Manual of the medical aspects of chemical warfare, 1926 / the War Office.

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MANUAL
OF THE
MEDICAL ASPECTS OF CHEMICAL WARFARE

1926

By Command of the Army Council.

H. J. Creedy
A. G. 2

THE WAR OFFICE,
6th August, 1926.

LONDON:
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26
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CONTENTS

FOREWORD

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Success in minimizing the incidence of chemical warfare casualties, and in their handling and treatment, is bound to be proportionate to the extent to which information concerning the use of these poisons and the nature of the injuries caused by them, and the lessons learnt during the Great War, are the common knowledge of all medical officers.

Very complete information on these subjects is to be found in the Official History of the War, Medical Services, Diseases of the War, Vol. II.

As it is likely that in the event of future wars a considerable number of temporary medical officers will be employed with the Forces, the nature of whose civil occupation will have precluded their taking any particular interest in the subject which is of such great importance from a military point of view, and as officers of the Royal Army Medical Corps will require to refresh their memories on it, it has been considered advisable to issue this manual, which embodies in a portable form those particulars which should be of practical value in the field.

Chemical warfare is a rapidly developing science and it is certain that an enemy will endeavour to circumvent our protective measures by using known substances more effectively and in higher concentrations over more extended areas and by the introduction of new poisonous gases. It is of paramount importance that immediate report should be made to the superior medical authorities on the appearance of cases showing symptoms in any way different from those described in this manual, in order that steps may be taken without delay to afford adequate protection, and that medical officers in areas which have not experienced the new poison may have timely warning of the possibility of its use and all information which may help in the prevention of casualties and in the treatment of those affected.

As fresh information is circulated it will be inserted in the manual. It is the duty of every officer to whom it is issued to ensure that this is carried out.

In addition to the more purely medical aspects of chemical warfare which are dealt with in the succeeding chapters, medical officers should realise that they are responsible for their own protection and for that of the personnel of their units, and of the patients under their care. They should therefore study the manuals on general defence against chemical weapons and take advantage of every opportunity of familiarizing themselves with the use of defensive appliances. They should also accustom themselves to the use of respirators so as to be able to carry out their duties whilst wearing them without loss of efficiency.

CHAPTER I

CONDITIONS UNDER WHICH CHEMICAL WEAPONS MAY BE ENCOUNTERED

The following facts must be borne in mind in considering the conditions under which warfare gases may be encountered.

1. Gases are of two main types, the persistent (*e.g.*, mustard gas) and the non-persistent. The former are given off as vapour from liquids with a high boiling point which are scattered over the ground or objects in the neighbourhood of the burst of the projectile in the form of a fine spray and are only gradually vaporized; the latter are relatively volatile and are vaporized on the burst of the projectile, and, if not immediately effective, their power is rapidly dissipated by dilution with the surrounding air.

2. Gas "clouds" produced by any method tend to keep close to the ground and to fill hollows and depressions and to enter unprotected dugouts, etc., and the rate of dissipation is retarded in enclosed and wooded country.

3. It has been found that with a high wind velocity it is practically impossible to obtain effective action from shells filled with non-persistent substances, and that heavy rain, or a very thick fog, is unfavourable to their use. As the wind tends to die down towards sunrise and sunset, such times are likely to be most suitable for their employment.

4. The heat of the sun increases the rate of evaporation of persistent substances (mustard gas), and if bombardments with this gas take place during the night, in addition to precautions taken at the time of bombardment, special precautions must be taken to prevent casualties occurring at and after sunrise.

5. Ground contaminated with "mustard" is dangerous, unless "disinfected," for a considerable time, depending upon such factors as temperature, rainfall, shelter from wind and nature of the soil.

6. Gases may be discharged by one or other or by a combination of the following methods:—from cylinders in the form of a cloud, by shell or projector bombardment; from bursting grenades, and from projectiles or sprayers carried in airships or aeroplanes.

7. The type of gas used and the form of discharge will depend on the effect it is required to produce. Towards the end of the Great War, as defensive measures against gas improved, an increasing use was made of the persistent substances as it was found that they had a greater casualty producing power than the lethal gases.

8. Lethal shells may be used as neutralizing fire, the object being to affect the moral and physical strength of the enemy. A surprise effect and a concentration of gas on the target is essential.

9. The lachrymators, sternutators and mustard gases may be used in harassing fire for the purpose of interfering with the enemy's movements at bridges or other points by which he is compelled to pass. The gas mask has to be worn for long periods. Asphyxiating grenades may be used to clear out captured dugouts.

10. Mustard gas may be used to render an area untenable. It is unlikely that the enemy will attack over an area recently shelled heavily with this gas. In mobile warfare this gas may be used to impede pursuit or as a means of defence over an area in advance of organized positions. This gas may be dropped from airships or aeroplanes on important points in the back areas, *e.g.*, refilling points, ammunition dumps, &c., to impede the working of the supply services. In view of the increasing flying range and weight-carrying capacity of aeroplanes and airships, it is likely that this form of attack will be frequent in future wars.

11. **Classification of Chemical Substances from the point of view of their physiological effects.**—Though poisonous gases and vapours may, under appropriate conditions of administration, have a widespread action throughout the body and affect a number of different organs simultaneously, they usually produce their most marked effect on some particular structure, especially when they are present in low concentration. Their action, therefore, may in some sense be regarded as specific and it is possible on this basis roughly to classify the gases used for offensive purposes during the war into groups according to the most prominent lesions produced by them. Such a classification is by no means rigid for each of the gases really partakes of the characters of two or more of the groups, but it has the merit of convenience. As the result of experience it has become usual to adopt the following classification of warfare gases:—

(*a*) *Vesicants.*—The typical effects are inflammation and blistering of the skin, acute conjunctivitis and intense inflammation of the mucous membrane of the

respiratory passages, these effects as a rule only commencing to appear an hour or two after exposure to the poisonous atmosphere. Death is rarely caused by the direct effects of the poison but, when it occurs, is nearly always due to severe bronchopneumonia dependent on secondary bacterial infection of the damaged necrotic mucous membrane of the bronchial tubes, or in rare instances to septicæmia following very extensive skin burns.

(*b*) *Lung Irritants.*—The characteristic feature of these is that they exert an intense irritant action on the deeper respiratory passages and in particular on the alveoli of the lung, with the resulting acute pulmonary œdema and death by asphyxia. Some of these gases are quite effective lachrymators.

(*c*) *Sensory Irritants*—of the eye, nose and upper respiratory passages (sometimes called sternutators owing to their liability to produce sneezing). These have an effective action in low concentrations. They give rise to intense burning and aching pain in the eyes, nose, throat and chest accompanied by nausea and extreme mental depression. The effects clear up rapidly, however, on withdrawal from the poisonous atmosphere.

(*d*) *Lachrymators.*—In extremely minute concentration these have an immediate and violent irritant action on the eyes, which causes so profuse a flow of tears and so much pain and smarting that vision becomes impossible, though the effects hardly outlast the exposure. Stronger concentrations may have the same action as acute lung irritants.

(*e*) *Direct poisons of the nervous system or paralysants.*—In sufficient concentrations these act with great rapidity on the vital functions of the nervous system, death being a matter of a minute or two, or less.

12. Broadly speaking the gases in groups (*b*) and (*e*) may be regarded as lethal agents and those in groups (*c*) and (*d*) as irritants capable of putting a man out of action immediately, though only temporarily, whilst those of group (*a*), though intensely poisonous have, when used against troops that are well disciplined in defence against gas, a casualty producing power enormously in excess of their killing power.

CHAPTER II

VESICANTS

The only warfare gas of this group employed during the Great War was dichloro-diethyl-sulphide, commonly known as "Mustard Gas" by the British and "Yperite" by the French. Lewisite, which is dealt with later, in addition to its irritant action has pronounced vesicant action.

Mustard Gas

13. In the crude state, as used in shell fillings, Mustard Gas is an oily liquid resembling brown sherry. The liquid is almost insoluble in water, is slightly soluble in paraffin or vaseline, but freely soluble in animal and vegetable fats and oils, also in alcohol, ether, chloroform and in benzene, kerosene and petrol. Its boiling point is 217° C. and melting point 14·1° C. (57° F. approx.). It vaporizes very slowly at ordinary temperatures, so that ground splashed by the liquid after the burst of a shell is a source of danger for a time depending upon conditions of weather and terrain, and men may unwittingly carry the liquid on their boots or clothing with them into dugouts and other shelters where it vaporizes in the warmer atmosphere. It is slowly hydrolysed in water, but is rapidly destroyed by dry bleaching powder. It has a characteristic mustard-like odour which, however, is neither quickly detected nor offensive. In an area heavily shelled with this gas, the odour may be readily perceptible on first entering the area, but the sense of smell rapidly becomes dulled and within ten minutes it will cease to be appreciated. This is of serious importance, as troops are only too likely to underestimate the danger in the absence of the warning afforded by strong odour or any immediate irritant effect on the sensory nerves.

14. Casualties depend on the concentration of gas and time of exposure. Concentrations as low as 1 part of vapour in 5 millions of air will produce casualties after an exposure of from 6-18 hours. Higher concentrations, of course, produce more rapid effects, *e.g.*, 1 in a million will produce severe conjunctivitis after exposure for one hour.

The conjunctiva is more sensitive than the skin, moist skin is more sensitive than dry skin and moist and greasy skin is still more sensitive.

Individuals vary greatly in sensitiveness to mustard gas burns, and persons once burnt are likely to show increased sensitivity.

The respirator, if properly adjusted, affords complete protection to the eyes and lungs.

15. **Mode of Action.**—Mustard gas is a direct irritant to the skin and mucous membranes; there is no proof that its action is due in any way to absorption and conveyance by the blood stream to parts remote from the point of contact or exposure. The mode of action is not yet fully understood, but its high lipoid solubility accounts for its rapid penetration and for the fact that unless completely removed within 10-15 minutes of application pathological changes may be expected to occur, whereas, if completely removed within that time, no ill-effects appear. Although clinical signs do not make their appearance until some hours after application, there is microscopic evidence to show that the effect of mustard begins within 10 minutes of application and becomes intensified as time goes on.

16. **History of a typically severe and unprotected case.**—On exposure to a vapour or a finely atomised spray of the substance nothing is noticed at first save the faint, though characteristic, smell.

After the lapse of two or three hours symptoms begin to appear and subsequently develop with some rapidity. The eyes begin to smart and water, the ocular conjunctiva is injected especially in the interpalpebral aperture. The nose also runs with thin mucus as from a severe cold in the head, and sneezing, which appears after the conjunctivitis and rhinitis has developed, is frequent.

Nausea, retching and vomiting associated with epigastric pain commence at about the same time as the pain in the eyes and they recur in attacks at frequent intervals for several hours.

During the next few hours the conjunctivitis increases in intensity and the vessels are deeply injected. The throat feels dry and burning, the voice becomes hoarse, and a dry harsh cough develops. Inflammation of the skin now shows itself in a dusky red erythema of the face and neck, which look as though they had been scorched, while the areas which are moist and greasy, as the axillæ, inner aspects of the thighs, genitals and other sheltered parts of the body are similarly affected, and should any part of the clothing have been actually splashed by the liquid, the underlying skin would be profoundly irritated. In this stage, the patient suffers from the most intense itching, particularly if he gets hot, which interferes with rest and sleep and is most wearing. Later,

small vesicles appear which quickly coalesce to form large blisters in the same area.

At the end of 24 hours a typical appearance is presented. The main distress is caused by the pain in the eyes, which may be very great. The patient lies virtually blinded, with tears oozing between bulging oedematous eyelids over his reddened and slightly blistered face while there is a constant nasal discharge and an occasional harsh hoarse cough. The respiration is fairly normal both in rate and depth. There may be frontal headache associated with the pain in the eyes and photophobia, and blepharospasm is always a marked symptom. Death practically never occurs during the first 24 hours.

During the second day the condition is aggravated by the development of the vesicles into large blisters over the erythematous areas, while the scrotum and penis become œdematous and painful. Acute bronchitis now sets in with abundant expectoration of muco-pus in which may be found actual large sloughs from the inflamed tracheal lining. An early indication of involvement of the respiratory system is that the temperature, pulse rate and respiration rate are all increased, and secondary infections of the necrotic mucous membrane in the respiratory tract soon lead to the development of a broncho-pneumonia with slight cyanosis, cardiac dilatation and death at any date from the second or third day to the third or fourth week in the more lingering cases, the higher death rate occurring at the end of the 3rd or 4th day after exposure. Rarely, abscess of the lung, bronchiectasis, and even gangrene of the lung supervene. The death rate is low, approximating two per cent. of cases with well-disciplined and protected troops; with ill-protected troops the death rate may be very high.

17. The main features of these casualties are, therefore, as follows:—

Delay of irritant effect for at least two or three hours and often longer.

Conjunctivitis to an extreme degree.

Erythema of exposed surfaces and of the moist protected skin areas, followed by blistering, excoriation and brown staining.

Inflammation of the trachea and bronchi with necrosis of the mucous membrane, and the development of secondary bronchitis or broncho-pneumonia.

18. **Morbid Anatomy.**—The most important pathological changes are those in the respiratory tract. There is intense inflammation of the mucous membrane from the anterior nares to the finest ramifications of the bronchioles which show in varying degree the caustic effect of this acute irritant.

The destruction of the membrane may have proceeded to such an extent that the whole area of the trachea, and the larger bronchi, is covered by a loosely adherent slough of a yellow colour several millimetres thick. Occasionally this slough can be separated as a whole and removed, giving the appearance of a cast of the bronchial tree. On removing this slough a raw, granulating surface is exposed, which may, in late cases, be pitted with minute ulcers.

The interior of the nose and naso-pharynx may exhibit a similar pathological change.

When the chest is opened small petechial haemorrhages may be observed on the pleural surface, but it is not common to find much pleural exudation. In cases where death has taken place early, the lungs on section will be found to contain areas of emphysema alternating with small patches of collapse, and small haemorrhages and areas of inflammation will also be visible to the naked eye. The lung, however, on section is dry, and in this respect forms a marked contrast to the post-mortem appearances following lung irritant poisoning, in which the lungs are saturated with oedema fluid, which pours out on section.

In cases which have survived to a later period, in addition to the appearances described above, which are to be regarded as the result of inflammatory reaction, the signs of a secondary septic infection appear, for as a result of the intense irritation of the bronchial tubes, pus is secreted, which in gravitating downwards carries with it micro-organisms and sets up new foci of broncho-pneumonia whilst intensifying those caused by the direct action of the mustard on the terminal bronchioles. In late stages, indeed, the whole of the lower lobes may be practically solid from the confluence of numerous patches of this broncho-pneumonia. Owing to their septic origin, many of the patches tend to break down and form small abscess cavities. On section of such a lung pus will be seen to exude from all the fine bronchial tubes. As a result of the patches of broncho-pneumonia the intervening areas of lung which are not consolidated are frequently œdematous, but this œdema is a secondary and partial effect in contrast with the primary and general condition induced by the lung irritants.

The skin exhibits all stages of burn from the primary erythema up to the final stage of a deep burn with necrosis and sloughing of tissues. The latter condition, of course, is only seen where life has been maintained for a considerable period, and ordinarily in the fatal cases the skin lesions will not have proceeded beyond the stage of vesication and stripping of the epidermal layers.

Microscopically the main changes seen in the skin are the damage to the blood vessels, which are engorged and rarely

thrombosed, the formation of tissue œdema with necrosis of superficial cells, invasion of leucocytes, and, after 24 hours, rupture of some capillaries. During the process of repair, the new formed capillaries tend to break down and this delays healing, which is brought about by cicatrization.

The resulting scar is usually pigmented for a long period.

The eyes share in the general inflammation of the skin and exhibit all stages of an acute conjunctivitis from the early chemosis up to ulcerative keratitis, which on becoming secondarily infected may cause onyx, hypopyon, perforation or panopthalmitis: These complications are, however, rare.

The abdominal organs show very few lesions. The mucous membrane of the stomach may be injected and contain a few small hæmorrhages. The intestinal tract, as a rule, escapes entirely, although occasionally the upper part of the small intestine shares in the inflammatory changes seen in the stomach.

There are no characteristic changes to be seen in the kidneys beyond the congestive swelling and, occasionally, on stripping the capsule, subcortical hæmorrhages.

The blood shows no special changes. Some observations suggested a decrease in the coagulation time. There is an early leucocytosis, especially of the polymorphs, and a leucopenia when the case is drifting to death. The figures for the blood-count are very similar to those for ordinary broncho-pneumonic infections of the lungs.

Punctate hæmorrhages have occasionally been seen in the white matter of the brain, but this condition is by no means so common as in phosgene poisoning, where it is a marked characteristic. The absence of cyanosis or marked oxygen want in these casualties is the probable explanation of the rarity of punctate hæmorrhages.

19. The main pathological lesions which cause death are, therefore, as follows:—

An acute inflammation of the air passages from the larynx downwards, followed by entire desquamation of the mucous lining, with a remarkable formation of false membrane. This membrane, in addition to the actual obstructive effect it produces, affords a suitable pabulum for organisms. An acute purulent capillary bronchitis is superadded, leading to collapse of lung tissue and then to broncho-pneumonia.

Further, the effect of burns leading to a general septic infection will be found in the late cases, and occasionally an inflammation of the mucous membrane of the large intestine.

The microscope bears out the naked eye observations, the lesions in the air passages being essentially those caused

by a necrosis of mucous membrane followed by a secondary broncho-pneumonia.

Detailed effects on individual organs and tissues:—

20. *The Eyes.*—The individual feels no discomfort at the time of exposure. The part of the conjunctiva covered by the lids is never severely affected. Neither necrosis nor ulceration of the conjunctiva occurs unless actually splashed by liquid mustard gas. The symptoms in all cases come on slowly, on an average from six to ten hours after exposure to the gas. The onset may be delayed for a very long period and then is probably due rather to the cumulative effect of minute doses than to one single exposure. Men, for instance, who have been living in contaminated dugouts for a long time and who have occasionally been forced to remove their masks will on each such exposure receive a minute dose which ultimately will be sufficient to cause effects.

21. In the slight cases there is severe stinging in the eye and lachrymation, the lids cannot be raised, the ocular conjunctiva becomes injected, especially in the outer palpebral aperture, but the cornea is not affected. In the more severe cases the pain is acute, there is blepharospasm and profuse lachrymation. There is much greater reaction, the skin of the lids becomes puffy, the conjunctiva in the interpalpebral aperture swollen and red and may project between the lids, but the cornea is not visibly affected. In the severest form the symptoms are very serious. There is intense and burning pain in and about the eyes associated with marked blepharospasm, and the eyes cannot be opened. There is profuse lachrymation between the closed œdematous lids, the skin of which may be blistered. The conjunctiva in the interpalpebral aperture, although only slightly swollen, has an opaque yellowish-white colour due to coagulative exudate in its substance. This exudate presses on and obstructs the capillary circulation, thus presenting much chemosis in this area. At the same time the ocular conjunctiva under the lids, which is much less affected, becomes greatly swollen so that two chemotic folds may be seen protruding between the lids and to the inexperienced observer may be thought to be more severely affected. The cornea in the exposed area, in the early stage, is grey and hazy, above this area its surface usually remains bright. Where grey, its surface is dull, stippled and roughened, due in the first instance to œdema of the epithelium and later to actual exfoliation of cells. The sensation of the cornea to tactile stimuli is often lowered and may remain so for weeks.

The condition of the cornea calls for the most careful and regular examination throughout, and it may be necessary

to use a lid retractor where there is much swelling or blepharospasm.

Ulceration in gassed eyes may result from exfoliation of the damaged epithelium, from an abrasion, or, in cases with severe chest complications, from exposure. Exfoliation and abrasion are especially liable to progress to definite ulceration in the presence of secondary infective conjunctivitis with muco-purulent discharge. An ulcer under these circumstances readily becomes infected and infiltrated leading to permanent opacities and impairment of vision.

In severe cases, therefore, impairment of vision may result from:—

(*a*) diffuse nebulæ of a temporary nature which may occur without definite ulceration.
(*b*) ulceration, leading to opacities.
(*c*) ulceration which on becoming secondarily infected may cause onyx, hypoyon, perforation or panopthalmitis.

Where actual splashing with liquid occurs, an infiltrated ulcer of the cornea may appear early and may be one-sided.

22. *Progress.*—In the mild cases resolution is rapid, and if the mental and physical tone are not lowered, under appropriate treatment the individual is usually fit to return to duty within a fortnight. In the more severe cases, especially where the cornea is affected, the period of convalescence may be prolonged to several weeks. The chemotic folds above and below the cornea subside in a few days and the ocular conjunctiva covered by the lids gradually pales and becomes white. The solid œdema in the interpalpebral aperture often takes a week or ten days to absorb. Vascularization usually spreads in from the upper and lower sides of the triangular patch until the whole white area disappears and the conjunctiva in the interpalpebral area becomes red. This stage is almost identical with the early stage of the mild burn.

The two symptoms liable to persist are lachrymation and photophobia. There is a tendency for a neurasthenic condition to supervene and unless this is firmly treated convalescence may be unnecessarily prolonged.

23. *Respiratory tract.*—Inflammation of the mucous membrane of the nose is accompanied by profuse watery secretion which later may be purulent and associated with the separation of large sloughs. Ulceration and epistaxis are rare.

Inflammation and erosion of the posterior pharyngeal wall may be sufficient to interfere with swallowing. The larynx is sometimes œdematous, but never so seriously affected as to necessitate tracheotomy. Later there is a mild laryn-

gitis or even ulceration. Prolonged exposure to a very low concentration of the vapour may often cause laryngitis, with loss of voice, to develop slowly even when there is no conjunctivitis at all.

The main pathological features in the trachea, bronchi and lungs have already been described. Death may occur solely from the action of the poison on the respiratory tract; and in severe cases it may ensue in 36 hours from the necrosis, or even be asphyxial by blockage of the lower air passages with loosened membrane, before secondary infections have had time to develop.

For the first 24 hours there may be only hoarseness of voice, substernal pain and a slight cough, but soon the rising temperature and quickening pulse-rate herald the onset of infection leading to bronchitis and fatal broncho-pneumonia. In the more protracted cases there is profuse thin purulent expectoration, and at autopsy the septic pneumonia is found to be confined to the lower lobes.

24. *Alimentary tract.*—The early vomiting due to the swallowing of saliva or nasal secretion, which has been infected with mustard gas, rarely persists for more than a day, and the epigastric pain vanishes shortly afterwards. Hæmatemesis is exceedingly rare. There are no lasting after effects in the stomach, and the bowels are not affected at any time.

25. *Urinary organs.*—Albuminuria has been described in the first 24 hours in cases of early fatality, but it is not found at a later date. Very rarely an acute haemorrhagic nephritis has been observed. Pain on micturition and even retention of urine may result from œdema and blistering of the penis.

26. *Circulatory system.*—The blood is unaltered; the heart is unaffected at first, except by the changes associated with pulmonary infection. During early convalescence some of the cases complain of headache, giddiness after exercise, and of shortness of breath associated with precordial pain and tachycardia. The symptoms are chiefly due to a nervous debility, and they yield quickly to tonics and graduated exercises under firm discipline.

27. *The skin.*—Skin lesions may be caused either by direct contact with liquid mustard gas, as in splashes from shell bursts, by handling leaky shells, or from contact with infected mud, or by the vapour which diffuses through clothing. The distribution of the injury will vary accordingly. As noted above, moist and greasy parts of the body are the most sensitive to the irritant action of the vapour.

The successive effects are:—

(*a*) A diffuse erythema which may appear in from 2 to 48 hours, and tends to spread rapidly, or may be delayed, either locally or generally, for several days.

(*b*) Very superficial blistering over erythematous areas, usually at first as small vesicles which ultimately coalesce into large blobs. These develop as painless collections of yellow or reddish serum just beneath the epithelium. If the latter is removed a raw weeping surface is left, and such burns may then become the seat of secondary skin infections and lead to a very painful eczematisation. This is particularly likely to occur in blisters of the scrotum and penis. The blisters may appear on the second day, but there may be an outcrop even in the week following exposure and long after the patient has been carefully washed and his clothing changed.

(*c*) Staining of the skin with a dark brown or brownish-purple tint usually occurs in areas that had previously been erythematous. The staining is of no consequence, and it vanishes in three or four weeks as the cuticle desquamates. In the severest cases, the bright red colour of the inflammation rapidly gives place to a bluish violet or brown coloration, while the swelling of the epidermis, cutis, and even subcutaneous tissue distinctly increases at the same time. These changes occur in the centre of the area of erythema within 8-24 hours after exposure. Blisters appear on the dark background. Their removal reveals a surface which is at first deep red in colour and slightly hæmorrhagic but soon becomes moist with viscous purulent exudation. These lesions progress slowly, the ulceration may spread beyond the limits of the original blister and 6-8 weeks or even longer may elapse before they are completely healed.

The majority of skin lesions from vapour contamination heal fairly rapidly, and unless they become septic there should be no residual trouble at the end of a month. In severe burns, however, caused by direct contact with the liquid, healing may be considerably delayed. All the lesions are very liable to infection by pyogenic organisms.

28. **Treatment.** *A. Prophylactic.*—It must be repeated that the respirator if properly adjusted, affords complete protection to the eyes and the respiratory tract.

Protective clothing has only a limited value in the field on account of the difficulty of obtaining gas proof garments in which men can do heavy work. It is, however, of value for personnel engaged on duties when they are liable to heavy contamination, *e.g.*, those engaged in handling heavily infected casualties in bulk, or in handling mustard shell. Such persons should wear respirators, special gloves, aprons or gas proof suits, which require to be cleansed or replaced at frequent intervals.

Ointments with a fatty basis and oily preparations are no protection, in fact they are a danger as they expedite the action of the irritant.

The first essential of treatment is to aim at preventing further infection from contaminated clothing or equipment, which is a source of danger to the casualty and those attending him, especially when brought into the warm atmosphere of an aid post or dressing station, as in such circumstances vaporisation increases in rapidity. It is necessary, therefore, to arrange for the removal of all the outer clothing at as early a stage as possible, and should this clothing have been in any way grossly contaminated, to strip the patient entirely.

The next procedure is to scrub the whole of the skin thoroughly with a nail brush, employing plenty of water, and either a sufficiency of soap or a weak alkaline solution, which helps to neutralize any of the poison left on the body.

If soap and water are not available a little bleaching powder should be taken, made into a paste and applied to the affected part. It should be washed off after two or three minutes, for bleach itself is liable to cause dermatitis.

29. *Decontamination of clothing.*—As the clothing is taken off it should be removed to the open and stored temporarily at a distance from any post occupied by troops. The heavily contaminated clothing should be destroyed as early as possible; that lightly contaminated should be removed and de-gassed before re-issue.

The following methods are effective:—

(1) If no other methods are available, exposure of the clothing or equipment in the open air for 2 days in hot weather or 7 days when cold will get rid of the gas.

(2) Washing in running water for from 5 to 30 hours.

(3) Soaking in hot—90°C.—soapy water for 2 hours, or at 50° to 60°C. for from 6 to 8 hours, followed by rinsing in cold water.

(4) Exposure to wet steam for 30 minutes followed by exposure to air for 15 minutes. This can be carried out in any of the forms of disinfector in use in the field.

Boots and articles of equipment can be de-gassed by brushing them with bleaching powder, dry or in the form of a paste. Care should be taken to rub the bleach well in.

30. *B. Curative.*—This can be best dealt with by taking in succession the various parts affected.

31. *The eyes.*—It is very necessary to reassure the individual at the earliest possible moment that the sight is not lost.

32. *Mild cases.*—Bathe the eyes frequently with bland, lukewarm lotion, such as boric acid, normal saline or 2 per cent. sodium bicarbonate. Drop liquid paraffin into the eyes three times a day. If liquid paraffin is not available, castor oil can be used but it is somewhat irritating.

33. *Severe cases.*—Where there is marked blepharospasm and continued pain, insert sterilised 1 per cent. atropine ointment between the lids at the earliest opportunity. Where the cornea is affected, in addition to frequent bathing, the regular use of atropine is very important and should be repeated sufficiently to keep the pupil well dilated, and continued until the cornea becomes quite smooth. While the pupils are dilated with atropine a shade should be worn, but the eyes must never be bandaged. *Cocaine should not be used,* for its anæsthetic properties are transient, while its use leads to exfoliation of the corneal epithelium.

If there is any catarrhal or muco-purulent discharge, a mild antiseptic should be instilled. A 2 per cent. solution of Argyrol or Protargol instilled twice a day is very suitable. This is particularly important whenever the cornea is grey or roughened, to prevent an infiltrated ulcer. When ulceration occurs the same measures should be adopted, but stricter care must be exercised to keep the conjunctival sac clean by gentle and frequent bathing combined with very hot applications over the closed lids four times a day. If the ulcer becomes infiltrated it should be cauterized by the light application of pure carbolic acid put on with a nearly dry brush slightly moistened with the liquid. It must be borne in mind that the nutrition of the cornea is already lowered and that the too free application of another caustic might cause extensive necrosis and perforation. If hypopyon supervenes and does not clear up with hot bathing, atropine and cleansing of the conjunctival sac, Saemisch section is indicated.

As soon as the cornea again becomes smooth, or, in milder cases, as soon as the primary irritation and swelling of the conjunctiva has subsided, atropine may be dispensed with, and astringent drops instilled three times a day, *e.g.*, Boric Acid grs. x, Zinc Sulphate grs. 1 to 2, Adrenalin drachms ½ to 1 and water to 1 ounce.

When the pupil regains its normal size, the shade or dark glasses should be removed irrespective of the wishes of the patient. Such protections in the later stages of convalescence only accentuate and prolong the neurasthenic symptoms. The normal balance should be restored by fresh air and stimulating treatment, mental and physical. Experience during the Great War showed that at least 75 per cent. of the cases were mild and became fit for duty within an average of two weeks, 15 per cent. had considerable conjunctival inflammation but no apparent changes in the cornea and were fit for duty in 4 to 6 weeks, while 10 per cent. had severe conjunctivitis with definite corneal changes and were not fit for duty under 2 to 4 months.

34. *Respiratory tract.*—For the rhinitis, a warm alkaline douche should be poured, not insufflated, through the nose three times a day. *For the laryngitis*, steam should be inhaled from a pint of boiling water with which is mixed a teaspoonful of a mixture of Tinct. Benzoini Co. 1 ounce, Menthol 10 grains. The laryngitis should be completely cured in a fortnight. It is apt to be followed by a functional aphonia that requires the ordinary strict methods in treatment. *For the tracheitis.* At first this may be eased by breathing through a Burney-Yeo's mask moistened with drops of some antiseptic mixture, *e.g.*, Menthol grs. 20. Tincture of Iodine minims 30, Oil of Eucalyptus minims 20, Creosote drachms 1, Chloretone grains 1, Alcohol to 1 ounce. *For the Broncho-pneumonia.* Venesection or oxygen may be useful in the cyanosis of secondary broncho-pneumonia, but such treatment is never needed in the early stage of poisoning by "mustard gas." Treatment should be on the usual lines. The bronchitis clears up in a month or less in the non-fatal cases, and the use of expectorant mixtures should not be continued after the sputum has ceased to be purulent. *For Epigastric pain.* Warm draughts of a weak solution of sodium bi-carbonate may be given to relieve pain. There is no need to induce vomiting. *The skin.* If the patient has been splashed with liquid thorough scrubbing with soap and water will obviate any but the most trivial burns if applied within 10 minutes. If this cannot be done, some degree of burning must be expected since the mustard will have penetrated into the skin, but thorough washing as described above will lessen its effect.

35. To allay the skin irritation so frequently present, especially in areas of more or less generalised erythema, the following may be used with some efficacy:—

(*a*) evaporating lotions,

(*b*) 1/40 carbolic acid lotion.
(*c*) potassium or sodium permanganate lotion.

Dusting powders are not efficacious and are not recommended.

Ointments are disappointing and increase the skin irritation, mustard burns heal in spite of, and not because of, their use. Aqueous dressings are much better, e.g. picric acid, boric, mag. sulph., or normal saline compresses. Areas of pyrogenic infection may be treated with hot fomentations, and it is often very advantageous to alternate these with a dressing of cold saturated magnesium sulphate solution. The dead and raised epithelium of the blister must be removed, with the usual aseptic and antiseptic precautions, before any of the above lines of treatment are adopted. In all cases care must be exercised to avoid making the affected area "soggy" or sodden, and from the first the attention must be directed to persuading the area to dry up as quickly as possible, which it will do fairly readily if and when aseptic conditions are secured and maintained. For the dry, somewhat harsh and scaly, condition of the skin which is a fairly frequent sequela of mustard burns, especially of the generalised erythema short of actual vesication, Lassar's paste is a useful application* or a mild ointment such as the following:—Boric acid, grs. 15, powdered lead acetate, grs. 5, zinc oxide, grs. 20, paraffin to the ounce.

For extensive burns the Americans recommend Eusol irrigation.

36. **General Treatment.**—In the first few days after exposure a light diet is desirable in all cases. Fluids, especially milk, may be given freely, and patients should be encouraged to drink water. No case should be moved if there is commencing fever, as this indicates the probability of broncho-pneumonia. As convalescence proceeds, a full diet is required, and this should be as varied as possible. The severe cases of pneumonia will naturally be kept on a fever diet, whilst patients with body burns require a generous diet and stimulants. The management of the convalescent period provides the great test of the medical officer's ability, because he is required not only to treat the disease, but to restore moral, to cut short hospitalization, and to lift men out of the slough of self-analysis which so often follows gassing. As soon as a man is convalescent and free from the danger of septic complications, he should be discharged from hospital to a convalescent centre, where a well-ordered routine of exercise, employment, amusement

* *Lassar's Paste*.—Zinc oxide (finely sifted) ozs. iii,, salicylic acid (in powder) 140 grs., soft paraffin, white, ozs. viii.

and rest will quickly restore him to a state of physical and mental fitness.

38. **Functional after-effects.**—This subject is of great importance from the point of view of wastage and duration of invalidity.

39. Functional disorders fall, in the main, into two classes. In the first, exposure to gas, often to a minimal and barely a toxic concentration, may yet prove the final factor in upsetting a nervous system already breaking down as the result of physical or mental strain. In such circumstances it will tend to produce an "anxiety state" similar in all respects to the war neurosis so common in the war.

40. The second class is a far more important one, because in these cases a local but real organic lesion from mustard gas causes certain irritant reflexes, such as coughing or photophobia, and these sensory reflexes are perpetuated by introspection, almost in a form of conversion hysteria, long after their organic cause has been cured. Lack of appreciation of this possibility will cause much delay in returning men to duty.

41. Functional photophobia and aphonia are responsible for the great majority of the cases. This is not surprising when it is realized that the initial trauma affects a highly organized special sense, and that fear of blindness or dumbness resulting from the injury may very well act to perpetuate the symptoms. Ill-advised and unnecessary treatment is also a probable factor in many cases. The acute conjunctivitis with blepharospasm and photophobia that characterize the early stages of the eye lesion is naturally treated by protecting the eye from light. Eye shields are almost universally applied at Casualty Clearing Stations, but they must not be retained in use after the necessity passes and actual manifestations of the eye lesion totally disappear. There can be no doubt that the suggestive influence of wearing a shade will perpetuate the functional manifestation.

42. Persistent aphonia, accompanied often by a useless harsh cough, is another striking manifestation of auto-suggestion arising from the initial laryngeal irritation. The characteristic cough is either dry or accompanied by watery sputum, mainly of salivary origin; it is usually much worse at night, and is of a ringing, harsh quality.

The functional aphonia yields very rapidly to treatment by suggestion and breathing exercises, when the medical officer realizes the nature of the condition and gives the patient confidence in his early recovery.

43. Of all after-effects, functional or organic, those which seem to affect the heart present the greatest difficulty in assessment. Shortness of breath and tachycardia from exercise, *i.e.*, "the effort—syndrome" or D.A.H. arise from so many diverse causes that gassing naturally was regarded as one of them.

44. It is clear, as the result of experience in the Great War, that under competent medical treatment the incidence of D.A.H. in mustard gas casualties should be very low when serious complications, such as broncho-pneumonia, are absent and that such an after result is not to be feared with mustard gas to anything like the same extent as it is with phosgene poisoning.

The treatment of the features of D.A.H. in mustard gas casualties is by graduated and carefully controlled exercises.

Lewisite

45. Lewisite is a substance which was isolated by the American Chemical Warfare Service. It has not yet been used in war. Its chemical name is β chlorovinyl dichloroarsine and it is thus analogous to the arsenical sensory irritants which are described in Chapter IV.

As however in addition to sensory irritation it produces burns like mustard gas, it is classified among the vesicant substances.

46. Lewisite is a liquid at ordinary temperature. It freezes at −13° C. and boils at 190° C. Its vapour pressure, 0.395 mm. of mercury at 20° C. is comparatively low, so that it may be regarded as a persistent substance. It is soluble in oils, benzene, and in ordinary organic solvents. In contact with water it hydrolyses rapidly; this action is hastened by elevated temperature and the presence of alkalies. It has an odour which is said to resemble that of geraniums.

Both in its liquid and vapour form it produces lesions similar to those due to mustard gas; but it is not so powerful in its effects. Thus, in the case of skin blisters, the injury does not extend so deeply and heals more readily under appropriate treatment.

The delay in appearance of the injury is not so long as in mustard gas and erythema may appear within 20 minutes of the application of the liquid to the skin. Individuals appear to vary considerably in their sensivity to this substance.

It has been suggested that in addition to the local injury produced, a lewisite burn if extensive may give rise to systemic symptoms of arsenical poisoning. The presence of arsenic can be demonstrated in the blister fluid.

47. *Preventive Treatment.*—The service respirator is a complete protection for the eyes and respiratory passages. Should injuries occur through failure to wear it, they should be treated on the lines laid down for mustard gas poisoning.

48. Success in the prevention of skin burns depends upon the promptness with which treatment can be applied. Thorough washing for 5 minutes with soap and water up to 25 minutes after exposure to the liquid is effective. Caustic soda should *not* be used.

49. In the treatment of a lewisite burn it is essential that the blister be removed as soon as possible, the contents evacuated and the raw surface thoroughly irrigated in order to minimise the danger of arsenical poisoning. The burns heal rapidly under a wet dressing of normal saline or a mild antiseptic unless bacterial infection occurs. In the latter case they follow the ordinary course of septic sores.

CHAPTER III

LUNG IRRITANTS

50. The acute lung irritant gases used during the war include phosgene, chlorine, chloromethyl chloroformate, trichloromethyl chloroformate, chloropicrin and phenyl-carbylamine-chloride. After the initial groups of cloud gas attacks, in which chlorine only was used, it was the almost invariable occurrence to find two or more gases of this group figuring in any cloud gas attack or gas shell bombardment.

51. All lung irritant gases cause essentially the same type of pathological effect this being most pronounced on the alveoli of the lungs and the smaller bronchial tubes, and the great danger to be feared is the onset of acute pulmonary œdema. It is in the main this œdema which, in the acute stage of poisoning, threatens the life of the subject, for if abundant it causes death by asphyxiation, the patient being in fact drowned by his own exudation.

The rate of onset and the degree of œdema are dependent on the particular gas and on its concentration, and, though in some cases to a lesser degree, on the duration of exposure.

Phosgene Gas

52. As a type of the group, the morbid anatomy, signs and symptoms of phosgene gas poisoning will be described, after which differences due to poisoning by other gases of the group will be indicated.

53. **Morbid anatomy.**—The essential lesions are pulmonary œdema, rupture of the pulmonary alveoli, and concentration of the blood, together with thrombosis.

In one case when death had occurred two hours after exposure to the gas the lungs were smaller than normal, heavy, uniformly airless and purple, and completely waterlogged. There was no emphysema. Thin serous fluid ran abundantly from the surface of the lung when it was cut across.

When death occurs in the latter part of the first day, the trachea is moderately congested, and this congestion becomes more marked in the smaller bronchial tubes. Both trachea and bronchi may be filled with a thin yellowish, frothy and highly albuminous fluid, which may be found escaping as a white froth from the nostrils and mouth after death. Occasionally there is remarkably little inflammation in the larynx,

trachea, and larger bronchi. The lungs are voluminous, heavily œdematous, and much congested with blood. Aerated patches of emphysema, which sometimes culminate in actual bullae, especially at the edges of the lung, alternate with depressed patches of collapse. On section frothy serous fluid mingled with dark blood drips abundantly from the lung tissue. Air that has escaped from the lung is sometimes seen as chains of bubbles below the visceral pleura, along the interlobar fissures, and even occasionally penetrating the tissues of the mediastinum. Sometimes petechial hæmorrhages are visible on the surface of the lungs. The pleural cavities almost invariably contain a quantity of serous, perhaps bloodstained effusion; the amount may vary from an ounce or two up to 20 ozs. on each side of the chest, but it is uncertain how much of this is a post mortem accumulation. The heart is sometimes dilated, sometime fairly normal in volume. The veins are greatly distended with blood that often clots rapidly after death.

In the case of deaths on the second and third day the general appearance of the thoracic viscera is much the same as on the first day, the main difference being that aeration of the lung is distinctly greater, while serous fluid does not drip so freely from the cut surface of the lung. The aerated condition is greatest in the lower lobes of the lungs where they are in contact with the diaphragm, the œdema persisting longest in the upper lobe.

On the fourth day serous fluid no longer drips from the lungs on section, but commencing broncho-pneumonia and pleurisy may indicate that secondary bacterial infection has set in.

The earlier that death ensues the greater is the degree of pulmonary œdema found at post-mortem examination. The greater aeration of the lungs of cases dying on the second and third days, taken in conjunction with the clinical history of the severe cases that survive makes it evident that the fluid is rapidly absorbed from the lungs from the second day onwards.

In severe cases a remarkable concentration of the blood may be present, the hæmoglobin percentage rising as high as 140 with a corresponding increase in the red cell count. This is brought about partly by the passage of œdema fluid into the lungs, and partly as a sequel to the condition of "shock" and want of oxygen. Associated with this concentration is the occurrence of thrombosis in the blood vessels of the lung, and also to a variable extent in those of other organs of the body.

Occasionally thrombosis takes place in the larger blood vessels, for rare instances are known in which the peripheral arteries to the limbs have become occluded. As a rule the threatening gangrene has cleared up in these cases without amputation of the limb proving necessary.

It seems probable that the primary cause of the thrombosis in these different situations is the same, viz., damage of the vascular endothelium due to anoxæmia coupled with some slowing of the general circulation and perhaps with increased tendency of the blood to clot.

In some cases where death has occurred after two or three days of persistent cyanosis and unconsciousness, the white matter of the brain has been found to be peppered with tiny petechial hæmorrhages. Microscopic examination shows that the hæmorrhages are of spherical shape, with a small area of necrotic brain tissue traversed by a capillary blood vessel in the centre. They appear to be dependent on local damage of the vessel wall, associated with the formation of capillary thrombi and stasis of the blood.

Precisely similar punctate hæmorrhages have been found in severe cases of carbon monoxide poisoning, as well as in other conditions, so their occurrence cannot be regarded as a specific effect of the gas. As a general rule symptoms caused by these punctate haemorrhages are unnoticeable owing to the extreme gravity of the patient's general condition. In one or two instances large cerebral hæmorrhages have occurred on the first or second day in cases of deep cyanosis, just as may occur in very severe and prolonged poisoning with carbon monoxide.

Petechial hæmorrhages and a slight superficial ulceration are frequently seen post mortem over the inner surface of the cardiac fundus of the stomach. How far these may owe their origin to the direct irritant effect of swallowed gas, and how far they may be dependent merely on the general venous congestion of the abdominal viscera and on the asphyxia is uncertain. In rare instances there has been serious hæmorrhage into the stomach owing to an extension of the ulcerative process.

The kidneys may be found to be enlarged and congested at autopsy, and in some instances capillary thrombi are found in the glomeruli. This change, however, rarely leads to any clinical features of renal trouble. It is very unusual for albuminuria to develop later.

54. **Symptoms and Signs.**—Casualties from poisoning by pulmonary irritants may be classified, according to their modes of onset, into two chief groups:—Acute with violent onset, and Acute, with insidious onset.

55. *Acute with violent onset.*—Exposure to an atmosphere containing phosgene causes immediate sensory irritation of the respiratory passages accompanied by smarting and watering of the eyes. This irritation of the respiratory passages causes catching of the breath, coughing and a sensation of tightness and constriction and pain in the chest. After the initial check, the breathing continues, but is gasping in character and interrupted by violent fits of coughing. After getting out of the poisonous atmosphere the respiration remains rapid and shallow, any attempt to draw a deep breath giving rise to painful discomfort and provoking a fit of coughing. Nausea, retching, and vomiting are prominent features in the early stages of poisoning. There is slight or profuse expectoration. Headache, and a sense of fatigue in all the limbs often prostrate the patient.

As œdema develops in the lungs, the breathing becomes rapid and panting, but of a characteristically shallow type, unlike the deep ventilation of a healthy man after running, and more resembling the fast respiration of a child with broncho-pneumonia. The ears, lips and progressively the entire face assume a cyanotic, bluish red tint which may deepen to the intense violet of fullest cyanosis and there may be visible distension of the superficial veins of the face, neck or chest—especially in persons gassed with pure chlorine. In phosgene poisoning this full cyanosis is often omitted, and the patient passes rapidly into a state of circulatory collapse, with a feeble, flickering pulse of over 120, a cold clammy skin, and a leaden hue in the face, in which only the lips and tips of the ears reveal the asphyxial cyanosis that underlies the failure of the man to win his fight for life. While in the stage of cyanosis whether "blue" or "grey", the patient is always restless and very apprehensive of the seriousness of his condition. The expression is anxious and distressed, with the eyeballs staring and the lids half closed. At this stage casualties can be divided into three types:—

(*a*) The milder case, with reddish flush in the face, with some hurry of respiration, and with pain in the chest and epigastrium which is increased by coughing.

(*b*) The severe case with "blue" cyanosed face, distended neck veins, and full strong pulse of 100.

(*c*) The severely collapsed case, with leaden "grey" cyanosis of the face, and rapid thready pulse.

The milder case is often drowsy and soon falls into a sleep from which he wakes refreshed. Coughing upon a deep breath, occasional vomiting after food or drink and a slight sense of rawness in the throat together with general debility,

may persist for a few days after which the patient becomes convalescent. During the early days of convalescence there is often a considerable slowing of the pulse from vagus action, which may bring it down to about 50 or even 45 in the minute. Such early bradycardia is often seen also in recovery from severer poisoning; it has no serious import, but is rather a sign that the patient is beginning to convalesce.

Cases of severer cyanosis, if the depth of the reddish-blue colour is well maintained and the pulse does not exceed 100, tend to recover in two or three days, and their recovery is generally similar to that of the milder cases. Provided that the circulation and the activity of the respiratory centre can be maintained, the œdematous fluid in the lungs is soon absorbed, most of it vanishing by the fourth or fifth day. At any time however, particularly if subjected to much physical effort, those cases may rapidly pass into the most dangerous condition of "grey" cyanosis and collapse. The pulse becomes rapid, thready and irregular. The patient, though obviously weaker, becomes more restless and slightly wandering in mind or semi-comatose.

Even the worse of the "grey" cases may recover with proper treatment, but the mortality among them is always distressingly high. Recovery from this state of depressed circulation may be succeeded by severe and even fatal broncho-pneumonia. When this infective complication develops, the sputum becomes purulent and the temperature rises. Death usually follows rapidly. If the case lasts into the third week after gassing, he may justly be expected to survive the acute infection.

In 81 per cent. of deaths due to poisoning by phosgene and chlorine the death occurred within 24 hours.

56. *Acute cases with insidious onset.*—Cases have not infrequently been reported in which men who have been exposed to gas have been able to carry on their work for an hour or two with only trivial discomfort, and even to march from the trenches to their billets, and then have become rapidly worse, and passed into a condition of collapse with progressive œdema of the lungs that may prove rapidly fatal. In such cases the ingestion of a heavy meal seems sometimes to have had a prejudicial effect. At other times men who have passed through a gas attack and have subsequently complained of only slight cough, nausea, and tightness of the chest whilst resting in the trenches, have collapsed and even died abruptly some hours later on attempting to perform some vigorous muscular effort. A minor degree of the same effect is sometimes shown when men who have been slightly gassed find on trying to walk down from the trenches that they get unusually

"done in" and breathless, and are obliged to rest frequently. In these cases the deficiency of oxygen, the result probably of pulmonary œdema already existing, has not been felt until muscular exertion increased the need for oxygen.

57. One very striking example of this delayed effect may be cited in which the patient was observed from start to finish after only a brief exposure to a strong concentration of phosgene. The greatest care was taken to prevent any muscular exertion, so that no complicating factor was introduced. The immediate irritant symptoms and coughing that were produced during the exposure soon diminished in fresh air, and an hour and a-half later there was no coughing and the patient seemed practically well, the pulse being normal. The condition remained quite good till four and a-half hours after exposure to the gas, when the patient became bluish about the lips. Coughing then recommenced with the expectoration of frothy sputum. Soon the lips and face became of a grey ashen colour, though the pulse remained fairly strong. About four pints of clear, frothy, yellowish liquid were coughed up from the lungs in the next hour and a-quarter, and at the end of this time the patient expired. At no time was there any great struggle for breath, nor did the patient realise at all how ill he was.

58. **Physical signs.**—The percussion note may remain resonant over the chest, notwithstanding the existence of marked pulmonary œdema. In many cases, however, the note is impaired, especially over the back. The breath sounds are weakened, especially behind; they may also be harsh in character, but are not otherwise altered, and are never tubular. Fine rales are heard more especially in the axillary region, and the back and sides of the chest. Rhonchi are also occasionally heard. With the development of inflammatory complications the physical signs become those of pleurisy, bronchitis, or broncho-pneumonia.

In the early acute stage, however, the physical signs on examination of the chest give little indication of the very serious extent to which the lungs may be damaged. The colour, the pulse, and the character of the respiration are the chief guides to prognosis.

59. **Symptoms during convalescence.**—Poisoning by the lung irritant gases is sometimes followed by recurring frontal headache, epigastric pain, which is often worse after food but is rarely severe and rapidly disappears, mild bronchitis, prolonged inability for severe muscular work or even for moderate exercise and associated with præcordial pain, tachycardia and a rapid, shallow type of breathing. Spasmodic attacks of nocturnal "asthma" sometimes occur.

These recur at varying intervals and last from three to thirty minutes. In uncomplicated cases unassociated with disordered action of the heart, exercise by day does not cause dyspnœa nor any tendency to increase of nocturnal asthma, but after the exercise there may be intense headache and giddiness and often an abnormally slow pulse. In these cases it has been found that the hæmoglobin percentage is always increased, up to 110 or 120 per cent., whereas this change is not found in pure disordered action of the heart after gassing. The red cells are correspondingly increased, a case for example having been recorded with 6,900,000 per cubic millimetre, with hæmoglobin 116 per cent., and a normal colour index.

60. It has been found that a fair proportion of the ordinary cases of dyspnœa and tachycardia could soon be hardened by carefully regulated exercises. There are, however, no satisfactory criteria for an early estimate of what recovery will be, except in the way in which the pulse and patient react to exercise. The majority, after a period of hardening at a convalescent depot, should be fit to rejoin their units within three months.

61. In some instances, partly drawn from severe cases of pulmonary œdema and partly from others less severely gassed, the features of short-windedness and disordered action of the heart persist and are undoubtedly the result of gassing alone. Barcroft and his colleagues at Cambridge have confirmed the observation that some of these cases showed a persistently high red cell count, that is, a true polycythæmia without reduction of the blood volume, and not the transient relative increase seen immediately after gassing. The condition could be reproduced in rabbits after a brief exposure to phosgene or chlorine, when there was first the early concentration of the blood, and after that a steadily developing and persistent increase in the red cell count. Rabbits with this condition, two months after gassing had their count restored to normal by life in a chamber containing 40 to 50 per cent. of oxygen, or twice the proportion in ordinary air. Similarly good results were obtained when gas casualties with disordered action of the heart and polycythæmia were placed for five days in a chamber containing 40 to 50 per cent. of oxygen. In the case of rabbits it was proved microscopically that the respiratory surfaces of the lungs had been damaged by a thickening of the pulmonary epithelium and by a bronchiolitis obliterans. No corresponding examination has been made of the lungs of gas casualties at a late date after exposure. But the close comparison of this condition with that seen in men living for a long time at high altitudes under conditions of oxygen shortage, and the fact that these

gas patients were temporarily improved by treatment in the chamber enriched with oxygen, did suggest that the condition was due to a persistent anoxæmia, indirectly weakening the heart, and perhaps itself caused by injury to the lungs.

62. Haldane, at Oxford, developed a different view. This laid emphasis on the rapid shallow type of breathing, and inability to hold the breath for long, that characterised these men. Rapid, shallow breathing, say at 50 a minute, does not adequately ventilate the lungs. In a healthy man it will, if deliberately maintained, eventually lead to giddiness, faintness, and various phenomena of oxygen shortage. In his view the anoxæmia and the consequent debility and circulatory deficiencies might be caused simply by the neurasthenic persistence of the rapid shallow breathing that had first been established when the man was poisoned by gas, brought about through changes in the sensitiveness of the Hering-Breur reflex in the medulla that depends upon afferent vagal stimuli from the lungs.

63. Whatever the evidence for anoxæmia might be, and whatever the deeper physiological explanation of this state, the certain fact was that a small proportion of gas casualties did develop an intractable form of disordered action of the heart, and that the tendency to this invalidism was increased if the men were pressed to physical effort too early and too fast at the beginning of convalescence. Some of these men showed polycythemia, others did not. It is almost certain that the disordered cardiovascular state did not have its pathological origin simply in the mechanical strain thrown on the circulation by the transitory asphyxial congestion after gassing. Some clinicians were inclined to see in it further evidence of a toxic action of phosgene on the muscle of the heart and blood vessels, akin to that which was originally assumed in explanation of cardiac collapse and death in the acute stages of poisoning. But physiological analysis was always opposed to the acceptance of this view either for the acute cases or for the chronic invalids.

64. There is no evidence that pulmonary tubercle or any other serious maladies have developed more frequently in individuals poisoned by pulmonary irritants than among any other classes of pensioners.

Chlorine

65. A much stronger concentration of this gas is needed to cause severe pulmonary œdema, or even lachrymation, than is the case with phosgene. It is, however, far more irritant to the respiratory passages than is phosgene. A very marked

feature in the early attacks, when chlorine alone was used, was the paroxysmal and violent coughing, which not only occurred during the exposure but also persisted for a long time afterwards. Emphysematous changes were pronounced, and subcutaneous emphysema of the neck and chest occurred in a number of instances. As a general rule the cases exhibited deep cyanosis rather than pallor and collapse, with a fairly full pulse and much dyspnœa. Copious frothy expectoration was common.

66. Delay in the onset of serious symptoms is not evident in chlorine poisoning. Though exudation of fluid into the lungs may not perhaps start at once, the violent paroxysms of coughing, the painful dyspnœa, and the repeated attacks of vomiting convey the impression that the case is severely ill from the start.

Chloromethyl Chloroformate and Trichloromethyl Chloroformate

67. Both these gases give rise to effects similar to those produced by phosgene. Trichloromethyl chloroformate has about the same toxicity as phosgene, but greater lachrymatory power ; chloromethyl chloroformate has a toxicity of the same order as that of chlorine.

Chloropicrin

68. This is a stronger lachrymatory agent than is trichloromethyl chloroformate, though it is a good deal inferior in this respect to the true lachrymators. For such lengths of exposure as are likely to occur in the field, chloropicrin must be at a distinctly higher concentration than phosgene to cause severe pulmonary œdema, but it is much more deadly than chlorine. It causes greater sensory irritation of the respiratory passages than does chlorine. Pain in the chest and epigastrium, abdominal discomfort, and violent attacks of vomiting are exceptionally marked. Brief exposure to strong concentrations may cause temporary unconsciousness.

The substance is semi-persistent and the gas may remain in considerable concentrations in the neighbourhood of a shell burst for as long as 12 hours.

69. Unlike phosgene, chloropicrin is a substance of considerable chemical stability when in contact with animal tissues, and it is cumulative in action, for experiments on animals have shown that prolonged exposure to very low concentrations may still give rise to serious toxic symptoms while equally low concentrations of chlorine or phosgene may be quite ineffective.

70. Frequent exposure to small doses of chloropicrin, which would have only a trivial effect in themselves, may gradually lead to a greatly increased susceptibility to the gas. A man who has acquired this susceptibility is liable to attacks of "asthma" whenever he has been exposed to a trace of chloropicrin in the air. The attacks usually occur at night, and are characterised by the sudden onset of a rapid, shallow type of breathing associated with a feeling of tightness of the chest and a sensation of suffocation, which causes considerable distress. There is usually a short, dry cough at intervals, which is occasionally followed by the expectoration of a small quantity of tenacious mucus. The attacks may last for as long as a couple of hours, and appear to resemble, though in exaggerated degree, the attacks of "nocturnal dyspnœa" which have already been described as occurring during convalescence from phosgene poisoning.

71. Chloropicrin has also an irritant action externally. The liquid applied to the skin may cause erythema or even ulceration and such lesions are prone to become septic. Chloropicrin vapour may cause conjunctivitis and the liquid splashed on the cornea may give rise to ulceration.

72. Chlorine, chloropicrin and the chloromethyl and trichloromethyl chloroformate cause much more damage to the mucuous membrane of the respiratory passages than does phosgene.

Phenyl-Carbylamine Chloride

73. This substance has a very offensive mustard-like smell, and is very liable to cause immediate nausea when inhaled. It is a lung irritant of only moderate power, and is apt to cause bronchitis. In addition, it is a moderate lachrymator.

The treatment of poisoning caused by the lung irritant gases

74. Cases of all degrees of severity may occur, and sometimes it is not easy for the Medical Officer to decide whether or not a man has really been gassed. The fact that delayed action is liable to be exhibited by the lung irritants introduces another factor of uncertainty.

In these doubtful cases the patient should be made to give his own account of the occurrence, in order to see whether it suggests that he may have been exposed to a significant dose of gas. He should be allowed to describe his own symptoms. No leading questions should be put to him. Some definite objective symptoms such as vomiting may have occurred. He may have been unduly exhausted by trying to walk to the

aid post, and have had to be helped down; evidence in support of this may possibly be furnished by the pallor of his face and by a rapid pulse. Careful examination should be made to see if there is any lachrymation, any sign of cough, or unduly short and rapid breathing. It should be ascertained whether he can take a deep breath without affording any evidence that this gives rise to discomfort or provokes a cough.

The benefit of the doubt must be given to the patient, but it should be borne in mind that if no objective symptoms have arisen after the lapse of 48 hours, the degree of gassing must have been very slight, and the case can be returned to duty with little delay.

Treatment in the acute stage

75. *Rest.*—The importance of rest cannot be exaggerated. In the earlier stages undue muscular exertion is liable to lead to great aggravation of the symptoms. When pulmonary œdema is well established, and the respiratory exchange in the lungs is seriously interfered with, it is of importance to keep the oxygen consumption as low as possible, and activity of the muscles is by far the most potent cause of increased oxygen consumption.

76. All gas cases should be evacuated as soon as possible to the point at which arrangements have been made for effective treatment (a Field Ambulance or a Casualty Clearing Station, according to circumstances). Whilst waiting for evacuation care should be taken that the cases do not undergo muscular exertion. All except the lightest cases should as far as possible be evacuated lying down, and walking cases should be given every assistance whilst going back along the trenches, so that they may avoid physical effort as much as possible. Walking cases should not be allowed to carry their equipment. If any walking case shows signs of increased severity in his symptoms (marked breathlessness, palpitation, loss of power in his limbs, or a feeling of being "done in") arrangements should at once be made to carry him. Care should be taken that the breathing of any cases showing material symptoms is not impeded by tight belts or braces.

77. When cases reach the point where they can be retained for treatment they should be kept lying down until any obvious symptoms due to the gassing have subsided. Those who show definite symptoms should not be allowed to leave their bed or stretcher for any purpose whatever.

78. Uniform should be exchanged for hospital clothing wherever practicable. The pure pulmonary irritants do not adhere for long to clothing during exposure, but the lachrymators, the arsenic substances and mustard do so, and the

general rule should therefore be observed with all casualties. If this is not done the patient is exposed to a longer action of the poison and moreover the hospital staff may be affected. Orderlies engaged in this task should wear respirators and protective clothing.

79. *Warmth.*—The greatest care should be taken to keep the cases warm, and attention must be particularly directed to this point if any of the clothing has to be removed. Warmth will not only help to combat shock, but will diminish any tendency to the muscular movements of shivering.

80. *Oxygen.*—As deficiency of oxygen is the essential pathological result of poisoning by a lung irritant, treatment must be fundamentally devoted to supplying the deficiency by administration of oxygen. The aim should be to tide the case over the critical period of the first two days.

Oxygen should always be given to casualties with serious pulmonary œdema, that is, to men with intense blue cyanosis or grey pallor. These need oxygen continuously and over a long period. If the supply permits of such use, it should be given also to milder cases of œdema in order to prevent their lapsing into a more serious state of asphyxia. It should be remembered that in every autopsy following early death from pulmonary irritant poisoning, extreme œdema of the lungs was found, that cyanosis is the main indication of such œdema, and that no case in whom it was possible to restore a pink colour by the proper use of oxygen died from simple pulmonary œdema. The oxygen, which does not require to be warmed, must be given with some special apparatus, such as a Haldane mask or nasal catheter, that will ensure its being adequately commingled with the respired air. The minimal current of oxygen should be used, from two up to even ten litres enrichment per minute, which will suffice to keep the patient's face pink, a change that is usually associated with improvement of the pulse; and the treatment must be maintained, even for one or two days and nights with progressive lessening of the oxygen supply, until recovery is assured and the patient does not lapse into cyanosis when the oxygen is intermitted. If no other apparatus is available, then the nitrous oxide anæsthetic apparatus, which delivers pure oxygen from the cylinder (the valve of the bag being, of course, set so that the patient expires into the air and does not breathe in and out of the bag), should be used intermittently, say at alternating intervals of five minutes, because pure oxygen may eventually be irritant to the lungs.

The Haldane oxygen apparatus allows of continuous administration of oxygen at any required concentration over long periods. It is designed so that oxygen only passes to the

face mask during inspiration, the oxygen being therefore used with the greatest possible economy. In practice the oxygen supply is increased until the patient's face becomes of a normal colour, and then the supply is kept constant at this level. Relief of the cyanosis shows that the hæmoglobin in the blood is properly oxygenated, and no additional advantage will be obtained by increasing the oxygen supply further.

When oxygen is given continuously for prolonged periods by whatever method, intermission should be made for 5 minutes at the end of each half hour.

If the Haldane oxygen apparatus is not available, or the patient, as sometimes happens, refuses to tolerate the mask, the best method to adopt is to administer oxygen through a nasal tube. A soft rubber catheter should be lubricated and gently introduced into the nostril until its extremity lies in the naso pharynx; it can be secured in position by adhesive plaster. A continuous stream of oxygen is allowed to pass from a cylinder through the nasal tube. This method is more wasteful of oxygen than is the Haldane apparatus, since oxygen continues to pass during expiration, and is lost to the patient at this time, and consequently a far greater rate of flow of oxygen is necessary to get a given result with the nasal tube than with the Haldane apparatus.

Subcutaneous injection of oxygen has proved valueless, neither have efforts to introduce oxygen intravenously met with any success.

The oxygen frequently gives obvious relief to the general condition of the patients. They become less anxious and restless, so that they are sometimes unwilling to have the administration interrupted when they have once got used to the apparatus. At first they may be very unwilling to tolerate any method of administration, and every effort should be made to gain their confidence.

If panting is present, this usually persists even when the cyanosis has been relieved, since it is mainly due to retention of carbonic acid. Sometimes in very severe cases administration of oxygen increases the panting. This is probably due to the fact that the respiratory centre itself has begun to fail from want of oxygen, and is responding inadequately to the natural stimulus of carbon dioxide. On relieving the want of oxygen the respiratory centre regains its normal irritability and reacts fully, but hyperpnœa will be exaggerated until the carbon dioxide which has accumulated in the body owing to the relatively deficient breathing has been washed out by the increased respiration. If it is feared that such hyperpnœa may in itself do harm to the patient, oxygen should be given intermittently for a time, and continuous administration can be started later on.

81. *Venesection.*—There is no doubt that cases of deep cyanosis with a full pulse and signs of venous engorgement may be greatly benefited by a venesection up to 20 ounces, the blood being withdrawn slowly. The headache often disappears, dyspnœa is somewhat diminished and sleep follows. By this procedure relief may be afforded at a critical period when the right side of the heart is beginning to give way under the strain.

Venesection is contra-indicated in those cases which show pallor and collapse with a very rapid, thready pulse.

Apart from its effect on the circulation, venesection has been advocated in cases of phosgene poisoning as a measure likely to diminish the amount of fluid exuded into the lungs. Early venesection as soon as pulmonary œdema is recognised has been recommended by Medical Officers attached to the South African mines in cases of poisoning with nitrous fumes, and there was an impression amongst Medical Officers at the Front, and this was supported by French opinion, that similar early venesection is beneficial in cases of phosgene poisoning and the like. Experiments made on animals late in the War indicated that when venesection was combined with the intravenous infusion of isotonic salt solution, still better survival results might be expected. No evidence appeared in the experiments to suggest that infusion, when performed sometime after the venesection, led to increase of lung œdema. This was not applied to human casualties, but it does appear that the method might prove a useful means of treatment in cases with pulmonary œdema where hæmoglobin estimation shows an unduly high concentration of the blood.

Drugs

89. *Atropine* has been used under the impression that it will relieve bronchial spasm and check the output of œdema fluid. There is, however, no clear evidence that it has any beneficial action in practice, and as it may lead to acceleration of the heart it should not be used.

90. *Cardiac Stimulants.*—On the whole brandy has proved one of the most effective stimulants. Pituitrin 0.5 c.c. hypodermically at intervals of not less than three hours has certainly been of value in some serious cases. Hypodermic injections of camphor (*e.g.*, camphor gr. 1, olive oil min. 5, ether min. 5, minims 10-20 for a dose), or of caffeine (*e.g.*, caffeine gr. 10, sodium salicylate gr. 17, distilled water to one drachm, minims 10 for a dose) have also proved of value. Neither digitalis nor strychnine have shown themselves of much use.

Oxygen is far the best cardiac stimulant. When once oxygen treatment has been started, and the major disadvantage

under which the heart is labouring has been removed, the cardiac stimulant drugs may have a valuable additional effect.

91. *Morphia* is a dangerous drug to use when the respiration is seriously affected. Its use should therefore be restricted to severe cases where restlessness is extreme, and can be controlled in no other way. The dose should be small, gr. $\frac{1}{6}$, or 15-20 minims of tinct. opii.

92. *Expectorants.*—These should not be given to severe cases during the first two days for fear of increasing the tendency to cough, and so augmenting the damage in the lungs. An ordinary expectorant mixture containing ammon. carb. and vin. ipecac. may with advantage be given to the milder cases, as well as to severe cases when the acute symptoms have definitely begun to abate.

93. *Phenacetin* should not be used for the relief of the headache that usually occurs; it is somewhat liable to bring on collapse, though probably the same objection does not apply to aspirin. Relief of oxygen-want is the best means of relieving headache.

Methods of aiding the discharge of exudate from the lungs

94. *Vomiting.* — Repeated vomiting frequently occurs spontaneously in cases of poisoning with the acute lung irritants. In the earlier stages of acute pulmonary œdema this may prove of considerable benefit in promoting the discharge of fluid from the lungs. If vomiting does not occur naturally, it may be encouraged at this stage by simple measures, *e.g.*, salt and water and tickling the back of the throat, but neither apomorphine nor ipecacuanha should be used for this purpose because of the great depression that they produce subsequently. As the effort of vomiting is very exhausting, it should not be encouraged when the patient at a later stage begins to fail.

95. *Posture.*—If much thin fluid is being expectorated, good results are sometimes obtained by turning the head of the patient sideways and raising the foot of the bed or stretcher three or four feet, or even higher, for a few minutes at a time, with the idea of draining fluid from the chest.

96. *Schafer's artificial respiration* has occasionally proved of service in expelling fluid from the chest, but it is necessary to watch the effect on the patient very closely lest disaster ensue owing to a large amount of fluid being suddenly forced into the bronchial tubes.

97. Open-air treatment is good under favourable conditions of weather, but the slight gain from a fresher atmosphere is more than counterbalanced by the difficulties of nursing the patients and of keeping them warm so as to counteract the effects of shock. It is therefore preferable to treat at least the more severe cases in a well-ventilated ward. In bad weather tents and marquees are apt to be very dark, which makes it difficult to appreciate the degree of cyanosis shown by the patients.

Bad cases should if possible be put to bed, rather than left on stretchers. The cases should be allowed to assume the posture that they find most comfortable; some prefer to lie down, others to be propped up.

Those with broncho-pneumonia should be segregated by at least six feet, if they cannot be treated in a separate ward. (*See* also "Vesicants").

Food should only be given in fluid form and sparingly in the acute stage, and the diet should be kept light until the patient is definitely convalescent. Pain in the epigastrium sometimes yields to small doses of sodium bicarbonate. Measures should be taken to keep the bowels open.

Severe cases complain greatly of thirst in the acute stage. There appears to be no valid reason for withholding fluids, and water (brandy may be added if desired), or tea may be given; the fluids should, however, be given in small quantities at a time.

The mouth usually becomes dry and foul, and attention should be paid to this, as it is a source of great discomfort to the patient.

So far as circumstances permit, no case should be evacuated to the L. of C. until definite cyanosis or serious symptoms have disappeared. It is most important that a note should be made on the Field Medical Card of the symptoms of those who have passed through a condition of gravity for the guidance of the Medical Officer on the L. of C. in his disposal of the cases.

98. *Treatment during the convalescence stage.*—Most of the milder casualties sent to the L. of C. are likely to become fit for duty after a short rest. Bronchitis and gastric disturbance as a rule subside quickly with ordinary treatment. Patients who develop secondary broncho-pneumonia, and the rare cases showing dilation of the heart, will naturally be regarded as serious and treated accordingly. All those who pass through an acute stage of cyanosis must be regarded as serious and given a prolonged period of convalescence. The cases which show tachycardia and dyspnoeic symptoms

ffer a problem of much greater difficulty. In practically all these cases examination of the chest reveals no obvious physical signs to account for the symptoms, and the cases usually look surprisingly well while they are resting, though the occurrence of attacks of nocturnal dyspnoea may call attention to the fact that the case is definitely abnormal.

In order to differentiate these cases recourse may be had to the reaction after exercise. The ultimate standard of a man's fitness for duty must be his capacity to perform muscular exercise without undue exhaustion, tachycardia, or breathlessness. The effect of exercise ought to be tried on all cases before they are sent from hospital or the convalescent camp to duty.

99. Cases of moderate severity which have been confined to bed for some days require testing carefully in this respect. Some such method as the following may be employed:—After the patient has been allowed out of bed for four days he is made to walk half a mile at a steady and moderate pace. If the panting and pulse rate diminish with normal rapidity after stopping the walk, a walk of one mile is taken the next day, and if this is not too much, a walk of three miles without stopping is taken on the following day. If, however, the test exercise results in undue tachycardia and breathlessness, the best method of treatment to adopt is a course of carefully graduated exercise, and the greatest care must be taken not to overdo this exercise at the start.

100. The mildest cases, who are perhaps only retained in a medical unit for a day or two (as well as other convalescents who are well on the way to recovery), should be allowed the opportunity of resting lying down during the daytime, if they desire to do so, so as to prevent them from unduly exhausting themselves and possibly doing themselves harm.

CHAPTER IV

SENSORY IRRITANTS

The Arsenical Warfare Gases

101. All the arsenical poisons used in the war may be regarded as substituted products of arseniuretted hydrogen (arsine), the hydrogen being replaced by chlorine, bromine, cyanide and phenyl or ethyl radicles. This change to a large extent masks the ordinary poisonous properties of arsenic, the compounds, even when present in extremely minute concentrations, showing an immediate and intense power of irritating certain sensory nerves, and it is this property which renders them valuable for military purposes. They do not cause gastro-enteritis, or hæmolytic jaundice or chronic peripheral neuritis.

102. Those arsines commonly used have a very high boiling point and it is difficult to get more than an extremely low percentage in the air. They are, however, readily dispersed without decomposition by the aid of heat, in the form of an intensely irritant smoke, *i.e.*, in actual particles of an extremely minute size. A substance in this very fine particulate form can remain suspended in the air for an immense time, and the effects produced during the Great War depended on the liberation of part at least of the poison as a particulate cloud by the heat and violence of the explosion of a shell.

Such irritant smokes can also be liberated from suitable generators, and at sea from special types of float.

103. In man, slight and transitory nasal irritation is appreciable after an exposure of 5 minutes to as little as 1 part of diphenyl-chloroarsine in 200 million parts of air, and as the concentration is increased the irritation shows itself sooner and in rapidly increasing severity. Marked symptoms are produced by exposure to 1 part of diphenylchloroarsine in 50 million parts of air, and it may be stated in general that this concentration forms the limit of tolerance of ordinary individuals for an exposure lasting five minutes. A concentration of 1 part in 10 million will probably incapacitate a man within a minute from the pain and distress, and nausea and vomiting accompany an exposure of from two to three minutes to this concentration. The Germans state that diphenylcyanoarsine is an even more powerful irritant than diphenylchloroarsine.

These substances are generally used to cause such sensory irritation that the victim is unable to tolerate a respirator, and they are therefore often followed by an attack with asphyxiant gases.

104. **Morbid anatomy.**—No fatal case of poisoning by these compounds occurred in our Army in France so there are no data available as to the anatomical changes occurring in man. Under appropriate experimental conditions with higher concentrations in the laboratory it has been shown that the substance is capable of exerting a powerful lethal effect on animals, death being due to pulmonary œdema and pneumonia, accompanied by destructive inflammation of the trachea and bronchi and a marked fibrinous bronchitis. Some of these animals die within a few hours of exposure, and death in such cases may be largely due to shock. In those dying later, it is due chiefly to want of oxygen following the pulmonary lesions. Arsenic in small quantities can be recovered from the blood and urine of such cases.

105. **Signs and Symptoms.**—The symptoms are immediate in onset and are quite characteristic; minute concentrations in the air cause burning pain in the nose, mouth and throat, pain in the gums and jaws, repeated sneezing, a burning sensation of the face, aching pain in the eyes and frontal headache, watering of the eyes and painful conjunctivitis, copious watery discharge from the nose, tightness and burning pain in the chest, salivation, pain in the stomach, nausea, retching and some times vomiting which in some cases is followed by tenesmus, though diarrhœa is practically never met with. A further characteristic of the sensory irritation caused by these compounds is that the symptoms do not diminish as soon as the person affected leaves the poisonous atmosphere, but actually increase in severity for a time before they begin to subside. It may take from ½ to 1 or 2 hours, depending on the severity of the initial symptoms, for the pain to disappear after pure air is reached.

The degree to which the different symptoms develop differ even in severe cases. This may be due to differences in the method of breathing, for the serious involvement of the nasal passsages are less likely to occur in the case of mouth breathers. The pain in the eyes is somewhat different from the smarting caused by the simple lachrymators, the impression being gained that small gritty particles have been driven into the eyes.

106. A very early condition sometimes complained of is giddiness, and in a certain number of cases consciousness is quickly lost and a comatose condition persists for several hours; others, without losing consciousness pass into a

lethargic condition for a period of from 12 to 24 hours. A remarkable feature in these severe cases is the intense mental distress which accompanies the symptoms already described. Even slight cases feel and look miserable until the irritation passes off, and the picture of utter dejection and hopeless misery furnished by severe cases has no counterpart in any other type of gas poisoning. Occasionally the physical depression results in the temporary loss of mental control and men have been known to act as though driven mad by their pain and misery.

107. In addition to the above changes in mental condition, alterations in motor power occur sometimes within an hour but in some cases are delayed in appearance. The commonest complaint is of formication mainly referred to the finger tips—and this has been observed in laboratory workers who would not be likely to exhibit functional phenomena—but temporary paralysis involving one or more limbs is seen in a fair number of cases. This paralysis rapidly disappears and in 24 hours there is no sign of it left. These cases are a strong argument in favour of a central toxic action of the gas affecting the cortical or spinal centres leading to a temporary abolition of function. In other cases a more generalized motor weakness appears.

108. These motor changes in the early stages must be clearly differentiated from the sensory changes, which occur later in the course of the illness. The former may, with some degree of certainty be ascribed as toxæmia, transitory but definite, of the central nervous system. It is far more difficult to come to a certain conclusion about the latter. The sensory changes are mainly a disturbance of sensation leading to anæsthesia more or less complete, a condition which commonly supervenes about the fourth day. The extent of anæsthesia varies from a mere numbness of the finger tips to a complete loss of sensation over a considerable part of one or more limbs. Commonly the affection is bilateral and conforms to the glove and stocking distribution. In these cases the reflexes are unaffected and the sensory condition is not accompanied by any motor change or any sign of trophic disturbance. Pressure in the nerve tracts is not painful nor is any evidence of peripheral neuritis obtainable. Naturally, the first suggestion is that an arsenical neuritis is present but prolonged and careful observations have tended to disprove this view. Progress in all these cases is towards recovery, and in no instance has any indication of involvement of motor nerves developed. Numerically, cases showing this manifestation are very uncommon.

109. The probability is that these sensory changes are functional in character. The distribution of the anæsthesia

is never of a segmental character but is almost always of that glove and stocking distribution which is so significant of functional disorders. Also, recovery is so rapid and so uniform that this forms part of the argument against an organic basis for the lesion. Whilst a final conclusion as to the true nature of these nervous phenomena is difficult to arrive at, since the dividing line between functional and organic changes is one which it is impossible to demarcate with firmness and accuracy, it is certainly true that no lasting organic lesion is produced.

In some cases there are symptoms in the respiratory tract in the shape of a mild and evanescent bronchitis. A rise of temperature is extremely uncommon.

The above description of the symptoms may be taken as applying to the most severe type of case met with in the field, but such cases are in the minority and in many instances the irritant effects are so slight and transitory that the affected men never leave their units. The progress of patients affected by the arsenical warfare gases, from whatever source, is in the main uniformly good and rapid to convalescence. The symptoms abate within 24 hours, and by 48 hours the great majority of cases have practically recovered. The last symptoms to disappear are gastric discomfort and pain in the nose and forehead, and when these have cleared up, beyond a general weakness with no physical signs and a certain amount of mental depression or mental irritability, the whole condition disappears within a week. So rapid is the progress on the whole that it was part of the army routine in France to retain the cases in the forward area rather than evacuate them to the base, and the great majority were fit for duty within ten days.

110. **Treatment.**—The respirator properly worn will protect from sensory irritant gases.

In the early stages pain is the one symptom calling for relief, beyond the general principles of treatment of all gas cases—rest, fresh air, removal of contaminated clothing and equipment, and light diet, preferably a fluid one. The pain is best relieved by inhalations of chloroform which may be put up in dark glass ampoules holding 1 or 2 c.c.

For the pharyngeal irritation and pain, glycerine or menthol jujubes were found useful.

In the later stages treatment should be directed to toning up the physical and nervous systems.

It must not be forgotten that quite different symptoms of true arsenic poisoning may arise from the drinking of water, contaminated with the arsines, from shell holes. The use of shell hole water for drinking or washing purposes should be prohibited.

CHAPTER V

LACHRYMATORS

111. Exposure to a concentration of one part of the vapour of such lachrymators as xylyl bromide or ethyl iodo-acetate in 2 to 5 million parts of air, causes profuse watering of the eyes in a moment or two, and with rather greater concentrations the smarting and pain in the eyes may become intolerable, so that it is impossible to keep them open. The consequent interference with vision is quite sufficient to put a man temporarily out of action. As the concentration of the vapour increases, further effects show themselves. The irritant action on the respiratory passages and lungs is rendered evident by a burning sensation in the throat and burning pain or discomfort in the chest, and unless the affected men can withdraw from the poisonous atmosphere, nausea, retching and vomiting soon commence, accompanied by pain in the epigastrium. A man affected to this degree may appear dazed and become somewhat torpid, mainly perhaps from the general intense discomfort and the repeated retching and vomiting, though a direct effect of absorbed vapour may also play a part.

112. Speaking generally, the casualties that resulted from the German lachrymator shell in France never exhibited more severe symptoms than the above, though a few instances occurred when death was caused by the bursting of one of these shells close to a man, and there was uncertainty in the absence of post-mortem examination how far the fumes were a contributory cause of death in addition to actual violence. Many of the troops experienced simple lachrymation, but the actual number of casualties that reached medical units was small, owing to the limited number of lachrymator shell used, and the high boiling point of the liquid prevented any high concentration being attained in the open air. The striking feature was the rapidity with which the cases recovered when once they had withdrawn from the poisonous atmosphere. The symptoms of those who were more severely affected had usually abated by the time they reached the advanced dressing stations ; at the end of 12 hours there was little wrong with them and even the redness and swelling of the eyelids and injection of the conjunctivae which had been conspicuous in the early stages had nearly disappeared.

In one instance when death occurred within 24 hours after exposure to the fumes as the result of an accidental explosion of a shell, autopsy revealed œdema and congestion of the lungs, and acute inflammation of the whole of the air passages from the larynx downwards, which increased in intensity in the smaller bronchial tubes, the surface of the mucous membrane being covered and the smaller tubes blocked by a viscid purulent exudation.

113. Occasionally, workers in factories engaged in the handling of ethyliodo-acetate have suffered severely from the poisoning, and fatal cases have occurred. Exposure to concentrated fumes causes severe conjunctivitis and if inhaled, inflammation of the respiratory passages may result. The fumes will also cause blistering of the skin and abrasions exposed to them very frequently become septic.

114. A lachrymator which has been extensively used in America is chloroacetophenone. This substance is detectable by the eyes in as low a concentration as 1 part in 200 million parts of air. In 1 in 20 million it causes definite symptoms of irritation of the throat and nose. It is thus an exceedingly useful substance for testing the fit of respirators. In this concentration it also causes a burning and tingling sensation of the skin.

115. **Treatment.**—The Respirator if properly applied affords perfect protection.

No treatment other than simple lavage of the eyes was found necessary.

CHAPTER VI

DIRECT POISONS OF THE NERVOUS SYSTEM

Hydrocyanic Acid Gas

116. The most important of these is hydrocyanic (prussic) acid gas. The actual concentration of the gas is of far greater importance than the duration of exposure. Professor Barcroft has proved by personal experiment that a concentration of 1 part of gas in 2,000 would have to be attained before much effect would be produced on troops in the field. Concentrations of the gas below 1 part in 10,000 have little or no effect.

When the quantity of gas in the air is small, it may be borne for a considerable time without ill-effects, but once the poisonous concentration is reached, death is very rapid. Unless the dose is a fatal one, recovery from the toxic effects is rapid, and no serious after effects need be feared.

117. **Mode of action.**—When death occurs it is attributable mainly to direct paralysing effect on the respiratory centre and the heart. The substance temporarily stops all oxidative processes in every cell of the body to which it has access, but the tissues may recover their full vitality if the circulation and respiration can be maintained, the poisonous substance is quickly eliminated. According to French observers there is marked constriction of the bronchial tubes by spasm of the muscle in cases where rapid death takes place. Apart from this there is no obvious pathological change. When death is caused by inhalation of this gas it is unlikely that the smell of the gas will be detected at the autopsy, as may be the case when poisoning is due to the ingestion by the mouth of a large dose of prussic acid.

118. **Symptoms.**—If the concentration of the gas is much below that which causes rapid death, only giddiness may be produced. If, however, the concentration is high, the symptoms follow in rapid sequence ; giddiness, confusion, headache, failure of vision, palpitation, and pain in the chest and over the heart culminate in a few seconds in loss of consciousness, the respirations become laboured, being slow with long drawn out inspirations, convulsions set in and death ensues in one or two minutes from failure of respiration and then of the heart.

Still higher concentrations cause immediate unconsciousness, dilatation of the pupils, a few gasping respirations and death with or without convulsions.

119. **Treatment.**—The respirator, if properly adjusted, affords complete protection.

The treatment must be immediate if it is to be effective. The case must be dragged at once into the fresh air, and if the respiration has stopped or if it is weak and gasping, artificial respiration must be commenced coupled with stimulation by splashing cold water on the face and chest, and by friction of the limbs.

This same treatment must be carried out for any casualty produced by a gas of this group.

Danger arising from a simple reduction of the Oxygen percentage in the Air

120. It should always be remembered that the air in wells, unventilated or disused mine galleries, underground shafts or chambers may be seriously deficient in oxygen, and that it may therefore be extremely dangerous to enter such places rashly. The reduction in oxygen percentage is caused by the oxidation of organic or mineral matter in the soil, and it may or may not be accompanied by the accumulation of carbon dioxide according to the precise nature of the oxidation.

121. If the deficiency of oxygen is moderate little abnormality may be experienced save, perhaps, for a feeling of dizziness or weakness of the limbs whilst doing muscular work, symptoms which may pass off rapidly if the work is stopped for a few minutes. If, in addition to the deficiency of oxygen, excess of carbon dioxide is present in the air, attention will be called to the fact by the unusual panting which will result. Not infrequently, however, the deficiency of oxygen may be so great that entry into such an atmosphere will result in immediate asphyxia with no warning symptoms. When the barometer happens to be rising the air in one of these places may be perfectly safe to breathe, and yet an hour or two later, if the barometer begins to fall, the oxygen may be grossly deficient, for with a falling barometer air from which the oxygen has been largely abstracted tends to well out of the soil into the adjacent cavity.

122. The essential thing to bear in mind is to test the air in any place about which doubt is felt before allowing a man to enter it. If a lighted candle is lowered into the place to be tested and remains alight the air will be safe to breathe; if it is extinguished steps must be taken to ventilate the place before attempting to enter it, or else some self-contained breathing apparatus (*e.g.*, a mine rescue apparatus) must be worn by those who descend the shaft or enter the gallery. In any case if there is the slightest suspicion about the quality

of the air—though good at one part of a gallery it may be bad at another—anyone who has to enter for testing purposes should have a life-line attached to him so that he may be pulled out of danger at once in the event of an accident. Naturally, the lighted candle test must not be used in old coal workings where fire damp (methane) is probably present for fear of causing an explosion.

123. There is also a serious risk of gross reduction of oxygen in the atmosphere in closed compartments, ships' holds, &c., in which grain or other oxidizable substances, *e.g.*, coal or vegetables are stored, owing to the absorption of oxygen unless adequate ventilation is provided. It should not be forgotten in this connexion that freshly painted surfaces and even rusting iron may absorb a large quantity of oxygen.

124. The only remedy if a man falls unconscious in an atmosphere deficient in oxygen is to pull him out into fresh air at once, and if the breathing has stopped to apply artificial respiration. Would-be rescuers must, however, themselves remember the danger of the atmosphere: it is no use adding to the toll of casualties uselessly, and it is for this reason that the provision of a life line is recommended.

CHAPTER VII

POISONOUS GASES NOT USED FOR OFFENSIVE PURPOSES, BUT LIABLE TO BE ENCOUNTERED BY TROOPS

Carbon Monoxide

125. This gas is formed in large volumes on the explosion or detonation of explosives, also when the combustion of carbonaceous material takes place in a limited supply of air. It may be met with under the following circumstances:—

(*a*) Mining operations.—The galleries may be flooded with the gas after the explosion of one of our own or of an enemy's mine or camouflet, or as the result of the explosion or burning of a blasting charge. The gas is liable to be driven into the ground disturbed by the explosion and to come welling out later, especially if the barometer commences to fall after the explosion, or it may be met with in the form of pockets of gas when new galleries are driven through ground disturbed by a previous explosion. This gas has even been known to be driven out of the shafts into adjacent trenches after the explosion of a mine.

(*b*) Fumes from high explosive shell. When a high explosive shell penetrates the soil and bursts in the neighbourhood of a deep dug-out, or other relatively confined space, the carbon monoxide generated in the explosion may find its way into the dug-out and poison the occupants.

(*c*) Fumes from the firing of guns.—Cases of carbon monoxide poisoning sometimes occur in closed machine gun emplacements or in gun pits owing to the blow-back from the gun.

(*d*) Burning buildings, &c.—There is considerable risk of carbon monoxide poisoning in the interior of burning buildings. Very serious amounts of this gas may be formed if the timbering of deep dug-outs or mine galleries catches fire.

(*e*) A burning coke brazier gives rise to carbon monoxide and is a great source of danger in a small ill-ventilated billet or dug-out.

(*f*) Carbon monoxide may be found in the interior of Tanks, especially in the vicinity of the exhaust side of the engine and is due to the escape of exhaust gases from the engine and to blow-backs from the gun, or in the interior of ambulance or closed motor cars if the exhaust gases leak into the vehicle.

(*g*) The exhaust gases of motor engines contain this gas, and such engines are dangerous if installed in ill-ventilated dug-outs or cellars.

126. The great danger from carbon monoxide lies in the fact that it is colourless, odourless and non-irritant, and that the onset of symptoms is so insidious that very often the first warning that a man may receive is failure in the power of the limbs which will prevent him from retreating into safety.

127. **Mode of action.**—This gas owes its poisonous properties to the fact that it combines with hæmoglobin to form a dissociable compound just as oxygen does, though the affinity of carbon monoxide for hæmoglobin is 240 times that of oxygen.

When a man breathes air containing a small proportion of carbon monoxide, a partition of the hæmoglobin of the blood between the two gases occurs, the final partition being determined by the relative concentration of the two gases. As the saturation of the hæmoglobin with carbon monoxide increases, its oxygen carrying power progressively diminishes and symptoms of anoxæmia begin to show themselves. There are no changes in the lungs hindering the access of oxygen to the blood as there are in the case of poisoning by an acute lung irritant gas.

128. **Morbid anatomy.**—At the autopsy the blood may be red in colour instead of dark if there is a considerable degree of saturation of the hæmoglobin with carbon monoxide. If the case has continued to breathe for some time after reaching an atmosphere free from carbon monoxide, this gas will have been partly or entirely displaced from the hæmoglobin and the blood after death will have its normal colour.

The simplest method of detecting the presence of carbon monoxide in blood is to compare the colour of a diluted solution of the suspected blood with a similar solution of normal blood. Take a drop or two of the blood from the finger of a normal person and dilute it in a test tube very considerably with water (a $\frac{1}{2}$ per cent. solution is a convenient strength), so that when examined by transmitted daylight the colour of this solution is a reddish yellow. Then take a drop or two of the suspected blood and dilute it similarly with water so that the *depth* of colour of the solution is the same as that

of the solution of normal blood when both are viewed by transmitted light. On examining the quality of the colour it will be found that the solution made with the suspected blood, if it contains carbon monoxide hæmoglobin, is definitely pinker than that made with the normal blood; though it will not have the full pink tint of the same normal blood solution if the latter be shaken with coal gas so as to saturate it completely with carbon monoxide.

The lungs show no abnormal changes in cases of rapid death. Small punctate hæmorrhages may be found in the white matter of the brain, and sometimes ecchymoses in the meninges and even large cerebral hæmorrhages if the case has been exposed to a concentration of carbon monoxide sufficient to cause prolonged unconsciousness.

129. **Symptoms.**—Except with very massive doses, when loss of consciousness is very rapid, the symptoms develop gradually as the gas is only absorbed slowly. If a man is at rest in a concentration of one part in a thousand, it will take two hours before giddiness appears, and he will not be definitely disabled until two and a half hours have elapsed. The rate of absorption of the gas is much accelerated by muscular exercise owing to the increase in the breathing and the circulation rate, while the symptoms become accentuated since the oxygen requirements of the body are much greater than at rest. With a concentration of 2 parts in 1,000 a man will be seriously affected in half an hour if he is performing a moderate amount of muscular work, and this concentration may prove fatal with prolonged exposure.

130. Small animals, *e.g.*, mice or canaries, are far more rapidly affected by carbon monoxide than is man, owing to their relatively high metabolism, which is 15 times that of man. If such animals are used to give an index of the presence of carbon monoxide in a suspected atmosphere, it must be remembered that though they show symptoms long before a man feels any effects, the man will in the end be reduced to the same condition as the animal, and he ought therefore to leave the dangerous atmosphere directly the animal shows signs of being affected, unless he is protected by a special apparatus.

131. With moderate doses, the symptoms, which are essentially those of anoxæmia, develop in the following sequence. The first sign frequently is a feeling of loss of power in the limbs. Giddiness, slight confusion of mind and breathlessness and palpitation on the least exertion show themselves. The confusion of mind and loss of power in the legs often preclude a man from withdrawing from danger, even though he is dimly aware that safety is only a few yards

distant. The failure of power in the limbs and the mental confusion rapidly increase and the man may appear drunk, shouting incoherently, laughing, swearing and praying. Apathy and complete helplessness supervene, and failure of the intellectual powers gradually passes into complete unconsciousness which may finally terminate in a painless death.

In a mild case of gassing with carbon monoxide a severe headache accompanied by nausea is very likely to develop.

132. **Treatment.**—It must be borne in mind that the box respirator does not afford protection against carbon monoxide; protection can only be attained by the use of special oxygen breathing apparatus (Proto or Salvus sets).

The case must be carried at once into the open air. Any increase in the oxygen requirements of the body must be avoided, and the case therefore kept at rest. The other essential is the proper administration of pure oxygen, for from ½ an hour to 1 hour, care being taken that the expired air is not rebreathed. This can be carried out with a Novita oxygen apparatus such as is kept at mine rescue stations or by means of the nitrous oxide anæsthesia apparatus; as an alternative the Haldane oxygen administration apparatus may be used with the oxygen delivery set at 8-10 litres per minute.

Very good results have also been obtained by breathing air enriched with carbon dioxide to the extent of 3 to 5 per cent., the rationale of this treatment being that the high percentage of carbon dioxide, stimulates the respiratory centre causing increase in the depth and rate of breathing and thus helping the elimation of carbon monoxide.

If the breathing is very shallow, administration of oxygen may be combined with artificial respiration. The case should not be evacuated until this has been carried out.

Collapse should be combated by external warmth and by friction of the limbs.

133. Cases of carbon monoxide poisoning have been known to recover, even when they have remained unconscious for so long as 48 hours after removal from the poisonous atmosphere. In cases that have been severely gassed, the possibility of subsequent cardiac dilation must not be lost sight of, and cases of severe gassing should not be returned to duty until confidence is felt that the circulation has recovered from the strain. As a result of damage to the nervous system while the blood was charged with carbon monoxide, paralysis of single muscles or groups of muscles, or different forms of mental disturbance are sometimes found as sequelæ.

Nitrous Fumes

134. Though these fumes caused no material cases of poisoning in the warfare on land, a number of instances were reported in the Navy owing to the liberation of these fumes from burning cordite.

The mode of action of this gas is described in Chapter XI. (para. 227).

135. The treatment is that described in chapter on lung irritant gases.

Arseniuretted Hydrogen

136. Cases of poisoning by this gas occurred during the war in certain submarines, owing to its production by the use of impure materials in the batteries.

This gas is typically cumulative in action. Exposure of animals for about six minutes to 1 part of this gas in 1,000 may cause death in 24 hours. With lower concentrations the effect is nearly proportional to the product of the concentration of the gas and the duration of the exposure, a concentration of 1 part of the gas in 100,000 being fatal after about twelve hours' exposure.

137. **Mode of action.**—The gas acts upon the red blood corpuscles, causing intense hæmolysis, and this effect seems to be the main cause of the symptoms. In slight cases there is only jaundice and anæmia, associated with a feeling of malaise, nausea, and pains about the body. In more severe cases there is hæmoglobinuria as well as jaundice and profound secondary anæmia. In bad cases vomiting sets in in an hour or two, with intense pain in the back, weakness, fainting and collapse; hæmaturia is intense and acute nephritis occurs with casts in the urine. In fatal cases there may be a total suppression of the urine. Death seems to be due either to the nephritis or to the want of oxygen caused by the destruction of the red blood corpuscles and loss of hæmoglobin. The nephritis appears to be largely dependent on the accumulation of hæmoglobin or its derivatives in the kidney. Peripheral neuritis is a not uncommon symptom in the latter stages of non-fatal cases.

138. In the cases which occurred in submarines, the main symptoms, were: vomiting—a constant and troublesome symptom often associated with burning and griping abdominal pain—dyspnœa on exertion, anæmia, jaundice, hæmoglobinuria, and albuminuria, headache and slight œdema of the face and eyelids. Many of the cases gave evidence of a slight degree of neuritis in the shape of tingling and "pins and needles" in the hands and feet. The anæmia was occasion-

ally severe, for some of the cases admitted to hospital showed only two million red corpuscles per cubic millimetre of blood and a hæmoglobin percentage of only half the normal amount. Hæmoglobinuria ceased within three days of leaving the submarine, though slight albuminuria continued in an intermittent fashion for some time longer. The jaundice usually disappeared within a week or ten days. The symptoms of neuritis took two or three weeks to pass off, and a considerably longer time was required before the blood resumed its normal character, though the cases had all recovered completely at the end of six weeks.

Poisoning by Aromatic Nitro Compounds used in the Manufacture of High Explosives

139. Although a consideration of these subjects does not come directly under the heading of Chemical Warfare, medical officers may from time to time be called upon to treat patients suffering from the effects of intoxication by them.

The toxic effects of the nitro-benzenes and nitro-toluenes are very similar, but the greater the number of nitro-groups in the molecule the higher is the toxicity. Further the chloro-nitro derivates are more dangerous than the simple nitro compounds.

The condition produced may vary from a general malaise with loss of appetite, headache, giddiness, and constipation, to dermatitis or severe gastritis, toxic jaundice, and death.

(T.N.T.) Tri-Nitro-Toluene

140. The effects of poisoning by T.N.T. may be taken as typical of the more severe affections.

The poison is absorbed not merely by inhalation but much more through the skin. The ill-effects produced by this substance may be classified as follows :—

(*a*) Dermatitis.
(*b*) An early, probably reflex, vomiting.
(*c*) Affections of the blood or blood-forming organs.
(*d*) Toxic gastritis.
(*e*) Toxic jaundice.

141. *Dermatitis.*—Workers vary greatly in their susceptibility to this condition. The parts most frequently affected are the wrists, ankles, and neck where rubbing with contaminated clothing occurs, but the facial and intercrural regions may also suffer.

The rash is usually a superficial follicular or wide-spread erythema, but on the hands a chronic eczema or cheiropompholyx type of eruption is common.

Secondary infection and thrombo-phlebitis are sometimes seen, though as a rule the skin affection yields readily to simple treatment. In all forms itching is often intolerable. Yellow staining of the hands and occasionally of the feet of T.N.T. workers is very common.

In very few cases do the same patients suffer both from dermatitis and constitutional ill-effects. Cuts and abrasions of the skin heal slowly in workers exposed to T.N.T.

142. *Functional or reflex Gastritis.*—Among new workers vomiting in the early morning and occasionally after food is a common complaint during the early days of employment. This condition, which is probably psychic in origin, rapidly passes off.

143. *Toxic Gastritis* is the outstanding ill-effect in factory workers with this substance. Pain is the most general and often the only complaint. This pain is always local in the epigastrium or lower chest, and varies from discomfort to pain of great severity. It is colicky in character and has no relation to meals. Rest relieves it, vomiting rarely coincides with the pain and does not give relief, nausea and aversion to food are concomitant symptoms, constipation is the rule in these cases.

On examination these patients are apathetic and show muscular weakness; their faces are pallid, drawn and wizened; their sclerotics are dulled, their tongues are clean. High coloured urine and frequency of micturition are common. Cyanosis of the lips and tongue are generally notable. There is some epigastric tenderness. These symptoms may come on at any time from a fortnight to nine months after employment on T.N.T. Two to six weeks may elapse before the patient is again fit for work.

Open air and purgatives are the best treatment. Relapses are uncommon; but if they occur are an indication that the patient should not be allowed to carry on with this type of work. Fear of return to work on shell-filling may lead to chronic invalidism.

144. *Toxic Jaundice.*—Young adults are frequently attacked, and when attacked experience a high mortality, so that employment on T.N.T. of workers below the age of 18 should be prohibited. The onset of jaundice may occur immediately after commencing employment, or may be delayed for months.

The early signs and symptoms of this condition are of paramount importance, since the prognosis depends to a great extent on early removal from work.

Early symptoms are dizziness, tiredness, headache and an overpowering desire to sleep in the daytime. Dyspepsia, abdominal pain and vomiting are sometimes present. On

the other hand the fatal toxæmia may develop without warning.

In many cases an absolute diagnosis of hepatitis is difficult in the early stages, but valuable evidence may be gained by a simple laboratory test. A little blood of the suspected worker is withdrawn into a collecting tube and allowed to coagulate. The serum above the clot shows occasionally a vivid yellow colour. A worker whose blood gives such a reaction should be removed from contact with T.N.T. without delay.

Vomiting in cases with toxic jaundice is often severe, recurring with each attempt to take solid food. Constipation with white hard stools is frequent. Abdominal pain when present is generally in the liver region; and marked tenderness may be elicited by pressure in the liver area. The area of liver dullness may be diminished.

145. *The Blood Changes.*—The commonest result is an alteration in the hæmoglobin (which is perhaps changed to methæmoglobin), so that the patient's lips and ears assume a cyanotic tint. With this there is no change in the blood count.

Much more rarely a grave anæmia of an aplastic type may develop. This has no direct relationship to the toxic jaundice.

The disease may show itself as a gradually increasing debility and breathlessness as found in pernicious anæmia, or the onset may be sudden and hæmorrhagic. The hæmorrhage may show itself first in the legs as a general purpura, or there may be a sudden bleeding, e.g. in the case of women workers, from the uterus.

146. **Preventive measures.**—These consist in the strictest observance of regulations framed to reduce or eliminate contact between the workers and the toxic material. Workers should wear overalls fitting closely at the neck, wrists and ankles, leather gloves, caps, and shoes fitted with wooden soles. It is specially necessary that the inside of the gloves and overalls should be inspected to ensure that they have not been contaminated by the toxic powder. When necessary, respirators should be worn.

Bathing should be compulsory before the workers put on their ordinary clothes to leave the factory.

No food should be taken in the workrooms, but canteens and mess rooms should be provided. Before going to these, workers should wash thoroughly and change their clothes.

A most important measure is the provision of a thorough ventilation system, the best practice being when the extraction of air is arranged at floor level.

Filling devices which obviate handling the toxic materials should be developed.

147. Medical inspection of all workers should be frequent and thorough. In suspicious cases a blood count for anæmia and the Van den Berg test of the blood for bile pigment should be carried out.

Remedial measures.—In mild cases a few days' rest, and the free use of aperients are usually all that is necessary. If considered desirable, a change of employment should be made. As soon as there is any indication of the onset of toxic jaundice, the patient should be removed from contact with the toxic material without delay, and given absolute rest in bed. Frequent doses of Mist. Alba or a similar aperient should be given, and the diet should be of the lightest, or simply of milk.

Phosphorus Burns

148. White phosphorus is one of the principal ingredients in hand and rifle smoke grenades. When these burst solid particles of burning phosphorus are widely scattered, and may cause severe burns.

For such, treatment should be as follows:—

First aid is directed towards stopping the phosphorus from burning. The wound should be covered with water.

Phosphorus melts at 112 F., so that if the part is immersed in warm water the molten substance can be removed under water, or wiped off with a gauze sponge held in a forceps. Great care should be taken to remove every particle.

Subsequent treatment follows the lines adopted for ordinary thermal burns.

CHAPTER VIII

INDIVIDUAL PROTECTION

The Respirator

149. The most important feature in safeguarding the individual against effects of chemical weapons is the protection of the eyes, respiratory passages and lungs.

150. Various methods of gaining such protection were tried in the early days of chemical warfare. It was, however, soon realised that complete protection would only be given by an airtight facepiece covering the eyes, nose, and mouth, and attached to a canister filled with materials which would neutralise or absorb toxic gas, and through which air could be drawn by means of a valve which only opened on inspiration; the exhaled air being got rid of by a spear head valve attached to the facepiece. The apparatus finally devised, which stood the test of war and which with some modifications is still the official protection for all services, is known as the box respirator.

151. In addition to the removal of toxic gas from the air, the main desiderata for such an appliance are:—

(*a*) That it should be easily and rapidly adjustable.
(*b*) That it should be light, so as not to add materially to the weight carried by troops.
(*c*) That it should be capable of withstanding rough usage.
(*d*) That it should offer little resistance to breathing.
(*e*) That it should interfere as little as possible with vision and with the effective handling of weapons, &c.
(*f*) That it should be capable of rapid production in large numbers by manufacturers.

152. It consists of the following parts :—

(*a*) The facepiece.
(*b*) The container.
(*c*) The connecting tube.
(*d*) The haversack.

153. The facepiece, Mark I, is of a pleated waterproof material, shaped to give pockets by means of which the inner surfaces of the eyepieces can be wiped by pushing the fabric against them with the finger. A narrow fitting edge is attached

to the material and the facepiece is kept in place by cotton and elastic tapes which pass over the top and sides of the head. The eyepieces are made of glass placed on either side of a celluloid disc and cemented to it.

On the inside of the fabric is a padded spring nose clip. An angle tube leads the air from the container to the inside of the mask. There it is fitted with a rubber mouthpiece which is thickened in two places to give a bite for the teeth and is provided with a flange which fits between the lips and gums. The air from the container is thus drawn directly into the mouth, the nose being closed by the clip. Expired air is expelled through a spear head valve fitted to an opening on the under side of the angle tube, just outside the fabric. On the distant side of this opening in the interior of the angle tube is a baffle which both directs the expired air to the expiratory valve and also prevents saliva trickling down into the container.

154. Though this facepiece stood the test of war, it has certain obvious defects. The chief of these are as follows:—

(*a*) Speech is heard with difficulty unless the mouthpiece is removed from the mouth.

(*b*) Vision is defective, both on account of dimming of the eyepieces by the accumulation of moisture, and on account of the mobility of the windows themselves.

(*c*) Considerable discomfort and pain are experienced from pressure of the fitting band on the brow, and of the nose clip. This discomfort increases with prolonged wearing.

(*d*) The pull of the connecting tube on the angle tube and mouthpiece, combined with limited vision, tends to upset the balance of the man when marching with a load, so that not only is it difficult to maintain a steady pace and distance in the ranks but also an uneconomical expenditure of energy ensues and the onset of fatigue is more rapid.

(*e*) The fact that there is no exchange of the air contained between the mask and the face interferes with loss of heat from the body.

155. The great point in favour of this facepiece is that it offers two distinct lines of defence (1) the air-tight mask, (2) the nose clip and mouthpiece.

Though most of these disabilities can be, and were minimised by thorough and prolonged training in wearing the respirator, it was considered that improvements could be made without sacrificing the essentials of protection.

156. Professor Tissot in France had devised a facepiece in

which the air is drawn not through the mouthpiece leading directly into the mouth, but through channels which lead from the angle tube through the fabric and direct the air stream over the inside of the glass windows, thereby helping to keep them clear of moisture. Moreover, with such a facepiece speech is easier, since there is no mouthpiece to be withdrawn from the mouth.

157. The Americans have adopted a facepiece of this type, and since the war British research has resulted in the adoption of two Tissot type facepieces, (1) the Mark II facepiece for the use of the Navy, and (2) the Mark III facepiece for the use of the Army.

Respirator, Anti-Gas (Naval use), Mark II facepiece.

158. The Mark II facepiece is of shaped rubber carrying on the outside a layer of stockinette and is of sufficient thickness to prevent collapse on to the face on inspiration. It fits closely on to the face for a mean depth of 2 inches all round, and is in contact with the skin along the forehead, down the cheeks and under the chin. No nose clip or mouthpiece is normally used and hence it is of the utmost importance to make certain that the mask seals satisfactorily to the skin all round, since the air inside the mask which is the supply for the lungs is inevitably contaminated if any leak is present.

159. The eyepieces are an improved pattern of those used towards the end of the war, and are bound into the mask. Good optical definition and the possibility of using optical instruments have been dealt with fairly satisfactorily. The Tissot principle is adopted for preventing deposition of moisture on the inside surface of the eyepiece, the purified air stream passing through the channels formed in the mask walls and emerging from air ports directed across the inner glass surface and thence to the nose and mouth.

160. The respiration of the wearer gives an intermittent motion to the air stream, while the two valves, inspiratory or inlet in the container and expiratory or outlet in the facepiece, secure that this motion is only in one direction.

161. The expiratory valve is similar to that used during the war and is placed immediately in front of the wearer's mouth, where it is held in a metal housing. The walls of this housing are hollow and a tube at the fore end connects this hollow annular space to the corrugated connection tube. Two holes at the rear end of the housing also give access to this space. Air is drawn from the container into the hollow walls of the housing and emerges through the two holes in the rear end directly into the channels leading to the air ports. This

metal housing is bound into the mask, but is so arranged that if the facepiece, owing to damage or other causes, ceases to give adequate protection, the end of the metal piece carrying the expiratory valve can be pushed back into the mouth. The purified air is then breathed direct into the lungs without danger of contamination from the mask. This second line of defence is only intended for use in rare and extreme emergency and it is in no sense a normal function of the facepiece.

The facepiece is retained in place by elastics which pass to buckles on a pad at the back of the head.

The Mark II facepiece is issued in a range of sizes and special facepieces having spaces in the walls to hold packing are also available to accommodate facial deformation, scars, &c.

Respirator, Anti-Gas (Army use). Mark III facepiece

162. The Mark III facepiece is in many ways similar to the Mark II pattern, but is lighter and simpler. A light head harness is attached to buckles on the mask edge. Improved vision has been obtained by using larger eyepieces set at a slight inclination to each other. The Tissot principle is retained for eyepiece clearing, but the mask is more compact than the earlier pattern. The second line of defence has been abandoned as superfluous with consequent simplification of design leading to increased facility in the use of weapons, &c. The early spearhead valve is retained for expiration, but is inclined downwards to save space. Aluminium metal parts are used throughout where possible.

163. *The Container* is the name given to the box filled with neutralizing agents through which the air is drawn and purified before it reaches the mouth of the wearer. Both the box and its contents have been considerably modified from the original design.

164. The containers now in use are of two varieties.

(1) The Container, Training, Mark II.
(2) The Container, Service, Mark II.

165. The training Container, Mark II, consists of a metal canister, in the bottom of which is a perforated metal lever lid, in the centre of which is a metal pin carrying a rubber disc valve, which allows air to be drawn in and at the end of inspiration falls back into place. The top of the box is fitted with a neck which is connected to the facepiece by corrugated rubber tubing. The expired air does not pass out through the box but through the spear head valve attached to the angle of the facepiece. A wire gauze dome holds the contents away from the inspiratory valve. The sides of the canister are

corrugated. The contents consist of a highly absorbent charcoal; the canister is two thirds filled with this material. The remaining third is occupied by a metal distance piece, gauze, and a spring. The last keeps the contents in place. In addition, pads are inserted, one of thin cotton wool above the dome to prevent charcoal falling on to the inspiratory valve, and one of cellulose half way up the canister (*i.e.*, between two layers of charcoal) to assist in filtering toxic smoke particles. The third, which is of cotton wool, is placed on the top of the charcoal filling.

166. The service container, Mark II, will replace the training container in war. It is similar in size, shape and resistance to breathing. It contains chemicals designed to protect against all gases likely to be encountered and also against particulate clouds and toxic smokes.

Diagrams of the Mark I, II and III facepieces and of the training container are given in the appendices.

167. *The Connecting Tube.*—The connection between the container and the facepiece is a flexible tube of corrugated rubber covered with stockinette. It is important in adjusing the respirator to ensure that this tube is neither kinked nor twisted, otherwise the wearer will have difficulty in breathing.

168. As the Mark II Respirator, Anti-Gas, (Naval pattern), is worn under the left armpit or on the back (to avoid difficulty to the wearer in getting through narrow manholes) its connecting tube is considerably longer than that issued with other patterns. It is restrained from undue movement or obstruction by an eyelet which attaches to a hook on the haversack sling.

The connecting tube of the Mark III Respirator (Army pattern) has been redesigned and is more flexible than that issued with the earlier patterns.

169. *The Haversack* is a waterproofed canvas satchel provided with a flap cover which closes by means of press buttons. It is suspended over the right shoulder so that the respirator when not in use is carried on the left hip. The interior of the satchel is divided into two compartments—the container being carried in the right and the facepiece, when not in use, in the left. When a container which has the inspiratory valve in the base is issued, a metal grid is sewn into the bottom of the pocket which contains it. This ensures free passage of air.

170. A lanyard is attached to the haversack and a pair of metal rings are sewn to each side. When the respirator is worn in the alert position this lanyard is passed round the

ody and tied, thus obviating undue movement of the haversack.

171. The Naval haversack, Mark II, is a departure from the normal design in that it is carried under the left armpit. For this reason it is fitted with adjustable shoulder and chest slings. The flap opening is at the forward side and is furnished with three press stud fastenings. It is of a somewhat irregular shape and is of large capacity to accommodate the Mark II facepiece and long connecting tube. It can be fitted with either training or service container. A small loop holds the metal cylinder, which contains anti-dimming composition and a rag for applying it to the eyepieces.

172. **Hygiene of the Respirator.**—The respirator is an article of personal equipment, the facepiece remaining in the possession of the individual throughout his services and the container being changed as often as is necessary. Facepieces returned to store may be re-issued.

To ensure that these appliances are maintained in a hygienic condition, regulations lay down that they are to be disinfected half-yearly and when exchanged, and cleansed after each wearing. It is also of importance that medical officers in charge of effective troops should take steps to ensure that disinfection is carried out when a man is admitted to hospital suffering from any disease where infection is likely to be carried by the respirator.

The following is the procedure to be adopted.

173. *For disinfection—*

(*a*) A solution of Izal is prepared, 3 parts of Izal to 100 parts of water.

(*b*) The corrugated rubber connecting tube is detached from the container and the middle finger inserted into the tube so as to block it. The expiratory valve is pinched between the first finger and thumb of the left hand.

(*c*) The facepiece is supported with the right hand while an assistant fills the cup so formed with the Izal solution.

(*d*) After 5 minutes' contact as much disinfectant as possible is run out through the expiratory valve and the remainder emptied from the facepiece.

(*e*) The whole facepiece is then thoroughly washed out with water and left to dry. In this process the inner rubber surface should not be directly exposed to the sun.

(*f*) The inside of the neck of the container is thoroughly swabbed out with a rag moistened with Izal solu-

tion, the greatest care being taken to prevent any of the solution penetrating to the inside of the container, and so damaging the contents.

174. *Routine Cleansing.*—After each wearing of the respirator, or, when used both morning and afternoon, at the end of afternoon parade, the facepiece is to be cleansed as follows:—

(*a*) The whole of the inside of the facepiece is swabbed over with a rag moistened with a solution of Izal, 1 part in 200 parts of water. Special care is taken to cleanse round the mouthpiece and nose clip, when these exist, and round the expiratory valve.

(*b*) The facepiece is then washed over with water and allowed to dry.

For routine cleansing the container should not be detached from the facepiece.

175. In addition to supervising the cleansing of respirators officers commanding units should cause frequent inspections to be made, to ensure that these appliances are in good condition.

The most serious causes of damage to respirators are:—

(*a*) Water entering the containers and damaging the contents.

(*b*) Injury to the mask.

(*c*) Injury to one or both valves.

176. To prevent the freezing of the expiratory or outlet valve during severe frost, two or three drops of glycerine should be inserted through the slits at the bottom of the valve by means of a match.

177. In the case of men working under high temperature conditions, inconvenience may be experienced by the pressure of the rubber on the moist skin of the forehead. Under these special conditions, the use of the following astringent antiseptic powder may be found useful:—

Zinc oxide	...	40 per cent.
Boracic acid	...	10 per cent.
Starch ...	...	50 per cent.

It is essential that this powder be dusted on the skin of the forehead only and not applied inside the facepiece.

178. **The physiology of the respirator.**—In determining the effects of the respirator on the wearer three main factors have to be considered.

(*a*) The psychological effect.

(*b*) The effect of dead space on breathing.

(*c*) The effect of resistance to breathing.

179. *The psychological effect.*—When an individual first puts on a respirator he at once feels restriction of his breathing and is inclined to gasp and fight for air. These feelings are to a great extent subjective, being suggested by the fact that the respiratory passages are covered and that, unconsciously perhaps, the individual expects his supply of air to be restricted. They are also no doubt to a slight extent due to the nervous stimulus to respiration given by the slight resistance which the respirator offers to breathing, necessitating an increase of effort on the part of the respiratory muscles.

As the wearer becomes accustomed to the apparatus, however. his breathing returns to the normal and he experiences no difficulty in obtaining all the air he requires, even during heavy work.

Much depends upon judicious training from the first, and the instructor should explain that the difficulty in breathing is only due to inexperience.

There is, however, another factor which is not so readily overcome, *i.e.*, the discomfort due to the pressure of the facepiece. How great this was with the 1918 pattern has been already pointed out; but the elimination of the nose clip and mouthpiece and the substitution of a band for a line fit in the post-war patterns has done much to eliminate this disability. Experiments have proved that men can wear these facepieces for a period of 24 hours (only removing them for meals) without serious discomfort.

179. *The effect of dead space.*—In estimating the effects which respirators exert upon the wearer, the dead space air has to be considered, *i.e.*, that portion which fills the respiratory passages and the passages from the container to the breathing organs, and which does not come in contact with the alveolar epithelium in the lungs. The dead space in the respiratory passages cannot be defined anatomically, but varies according to the condition of respiration, *e.g.*, whether the individual is at rest or performing light or heavy work. Since the first air to move into the alveoli on the beginning of inspiration is that present in the dead space, *i.e.*, the last air expelled from the alveoli on expiration, it is of no value in purifying the air already present in the alveoli. For instance, if a total inspiration amounts to 500 c.c. and the functional dead space is 150 c.c., only 350 c.c. of the outside air reaches the alveoli and in the subsequent expiration there are 150 c.c. of outside air which had lodged in the dead space plus 350 c.c. of alveolar air. If to the dead space in the respiratory passages a further addition is made by the respirator, the supply of pure air to the alveoli is lessened, and complete respiratory exchange is not obtained until the volume breathed in and out is

sufficient to sweep out the air remaining in the dead space during each complete breath.

In constructing respirators it is therefore of importance to ensure that in the case of the Tissot type of facepiece the dead space between the mask and the face is reduced to a minimum.

180. *The effects of Resistance.*—As has been mentioned above, even a slight resistance to breathing calls for increased work on the part of the respiratory muscles, and so puts a slight strain upon the individual. This additional strain is shown by the increased response of the pulse rate to exercise when wearing respirators, and delay in the time taken to return to the resting rate after completion of the work. Such an increase is shown even by well-trained individuals who are thoroughly accustomed to wearing respirators, and it is therefore to be expected that the strain will be greater in the untrained or tired individual and in the individual who is unaccustomed to their use.

The initial discomfort in breathing experienced when the respirator is first put on quickly disappears, and prolonged training enables the individual to work without ill-effects with a respirator up to a resistance of 4 inches of water at a flow of air of 3 cubic feet per minute through the container, though, of course, the lower the resistance the greater his comfort.

The upper limit of resistance to which the respirator may go has therefore been fixed at $3\frac{1}{2}$ inches of water, and at this figure with trained men no difficulty in breathing need be anticipated.

181. **General effects of respirators on military efficiency.**—The chief factors in the old respirator which interfered with manipulative dexterity (and military efficiency), namely defective vision, interference with handling of weapons, and the general discomfort of the apparatus have been eliminated, and there should, therefore, be little loss of efficiency in trained troops using the new design. Training must, however, be prolonged and thorough, so that the individual comes to regard his respirator as a normal part of his equipment as a soldier.

182. **Protection against Carbon Monoxide.**—The respirator does not protect against carbon monoxide, and in going into an atmosphere where it is likely to be present, a self-contained oxygen breathing apparatus such as the Proto or Salus set must be used.

183. **The protection of Helpless Patients.**—It is the duty of the medical officer or orderly to see that the protective appliances of his patients are in good order and in readiness for

use; and it must be remembered that in future this may apply not only to forward areas, but also to areas on the lines of communication or at the base which may be subjected to gas bombardments from the air. It is particularly necessary to ensure the safety of patients who cannot help themselves. In this connection it is to be remembered that an unconscious person can breathe comfortably both in the Mark III Army facepiece, and in the 1918 facepiece, if the mouthpiece be left out of the mouth.

184. **Protective clothing.**—Although the respirator gives complete protection to the eyes and the respiratory organs, additional defence must be supplied against vesicant substances, such as mustard gas, which blister the skin.

Ordinary clothing being porous is unable to keep out such vapours or liquids and protection must be sought either by impregnating fabric with some neutralizing substance or by providing non-porous clothing.

185. Fabric impregnated with such a substance as chloramine will neutralize mustard gas, but its time of efficiency is very limited and the neutralising agent does not keep well.

Considerable success has, however, been gained in devising non-porous clothing. The material for such must possess certain essential qualities:—

(*a*) It must be flexible.
(*b*) It must be non-porous.
(*c*) It must not dissolve the mustard gas.
(*d*) It must not tear readily.
(*e*) It should be capable of decontamination.
(*f*) It should not be affected by water.
(*g*) Furthermore, the design of the clothing should be such as to interfere as little as possible with free movement and handling of instruments, weapons, &c.

186. The material which has proved most effective is a closely woven cotton fabric impregnated with a vegetable oil such as linseed.

The use of clothing of this nature is, however, limited, because the free loss of heat from the body by evaporation of sweat is interfered with owing to the lack of ventilation. When heavy work is done in such clothing in high atmospheric temperatures the conditions leading to heat stroke are approached, as indicated by a rapid rise in the pulse rate and the body temperature, and the onset of fatigue is rapid.

Such complete protective clothing cannot therefore be made a general issue, both on account of the danger mentioned above and also because it hampers movement to some extent. It

is, however, of the greatest use in laboratory and factory work and also for selected individuals employed on duties which render them specially liable to gross contamination, for example, personnel engaged in cleansing a contaminated room or area, or orderlies removing contaminated clothing from patients; but when such work is heavy, the spells should be strictly limited in duration.

In addition to protective suits, gloves and boots have also to be provided.

187. Gloves can be made of the same material as the suits and worn either alone or with cotton covers which can be destroyed or boiled after use.

188. Boots of the type of the Canadian field boot keep out mustard for a considerable time.

189. When protective clothing, &c., has been worn in an atmosphere of mustard, it should be decontaminated by immersion in boiling water, or in a cold saturated solution of bleaching powder, for 15 minutes. The material will stand such treatment on three or four occasions.

If grossly splashed, clothing should be destroyed.

The individual wearing protective clothing should not attempt to remove it himself after exposure to contamination, but should get an assistant similarly protected to remove it.

CHAPTER IX

COLLECTIVE PROTECTION

190. Collective protection so far as the Medical Services are concerned may be considered under the following headings :—

(*a*) Training of personnel in the recognition of the different types of gas attack, meteorological conditions suitable for such, and in the various methods of spreading gas alarms.

(*b*) The protection of buildings, dug-outs, and other shelters used for the accommodation of patients.

(*c*) Neutralization of poisonous substances and their removal from confined spaces.

(*d*) Cleansing of contaminated clothing and equipment.

(*e*) Protection of food and water supplies.

To these for convenience may be added considerations of the principles which should guide medical officers in estimating the probable number of casualties likely to arise from the use of particular chemical substances, and handling and caring for them.

Detailed instructions regarding (*a*) and (*b*) will be found in manuals of defence against chemical weapons.

191. **The protection of buildings, etc.**—In the selection of sites for dressing stations, &c., medical officers should consider the suitability of a particular location not only from the point of view of shelter from shell fire but also as regards exposure to gas. If chemical weapons are being extensively employed, it is well to avoid such places as narrow ravines where there is no free current of air and where gas may hang about for a considerable time.

When a building, cellar, or dug-out is selected for accommodation of patients, steps should be taken to protect it by means of gas-proof curtains or similar appliances.

The following is the accepted design for gas-proof dug-outs (*vide* Manual of Field Works (all arms), 1925, chapter IX, Section 66.).

192. "The entrances to all dug-outs. shelters, and mine shafts within the alert and ready zones should, if possible, be provided with gas-tight doors or with curtains of anti-gas material, fitted so as to give a good joint at the sides and bottom of the doorway, thus stopping all draughts. If two

curtains are used with a space between them complete protection is obtained, and it is possible to enter or leave the dug-outs without introducing appreciable quantities of gas."

A frame of 4 inch by 1 inch, timber, covered with anti-gas material is fixed flush with the wall, sloping outwards at an angle of 20° from the vertical. Anti-gas material is cut to the required size, so that when fastened to the top of the frame it will close the entrance completely with about 9 inches resting on the ground (Plate 1, page 90.) Three pairs of laths are nailed horizontally to the curtain to keep it stretched. The lath on the underside must be one foot shorter than the one on the front so as to clear the frame (Plate 2, Fig. 1, page 91). The lowest of the laths should be four inches from the floor. Two curtains should be provided, as shown in the diagrams. The frame for the inner curtain should slope inwards, as shown in Plate 3, page 92. All wires and pipes must pass through the frame, which may be widened on one side to allow of this, and the hole through which they pass must be made gas-tight. They must not interfere in any way with the adjustment of the curtain (Plate 2, Fig. 2). The curtains should not be less than three feet apart, so as to allow a man to stand between them and adjust one before raising the other. The distance must be increased for dressing stations to allow stretcher cases to be carried in.

193. "Frames for gas curtains should be built into the entrances of pill-boxes and other shelters while the entrances are in course of construction. Machine gun loopholes in pill-boxes should be lined with wood on the inside edges, so that they may be closed with frames covered with anti-gas material. Openings in the sides and roofs of shelters and cellars must be provided with curtains or closed with sandbags, so that no gas can enter. Care must be taken to provide means for closing ventilating shafts and flues.

"When not in use curtains must be kept rolled."

194. When a gas alarm is given the following general precautions should be taken in an occupied building or other shelter.

(*a*) All windows and doors should be closed and rendered as gas proof as circumstances permit.

(*b*) Fires should be extinguished.

(*c*) Ventilators should be plugged.

195. **The neutralization of poisonous substances and their removal from confined spaces.**—After a gas attack *when the surrounding area is free from gas*, fires should be lighted in occupied rooms or shelters, as these help to dissipate any gas which may have entered.

In trenches the lighting of fires so as to cause an upward current of air and the use of fans improvised from sand-bags or other materials are also recommended.

196. The removal of persistent gases is more difficult. Mustard gas liquid spilled upon the ground will continue to give off vapour for a considerable time.

However, bleaching powder reacts with this substance to form a harmless compound. The following examples will serve to illustrate its use for this purpose.

(*a*) An area contaminated by mustard gas liquid, *e.g.*, a shell or bomb hole, should be treated with a mixture of bleaching powder and dry earth (one part bleach to two of three parts of earth), the operator taking care to work from the windward side and afterwards to cleanse spades and other implements used during the process. The bleach and earth mixture should be spread in a layer about 3 inches deep over the contaminated area and for 2 or 3 feet round it. It is obviously necessary to limit this method of treatment to ground in close proximity to areas which must be occupied. If no bleaching powder is available freshly dug earth sprinkled thickly over the contaminated ground will help to neutralise mustard gas liquid.

(*b*) If the floor of a building is contaminated sufficient earth (dry if possible) should be sprinkled over the contaminated area and for 2 or 3 feet round it to form a thin covering. A mixture of bleaching powder and dry earth (1 part bleach and 2 or 3 parts earth) should then be sprinkled over this layer and should be left in contact for at least 24 hours. The building should be vacated and thoroughly ventilated for at least a day. An alternative method is to treat with a solution of bleaching powder or of hypochlorite. This is particularly applicable to wooden floors.

If the floor is of wood the contaminated portion if heavily infected should, after treatment as above, be cut out and burnt; if this is not practicable the treatment with bleach should be repeated.

If the floor is of stone or brick, after treatment as above, the contaminated area should be washed with a solution of sodium silicate (1 part silicate to 3 parts of water), allowed to dry, and then again washed with the same solution.

Bleaching powder by itself should not be applied directly to mustard gas liquid, since the reaction between them is accom-

panied by generation of great heat, which may cause severe burns or may even give rise to fires.

Bleaching powder rapidly loses its efficiency when exposed to air and supplies should be renewed at frequent intervals and kept sealed.

To avoid casualties it is important to limit as far as possible the number of persons engaged in cleansing or neutralizing contaminated places.

All persons not actually employed in the operation should be forbidden to approach the spot.

197. Transport, such as stretchers, ambulance wagons and motor ambulance cars used for the conveyance of patients whose clothing is heavily contaminated with mustard gas should be cleansed before again being used. For this purpose it is sufficient to wash them thoroughly with a solution of commercial sodium hypochlorite and bicarbonate of soda (1 to 1½ lb. bicarbonate of soda to a 4 gallon bucket of hypochlorite solution).

198. **Cleansing of Contaminated Clothing and Equipment.**—The methods available for cleansing clothing and equipment contaminated by mustard may be classified as follows:—

199. *Evaporation.*—Clothing lightly contaminated by vapour may be rid of it by exposure in the open air. Two to seven days usually suffice in summer, but a longer period is required in winter.

Fairly heavy vapour contaminations may be removed by exposure to a current of air heated to 100-120°C. for 3 hours.

200. *Hydrolysis.*—Cold water slowly hydrolyses mustard gas, and articles contaminated with the vapour may be cleansed by immersion in running water for a period of from 5 to 30 hours. Immersion in hot water at about 90°C. accelerrates the process, which is further aided by the addition of soap to the water or of washing soda (2 per cent.) or of sulphonated oils, such as Turkey Red Oil.

201. The most practical field method for cleansing large quantities of clothing contaminated by vapour is the use of current steam. In the majority of cases an exposure of 10 to 20 minutes from the time the steam issues from the receptacle in which the articles are placed is sufficient, but if on removal any of the articles continue to smell of mustard the process should be repeated. Any of the field steam disinfectors such as the Lelean Sack, the Serbian barrel, or the Manlove-Alliott apparatus are suitable for the purpose.

Steam, however, cannot be relied upon to cleanse grossly contaminated articles, *e.g.*, when spattered with drops of the liquid.

202. *Oxidation.*—Bleaching powder is the substance used for the destruction of mustard by this method, which is chiefly applicable to such articles as boots, gloves, equipment, rifles, &c. Dry bleach may be used or a thick paste of bleach may be made with water (1 part bleach to 3 parts of water), and this should be smeared by means of a rag over all parts of the article to be cleansed and should be left in contact for 3 to 4 hours. In the case of boots dry bleach may also be brushed into the seams, and it is useful to have a receptacle full of bleach at the entrance to dug-outs, &c., so that persons entering may dust their boots with it, and so avoid carrying in mud contaminated with mustard.

203. *Chlorination.*—Exposure to an atmosphere of chlorine gas (1 part per 100 of air) for 5 minutes will cleanse lightly contaminated articles.

204. *Extraction.*—Methylated spirit, naphtha, benzene, kerosene, petrol, and similar solvents may be used for extracting mustard gas from contaminated articles. The method is chiefly applicable to articles such as leather, which cannot be cleansed by other means. Since fat is extracted with the mustard, leather articles must subsequently be re-greased.

205. When articles are grossly contaminated, *e.g.*, with drops of liquid, the above mentioned methods, with the exception of extraction, are either ineffective or else hydrochloric acid is liberated during the reaction in such quantities as to destroy the fabric, *e.g.*, in the case of clothes. Therefore, in cases of contamination of this nature if some method of extraction is not available the articles must be destroyed.

Such destruction should be carried out under skilled supervision by personnel wearing protective clothing. Contaminated articles may be either buried or burned. If buried they should be covered by at least 18 inches of earth, which should be well pressed down. If burned, it should be remembered that a considerable amount of mustard gas vapour may be driven off in the process, so that during the operation due precautions should be taken to prevent contamination of the personnel engaged or of other persons.

206. It must be remembered that if in the future mustard gas is used from the air not only personal equipment and clothing but also the equipment of units may be grossly contaminated. After such an attack responsible officers should carefully inspect the equipment on their charge to determine which articles are contaminated, which can be cleansed and

which must be destroyed and replaced. In cases of doubt the advice of an expert should be sought.

207. **Protection of Food and Water Supplies.**—Where food, unprotected by tin containers, has been exposed to contamination by liquid mustard, lewisite or the arsenical warfare gases it should be destroyed. Tinned foods are safe to use after the tins have been decontaminated. The gaseous vapours alone will not render food harmful.

208. **Decontamination of the Respirator.**—The respirator consists of:—

(*a*) The facepiece with the connecting tube.
(*b*) The container.
(*c*) The haversack.

209. The decontamination of these different parts will depend upon the degree and mode of contamination, that is to say, whether by vapour or by liquid.

210. In the case of the facepiece contaminated by vapour, the best method is by exposure of the whole facepiece to a current of hot air. Should hot air not be available, a slower and less reliable method would be to hang the facepiece in the open air for varying periods according to the temperature, the period being shorter for high temperatures. The facepiece should not be subjected to the direct action of the sun's rays, which have a deteriorating effect on the rubber. This is particularly the case in tropical countries. The chlorine method of treatment mentioned in para. 203 may also be applied. If the contamination is by liquid mustard gas, it is advisable to destroy the facepiece as the liquid will inevitably penetrate it.

211. As regards the container, contamination by vapour can be disregarded. Contamination by liquid mustard may, however, be caused by heavy contamination of the haversack. In such a case the container should be treated by carefully wiping with mineral naphtha. Methylated spirit should not be used, since this may remove the lacquer. Under no circumstances should the naphtha be allowed to get inside the container.

212. In the case of the haversack, the same methods of decontamination as are applied to the facepiece hold good. Liquid contamination entails the destruction of the haversack.

212a. Water contaminated by mustard gas or lewisite should not be used for washing or drinking purposes.

It must be remembered that if water contaminated with arsenical compounds is taken, it may lead to arsenical poisoning.

CHAPTER X

PREVENTION AND HANDLING OF CASUALTIES FROM CHEMICAL WEAPONS.

213. In chemical warfare the element of surprise and the effects which gas has on moral are factors of great importance. Surprise can be combated by prolonged training in defensive measures, particularly as regards wearing respirators and by strict discipline.

The effect on moral is more difficult to deal with, since it is brought about both by the fear of the unknown and also by the strain which constant watchfulness for gas alarms imposes upon troops.

214. The best measures to adopt in maintaining moral are:—

(*a*) Careful and thorough teaching upon the uses and limitations of chemical weapons, and

(*b*) Watchfulness on the part of medical and other officers for the incipient signs of nervous strain. As soon as these appear in any individual he should be given a rest or removed to a locality of comparative safety.

Moreover, medical officers should remember that all men reporting themselves as gassed are not necessarily genuine cases. Men may quite honestly believe themselves to be gassed when in reality they have only smelt the fumes of high explosive, or of more toxic substances in such concentrations and for such a length of time as will do them no harm. Such cases require firm handling and no patient should be labelled as a gas case without careful examination and sifting of evidence.

215. Casualties from chemical weapons may be classified as follows:—

(*a*) Slight cases.
(*b*) Early acute cases.
(*c*) Late acute cases.

In each class correct treatment and disposal depends upon accurate knowledge on the part of medical officers both as regards the clinical conditions to which poisoning gives rise and also as regards the tactical uses of this arm.

The slight cases include those mentioned above, cases suffering from the effects of lachrymators and a large percentage

of the cases of exposure to toxic smokes, *e.g.*, the arsenical compounds.

For many of these, removal from the toxic atmosphere, rest and refreshment are all that is necessary, and the majority do not require evacuation beyond the divisional area.

Exposure to arsenical compounds may, however, in some cases result in acute illness which renders the patient unfit for duty for a period varying from a few days to a fortnight.

The early acute cases are those arising from exposure to the lung irritants and the necessity for care in the time and mode of evacuation of these has already been emphasised.

The late acute cases are those arising from the vesicants. The lesions do not appear until some hours after exposure, and it is therefore difficult to estimate how soon after an attack or in what numbers they will arrive at medical units. In the early stages of the lesions these casualties may be evacuated as walking or sitting cases. It is necessary to rid such cases of their contaminated clothing as early as possible so that they may not further infect themselves or others.

216. **Gas Centres.**—When gas casualties are numerous and the military situation permits (*e.g.*, in position warfare), it may be advisable to tell off certain units, *e.g.*, Field Ambulances or Casualty Clearing Stations as Gas Centres, and to equip and organise them for this special purpose. Normally, however, all forward Medical Units should be prepared to receive and treat any kind of casualty.

217. If such special centres are established it is advisable to locate them as far forward as possible, so as to avoid unnecessary movement for patients suffering from œdema of the lungs and also so that mustard gas cases may be kept as near their units as possible. In many of these cases there is a tendency to develop neurosis in one form or another; and the further such patients are removed from their units the more difficult will it be to get them back.

218. Such centres should be so organised as to facilitate rapid sorting and treatment. Accommodation should consist of a receiving room, a place for contaminated clothing and equipment, a lavage room for eye cases, baths, and wards for serious and slight cases. The wards for the serious cases should be equipped with apparatus for continuous administration of oxygen either by the Haldane apparatus, or, if this is not available, by some such methods as the following:—

A lead from the oxygen cylinder fitted with a fine adjustment valve is taken to an oil drum which acts as a pressure reducing chamber, and from this several rubber leads branch off to nozzles which can be taken to the bedside, each being con-

trolled by a stop-cock. This method may be developed by distributing the oxygen through lead piping having a nozzle over each bed.

Another device enables patients already gassed to have oxygen continuously even though a wave of gas reaches as far back as the gas centre. At the bottom or top of respirator containers nozzles are fitted. These communicate by means of rubber connections with the oxygen delivery pipes. Thus when the facepiece is adjusted the patient can obtain oxygen through his mask.

219. Though it is unnecessary to establish special hospitals at the base for the treatment of gas cases, it may be advisable to allot certain wards for research on new forms of treatment and also to arrange in Convalescent Depots for special instructors to train by graduated exercises patients who suffer from functional disorders of the heart.

220. It may also prove necessary to have available at the base teams of specially trained medical officers, nurses and orderlies to supplement the personnel in forward medical units in times of stress.

221. Further, gas cases should, when evacuated to the United Kingdom, be sent to hospitals staffed by personnel who have experience of their complaints. In the Great War through lack of such experience patients were frequently retained in hospital for unnecessarily long periods to the detriment of themselves and the service.

222. **Estimation of Casualties.**—Experience does not allow of any close estimation of the number of casualties likely to arise in the future from an intensive use of chemical weapons, but it may be stated that with highly disciplined troops who have been thoroughly trained and accustomed to the use of the respirator the percentage of casualties from lung irritants and toxic smokes should be low. Such casualties would chiefly arise as a result of a surprise and concentrated attack.

223. In the case of mustard gas the number of casualties must to a great extent depend upon whether the military situation demands traversing or holding for a time a contaminated area. Should such a situation arise medical units must be prepared to deal with much larger numbers of casualties than those allowed for when only weapons other than chemical are used.

CHAPTER XI

FIRST-AID TREATMENT AND DISPOSAL OF CASUALTIES ON BOARD SHIP

224. The medical officer will be called upon to deal with casualties arising from persistent and non-persistent gases. He will have made himself acquainted with their mode of action, the symptoms and pathology produced by them and their treatment, and be in a position to determine the kind of gas producing casualties at the time. It is not anticipated that casualties caused by lung irritants, except nitrous fumes, will be met with at sea, and the probability of any casualties arising from the use of lachrymators and sensory irritants is a remote one. Should such gases, however, be used, the immediate wearing of the respirator will afford complete protection. It is extremely important that the medical officer should bear in mind the possibility of some of the personnel seeking medical advice on flimsy grounds of being gassed. It is of the greatest importance that every man in a ship should remain at his post, and it is incumbent upon the medical officer to impress upon all personnel in a ship that the inhalation of a moderate amount of sensory irritants, or the irritant effects of a lachrymator, present no danger, and cause nothing more than a temporary discomfort. There should not be any cases calling for first-aid treatment and there will be no necessity for any of the personnel to leave their post. He will, however, have to exercise the greatest care in the differentiation of such cases from those caused by the inhalation of nitrous fumes, which are of a severe and dangerous nature. These cases will be dealt with later.

225. The only important persistent gas will be mustard gas. Those cases contaminated with liquid mustard are the only cases who should be permitted to leave their posts and receive first-aid treatment. If necessary, they can continue in action without fear of fatal consequences as long as they wear their respirators. When permitted they should proceed immedately to a special station previously selected as near the medical distributing station as practicable, discard their clothing, be given a bath using plenty of soap and hot water, be supplied with a fresh change of clothing and return to their post at once. This first-aid treatment should be carried out within 15 minutes

of the time of contamination, as a greater delay would inevitably involve vesication of any contaminated parts. This treatment refers to somewhat grossly contaminated cases. Should any particular part of the body, whether exposed or not, be known to be contaminated, it will then only be necessary to remove the clothing, if contaminated and treat the affected part by washing with soap and hot water as laid down in the *appendix* to this manual. The rating detailed for this special duty should wear protective clothing, gloves and, if need be, a respirator.

The contaminated clothing will be first removed to the open air and then either destroyed or decontaminated according to its degree of contamination. The station will also have to be decontaminated.

In the event of cases of blistering resulting, those extensively burnt or requiring prolonged or special treatment, for instance, eye cases, should be transferred to a hospital ship or hospital. The less serious cases can be treated on board.

Toxic Gases Not used as Offensive Weapons.

226. Of all the toxic gases not used as offensive weapons, the most important and those most likely to be met with are :—

(*a*) Nitrous fumes.
(*b*) Carbon monoxide.
(*c*) Arseniuretted hydrogen.
(*d*) Chlorine.
(*e*) Ammonia.

227. (*a*) **Nitrous fumes.**—These are given off when detonation is incomplete or from burning cordite. The more imperfect the combustion, the greater will be the amount of nitrous gases produced. The period of exposure for the production of symptoms varies with the percentage of the nitrous gases present, the more prolonged the exposure, the more rapid and serious will the results be. In some cases a very short exposure may produce serious results. The initial symptoms at the time of exposure are slight irritation in the nose and throat, a feeling of constriction and perhaps pain in the chest, some irritating cough, accompanied by headache, smarting of the eyes and perhaps a slight attack of vomiting. These initial symptoms are merely transitory and then follows a latent period during which the patient feels quite well again. This latent period or time of delayed action varies from two to twenty-nine hours, taking the extreme cases. The greatest number of cases occur, however, between the tenth and twentieth hour after exposure to the fumes. Because of the slight initial effects, these fumes are particularly dangerous,

as men may fail to realise the danger. Once the latent period is over, the symptoms and signs of acute pulmonary congestion and œdema with its accompanying cyanosis appear rapidly. This condition may be ushered in by a stage of irritation and spasm, just as in the cases of chlorine poisoning and is followed by a state of acute pulmonary congestion and œdema, which in fatal cases may occur with almost explosive violence, frothy blood-stained fluid pouring from the mouth and nostrils, while the patient tosses wildly about in bed, vainly struggling for breath, and acutely conscious of his sufferings all the time.

With regard to treatment, in the case of men who have undoubtedly been exposed to nitrous fumes, from whatever cause, it is most important to take them off duty for the next 48 hours, and keep them under observation, and at rest, for the period of the delayed action, so that the cases as they arise may receive the immediate medical attention that is so essential for their cure.

To relieve spasm before secretion is great, and when it has begun, an emetic such as zinc sulph. grs. xxx is very useful in cases where vomiting has not occurred, as the vomiting is accompanied by a great amount of frothy fluid.

228. Oxygen administration and venesection are extremely important. These two forms of treatment will be found detailed at paras. 80 and 81 of this manual. The use of cardiac stimulants and expectorants will be helpful as the occasion arises. The same precaution of keeping the patient at rest after being gassed, as pointed out in the case of phosgene earlier in this manual, is imperative.

229. Men should be warned that air which has even the slightest odour of nitrous gases is dangerous, and that, although, it may only give rise to trivial respiratory discomfort at the time, serious results are likely to follow later. When explosions or fire involving explosives occur on board a ship, the area involved should be a prohibited one unless masks are worn. The service respirator protects against nitrous fumes for a short time, but the compartment should be vacated and ventilated as quickly as possible.

(*b*) **Carbon monoxide.**—This gas will often be found associated with nitrous fumes. Its mode of action, pathology, symptoms and treatment will be found at para. 125 *et seq.* of this manual. Special attention must be drawn to the treatment by breathing air mixed with carbon dioxide to the extent of 3-5 per cent. in view of the fact that cylinders of carbon dioxide are always available in most ships. As the service respirator does not afford protection against carbon monoxide, the service shallow water diving dress, which is a self-contained oxygen apparatus can be used.

(*c*) **Arseniuretted Hydrogen.** (Arsine).

This gas has been met with in submarines during the war when casualties occurred. Its origin was traced to the use of impure material in the battery. A detailed account of its mode of action, and symptoms will be found at para. 136 *et seq.* of this manual.

The service respirator protects against arsine for short periods.

(*d*) **Chlorine.**—This gas may be encountered particularly in submarines through the accidental access of sea water to the batteries when chlorine is evolved by electrolysis. The respirator gives complete protection.

(*e*) **Ammonia.**—This gas may occasionally be met with in certain ships in which it is utilised for refrigerating and cooling purposes. It is carried in the liquid form in cylinders. The casualties likely to result from the accidental liberation of this gas will be from inhalation affecting the respiratory passages, and from its action on the eyes and skin. The upper air passages and bronchioles are chiefly affected, these parts exhibiting well-marked signs of irritation and inflammation with formation of tenacious mucus, suggestive of an acute bronchitis. Coughing, burning in the throat and vomiting are frequently present. The severity of the symptoms will depend upon the concentration of the gas. As regards skin effects these again will depend upon the concentration, varying from marked and immediate skin irritation in high concentrations to a chronic dermatitis in the case of a long-continued exposure to a low concentration. As regards the eyes, well-marked lachrymation is produced, and in the case of long-continued exposure to low concentrations, a chronic conjunctivitis is likely to develop.

230. *Treatment.*—In case of casualties resulting from inhalation, immediate removal from the atmosphere containing the fumes is the first essential. A cloth dipped in vinegar and applied to the mouth and nose will afford relief. Irritation to the eyes should be treated by bathing with boric lotion. Skin trouble should be treated on the ordinary lines.

913. The service container will protect against ammonia in a concentration of 1 in 50 by volume (which is of course very high) for 6½ minutes. and for longer periods against lower concentrations. As ammonia is very soluble in water some measure of protection is afforded by the application of a cloth soaked in water and applied to the nose and mouth. For the same reason if water is sprayed on a leak, the concentration will be greatly reduced.

APPENDIX I

PROCEDURE IN CASE OF ACCIDENTS WITH MUSTARD GAS

In the event of contamination or suspected contamination of the skin with mustard gas liquid, the following procedure will be followed:—

(*a*) The affected part should be thoroughly scrubbed with soap and water *for* 5 *minutes*, changing the water and rinsing out the brush two or three times during this period. A nail brush (or pumice stone) should be used except on tender parts of the skin. The nail brush should be boiled in water afterwards.

(*b*) If soap is not available, bleaching powder should be made into a cream, lathered all over the affected part, and left for 2-3 minutes. At the end of that time, the bleach should be washed off thoroughly with water.

N.B.—The above treatment should be carried out immediately after contamination, or with the least possible delay. Should delay be unavoidable, the treatment should still be carried out, as subsequent injury will thereby be greatly diminished.

1. *Persons exposed to the vapour of Mustard Gas should*, as soon as possible, remove their clothing, and bathe from head to foot, using plenty of soap.

2. *If any mustard has got into the eye*, wash the eye thoroughly with the special lotion (normal saline) provided, getting an assistant, if available, to pour it into the eye. If no special lotion is available, carry out the same procedure with ordinary water, tepid if possible. In either case, report to the Medical Officer without delay after above treatment.

3. *The chief things to do* are to have any contaminated clothing removed, and to cleanse the affected part from Mustard as directed above, *without spreading contamination to other parts*, and without a moment's avoidable delay.

4. *Disposal of contaminated clothing*:—

(*a*) Clothing which has been exposed to Mustard Gas vapour or liquid should be regarded as dangerous. It should be collected in a covered air-tight

receptacle such as a bin and transported to a place where it can be dealt with under expert supervision.

(*b*) When it is certain that the contamination is slight, by vapour alone, decontamination of clothing can be carried out by hanging in a current of air for 24 hours or longer until all smell of mustard has disappeared.

(*c*) If grossly contaminated by vapour, cleansing can be effected by exposure to current steam for 20 minutes.

(*d*) If clothing is splashed with liquid mustard, it should be burned in a bright fire. Care should be taken that personnel engaged in the operation are not contaminated by vapour given off during the process.

NO CONTAMINATED CLOTHING MUST BE WORN AGAIN UNTIL IT HAS BEEN THOROUGHLY DISINFECTED.

5. *Treatment of a spill of mustard on ground or on floors, &c.*

(*a*) *In the open.*

(i) Spread a layer, about 3 inches deep, of a mixture of dry earth and bleaching powder (2 or 3 of earth to 1 of bleach) over the contaminated area, and for 2 or 3 feet all round it.

(ii) Then cover over with a layer of earth, and erect a danger board.

(*b*) *On a wooden floor.*

(i) If in a building, open all windows, &c., to get all the ventilation possible.

(ii) Sprinkle sufficient earth so as just to cover thinly the contaminated part and 2 or 3 feet all round it.

(iii) Over the earth, spread a layer 2 or 3 inches deep, of mixture of earth, (dry if possible) and bleaching powder (2 or 3 of earth, to 1 of bleaching powder).

(iv) Leave for at least 24 hours. Then remove the earth and bleach mixture and bury it. After this, it is advisable to pull up any heavily contaminated parts of the flooring and burn it in the open.

An alternative method is to treat with a solution of bleaching powder or green solution.

(v) If there is a possibility of the walls of the building being splashed, these should be treated with bleaching powder or green solution left for 24 hours, washed down and the treatment repeated.

(Mustard is very readily absorbed by wood, and as yet, no efficient method of complete decontamination has been devised. Hence the advisability, for the present, of destruction of wood after the preliminary treatment detailed above).

(*c*) *On a stone or brick floor.*

As for wood floor in regard to (i), (ii), (iii) and (v).

After removing the bleach and earth as in (iv) above, wash the contaminated area with sodium silicate solution (1 part of sodium silicate solution to about 3 parts of water), allow to dry and repeat the treatment.

(*d*) *On machinery.*

In removing mustard gas from machinery, iron work, &c., "green" solution has some advantages over bleaching powder, but has to be made up as required, and is not so convenient for transport. As alternatives, a mixture of bleaching powder and water or a solution of sodium hypochlorite can be used. These solutions can also be used conveniently for spraying areas, walls, &c., which have been contaminated by mustard gas and are best applied when the bulk of the contamination has been destroyed by the methods recommended above.

"Green" solution is prepared by adding 1½ to 2 lbs. of sodium bicarbonate to 2 gallons of "Commercial" sodium hypochlorite solution, allowing to stand for about half an hour, while stirring frequently.

Note 1.

Contaminated clothing on a man should not be removed by the man himself, unless this is inevitable. Wherever possible such clothing should be removed by another man wearing protective clothing, but who has not been exposed to any contamination.

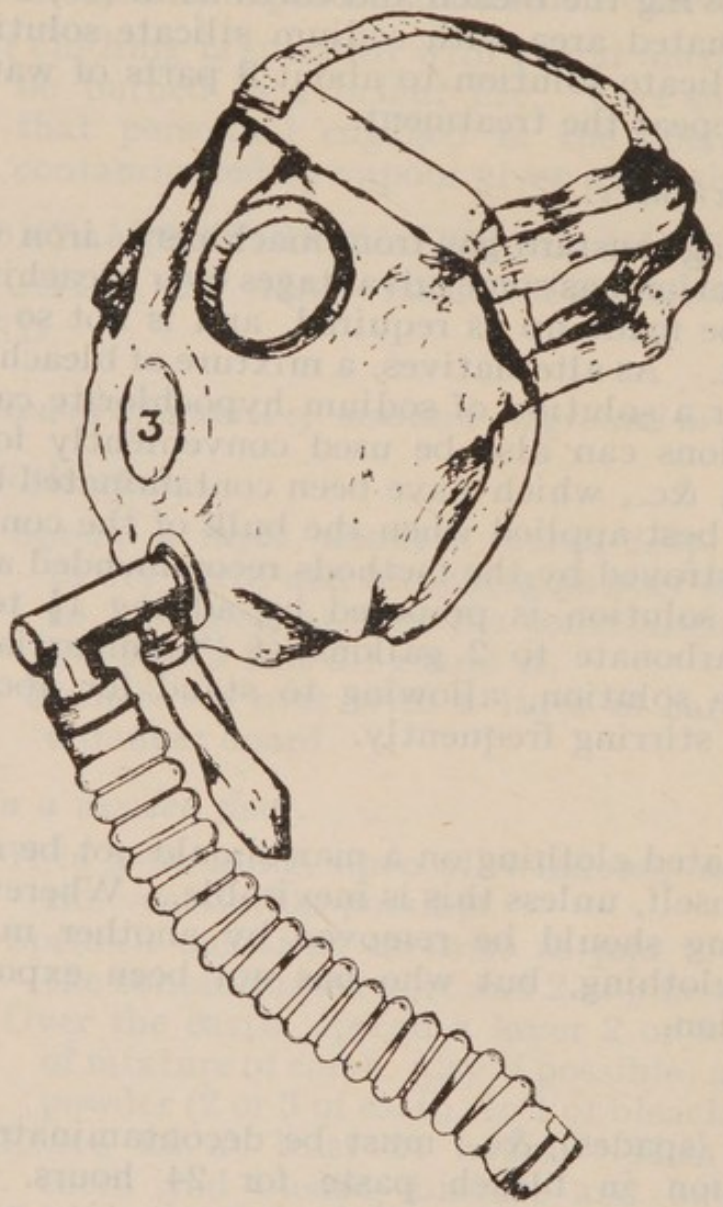
Note 2.

All tools (spades), &c., must be decontaminated after use by immersion in bleach paste for 24 hours. Protective clothing must be worn by all decontaminating personnel.

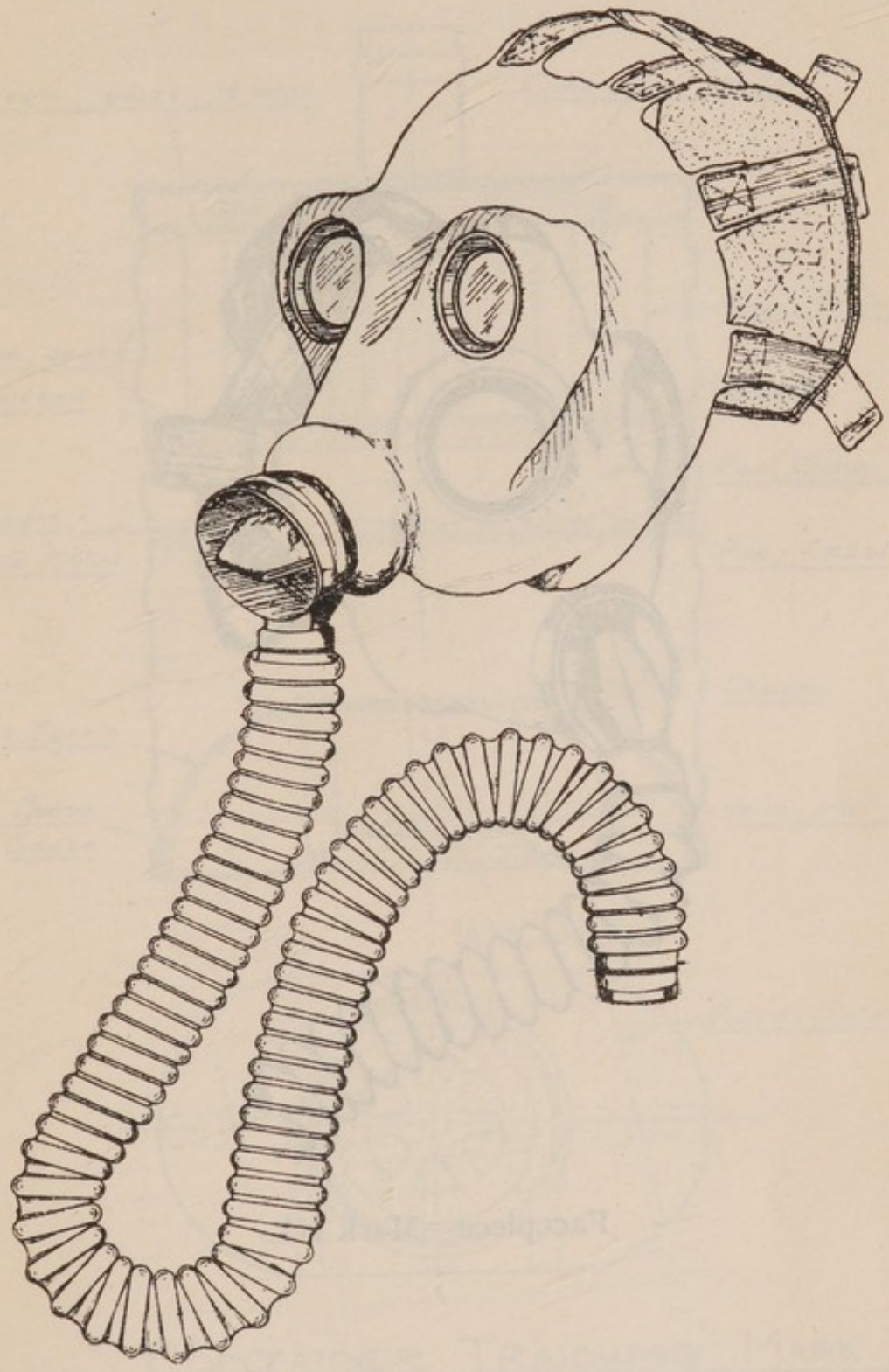
Note. 3.

It is important that the bleach used for decontamination should be kept in opaque airtight receptacles, and that fresh issues should be made at frequent intervals. Bleach exposed to the air and light quickly loses its value as a decontaminating agent.

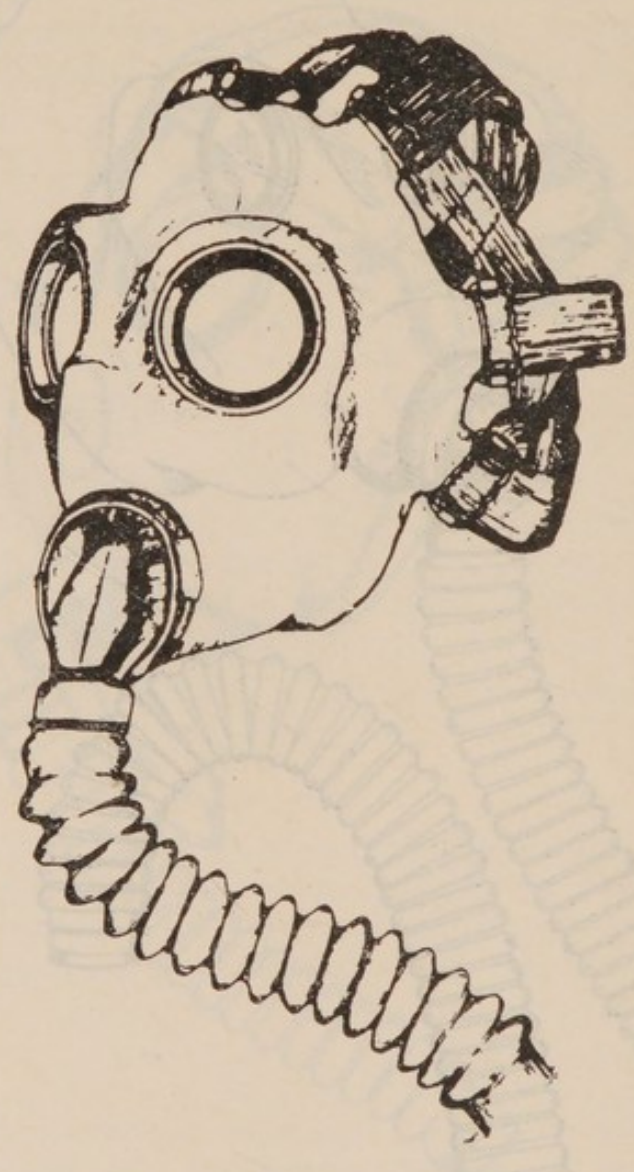
APPENDIX II



Facepiece—Mark I.

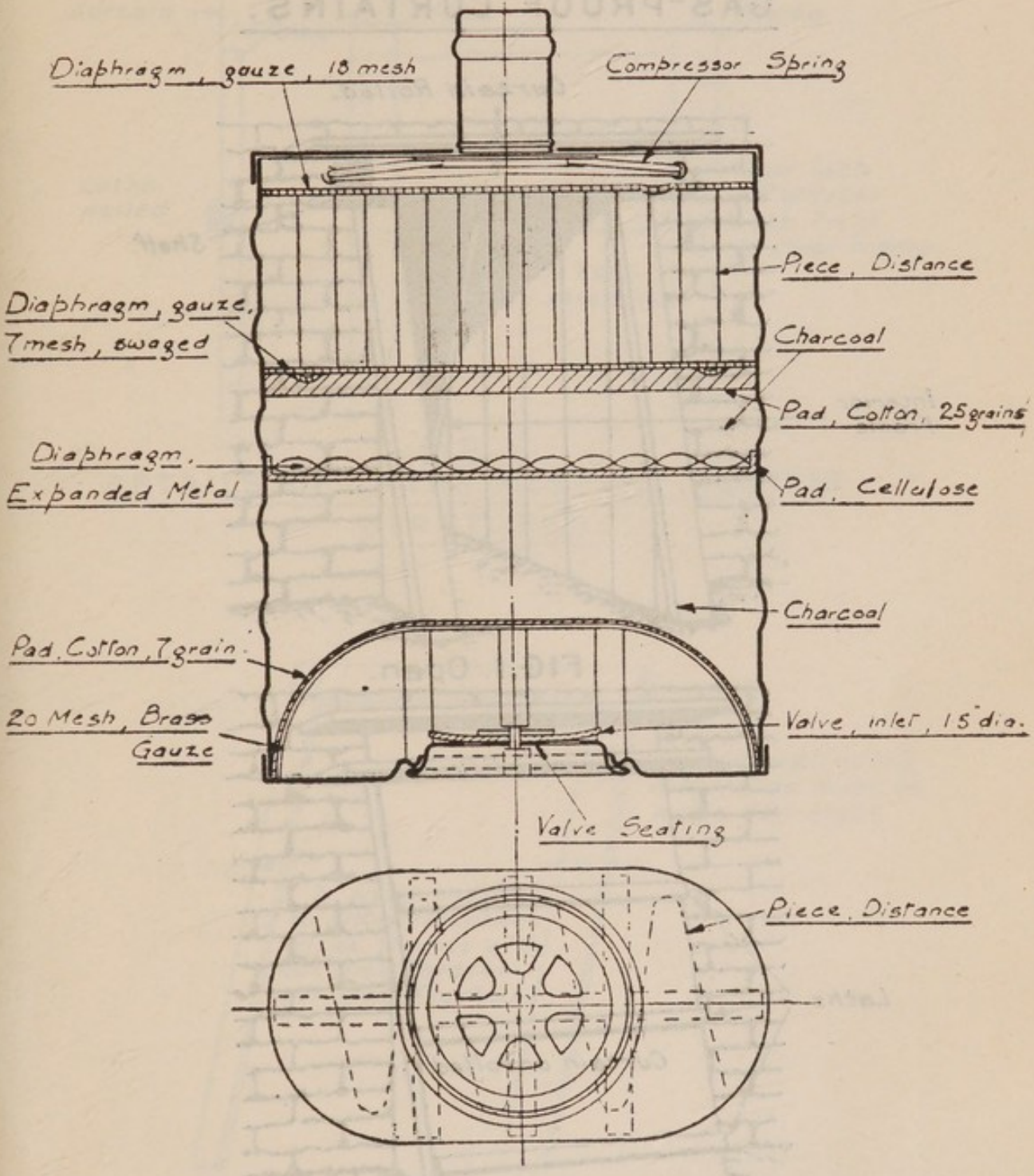


Facepiece—Mark II.



Facepiece—Mark III.

APPENDIX III



CONTAINER TRAINING. MARK. II.

METHOD OF FILLING

GAS-PROOF CURTAINS.

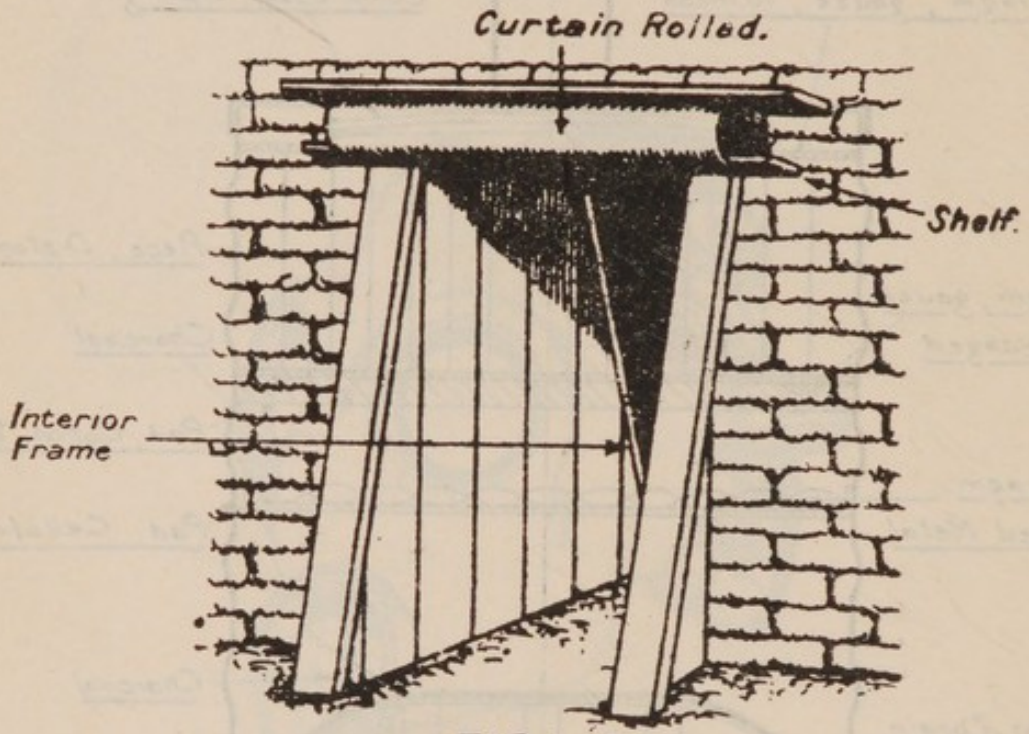


FIG. 1. Open.

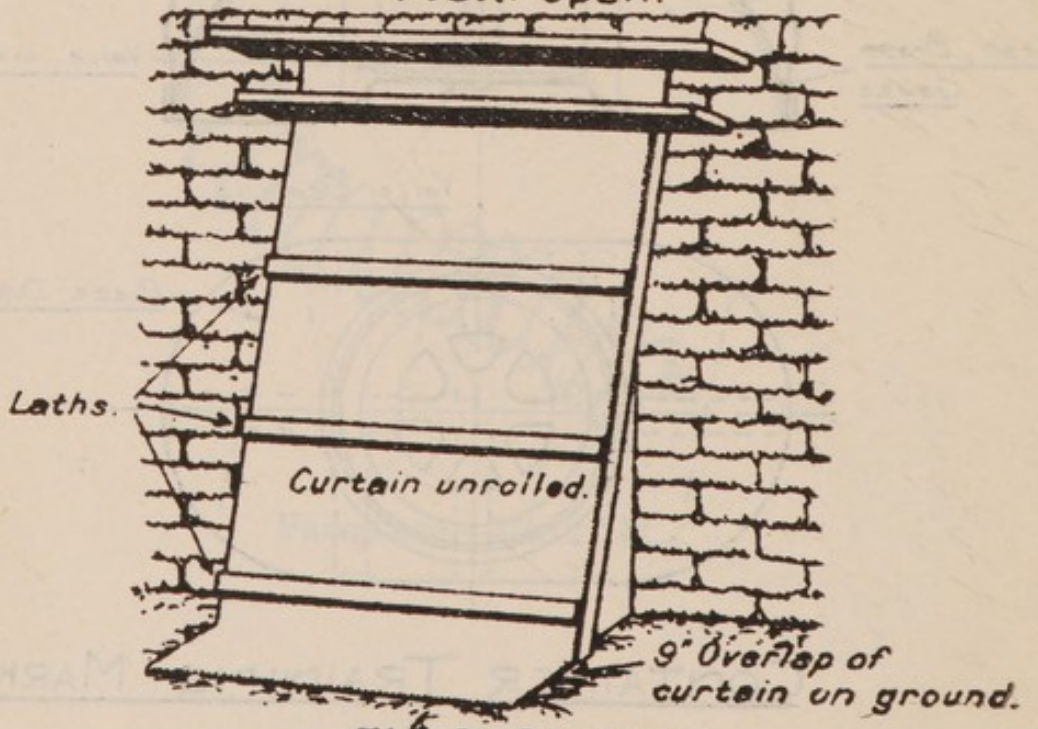


FIG. 2. Closed.

see page 71.

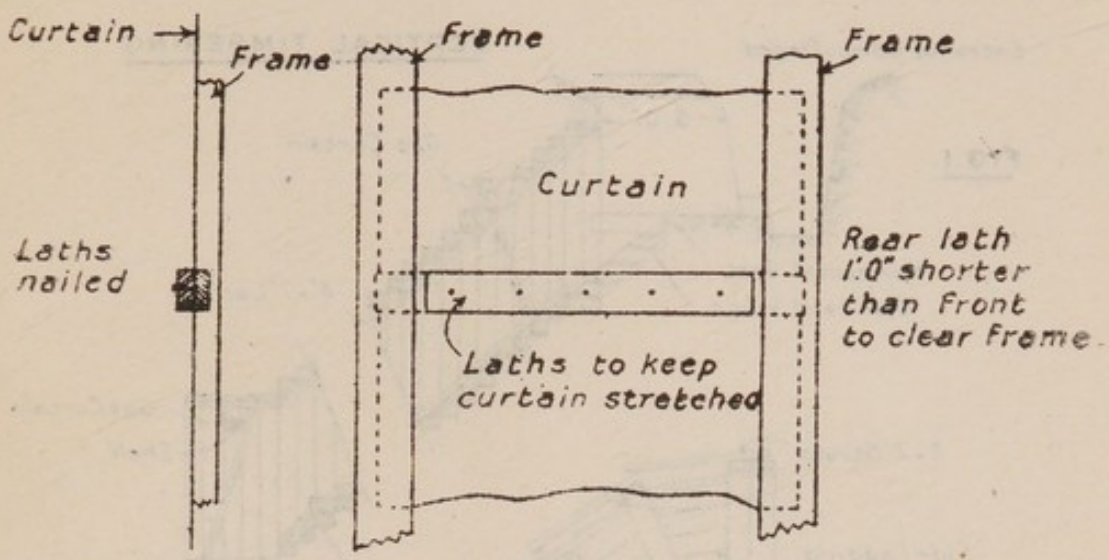


FIG. 1.

DETAILS OF LATHS KEEPING CURTAIN STRETCHED.

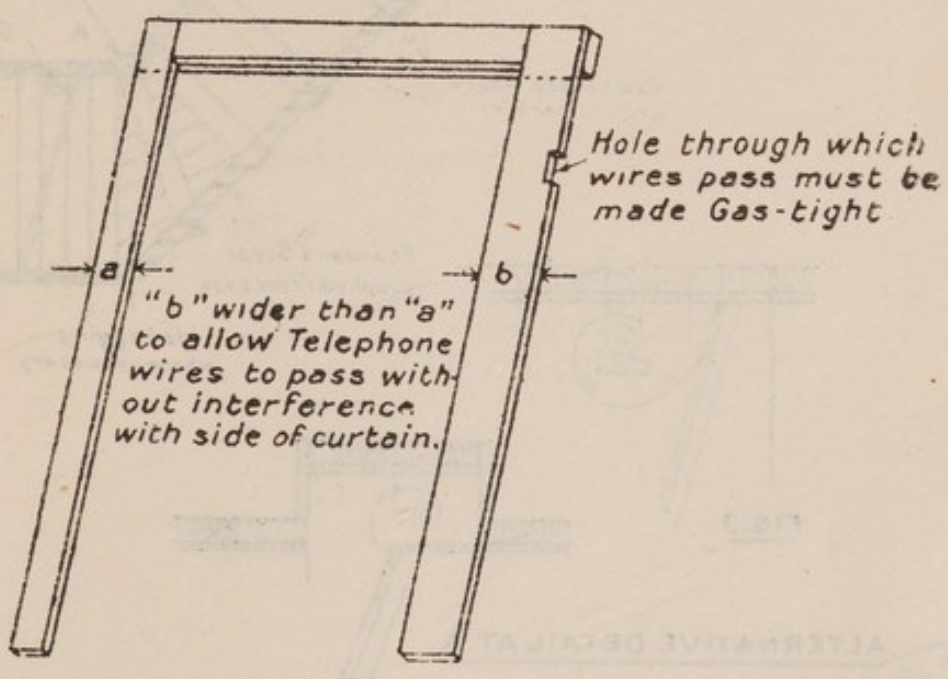
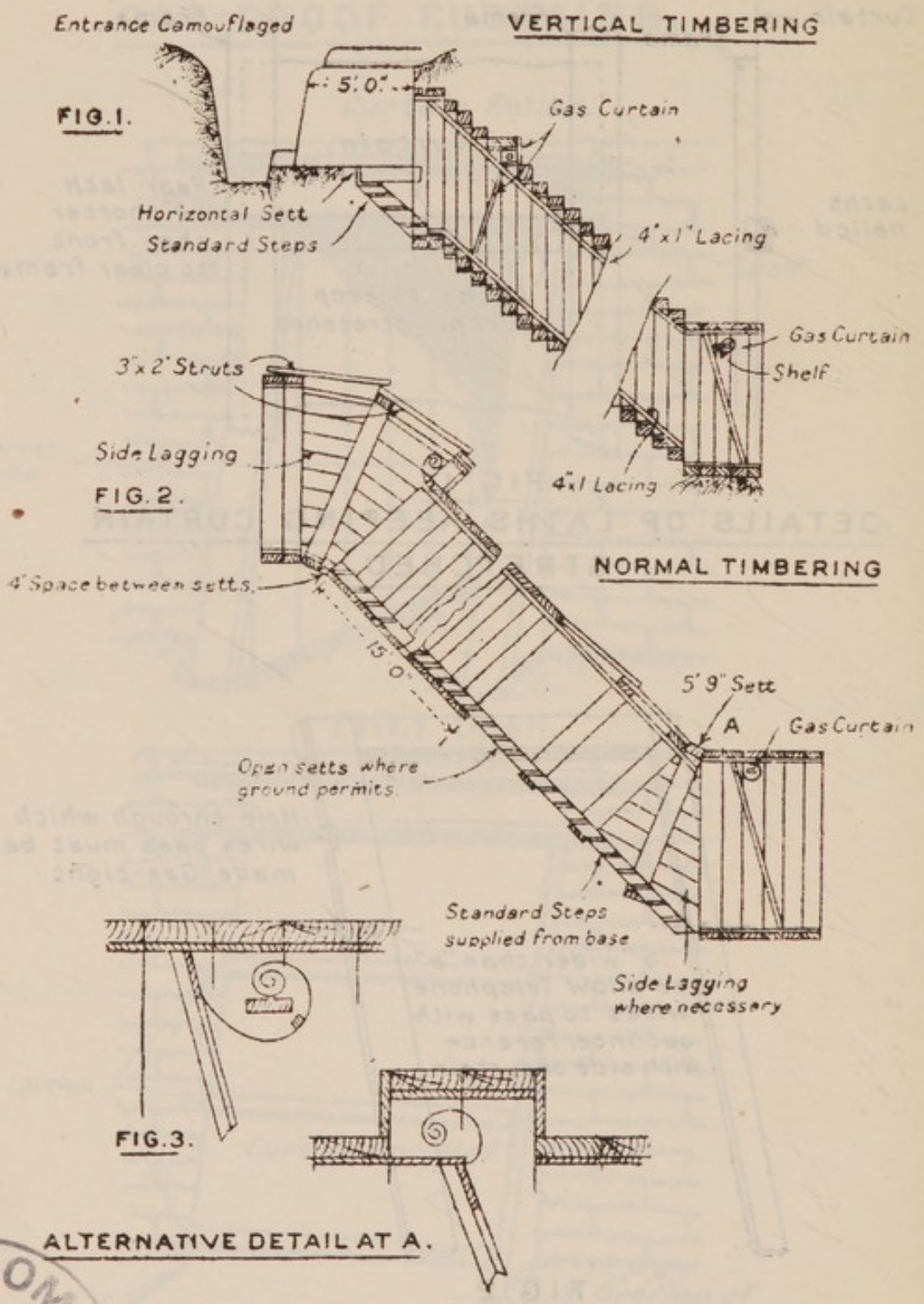


FIG. 2.

PERSPECTIVE OF FRAME WHEN TELEPHONE WIRES PASS ALONG GALLERY.

PLATE 3.



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