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PROBLEMS OF NAVAL WARFARE UNDER CLIMATIC EXTREMES*

BY

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PART I.—LECTURE I

In these lectures an attempt will be made to show how medical research, especially during this war, has assisted the Royal Navy in its function of engaging the enemy in every type of climate. My task is rendered difficult by the fact that for considerations of security one is debarred from referring to the very numerous and important researches which have been prosecuted since the war began. These lectures, therefore, stripped of the names and labours of the many research workers in Australia and the United States, as well as at home—especially in the Medical Research Council—will appear, for that reason, bald, discursive, and unscientific. The full story cannot yet be told.

Prevention of tropical and cold-weather disorders will not be discussed, for it is intended to concentrate on three climatic aspects of naval medicine—namely, (1) naval construction; (2) clothing; and (3) efficiency. Under the first heading will be discussed how naval architects enable a ship's company to tolerate both high and low temperatures. This section will also deal with such problems as the cooling of ships, ventilation, and, in short, general habitability. The second heading will concern the modern science of clothing as an ideal means of protection against environment—"ideal" when one is mindful of the Service restrictions imposed by considerations of appearance, ruggedness, and economy in bulk. Lastly, one will discuss the impairment of efficiency under unpropitious environmental conditions; the subtle ill effects which are attributed to long service in polar or tropical waters; the selection of those best fitted to stand up to Arctic or tropical service, and the early identification of those inherently unsuited for duty under such stresses.

On looking back over naval medical history, it is clear that the sea-surgeons of Great Britain during the eighteenth century were in many respects well ahead of their colleagues ashore and that their observations were pioneer efforts in preventive medicine. But in the nineteenth century the French marine was conspicuous not only in the early adoption of steam and of ironclads but by reason of its hygienists. One recalls the excellent work of Fonssagrives and of Méricourt in this connexion and their great interest in the increasing problems of ventilation. But, all along, naval medicine can be visualized as the closest approximation to what we now choose to call social medicine, for in the Service the total environment of our personnel comes under the closest study and care of the medical branch.

NAVAL CONSTRUCTION

Ventilation has always constituted a difficult problem in ship construction. In the early days seamen relied upon natural ventilation, which later was made to supply spaces below decks by means of wind-sails and scoops, down-take shafts or "aspiratories," to which was afterwards added a system of uptakes. Artificial ventilation eventually becomes imperative. While Desagulier's fans were being installed in the House of Commons in 1734, attention was drawn to the heavy sickness rate in the fleet at Spithead. To combat this it was suggested that the

Desagulier system should be incorporated within one of the ships, but the idea was turned down by the Naval Surveyor.

About that time a Mr. Sutton became interested in marine ventilation, but could not secure the sympathy of the authorities. "I particularly remember," he wrote, "that being at a coffee-house near the Admiralty, I placed myself nigh some gentlemen of the Navy, and inquired of them, as I had before of others, as to the usefulness of a change of air; all, to a man, acknowledged it would be of the utmost service. I told them I could procure it; upon which one of the company went to another table and the rest followed him; and I heard him tell the others that he heartily pitied me, as being really mad and out of my senses." Within a few years, however, Hales's bellows ("ship's lungs") were used to circulate air throughout naval vessels. Various other mechanical systems were tried, including some which worked automatically with the roll of the ship. By 1873 the plenum principle had been introduced into monitors, and though reported upon unfavourably by Surgeon McCarthy, became adopted as the basic scheme for ventilation throughout ships of the Royal Navy.

It is obvious that both naval and civil engineers were pre-occupied at that time with the question of odours from stagnant water in the bilges and vitiation of the air from animal exhalations and fumes and gases of various sorts. Later they spoke in terms of CO₂. Only to a lesser degree was humidity considered, while the temperature of the environment was rarely, if ever, discussed.

Ventilation

The 1910 conference on tuberculosis in the Royal Navy led to an Admiralty Committee on Ventilation, which submitted its final recommendations in 1914. A minimum supply of 3,000 cu. ft. of air per man per hour was required. As an index of adequacy of air supply it was enacted that samples of air from any living-space must always contain less than 0.12% CO₂. Cubic space should not be less than 20 cu. ft. per man in sleeping-spaces, with a gap of not less than 20 in. between hammocks. A temperature of 55 to 60° F. was aimed at for living-spaces in cold weather. But the inter-wartime period was one of great mechanical achievement, so that the expansion in both matériel and personnel always outpaced the adequacy of air supply. It was evident that some of the standards set could not in practice be attained. In 1937 it became necessary to appoint a further Ventilation Commission. As the desired 3,000 cu. ft./man/hr. had proved unattainable, they tried for a standard 2,000 cu. ft., insisting that the volume should never be less than 1,500 cu. ft./man/hr. (i.e., a change of air every five minutes). They found it impracticable to lay down a definite minimum cubic space per man in sleeping-quarters, but advised that there should be a distance of at least three feet between the mouths of the sleepers. This could be obtained in the case of hammocks by slinging alternately head to foot. The use of punkah louvres, which had gradually come about since 1912, was approved; but for cold weather (when the openings were often sealed), an additional relief vent, suitably baffled, was suggested. Mess-deck temperatures of between 60 and 65° F. were recommended for cold climates. The committee was concerned with the obvious inefficiency observed in cordite-handers under action conditions during the Mediterranean summer and the improvement when

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coolers were installed. The inference, however, was that cordite fumes were responsible, and coolers were advised only as an interim measure until some kind of non-porous containers for the cordite charges could be issued. Air-conditioning was discussed and was envisaged as beneficial, but, because of size, weight, and cost of the plant, was not regarded as an essential requirement.

With the onset of this war the recommendations of the second committee became out of date. Conditions within living- and working-spaces changed for the worse. All ships now carry a complement far exceeding the original design, in some cases by as much as 60%. Ships remain at sea for inordinate periods, and operational needs dispatch them to regions where extremes of climate add to the discomforts, unlike the peacetime cruising practice. Darkening ship demands a sealing of all scuttles after nightfall. The menace of air attack necessitates additional high-angle armament and radar equipment, which all means more men. Dangers of fire led to the removal of woodwork, and hence the sacrifice of the lagging or insulating lining of the ship's sides. (This is a practice which has come and gone according to the fluctuating policies of the last 60 years at least.) Finally, the risk of losing the vessel from rapid flooding after enemy action has been met by an elaborate system of "damage control" whereby the ship, immediately action is joined, is divided into a large number of air-tight and water-tight compartments. As soon as a ship enters dangerous waters it is battened down and hermetically sealed, the personnel standing by at first or second degrees of readiness. Ventilation suffers drastically. Indeed, in some compartments, such as the magazines and shell-handling rooms, circulation of air ceases. A steady rise of temperature follows, which in the Tropics may attain potentially dangerous levels.

Hence there arises a clash between two conflicting policies. On the one hand there is the operational need for keeping a ship afloat even after severe underwater damage. To effect this, damage control aims at converting the ship into something like a honeycomb. On the other hand there is the hygienist's concern over the personnel and their discomforts, the menace to their health, and the toll on their fighting efficiency.

First among the defects of habitability that accrue from battle conditions during this war are the *high temperatures* below deck, especially in the Tropics. Even in cold climates mess spaces tend to develop a temperature well above that outside, and a man coming off watch on the bridge passes from extreme cold to an atmosphere of hot, moist, and stagnant air. In the Tropics the conditions are worse. With an ambient air temperature of 85 to 100° F. (dry-bulb) the compartments where men work, eat, or sleep reach temperatures around 85 to 95° F. (wet-bulb). Consequently men strip except for shorts and sandals. Sweating continuously and profusely, most of them develop prickly heat, and often superadded septic or fungous infections.

Even more significant than raised temperature is *high humidity*. This feature may be conspicuous even in the Arctic, where the internal warmth, contrasting with the icy-cold un-insulated ship's sides, causes water of condensation to stream down on to the deck. Added to this is the moisture from wet duffel coats and oilskins which hang up to dry in the mess-decks. The question of humidity has exercised the medical branch for years, for cleanliness demanded frequent washing and hollystoning of the decks, and this by evaporation produced a high water content of the air. To-day the question mainly turns on the lack of drying-spaces, with the result that wet garments are constantly hanging in places where men sleep. In the Arctic it is the wet top gear which is at fault; in the Tropics the shorts and singlets, which require at least daily drenching.

Overcrowding from expansion in ships' complements may be endurable in the Arctic, as the heat engendered helps to warm the air. But in the Tropics it is a serious matter, affecting comfort as well as health. The cubic capacity allotted to a man may be far below the old minimum standard of 200 cu. ft. As many as possible sleep on the weather-decks, but this is usually impracticable at sea. At action stations working-spaces are grossly congested, and gun turrets, radar and wireless cabinets, transmitter stations, and so on may be crowded with personnel on watch, standing by, or dozing.

In cold climates there is the problem of *exposure* of watchkeepers. Men on look-out, on the bridge, or in control tops

may be unprotected against driving sleet, high winds, and temperatures far below zero. How to keep alive—let alone alert—is not an easy problem.

All these are medical considerations which tie up with inadequacies in ship construction. Though far from novel, most have been greatly increased by the changing trends in modern naval warfare. That is why no serious attempt has been made to correct these defects until recently.

To investigate the problems in the widest fashion, and to justify any sweeping changes which may seem called for in the construction or ventilation of fighting-ships, the Admiralty in 1943 requested the R.N. Personnel Research Committee to appoint a Habitability Subcommittee. At once gaps in our knowledge became evident. There is the question of whether efficiency falls as environmental temperature and humidity rise, and of whether any such change is a progressive one. It was actually quite difficult to furnish the required answers or to make recommendations. The wide ranges of climate mean that naval engineers would have to raise the interior temperatures considerably in the Arctic, and lower them—if possible—in the Tropics, in order to maintain the efficiency of the personnel. Too exacting requirements on the part of the medical branch run the risk of being rejected out of hand as unreasonable. Moreover, there was the question of what we should use as a yardstick to measure habitability: should we speak in terms of dry- and wet-bulb temperatures, atmospheric humidity, katathermometer cooling power, or effective temperature?

This last seemed most promising, for it accords with modern ventilation practice, and embraces both dry- and wet-bulb readings and measurements of air movement. There are certain weaknesses, however, in the conception of effective temperature. It does not allow for acclimatization. It does not cater for men engaged in physical work. It is an empirical standard drawn up from the work of a relatively small series of Americans, whose ideas of environmental comfort might not be ours. Its validity in the higher ranges of temperature and air velocities has been impugned. The chief drawback is that it is inapplicable when there are sources of radiant heat—which actually is a characteristic feature in warships.

On the advice of Dr. T. Bedford, the Habitability Subcommittee has provisionally adopted Vernon's "globe thermometer" for use in ships, as it can be employed for measuring the radiant heat from the surroundings. Globe-thermometer readings, therefore, replace dry-bulb readings in the effective temperature charts, and the result is spoken of as "corrected effective temperature" or (C.E.T.).* Air velocities are determined by means of the silvered (high-temperature) dry katathermometer.

To comply with the standards of the Habitability Subcommittee for ships serving in the Tropics considerable changes might be required in the methods of ventilation. In new ships, and ships still on the stocks, drastic changes might be feasible, but in those already commissioned, and especially in the older ones, it is more a question of "patching up," as operational requirements take precedence and the ships cannot immediately be spared for dockyard hands. Some of the changes in mind could be made immediately; others would have to wait until the opportunity arose for a refit; others were still for the future.

The terms "tropicalization" and "arcticization" of ships are sometimes applied to the measures adopted to render vessels habitable in extremes of heat or cold. Though the methods are of recent origin, the idea is an old one. For many years special ships have been constructed for polar expeditions. "Tropicalization" would seem to be a newer conception, but we find the project being undertaken as long ago as 1740, when Commodore Anson made structural alterations in a squadron for the Pacific; and in 1841, when Dr. David B. Reid and Captain H. D. Trotter built ships for the Niger River exploration with extra ventilation and the introduction of "medicators."

* The effective temperature scale is referred to the standard conditions of still and saturated air, so that the effective temperature of an environment indicates the temperature of still air saturated with water vapour, in which an equivalent sensation of warmth was experienced in a long series of tests. When the reading of the globe thermometer is used to arrive at the corrected effective temperature (thus applying a more or less adequate correction for radiation) the standard of reference is an environment in which the air is still and saturated with water vapour, and in which the surrounding surfaces are at air temperature.

The *Victor Emmanuel* was the first hospital ship to be specially equipped for tropical service during the Ashanti War.

Air Conditioning

Chief among the items envisaged in modern tropicalization and arcticization are: the installation of air-conditioning plant; a return to the practice of lagging or sheathing; more extensive insulation of steam-pipes and other heat-producing machinery; reduction in C.E.T. by drying the air or by increasing air movement; the correction of the more obvious faults in the siting of intakes and exhausts (faults which had often resulted from structural alterations long after a ship's commissioning); and, finally, a general indoctrination of naval officers of all branches in matters pertaining to ventilation and habitability.

Air conditioning might appear at first sight to be the complete answer to all these problems, for incoming air is automatically cleansed, dried or moistened, warmed or cooled, as required. The problem bristles with difficulties, however. Air-conditioning plant is scarce, bulky, and heavy. Even were sufficient apparatus available for immediate installation, it would occupy so much space in a ship and add so much to the weight that fighting efficiency would suffer. Thus, to air condition a warship might require a great deal of extra weight and space—perhaps as much as a heavy gun and its turret—as well as several extra hands. This addition to an already congested ship means the sacrifice of some part of the existing offensive or defensive equipment. Whether such a policy is a business proposition which will pay dividends in the way of enhanced human efficiency is still a matter of conjecture rather than knowledge.

If one compromises by adopting air conditioning only in certain regions of a ship a fresh problem arises as to which spaces should be so equipped. Is it better to cool the working compartments (in order to ensure vigilance and accuracy) or the mess-decks (to afford a refreshing spell of sleep before the hands go on watch)?

There are other medical and paramedical problems. If air conditioning is to be the rule, what standards of temperature and humidity should be adopted with reference to the outer air? The phenomenon of "cold shock" is known to occur on passing abruptly from a tropical climate into a much cooler environment—as, for example, on entering a cold-storage room. An undue dryness of the inspired air is believed to produce an unhealthy state of the mucous membranes, as in the case of American railroad employees. Again, are ill effects to be expected from changing many times daily from one sort of environment to another? Thus, are upper respiratory infections facilitated by frequent changes from a hot humid to a relatively cool dry climate, or vice versa? What is the effect upon the process of acclimatization? Can it be that men conditioned to a tropical climate suffer as the result of a sojourn of some hours daily in an air-conditioned room?

Even more important is the risk that re-circulating air may increase the incidence of air-borne disease, quite apart from the possibility that an artificial climate may alter the virulence of droplet infections or the relative immunity of the occupants, or both. The use of chemical disinfectors or ultra-violet treatment of the incoming air needs careful thought.

Cooling or heating the incoming air may of course turn out not to be the ideal for naval purposes, and possibly the so-called "radiant reflective conditioning" might prove better. In this system the air is unaltered, but specially cooled (or heated) panels let into the bulkheads bring about the necessary thermal change in the occupants. This practice has not yet been tested in ships.

Some of these questions are, or will be, the subject of specific inquiry in our research laboratories in this country and those to be erected in the Tropics. Nevertheless we believe we have been justified in installing cooling plant in certain places in certain ships. As regards the temperatures at which they are maintained, we believe the tendency is to keep them too cool. It is rarely necessary, or indeed wise, to reduce them below an effective temperature of 78° F. (with a high outside temperature). An alternative ruling is to accept no more than 10° F. difference in temperature between the treated and the untreated air; or to adopt the Mayer-Fittz formula. The last word on this subject is still to be said.

Interim reports on air-conditioned compartments are most encouraging, though scientific data as to output and efficiency are not yet available.

Reducing the dry-bulb readings is only one way, of course, of lowering effective temperature, and something might be done in this direction either by decreasing the humidity or by increasing the movement of the air. The former can be brought about by means of various types of dehumidifiers or by silica gel desiccators. Both methods are used in the Service for the drying of certain compartments, and the practice has materially extended since the war. Both systems have drawbacks which prevent them from being adopted more generally, not the least being the fact that the act of withdrawing moisture from the air in itself generates heat.

Increasing the air movement is a much more practicable means of reducing effective temperature, and the improvement in comfort and efficiency is beyond what might be expected from the change in effective temperature. In H.M. Ships air movement is obtained below decks first by the blower system of ventilation and secondly by means of table, bracket, or punkah fans. In the blower system air is driven along trunks by means of electric fans and injected into the compartment by way of punkah louvres. This is in effect a miniature "spot-cooling" system, which on a larger scale proves so successful in making engine- and boiler-rooms tolerable despite the very high temperatures. In some locations—e.g., machinery spaces, galleys, heads—there is a forced-exhaust system, but elsewhere the peacetime practice was to rely upon natural means of exhaust—i.e., hatches and scuttles. Since this war, however, these natural vents are sealed.

The obvious way to improve habitability in ships under war-time conditions, especially in the Tropics, would be an increase of the air flow in volume and velocity. This would be an easier task than to cool the incoming tropical air to tolerable levels. Greater air movement could be obtained by increasing the size, the number, and the speed of fans in the trunkings; by providing more table, bracket, or punkah fans; and by installing exhaust fans in those compartments which used to rely on natural vents.

Other Methods of Increasing Habitability

Other methods of increasing the habitability of ships in climatic extremes may be mentioned briefly. The great sources of wild heat must be shut off from the rest of the ship by means of thermal insulation. The risk of fire precludes the use of wood except to a limited extent. Newer insulating materials have been introduced with various advantages. Hawkyns used a layer of tar and hair between two layers of wood—a practice which lasted till the end of the eighteenth century. The aluminium foil which is the most usual intermediate layer can now be replaced by far lighter plastics which are non-inflammable. These plastics still require an inner sheathing, however. A more extensive use of cork would combine the properties of thermal insulation with protection against the spread of fire. One of the most difficult regions of a ship to render habitable is a gun turret, which in the Arctic is bitterly cold, with its masses of steel and its water of condensation, and which in the Tropics is almost intolerable by reason of solar radiation. An attempt at a solution of the problem lies in the use of layers of cork inside the turret.

The sheathing of steam-pipes is being improved, especially where they traverse mess-decks. Steam leads, which add so much to the atmospheric humidity below decks, require stricter sealing.

The choice of appropriate colours in painting the hull and superstructure of ships is a problem of camouflage, but it has a medical bearing also. In the Tropics white paint reflects solar radiation best of all, while black absorbs most heat. Black pigments do not all behave alike, however, and radiation studies reveal that the composition of the paint may be as important as the colour as regards its reflection and absorption of infra-red radiation. Thus aluminium paints are the most efficient reflectors of the sun's rays.

Artificial lighting of the mess-decks contributes to the final temperature. Two 60-watt lamps produce rather more heat than one resting man. It is possible that fluorescent lighting might render a mess-deck cooler in the Tropics. Modern improvements do away with the disadvantage of the former feeling of the blue colour.

There is also the point whether the colour of the sides of the mess-deck has any effect upon the *feeling* of warmth or of coolness, even though this may operate through suggestion only. It has been the tradition to paint the interior of sick-bays a pale green in tropical-going ships. F. C. Houghton, H. T. Olson, and J. Suci found no objective change in skin temperatures in different coloured environments, but they affirmed that occupants might experience a subjective sense of warmth or of coolness in the presence of this colour or that—which, from the human standpoint, is significant.

Body-cooling in hot atmospheres may be obtained by adequate draughts of cold water; in any event the need for drinking, over and above the call of thirst alone, is important for maintaining mental and physical efficiency in high temperatures. There is a rationale, therefore, for supplying cooled drinking-water in working- and living-spaces, though the American habit of iced water may not be a physiological ideal. Whether the water should contain salt or oatmeal needs closer investigation.

Lastly, the innovation of laundries in H.M. Ships has much to recommend it, not only because they promote cleanliness (and so avert skin infection) and avoid the wearing of sweaty garments (which aggravates prickly heat), but chiefly because they abolish wet garments from the mess-decks. There is the point, too, that sweat-soaked garments will not readily dry except in an atmosphere of extreme desiccation—a condition which does not obtain in the mess-decks.

(These lectures will be continued in the issue of Aug. 11 and completed in that of Aug. 18)

BACTERICIDAL EFFECT OF MIXTURES OF ETHYL ALCOHOL AND WATER

WITH SPECIAL REFERENCE TO STERILIZATION OF THE SKIN, AND A NOTE ON THE COMPARABLE EFFECTS OF ETHER

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Although much work has been done by a number of observers on the antibacterial effects of alcohol on the one hand and on the value of various substances as sterilizing agents for use on the skin on the other, agreement would appear not to have been reached regarding the optimal dilution of alcohol for use on the skin before puncture or surgical incision. Precision on two points is necessary for a final assessment: first, percentages of alcohol in water should be accurately defined in respect of any observations made; and, secondly, the requirements of a fluid for use on the skin should be considered in terms of its physical properties as well as its bactericidal power. Further, due consideration must be given to the bacterial species which it is most necessary to eliminate.

Percentages of Alcohol

For scientific accuracy it is probably desirable that the strength of an alcohol mixture should be recorded as percentage by weight. On the other hand, under ordinary conditions the preparation of volumetric percentages can more readily be carried out. There are appreciable differences in the strength of mixtures produced by (a) making up a measured volume of alcohol to a total volume by the addition of water; (b) making up a measured volume of water to a total volume by the addition of alcohol; and (c) mixed measured volumes of the two fluids. These differences are due to concentration during admixture. The first is the correct percentage by volume. The following figures, calculated from tables given in *The Chemists' Year Book*, 1942, illustrate the differences in strength between solutions made up by the methods referred to:

- (1) 76% by weight is approximately equal to 82% by volume, at 60° F.
- (2) 70% by weight is approximately equal to 77% by volume.
- (3) A mixture made by making up 30 parts of water to 100 parts by the addition of alcohol is approximately equal to 73% by volume.
- (4) A mixture made by the addition of 30 parts of water and 70 parts of alcohol is approximately equal to 72.5% by volume.

Physical Properties of Alcohol-and-Water Mixtures

From a practical point of view *surface tension* is probably among the most important variable characteristics of alcohol-and-water mixtures. It is likely that low surface tension is the factor mainly responsible for the improved spread (Bonney and Allen, 1944), penetration (Lovell, 1945), and complete wetting observed when alcohol is used on the skin. The variation in surface tension which occurs as alcohol is progressively diluted with water is illustrated by the following experiments. It was also apparent in some of the experiments on plates of solid media referred to later in this paper:

Experiment A

Mixtures of water and alcohol of 65 volumes of alcohol and 35 volumes of water, and of 30 volumes alcohol and 70 volumes of water respectively, were dropped from a Dreyer's pipette on to a porcelain tile which had been rubbed over with Congo-red powder. The diameters of the circles of spread of the alcohol were measured and the volume of the drops calculated by counting the drops in 0.5 c.cm. The mean diameter of the area wetted by the drop of the stronger mixture was 2.7 cm. (mean of 10 observations), while the mean volume of the drop was 16.6 c.mm. The figures for the weaker alcoholic mixture were 2.05 cm. (mean of 10 observations) and 19.23 c.mm. respectively.

Experiment B

A somewhat more careful observation, using absolute alcohol and a mixture of 65 volumes of alcohol and 35 volumes of water respectively, was made by tracing the outline of the wetted areas produced on a similarly prepared tile, measuring the areas enclosed, and calculating the diameter. The drop volumes were obtained by measuring the volume of 200 drops of each strength of alcohol. In this experiment the mean diameter of the area wetted by 16.375 c.mm. drops of absolute alcohol was 3.37 cm., while that of the area wetted by 17.625 c.mm. drops of "65%" alcohol was 2.85 cm.

Species of Pathogenic Bacteria Liable to be Found on the Skin

Bacteria encountered on the skin may be divided into "resident" and "transient" organisms. The former cannot be completely eliminated by any process which will not injure the tissues (Colebrook, 1941). Much of the "resident flora" is located in the pilonidal follicles; these are not penetrated by 70% alcohol or by acetone (Lovell, 1945). According to Colebrook (1941) *Str. pyogenes*, *Proteus*, and *Ps. pyocyanea* are among the transient flora, and *Staph. pyogenes* is difficult to place, being intermediate between the transient and resident flora. He quotes various workers as finding *Staph. aureus* (*pyogenes*) on the skin of from 5% to 30% of normal individuals. Martin (1942) reports the occurrence of *Staph. aureus* on the face, wrist, and chest respectively in 38%, 24%, and 14% of normal individuals, the corresponding figures of *Str. pyogenes* being 5%, 3%, and 1%. Miles *et al.* (1944) report the skin carriage of *Staph. aureus* in 18.4% of individuals. Cruickshank *et al.* (1942) quote Lockemann *et al.* (1941) as finding *Staph. aureus* more resistant to all strengths of alcohol than either *Bact. coli* or *Ps. pyocyanea*.

It would thus seem that the power to kill *Staph. aureus* may be considered as a suitable index of the value of alcohol in skin sterilization. It should be noted, however, that, owing to the alcohol-fast nature of the genus *Mycobacterium*, alcohol may be expected to be inefficient as a bactericidal fluid for *M. tuberculosis*. It is possible, though hardly probable, that failure in this respect led to an accident following which the use of alcohol for sterilizing syringes for the administration of parenteral injections was condemned by Bigger *et al.* (1940), though these workers also showed that alcohol failed to destroy streptococci in sputum used to contaminate syringes in certain of their experiments.

Recommendations by Previous Observers regarding Suitable Strength of Alcohol

Where contact may be prolonged weak mixtures are effective. Cruickshank *et al.* (1942) have shown that *Staph. aureus*, *Bact. coli*, and *Ps. pyocyanea* may be destroyed in from 0.5 to 24 hours by 25% alcohol. The length of time necessary to achieve sterility in certain of their experiments shows that 25% is obviously an ineffective strength for use in skin sterilization, where contact of the reagent with the skin is limited by the volatile nature of alcohol and by considerations of practical