THE USE OF GAS-PROTECTIVE CLOTHING IN SINGAPORE

BY

Surgeon Commander E. R. SORLEY, M.D., D.P.H.

Principal Medical Officer, H.M. Naval Base, Singapore

In recent months much has been said and written about the menace of gas warfare. It is indeed a commonplace to say that protection against this product of "civilization" has become a vital matter to all the peoples of the globe. The science of gas attack and defence has been studied in considerable detail, and no problem has aroused more interest or discussion in Great Britain than the practicability of gas-protective clothing under the conditions of a modern war.

During the last year it seems that the most valuable contribution to the literature of the subject has been made by Major G. P. Crowden (1938), R.A.M.C., who instituted a series of tests in England, seeking to evolve a method which would make possible prolonged muscular effort in gas-protective clothing without the development of undue discomfort or danger to the wearer. He carried out three field tests, in which volunteers dressed in protective clothing performed strenuous muscular work for periods not exceeding forty-four minutes. Observations on body-temperature control and physiological reactions were made during and after the tests. An important object of Crowden's experiments was to ascertain to what extent bodily discomfort could be reduced by the wearing of a wetted layer of clothing closely adapted to the gas-impermeable layer of the protective suit. The materials which were used to form this external layer were flannel-ette, towelling, and khaki drill. Crowden also included in his tests an ordinary gas-protective suit (unwetted) and a gas-proof material faced with an outer fabric which could be periodically wetted.

As I have said, Crowden's experiments were conducted in England—in July, under average summer conditions. In presenting his conclusions, he claimed to have proved definitely the value of maintaining a wet outer surface on gas-protective clothing during the performance of heavy muscular work. His conclusions were:

"(a) The free evaporation of water which takes place from the wet outer surface of the protective garments increases body-heat loss provided the wet surface is in close apposition to the gas-impermeable layer of the protective clothing.

"(b) As a result of severe tests on a number of subjects working under conditions of temperature and humidity as high as are likely to be encountered in the English climate, it is concluded that if the outer surface of gas-protective clothing is maintained wet during the performance of muscular work, then the accumulation of body heat is prevented, sweating is much reduced, and the risk of heat collapse, even under hot summer conditions, eliminated.

"(c) In addition to indicating the general principles governing the effective use of artificial evaporative cooling, the tests carried out on various types of gas-protective clothing have established the following facts:

"(i) That an outer suit of wettable and wetted material, such as khaki drill, worn over Service protective oilskin clothing, enables muscular work to be carried out unimpeded and without discomfort under field-service conditions in summer weather.

"(ii) That gas-protective clothing of Service pattern but made up of gas-proof material faced with an outer wettable fabric layer periodically wetted is superior to the double garments described under (i) in facilitating the elimination of body heat.

"(iii) That a totally enclosing single-piece suit of gas-proof oilskin may be worn in safety provided an outer close-fitting single-piece suit and hood of wet fabric is also worn.

"(iv) That any one of the protective outfits described under (i), (ii), or (iii), when used as recommended, is notably superior to Service gas-protective clothing consisting of oilskin only."

Following the publication of Crowden's work, Lieutenant-Commander B. M. Douglas, R.N.(ret.), Passive Defence Officer, H.M. Naval Base, Singapore, invited me to co-operate with him in pursuing similar investigations in the climate of Singapore. We decided to perform two tests, using three subjects in each and choosing the days for performance of the tests as being typical of the Singapore climate—one day cloudy, the other unclouded. The clothing we chose for the tests was, first (Subject A), an ordinary gas-protective suit with hood and respirator; secondly (Subject B), a suit of wettable double cellular cotton with a hood of the same material and respirator worn over gas-protective clothing; and, thirdly (Subject C),

TEST 1.—Performed on Saturday, August 13, 1938

Meteorological conditions: sky cloudy; occasional sunshine; slight northerly breeze.
Dry-bulb temperature at start of test, 86°; wet-bulb temperature at start of test, 80°. Relative humidity, 77 per cent.
Dry-bulb temperature at finish of test, 87°; wet-bulb temperature at finish of test, 80°. Relative humidity, 73 per cent.

	SUBJECT A (Sick-berth Attendant Thomas, aged 30)	SUBJECT B (Leading Sick-berth Attendant Sanigar, aged 30)	SUBJECT C (Surgeon Commander Sorley, aged 36)
Clothing worn under protective clothing	Singlet, shorts, and socks	Singlet, shorts, and socks	Singlet, shorts, and socks
Observations before dressing in protective clothing	(a) General reactions: Feeling normal (b) Body temperature, 97.8° (c) Pulse rate, 78 (d) Blood pressure, 134/90 (e) Weight 12 st. 13 lb.	Feeling normal 97° 60 120/88 9 st. 8½ lb.	Feeling normal 97.8° 64 132/90 12 st. 12½ lb.
Protective clothing worn	Ordinary anti-gas suit: oilskin jacket, trousers, gloves, hood; service respirator. Rubber sea boots worn under trousers	As for Subject A plus outer suit (jacket, trousers, and hood) of double cellular cotton	As for Subject A plus outer suit (jacket, trousers, and hood) of surgical lint
Time work started	11.42	11.42	11.42
Condition of clothing at start	Dry	Wetted all over: felt appreciably cooler	Wetted all over: felt appreciably cooler
Observations during work	Began shovelling at 22 per minute Wetted all over at 11.45 Felt cooler Rewetted 11.54: said he felt "like ice" 11.58 (then shovelling at 25 per minute)	Began shovelling at 25 per minute Rewetted 11.47: cooler " 11.50: " " 11.54: " 11.58 (then shovelling at 18 per minute)	Began shovelling at 32 per minute Rewetted 11.46: much cooler " 11.52: asked for rewetting " 12.5: asked for rewetting 12.7 (then shovelling at 28 per minute)
Time work stopped			
Observations just after stoppage of work	(a) General reactions: Not fatigued. Perspiration + + +. Shorts and singlet wet; socks damp. Hands "waterlogged" (b) Body temperature, 100.6° (c) Pulse rate, 140 (d) Blood pressure, 120/85 (e) Weight, 12 st. 11 lb.	Not fatigued. Perspiration + +. Shorts and singlet damp; socks dry. Hands "waterlogged" 100° 114 100/80 9 st. 6½ lb.	Not fatigued. Perspiration + + +. Shorts and singlet wet; socks dry. Hands "waterlogged" 99.6° 150 120/86 12 st. 10½ lb.
Summary of work done	Worked steadily for 16 minutes without rest, and nothing approaching serious fatigue resulted	Worked steadily for 16 minutes without rest, and showed no signs of serious fatigue	Worked steadily for 25 minutes without rest, and nothing approaching serious fatigue resulted

TEST 2.—Performed on Friday, August 19, 1938

Meteorological conditions : sun bright ; sky clear ; northerly breeze.
 Dry-bulb temperature at start of test, 85° ; wet-bulb temperature at start of test, 80° . Relative humidity, 79 per cent.
 Dry-bulb temperature at finish of test, 90° ; wet-bulb temperature at finish of test, 78° . Relative humidity, 57 per cent.

	SUBJECT A (Leading Sick-berth Attendant Scott, aged 28)	SUBJECT B (Sick-berth Petty Officer Williams, aged 36)	SUBJECT C (Sick-berth Attendant Thomson, aged 39)
Clothing worn under protective clothing	Singlet, shorts, and socks	Singlet, shorts, and socks	Singlet, shorts, and socks
Observations before dressing in protective clothing	(a) General reactions : Feeling normal (b) Body temperature, 98° (c) Pulse rate, 66 (d) Blood pressure, 125/80 (e) Weight, 9 st. 7 lb.	Feeling normal 97.8° 74 120/84 7 st. 7 lb.	Feeling normal 97.6° 62 130/85 9 st. 7½ lb.
Protective clothing worn	Ordinary anti-gas suit : oilskin jacket, trousers, gloves, hood ; service respirator. Rubber sea boots worn under trousers	As for Subject A plus outer suit (jacket, trousers, and hood) of double cellular cotton	As for Subject A plus outer suit (jacket, trousers, and hood) of surgical lint
Time work started	11.10	11.10	11.10
Condition of protective clothing at start	Wetted all over : felt cooler	Wetted all over : felt cooler	Wetted all over : felt cooler
Observations during work and notes on stoppages	Began shovelling at steady rate Stopped 11.22 : temperature 100.2° ; pulse 140 Resumed 11.32 (rewetted) Rewetted 11.35 Stopped 11.38 : temperature 100.6° ; pulse 140 Resumed 11.47 (rewetted) Rewetted 11.52 Stopped 11.54 : temperature 101.2° ; pulse 100 Resumed 12.1 (rewetted) At 12.8 showed signs of flagging, but went on to finish at 12.10	Began shovelling at steady rate Rewetted 11.19 Stopped 11.22 : temperature 99.4° ; pulse 120 Resumed 11.30 (rewetted) Finished 11.33—said breathing was difficult (mask badly fitting and faulty)	Began shovelling at steady rate Stopped 11.16 : temperature 98.6° ; pulse 100 Resumed 11.22 (rewetted) Rewetted 11.35 Stopped 11.36 : temperature 100.2° ; pulse 140 Resumed 11.45 (rewetted) Rewetted 11.53 Stopped 11.56 : temperature 101° ; pulse 142 Resumed 12.8 (rewetted) Finished 12.14
Observations just after final stoppage of work	(a) General reactions : Rather tired, but not seriously fatigued. Perspiration + + + . Shorts and singlet wet ; socks dry. Hands " waterlogged " (b) Body temperature, 102° (c) Pulse rate, 152 (d) Blood pressure, 120/80 (e) Weight, 9 st. 6 lb.	Not at all tired, but held up by respiratory difficulty. Perspiration + + . Shorts and singlet wet ; socks dry. Hands not " waterlogged " 99.8° 132 110/80 7 st. 5 lb.	Rather tired, but not seriously fatigued. Perspiration + + + . Shorts, singlet, and socks wet. Hands " waterlogged " 101.2° 150 125/80 9 st. 5 lb.
Summary of work done	Worked for one hour, with three stoppages (26 minutes) : 1st, 10 minutes' rest 2nd, 9 " " 3rd, 7 " " In all did 34 minutes' actual work	Worked for 23 minutes, with one stoppage (8 minutes) In all did 15 minutes' actual work	Worked for 1 hour and 3 minutes with three stoppages (27 minutes) : 1st, 6 minutes' rest 2nd, 9 " " 3rd, 12 " " In all did 36 minutes' actual work

a suit of white surgical lint with a hood of the same material and respirator similarly worn over gas-protective clothing. We conceived the idea of the cellular and lint materials from the suggestions put forward by Crowden on the cooling power of the materials wetted and thus made closely adherent to the gas-impermeable layer of the oilskin suit.

So far as I am aware the use of gas-protective clothing in the Tropics has not yet been fully investigated ; at least, no observations have been published. This article describes investigations into the practicability of such clothing for passive defence duties in the climate of Singapore, with special reference to body-temperature control and physiological reactions during and after the performance of strenuous muscular work. In Test 1 observations were made before and after the work ; in Test 2 before, during, and after the work.

I have often heard it said that the use of gas-protective clothing in the Tropics is impossible for any useful period of time, such as would be necessary for decontamination duties in war, owing to the extreme discomfort and danger of heat exhaustion to the wearer. In the absence of any literature on the subject it seems that such statements have been made purely on assumption. It is my aim to attempt to prove or disprove this assumption and to determine whether it is possible to reduce discomfort or danger to personnel who may be called upon to perform passive defence work in Singapore.

Summary and Comments

It is interesting to make certain comparisons between the conditions obtaining in Crowden's tests and those observed in Singapore.

Type of Work Undertaken.—The work undertaken in Singapore was exactly as described by Crowden in his

experiments—namely, the shovelling of sand with Service shovels, this effort being chosen to simulate closely the mixing of bleach and earth in the duties of decontamination.

Age and Physical Condition of Subjects.—The average age of Crowden's subjects was between 26 and 27, while that of the subjects in the tests described was between 33 and 34. It is impossible for me to deduce the physical condition of Crowden's workers, but presumably they were robust men, and to be regarded as average subjects. The Singapore workers can be looked upon physically as average members of a fighting Service personnel. They were recruited entirely from the medical department of H.M. Naval Base, Singapore.

Meteorological Conditions.—Here, of course, is an obvious and pertinent comparison. While Crowden's work was performed in the summer in England with wet-bulb and dry-bulb readings not rising above 68° and 62° respectively, the Singapore work was undertaken in tropical conditions.

Amount of Work Achieved.—Considering the comparisons between the air-temperature records and the age levels of the subjects in the two series of tests, I think it will be granted that the Singapore tests were calculated to try bodily endurance more severely than those performed in England. The best of Crowden's subjects produced forty-four minutes' continuous work without distress ; the best results in the Singapore series were in Subject C in Test 1, who worked continuously for twenty-five minutes and showed no signs of fatigue ; and in Subject C in Test 2, who performed over one hour's work with three stoppages amounting to twenty-seven minutes. It was unfortunate that, owing to a defect in his respirator causing respiratory embarrassment, Subject B in Test 2 was unable to continue beyond twenty-three minutes.

Physiological Reactions.—The highest body temperature after work recorded by Crowden was 100°; in Singapore the highest was 102°. Both these records were shown by subjects who worked unaided by a wettable external layer to the protective suit. (A medical friend with whom I discussed the significance of the Singapore tests raised the objection that removal of the respirator during stoppages in Test 2—for the purpose of recording temperature and pulse—could not be permitted in war conditions, and so detracted from the value of the tests. I maintain, however, that the objection cannot be regarded seriously, since removal of the respirator—purely for recording purposes and unnecessary, therefore, in war conditions—could not aid to an appreciable extent the degree of heat elimination. Moreover, Lieutenant-Commander B. M. Douglas has suggested that, in war, situations might arise where—after the first or principal covering or removal of contamination had been achieved—it might be possible for the men who had performed this work to walk a short distance to windward and remove their respirators with safety.) The highest pulse rates recorded in the England and Singapore tests respectively were 180 and 160. A puzzling feature at first sight is the constant fall of blood pressure observed in all the subjects in Tests 1 and 2. After strenuous exercise, in the absence of circulatory collapse, one would anticipate a raised pressure. I can attempt to explain the phenomenon only by suggesting that the abrupt production of artificial pyrexia led to a pronounced vasodilatation. The loss of body weight is of little academic interest, being explained, of course, by fluid loss through profuse perspiration.

Personal Reactions.—Having taken the role of one of the workers (Subject C in Test 1), I feel entitled to record my reactions during and after the test. The discomfort I experienced had two main sources: first, the incessant pouring of sweat from my face into the respirator; and, secondly (a feature which would have been produced irrespective of protective clothing), considerable aching in the muscles of the back due to the posture adopted in the act of shovelling. The other subjects confirmed these sensations. As for my physical condition at the end of twenty-five minutes' work, I can say truthfully that I was not seriously tired, although naturally uncomfortable. I felt I could have continued work for a further fifteen minutes at least without distress.

Conclusions

It seems that the assumption regarding the impracticability of gas-protective clothing in the Tropics, at any rate in the climate of Singapore, is unwarranted, because it is possible for men of average physical condition to carry out strenuous muscular effort in gas-protective clothing for the periods of time which would be necessary under war conditions without their undergoing serious danger of heat exhaustion. Much discomfort is inevitable, but in any case it is apparent that war-time and discomfort are necessary bedfellows. Even so, it is considered extremely unlikely that any man would be required to shovel continuously for as long as twenty-five minutes without a respite.

The continual wetting, during muscular efforts, of an ordinary gas-protective suit enables considerable work to be performed, diminishing discomfort and lessening the danger of heat exhaustion. Indeed, the standard and persistence of the work displayed by subjects who wore no external water-retaining layer scarcely fell below that shown by other workers who wore water-retaining material. It seems, then, that the ordinary gas-protective suit can be made practicable for use in the climate of Singapore, provided it is kept continually wet during use.

It has been possible to confirm only in part the findings of Crowden regarding the advantage of a wetted outer layer of material closely adapted to the gas-impermeable

layer of the gas-protective suit. The imposition of a wetted outer layer certainly can achieve reduction of body temperature and discomfort, but not to an extent which renders essential the use of such a precautionary method. Wetted cellular cotton and surgical lint materials have some value as cooling agents when worn over protective clothing, but in this respect probably have no advantages over the wettable and water-retaining fabric adherent to the gas-impermeable layer, as described by Crowden. Cotton and lint in actual practice have these disadvantages: (a) their use necessitates increase of dressing and undressing times (highly important factors); (b) they would be apt to perish and shrink after boiling.

I have to acknowledge the co-operation of Lieutenant-Commander Douglas in the conception and conduct of the tests described above. I am also indebted in large measure to the sick-berth staff, H.M. Naval Base, Singapore, who, in the investigations, made of themselves willing victims, and whose enthusiasm for work remained undamped long after their persons and clothing could be so described.

REFERENCE

Crowden, G. P. (1938). *J. R.A.M.C.*, 70, 217.

Clinical Memoranda

Metastasis in Gasserian Ganglion following Carcinoma of Breast

The metastases in the various organs recorded below must have been blood-borne and had probably left the primary growth before the operation was performed. In other words, it was the floating cell leaving the primary growth early by means of the blood stream which was the cause of failure of the operation, a process which is gradually becoming more and more recognized as the cause of failure in these early cases. The lymphatic spread probably was held up in the lymphatic glands.

A married woman aged 37 was admitted to St. Mary's Hospital on March 30, 1937, with a lump in her left axilla, which she had noticed for less than a week. Previously she had been quite healthy, and had had one child eleven years before, which she had nursed.

On examination a hard lump was felt in the left axilla, not tender, the size of a hazel nut, free from the skin and deeper structures. It was thought to be a gland. The breast was mastitic and indurated, but no lump could be made out. There is no record of transillumination. The other breast and glands appeared normal.

On April 2 a complete operation was performed; three 3-mg. radium needles were placed in the axilla and three thrust down behind the clavicle. A dose of 1,368 mg.-hours was given. The pathological report stated: "Solid alveolar and trabecular polygonal-celled scirrhous carcinoma of the breast with metastases in the axillary glands. Mitotic figures were numerous." On October 18, 1937, she was readmitted for a radium plaque, and had 12,600 mg.-hours at 1 cm. distance over a local area. The skin desquamated.

In October, 1938, having been quite well in the interval, she consulted a physician for violent headaches, generalized in distribution, which had come on suddenly three weeks previously. They had continued without remission, and were associated with nausea, retching, and, finally, vomiting and running at the eyes. Both legs felt numb and she could not walk properly. Pain and numbness were present on the right side. There was loss of appetite. She had experienced mental disturbance, especially resentment of the presence of other people, and had failed repeatedly to recognize her husband. Up to the onset of these symptoms she had been able to do