used in inhalation therapy is shown in the accompanying illustrations. (See Figs. 1 and 2.)

When oxygen is inhaled for exercise from a large cylinder its cost is so small that it is considered convenient to allow it to run during inspiration and expiration. When the small, portable Oxy-Hale apparatus is employed, the regulating valve is turned on during inspiration only.

In patients who are short of breath, a flow of 8 liters per minute is used at the start of an oxygen-exercise program. In the majority of cases 6 liters per minute is adequate; after the program has been in effect for two or three weeks or more, 4, 5 or 6 liters of oxygen per minute may permit exercise to take place without undue increase in the volume of air breathed. The actual percentage of oxygen in the air inhaled varies considerably, depending upon the volume of the ventilation per minute, i.e., the amount of air inhaled. At an inspiratory flow rate of 20 liters per minute, 4 liters per minute would theoretically provide 36.8 per cent oxygen. In dyspneic patients 4 liters per minute flow would almost always provide above 28 per cent oxygen in the inspired air, 6 liters above 32, 8 liters above 38, and 10 liters above 40 per cent oxygen. The physician directing the program will prescribe the liter flow of oxygen desired.

When 8 liters per minute is used, the average patient may begin by walking 50 steps back and forth across the room, carrying the oxygen tubing in his hands. When this walking exercise is concluded, he should breathe oxygen at rest for 5 minutes, then walk half the amount, viz. 25 steps, breathing air and rest at the conclusion of this walking exercise with air. If he finds himself quite short of breath, he should reapply oxygen at a flow of 4 liters per minute, for 2 to 5 minutes, which is adequate to relieve the lack of oxygen (or oxygen debt) that might be produced by walking in the air atmosphere. In addition, manual compression of the lower chest, as previously described, is frequently helpful to reduce alveolar overdistention. In addition, prior to exercise it is helpful to inhale a bronchodilator aerosol, such as 2.5 per cent racemic epinephrine (Dylephrin) or 0.4 per cent isoproterenol with 2.0 per cent phenylephrine (Nebu-Prel).*

Graduated exercise with oxygen is generally followed by increased exercise capacity breathing air. In our clinic the number of steps is usually doubled every day or every third day until 700 steps are walked twice daily. Some individuals are more comfortable by maintaining this degree of walking with oxygen, with half the number of steps breathing air for a period of several weeks, or until sufficient cardiorespiratory reserve has been developed to prevent undue shortness of breath or palpitation. From 700 steps to 1,000 steps, the increase in daily walking is changed at weekly intervals. If the patient is unable to walk one half the number of steps in air without undue shortness of breath, he is told to stop at that point where breathing difficulties begin, and to inhale oxygen at 4 liters per minute for five minutes after exercise with air.

The oxygen exercise program is never carried out after eating, but preferably one hour to half an hour before eating, thus, in the late morning and in the late afternoon. As a rule, two sessions a day of walking

*Made by Irwin Neisler Co. and the Thomas J. Mahon Co.
are employed although in some instances, the patient may wish to walk three times daily, which is all to the good.

Although higher concentrations of oxygen with relatively smaller liter flows of oxygen are obtained in mask oxygen therapy, there is at the present time no comfortable mask or face tent available for this purpose suitable to the majority of patients. However, in some instances a light plastic device may be found useful. Research is now in progress aimed at the development of a new type of breathing apparatus that will be more comfortable for this purpose.

The Light Weight Oxygen Cylinder

A two and three-quarter pound oxygen cylinder containing approximately 180 liters of oxygen under 1800 pounds pressure has recently become available.* The advantage of a light-weight cylinder of this kind is that the patient may have a total of one-half hour of walking exercise at 6 liters per minute. In a number of instances 4 liters per minute may be sufficient to enable the patient to walk at a moderate rate without shortness of breath. This 4 liter flow to a mask has been used by Cotes and Gilson\(^4\) in England for an exercise program. The cylinder, strapped over the shoulder or over the neck of the patient, hangs at the side with the regulator set at the flow desired. When the cylinder has been emptied, it may be refilled from a large high pressure cylinder up to a pressure of approximately 1800 lbs. per square inch. This may be done by an oxygen company or by an inhalation therapy service technician, or by the patient himself trained to do so. The process is simple: the small cylinder may be refilled seven times before the pressure drops below 1800 p.s.i in the larger cylinder.

The oxygen cylinder is first turned to expel any dust that may be in it and the low pressure light cylinder is then screwed into a fitting attached to the large cylinder and then attached by a wrench. The large circular wheel at the top of the high pressure cylinder is turned gently and oxygen allowed to flow into the light-weight cylinder until the pressure of 1800 pounds per square inch is registered on the dial; it is then turned off, the light-weight cylinder unscrewed from the attachment provided for refilling and the oxygen valve attached to it. The valve at the top of the light-weight cylinder is automatically closed when it is released from the cylinder attachment.

These light-weight cylinders are also convenient for patients to take along on automobile trips, visits to the doctor or for x-ray when intermittent or continuous oxygen is required. A flow of 4 liters per minute of oxygen is adequate for the large majority of patients with pulmonary emphysema and a cylinder of this kind is easily carried by the patient himself, a relative or nurse. Two of them would, of course, give an hour and a half of continued treatment if necessary. It is also true that two liters per minute of oxygen is adequate to give a certain number of cases of pulmonary emphysema relief from burdensome dyspnea when at rest. These cylinders are also preferable to the heavier type of cylinders employed in hospitals to bring patients from the room floor to x-ray or to the

\*This cylinder is supplied by Controlled Pressure, Inc., Erie, Pennsylvania. It is imported from England. A similar cylinder will be made here.
operating room when indicated. However, still smaller equipment may be used if oxygen is employed during inspiration only, as is described in the next section.

**High Portable Oxygen Therapy Equipment**

**The Oxy-Hale**

The Oxy-Hale is a device with one cylinder somewhat larger than a fountain pen and may be conveniently carried in a man's pocket or a ladies' handbag; a 3-liter oxygen cylinder under 5,000 pounds pressure is used. This device is also available with 3, 5 and 8 cylinders providing 9 to 24 liters of pure oxygen. Attached to the cylinder case is a venturi or a mixing device whereby the three liters of oxygen may draw in 3 to 18 liters of air (or more), thus increasing markedly the total volume of oxygen-enriched air available for inspiration.

The CP oxygen cylinder* contains 3 liters under 5,000 pounds pressure per square inch (p.s.i.). Other gases, such as helium 80 per cent and oxygen 20 per cent, carbon dioxide with and without oxygen, may also be employed for different purposes. The escape of oxygen is into a venturi which provides various admixtures of air in the oxygen stream, depending on the size of the openings. The sleeve arrangement shown in the picture of the apparatus may be moved to various positions.

The aim of treatment is to supply a pre-mixed oxygen-enriched atmosphere of sufficient volume to be effective and comfortable. The subjective feeling of the flow of this air into the mouth (or nose) provides a sensation of treatment in action, as it were, that is not accomplished when 1, 2 or 3 liters per minute are inhaled in a mask. In table I the volumes of oxygen-enriched atmospheres are shown for the various

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*The device called "Oxy-Hale" is manufactured by Controlled Pressures, Inc., Erie, Pa.

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**TABLE I**

**VOLUME OF AIR-OXYGEN MIXTURES DELIVERED AT MOUTHPIECE OF VENTURI AT VARIOUS PRESCRIBED OXYGEN CONCENTRATIONS**

<table>
<thead>
<tr>
<th>Oxygen Concentration Prescribed</th>
<th>Air Intake per 1 liter of oxygen Flow</th>
<th>Volume of Air-Oxygen Mixture Provided by</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Per Cent</td>
<td></td>
<td>3 Liters 1 Cylinder</td>
<td>9 Liters 3 Cylinders</td>
</tr>
<tr>
<td>26</td>
<td>16</td>
<td>51</td>
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<td>28</td>
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<tr>
<td>32</td>
<td>6.1</td>
<td>21</td>
<td>63</td>
</tr>
<tr>
<td>40</td>
<td>3.1</td>
<td>12</td>
<td>36</td>
</tr>
<tr>
<td>45</td>
<td>2.3</td>
<td>10</td>
<td>30</td>
</tr>
<tr>
<td>50</td>
<td>1.7</td>
<td>8</td>
<td>24</td>
</tr>
</tbody>
</table>
concentrations provided, in a 3 liter and 9 liter apparatus. Thus, at a concentration of 32 per cent, the 3 liter cylinder supplies 21 liters of mixed gas at the mouthpiece end of the venturi. If the patient's inspiratory flow rate is 20 liters per minute, and the valve is turned on in inspiration, the duration of use of one cylinder would be 2 minutes, assuming that the flow of oxygen plus air from the venturi is at 20 liters per minute. If 40 per cent oxygen is inhaled and the patient's inspiratory flow rate increased to 24 liters per minute, a single cylinder would last one minute and the three cylinder device 3 minutes, at a flow rate of oxygen plus air of 24 liters per minute from the venturi. The 8 cylinder apparatus, or the use of 8 cylinders, would supply 168 liters of 32 per cent oxygen. With a supply of 10 or 15 cartridges, treatment could be maintained for longer periods, or perhaps until continuous oxygen therapy could be obtained, if needed.

The unit is produced in Anodized Aluminum in a glossy green finish which is the code for oxygen. It can be sterilized in alcohol or in regular autoclaves.

A concentration of 32 per cent oxygen is adequate to relieve the shortness of breath of most patients with pulmonary emphysema. However, if the patient is being treated for more severe lack of oxygen or cardiac pain, approximately 40 per cent oxygen is employed by setting the venturi sleeve on the No. 4 dial; since the one-cylinder apparatus would last one minute when inhaled during inspiration at an inspiratory flow rate of 24 liters per minute, another cylinder or two may be used, the replacement time taking 8 seconds. When a 3 or 5 cylinder apparatus is used, one cylinder is used until empty, then the second turned on.

Although the relief of shortness of breath on inhaling oxygen is greater in pulmonary emphysema than in other chronic pulmonary diseases, there is some relief in conditions such as the granulomatous and fibrotic conditions of the lung; an oxygen-exercise program may be employed in these conditions as well. The Oxy-Hale apparatus is particularly suitable for patients who are traveling short distances and who wish to be relieved promptly of exertionally induced shortness of breath. The highly portable nature of this equipment makes possible visits to the doctor, or to friends, or to the theatre, or a variety of excursions where shortness of breath is precipitated by moving about, but is relieved promptly by inhalation of oxygen. Since five or six cylinder may be taken along, and the cylinder changed quickly, the practical nature of this device for the purposes for which it is intended is apparent. The use of oxygen inhalation in the treatment of coronary insufficiency and at high altitudes will be discussed below.

Although periods of rest are indicated for the patient with chronic pulmonary disease, especially after meals, exercise is unquestionably of very real value in preventing atrophy of the voluntary muscles as well as those involved in breathing, the involuntary muscles of respiration. It is also of considerable importance to encourage these patients to take excursions that will contribute to their enjoyment and interest in life. An apparatus such as the Oxy-Hale is of particular value in allaying apprehension in making expeditions away from home. Its use is quite simple since the patient only needs to learn to close his lips over the
mouthpiece and turn the regulator on while inhaling as slowly and deeply as possible, and turn it off during expiration.

Although the physiological basis for the use of oxygen has been reviewed in recent years\textsuperscript{1-4, 6} the following discussion is relevant to the ambulatory use of oxygen.

It was mentioned above that earlier studies showed that the patients with pulmonary emphysema were frequently in oxygen debt, that is to say, so lacking in oxygen that when given oxygen to breathe after exertion they consumed considerably more oxygen than when breathing air for two to five minutes.\textsuperscript{7-10} However, an understanding of the importance of lack of oxygen in this condition is not generally appreciated. Inhalation of oxygen is often of critical value in the treatment of heart failure, either secondary to pulmonary disease, arteriosclerotic or coronary heart disease, as well as in the treatment of coronary thrombosis and anginal pain. It is also known that lack of oxygen is the cause of anginal pain and that it plays a significant role in the production of pulmonary hypertension which precedes heart failure in pulmonary emphysema.\textsuperscript{18}

Oxygen therapy is indicated at times at rest but it is important to realize that the deficiency of oxygen in the blood and the tissues and inability to increase pulmonary blood flow \textsuperscript{6}, \textit{cf. Molley} incapacitates patients from walking or simple exercise without burdensome dyspnea and/or over-distention of the lungs; inhalation of oxygen in these cases while walking at a moderate pace not only provides oxygen for prevention of dyspnea but also offers an opportunity for the development (by exercise itself) of a significant enhancement of cardiorespiratory reserve, with the ultimate gain of permitting more exercise at rest without the same degree of shortness of breath that was previously present before the exercise program was used.* In recent studies with Bickerman and Beck, the relief of dyspnea has been correlated with a decrease in pulmonary ventilation. Thus, as seen in Figure 3, in a patient who was tested in this respect before and after a 2-step test, the minute volume of respiration at rest was 7.9 liters, after exercise breathing air 16.6 liters and after breathing oxygen 11.1 liters. In each instance the ventilation was recorded while inhaling air.

In the previous studies referred to, the \textit{O}_2 consumption breathing oxygen had been found to be substantially increased over that recorded when air was breathed. It is noteworthy that the pulse rate is consistently lower when oxygen is breathed during exercise, as has long been known even in normal subjects.

Inhalation of oxygen at high altitudes is now required in jet airplane flight for possible emergency use. The administration of far smaller oxygen flows than are used in the treatment of hypoxia in clinical illness

*It is desirable that the patient be at the most optimal physiological state before the exercise program is carried out. Thus, the stomach should be empty and, in addition, a bronchodilator aerosol should be used immediately before the walking oxygen exercise program is undertaken. This can be done either with a hand bulb nebulizer or by means of one of the devices employed for the inhalation of bronchodilator aerosols.

It is also of interest to mention the favorable effects of exercise on men between 45 and 70 as reported to the Royal College of Physicians this year (1958) by Dr. Jeremy Morris: "Like many entities with an apparent bearing on coronary heart disease, the exercise factor seems to protect against the disease particularly in the earlier part of middle age—the prime of life."
could be provided for each passenger in the Oxy-Hale portable apparatus.

The expansion of gas as a result of reduced barometric pressure is a critical factor in determining the oxygen concentration and oxygen flow needed. The average individual will tolerate a degree of lack of oxygen equivalent to a 10,000 foot altitude for short periods without any ill effect. An illustration of the use of small flows of oxygen may be seen in accompanying Table I, in which it is shown that a flow of 1.57 liters per minute of dry oxygen will provide 93 per cent in the inspired air and a total flow of 10 liters saturated at 37°. This same flow of oxygen, viz. 1.57 liters per minute (at sea level, 760 mm. Hg, dry, 37°) will provide 10 liters of 100 per cent oxygen saturated with water vapor at 37° at an altitude of 36,000 feet, in this instance providing an oxygen tension equivalent to a 5,000 foot ceiling. Even less oxygen could be used to provide a 100 per cent oxygen concentration at 39,500 feet; 1.28 liters per minute will expand to 10 liters of gas saturated with water vapor at 37°F., providing an oxygen tension equivalent to a 10,000 foot altitude.*

The basal pulmonary ventilation of an adult is between 4 and 7 liters per minute. If we assume a moderately increased ventilation of 10 liters per minute the liter flows mentioned above would be adequate to provide equivalent altitudes of 5,000, 8,000 and 10,000 feet as described, either in a demand apparatus or an apparatus in which a collecting bag was used to store the oxygen provided. Under these circumstances an assumption is made that the inspiratory flow rate would be 20 liters per minute. If the individual is breathing at a higher ventilatory flow rate the oxygen required would be proportionately increased.

In planning for emergency oxygen use at altitudes in the neighborhood of 30,000 to 35,000 feet, it will be seen in Table II that the provision of 1.3 liters (760 mm. Hg., 37° dry) per minute of oxygen would give the individual a ceiling equivalent to 10,000 feet. The liter flows of oxygen required to provide a 10,000 ft. atmosphere would vary from 0.3 to 1.3 liters per minute between 15,000 to 35,000 feet. If the supply of oxygen was above this basic requirement, it would make allowance for an increase in ventilation or else provide an oxygen tension equivalent to a lower altitude if the individual was breathing at 20 liters flow rate during the inspiratory cycle. Therefore, 1.4 to 1.6 liters per minute of oxygen

*To convert dry gas volume at any altitude to saturated gas, the following formula may be used:

$$\text{Volume dry} \times \frac{\text{Bar (altitude)}}{\text{Bar (altitude)} - 47} = \text{vol. sat. 37}^\circ$$

Thus, 1 liter of dry gas at sea level = 4.57 liters at 36,500 feet

And 4.57 dry $\times \frac{166.4}{119.4} = 6.4$ liters sat. 37°

Therefore, each liter dry gas at 37° at sea level will become 6.4 liters of sat. gas 37° at 36,500 feet.

If the pulmonary ventilation is 10 liters per minute (inspiratory flow rate 20.1 p.m.), we can calculate the O₂ flow as follows:

$$\frac{10.0}{6.4} = \frac{X}{1} \text{ or } X = 1.57 \text{ liters.}$$

This oxygen flow will provide a ceiling equivalent to 5,000 ft. A similar calculation indicates that a pulmonary ventilation of 12.4 liters will provide an altitude equivalent of 10,000 feet, with a similar flow (1.58 liters).
from the oxygen cylinder would be an adequate flow if used with a collecting bag and a mask.

As an airplane descends to altitudes lower than 35,000 feet, the advantage of gas expansion diminishes, but the requirement for high oxygen concentrations likewise decreases. A concentration of 33 per cent oxygen provides an altitude equivalent to 10,000 ft. if the plane is at 20,000 feet. This concentration of oxygen may be obtained with a venturi in which 1 liter of oxygen is mixed with 5.5 liters of air. Although an 0.61 liter oxygen flow would supply an adequate oxygen tension, a total flow of oxygen-air mixture would have to be provided by an inspiratory valve on the mask that would open at a slight negative pressure. A total flow of oxygen plus air of 6.5 liters per minute would provide 33 per cent oxygen.

In order to produce an inspiratory flow rate of 10 liters per minute, an inspiratory valve on the mask would be provided; this would open to the atmosphere when the volume of the oxygen-enriched atmosphere was insufficient to meet the ventilatory needs of the individual. At this altitude under consideration, viz. 20,000 feet, 1.4 liters of oxygen mixed with 7.7 parts of air would provide a ceiling equivalent of 10,000 feet, in terms of oxygen tension.

The question of security at altitude in respect to oxygen supply may be discussed in the light of the provision of an oxygen flow in excess of

| TABLE II |
|------------------------|------------------------|------------------------|------------------------|
| VOLUME OF O\textsubscript{2} (760 mm. Hg. 37\textdegree) WHEN MIXED WITH AIR AT VARIOUS ALTITUDES TO YIELD 10 LITERS OF MIX (sat. at 37\textdegree) |
| Altitude Feet | Sea Level Equivalent O\textsubscript{2} per cent | 5,000 ft. Equivalent O\textsubscript{2} per cent | 8,000 ft. Equivalent O\textsubscript{2} per cent | 10,000 ft. Equivalent O\textsubscript{2} per cent |
| Sea Level | 21 | 25 | 0 |
| 5,000 | 21 | .73 | 21 | 0 |
| 10,000 | 31 | .14 | 28 | .45 |
| 15,000 | 39 | .43 | 36 | .78 |
| 20,000 | 49 | 63 | 46 | .97 |
| 25,000 | 63 | 84 | 61 | 1.24 |
| 30,000 | 83 | 1.57 | 72 | 1.31 |
| 33,000 | 100 | 100 | 83 | 1.24 |
| 35,000 | 100 | 100 | 76 | 1.24 |
| 36,500 | 100 | 100 | 81 | 1.24 |
| 39,500 | 100 | 100 | 72 | 1.24 |

NOTE: Ventilation of 10 l/min. ambient pressure and saturated 37\textdegree are assumed at each altitude shown; since gas will be fed only during inspiration (approximately 1/2 the time) each of the figures shown should be multiplied by 2, to obtain velocity or flow rate. With collecting bag, 10 liters per minute will provide flow rate needs, i.e., 20 l/min. for 1/2 minute. In addition, in a demand system 20 liters per minute flow rate will be provided by a 10 liter per minute total flow, since inspiration is calculated to take one-half minute. Thus, a 13.33 l/min. per minute O\textsubscript{2} flow up to 35,000 feet and a 1.57 l/min. per minute oxygen flow up to 36,500 ft. will be adequate to provide an 8,000 ft. altitude equivalent atmosphere, with the subject's minute ventilation being 10 liters per minute.

*Sea level pressure.
that required under the circumstances outlined, namely to compensate for hypoxia at altitudes between 15,000 and 36,000 feet or even as high as 39,500 feet. If the disposable cylinder unit was employed with a collecting bag and an inspiratory inlet valve that would only open when the bag was collapsed, any oxygen inlet flow above 1.4 liter oxygen flow could be instituted when needed at high altitudes and maintained until a lower altitude was reached.

As will be seen in Table II, an oxygen flow of 1.4 liters per minute between 30,000 and 39,500 feet would be adequate to supply a pulmonary ventilation of 10 liters per minute as well as enough oxygen to overcome the decrease in oxygen tension in the atmosphere. Between 10,000 and 30,000 feet, a flow of 1.4 liters per minute oxygen would be sufficient to provide the oxygen concentration required to overcome hypoxia but the system would then make use of dilution of air from the atmosphere obtained by the operation of the inspiratory valve attached to the mask.

A 4-cylinder Oxy-Hale apparatus, supplying 12 liters of 100 per cent oxygen, would provide 8½ minutes oxygen inhalation at a 1.4 liters per minute flow; if the oxygen flow were increased twenty per cent, i.e., to 1.7 liters per minute (to compensate for an increase in ventilation), the 4 cylinder apparatus would last 7 minutes.

An additional calculation provides information as to the safety of the oxygen flows if the ventilation of the individual reached double that of the average basal ventilation; namely, 12.5 liters per minute. If an oxygen flow of 1.2 liters per minute were provided under these circumstances, the oxygen tension in the inspired air would always be above that needed

**EFFECT OF OXYGEN INHALATION ON THE PULMONARY VENTILATION AFTER EXERCISE**

![Diagram](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21322/

EXERCISE BREATHING AIR

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EXERCISE BREATHING OXYGEN

<table>
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<th>AFTER</th>
</tr>
</thead>
<tbody>
<tr>
<td>9063</td>
<td>11.077</td>
</tr>
</tbody>
</table>

(a) THE PULMONARY VENTILATION IN ALL Instances WAS DETERMINED.

(b) OXYHALE WAS USED TO ADMINISTER 32% OXYGEN

**FIGURE 3**
for a 14,000 feet ceiling. An oxygen flow between 0.42 and 0.96 liters per minute would give an altitude equivalent of 14,000 feet between 20,000 and 30,000 feet at 12.5 liters per minute ventilation; oxygen flows between 0.34 and 0.77 liters per minute would be needed with a 10.0 liter per minute ventilation. The oxygen flow administered above these requirements would increase the O\textsubscript{2} tension in the atmosphere to levels in effect providing altitude equivalents nearer 10,000 feet, as seen in previous talks.

In the event that the subject should ventilate with an inspiratory flow rate as much as 40 liters per minute, an oxygen flow of 2 liters (dry 760 mm. Hg) would be an additional safety measure. This high flow would be all the more appropriate in the case of sudden decompression of a cabin in which case it would be desirable to take six deep breaths rapidly to wash out the air in the lungs.

Reference may be made to a considerable literature on the use of oxygen in the treatment of coronary insufficiency and thrombosis and anginal pain;\textsuperscript{18} these studies are now applicable to the use of more portable oxygen equipment than has been hitherto available. Current investigation is concerned with the employment of the Oxy-Hale device for the relief of anginal pain and related types of coronary insufficiency.

SUMMARY

The use of new types of portable oxygen apparatus which are adapted to ambulatory oxygen is described. The relief of dyspnea on exertion in patients with pulmonary emphysema and related clinical disorders characterized by chronic respiratory and cardiorespiratory insufficiency at home or in the street by the pocket Oxy-Hale device is discussed. The employment of ambulatory oxygen inhalation in patients with anginal pain and coronary insufficiency, as well as in high altitude flight, is presented.

REFERENCES

5 Miller, William F.: "Personal communication."