FIRE SERVICES EXAMINATIONS BOARD

STUDY NOTE

EXAMINATION	LEADING FIREFIGHTERS EXAMINATION
PAPER	OPERATIONS
SUBJECT	SCIENCE & FIREFIGHTING
ITEM	RESPIRATION
STUDY NOTE No.	1110

INTRODUCTION TO THE STUDY NOTE

This study note has been prepared as the basis of study in connection with the qualifying examinations for promotion.

Candidates will be expected to demonstrate knowledge of the information contained in the study note and understand how it should be applied:

The 'References' made at the end of the Study Note are included for information only and candidates will not be expected to study these as part of the bibliography.

RESPIRATION

1. Introduction

In order to understand fully the principles which govern the use of breathing apparatus, it is first necessary to know something of the composition of the atmosphere and of the process of respiration.

The human body needs a constant supply of oxygen in order to survive. Oxygen is a constituent of air, and the body normally obtains this from the atmosphere. When at rest its requirements are comparatively low, and air is sucked into and out of the lungs by breathing movements at a rate of about 15 to 18 times per minute. When more energy is exerted, either through work or nervous excitement, the breathing rate is increased and may be as much as 30 times a minute, or even more.

At rest about ½ litre of air is normally inhaled at each breath and about the same quantity is exhaled, this amount is known as TIDAL AIR. By taking a very deep breath, a further 2 litres may be taken in, and on subsequent very deep exhalation, this may be increased by a further 1½ litres. The total amount thus exhaled, i.e. about 4 litres on average, is known as the VITAL CAPACITY and varies with different people. This variation in lung capacity is the reason for the varying demands on breathing apparatus by different wearers doing the same work.

2. Composition of air

The air, which is drawn into the lungs, consists of three principal gases in the following proportions by volume:

	PER CENT
Nitrogen	79
Oxygen	21
Carbon dioxide	Traces

It also contains small percentages of five other gases, but for practical purposes these can be included in the percentage of nitrogen.

Oxygen, as stated above, is the vital ingredient. Nitrogen takes no active part in respiration at ordinary pressures, being merely an inert gas, which passes in and out of the body practically unchanged.

3. The respiratory cycle

The body must draw air into the lungs, hold it for a sufficient time for the oxygen required to be absorbed, and then expel it. This process is known as respiration, and consists of two spontaneous actions, inhalation (breathing in) and exhalation (breathing out). Inhalation is effected by a muscular effort, which raises the ribs and lowers the diaphragm, thus enlarging the chest cavity and creating a partial vacuum, which causes air to enter. Exhalation normally requires no effort, as, when the breath is released, the ribs fall and the diaphragm rises automatically, thus contracting the chest cavity and forcing the air out.

The transfer of the inhaled oxygen from the lungs to the rest of the body is effected by the blood, which in its circuit of the body passes through the lungs, where it absorbs a certain quantity of oxygen. This travels with the blood through the main arteries to the lesser arteries, and finally into a vast network of blood vessels known as capillaries. These vessels have very thin walls through which a continual discharge of oxygen takes place. At the same time, carbon dioxide, which the body generates as a waste product, is transferred to the blood. Having now changed from a bright to a dark red, the blood is then driven back by the action of the heart through the veins to the lungs where the carbon dioxide is given off and exhaled, and a further supply of oxygen is taken up.

In this process the composition of the air changes to approximately:

	PER CENT
Nitrogen	79
Oxygen	17
Carbon dioxide	4

That is to say, about 4 per cent of oxygen is absorbed and an equal amount of carbon dioxide given off.

4. Breathing under varying degrees of effort

The amount of oxygen required by the body varies with the amount of work performed. In heavier work, such as ascending an incline or running, the oxygen consumed may amount to 3 l/min, while the volume of air breathed may reach over 100 l/min.

An increase in the amount of oxygen required may also be due to the effects of disease, obstruction of the air passages, emotional excitement etc. The latter, for example, causes some people to faint on hearing bad news, the shock of which causes a sudden demand for more oxygen than is immediately available. Since nervous excitement causes the breathing rate to be automatically increased, it is particularly important that firefighters are emotionally stable, so that abnormal demands on any BA that they may be wearing are reduced to a minimum.

5. Irrespirable atmospheres

The fact that an atmosphere cannot safely be breathed will be due to one of two main causes - oxygen deficiency or the presence of a poison or irritant.

For satisfactory functioning of the body, the air inhaled must contain at least 20 per cent of oxygen. Air with oxygen content only a few per cent below this figure may cause headache and lassitude, and further reductions can produce loss of consciousness and death.

At fires, smoke of varying density with solid particles in suspension may cause inflammation of the lungs with the formation of sputum, which considerably affects breathing. Many toxic gases may also be encountered, eg carbon monoxide, ammonia, hydrogen sulphide, sulphur dioxide, fumes from paint and other industrial processes, petrol fumes etc. Carbon monoxide is particularly dangerous in that it affects the red blood corpuscles and thus prevents the blood from taking oxygen from the lungs. An atmosphere containing only about 0.1 per cent of carbon monoxide, if breathed for half

an hour, will put about a quarter of the body's red corpuscles out of action. Inhalation of the pure gas causes almost instantaneous unconsciousness.
It will be seen, therefore, that slight variations of the normal atmosphere can seriously affect the functioning of the human body. Oxygen deficiency cannot normally be detected, and while some gases such as ammonia or sulphur dioxide make their presence known by their pungent smell, others, such as carbon monoxide, have no smell. People operating in such conditions may therefore be quickly overcome without realising that the atmosphere is other than normal.

Firefighters will often be required to work in atmospheres, which are oxygen-deficient and/or toxic. To survive in such conditions they must be given equipment, which will provide adequate protection and a supply of air or oxygen sufficient to meet all demands likely throughout the operation.

6. Hot and humid atmospheres

In hot, humid conditions with no air movement, especially when a high work rate is necessary, it will be the firefighter's ability to withstand the conditions and not the working duration of the BA that will determine how soon a relief is required. There have been incidents where it has been found necessary to relieve teams every 10-15 minutes. Even if firefighters are able to work for the complete working duration of their sets in such conditions, they should be rested before being required to undertake further work.

Firefighters may occasionally develop heat stress, typical symptoms of which are dizziness, lassitude, nausea, abdominal discomfort or a burning sensation of the skin. Anyone exhibiting such symptoms should be withdrawn from the incident immediately and given appropriate treatment. Heat stress is a particular danger when gas-tight chemical protection suits are worn.

The cooler the air provided by a BA set, the better the wearer can cope with hot and humid conditions.

It is well known that a person can stand working under hot conditions for longer if the atmosphere is dry than if it is humid.

High humidity combined with high temperature is a condition that takes time to develop, and it can occur only where ventilation is negligible. It will, however, be encountered from time to time, and it is therefore considered useful training for a BA wearer to experience the effects of hot and humid conditions.

7. Pressurised atmospheres

When, for example, a tunnel is bored under a river or in very wet strata, it is usually necessary to pressurise the workings to prevent flooding.

Regulations under the Health and Safety at Work etc Act 1974 are in place in respect of persons employed in pressurised workings which include health monitoring.

In view of these regulations it is unsuitable for firefighters to enter such workings as the working duration of a BA set is directly proportional to the increase in the ambient pressure.

The task, therefore, of rescuing persons employed in pressurised workings, and for first-aid firefighting in such workings, is the responsibility of the contractor on site. The Service would continue to respond to a call to pressurised workings and might stand-by to give advice and provide back-up facilities as necessary. The aim, however, is that contractors' arrangements under the HEALTH AND SAFETY AT WORK ETC ACT 1974 should make it unnecessary for the Service to be required to deal with an incident inside pressurised workings.

The fire service could, however, assist in the training of contractors' firefighting and rescue teams.

References

Manual of Firemanship Book 6, Chapter 1 and Chapter 6.