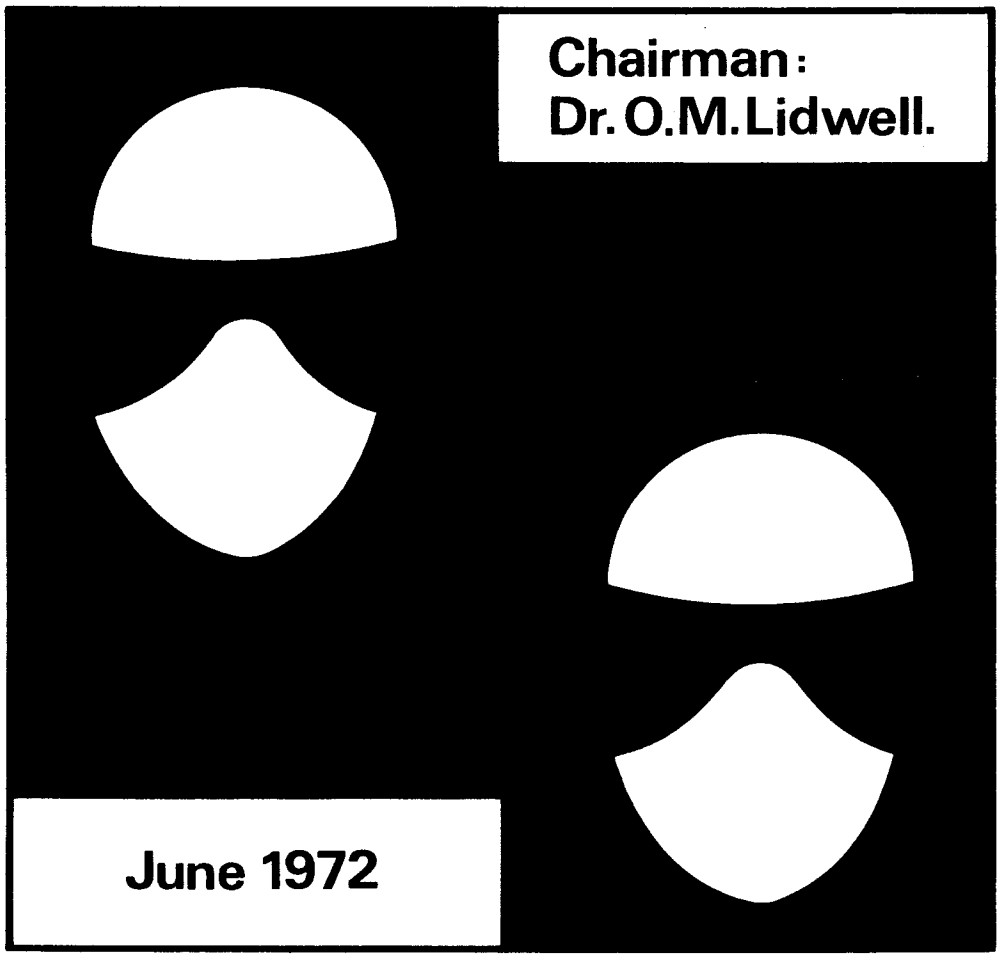
The report of a joint working party on



Ventilation

in

Operation Suites

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TERMS OF REFERENCE

The Joint Working Party was set up in December 1969, with the general support of the Department of Health and Social Security, the Medical Research Council and the Regional Engineers Association, to consider and examine existing recommendations for ventilation in the operation suite, and to report on the code of standards that should be observed to ensure a safe and comfortable environment for the patient and surgical team.

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VENTILATION IN OPERATION SUITES

1. REQUIREMENTS

The purpose of ventilation in the operation suite is to provide an environment that is safe and comfortable for the patient and the surgical team. The requirements considered here concern bacteriological safety, removal of anaesthetic gases, and comfort.

2. AIRBORNE INFECTION IN OPERATION ROOMS

2.1 Some 10% of surgical wounds currently show clinical signs of infection. For a few of these the results are serious in terms of life or health. For most the consequences are rarely more serious than a few days' prolongation of the stay in hospital; but this, purely in health-service terms, involves a substantial cost in money and in the use of skilled staff. Reduction of the incidence of wound infection is therefore a worthwhile objective.

2.2 The purpose of ventilation in this context is to prevent infection of the patient's wound – and possibly the respiratory tract- by micro-organisms that are transported about the operation room on airborne particles. In a sterile atmosphere no such transport could occur but, as with most absolutes, each successive step towards it involves more effort for a lower return. A compromise has therefore to be reached; this could be determined by two principal factors;
a) the level of airborne infection that is acceptable in relation to the cost of further reduction and
b) the point at which infection involving airborne transport falls substantially below that from other routes, e.g. self-infection and contact infection.

2.3 Information on the relative contributions of airborne and other routes to the genesis of surgical-wound infection is very limited, despite substantial research effort. There are documented instances indicating that airborne infection is sometimes important, but the available information does not give a quantitative estimate of what it is in the average situation. The proposals for operation-suite ventilation have then – apart from special situations and research – to aim at making the best use of ventilation systems of reasonable capacity and cost. The guide-line for this will have to be found by rational deduction from the bacteriological results, assisted by the few pieces of clinical evidence.

2.4 The bacteriological requirements of ventilation in operation suites may be broadly stated as the prevention of airborne infection from sources outside the hospital (see requirements 3.1 and 3.2) from hospital sources outside the operation room (requirement 3.3), and from sources in the operation room (requirement 3.4). The requirements are given in more detail in Section 3, and notes on the ways by which they may be achieved are given in Section 4.

3. BACTERIOLOGICAL REQUIREMENTS

3.1 Air delivered to the suite by the ventilation equipment should not contain more than 1 colony of Clostridium welchii or Staphylococcus aureus in a sample of $30m^3$ ($1060\ ft.^3$) of air (4).

Aerobic cultures on non-selective medium should indicate not more than 35 bacteria carrying

particles in 1 cubic metre (1 per ft.^{3}) of ventilating air, (see para 4.1).

3.2 The heating, cooling, and humidifying equipment should be easily accessible for cleaning (see para. 4.2).

3.3 Air movement through doorways should be from cleaner to less clean zones (see Section 4.3).

3.4 During surgical operations the concentration of bacteriologically-contaminated airborne particles in the operation room averaged over any 5-minute period should not exceed 180 per m^3 (5 per ft.^{3}) (see para 4.4).

3.5 For some special types of surgical operations, higher standards of air cleanliness may be justified (see para 4.5).

3.6 Recirculatory ventilation systems are acceptable if they fulfil the above requirements, but see para 4.6.

3.7 In each operation room there should be indicators of an adequate airflow volume to the room, of room temperatures, and of room humidity.

4. NOTES ON BACTERIOLOGICAL REQUIREMENTS

4.1 Filtration

The only common organisms of known surgical significance in outdoor air are members of the genus Clostridium, causing gas-gangrene and tetanus. In the neighbourhood of occupied buildings – for example the hospital itself – a few Staph. aureus will also be present. Both are removed by filters of 95% gravimetric efficiency against B.S. test dust No. 2 tested in accordance with BS 2831 (4). These filters – as opposed to any preliminary coarse filters – should be in the positive-pressure section of the duct, after the fan. (see para. 4.6 for special requirements in recirculatory systems). Filtration to this standard will not always prevent visible dirt staining. If this is objectionable then a higher degree of filtration will be necessary, probably involving an additional stage of filtration.

4.2 Cleaning

Micro-organisms often multiply in moisture on cooling coils, on eliminator plates, and in water reservoirs of humidifying apparatus, and may contaminate the air (1). This contamination should be controlled as far as possible by design of the equipment; recirculatory water reservoirs should not be used; humidification should preferably be by injection of clean steam. If this is not possible, humidification by fresh soft water, i.e. water with a low content of dissolved solids, from spinning discs may be used. There should be easy access for routine cleaning of all mechanical components, but provision for cleaning ducts is not considered essential. The discharge grilles or diffusers should be easily cleanable because local turbulence often causes dust to accumulate on them.

4.3 Airflow through doorways

The main requirements are that air should flow from cleaner to less clean areas even when a door is open and should not enter the suite from adjoining hospital areas, see Fig.1. Self closing doors should be provided.

4.3.1 Movement of air in either direction between designated 'dirty operation rooms' and adjoining areas is undesirable. It can be reduced by the use of 'balanced' ventilation systems and airlocks.

4.3.2 The directions of airflow between rooms of the suite outside the sterile zone are probably less critical, but the general principle of the requirements in Section 3 should be followed. The figure groups the various kinds of rooms in descending order of cleanliness but it is not intended to imply a rigid classification. The allocation of rooms to cleanliness zones in particular suites is not always easy, but there is guidance on this in Fig.1 of the Medical Research Council report (2).

A separate route for the disposal of used material does not seem to be required on bacteriological grounds. Soiled and used articles can be placed in bags which are then sealed and safely removed by the most convenient route (3).

4.3.3 There is no difficulty in maintaining the desired direction of airflow through gaps around a closed door. When a door is open, the intended flow should be maintained through all parts of the doorway. The volume of air needed to do this is related to the area of the doorway and the temperature difference across it, not to the volume of the room.

Observation in operation rooms (4) has suggested that a flow rate of not less than $10m^3$ per minute per m^2 of door opening is required ($33ft^3$ per minute per ft^2). More recent work at the Building Services Research Unit, Glasgow (5) has shown that a flow of about 15 m^3 per minute for each 1 sq.m. (50 cu.ft. per minute for each sq.ft.) of doorway is needed when the temperature difference between the rooms on either side of the door is 1°C (2°F).

It is often impracticable, especially for an operation room, to base this provision on the aggregate door area. The flow required should therefore be determined by the area of the largest doorway. Doors should be kept closed during operations and no more than one door in any room should be open at a time. A double door, with an area of 3 m^2 (30 ft^2) will need an airflow of about 45 m^3 per minute (1500 $ft.^3$/minute) to allow for temperature differences up to 1°C (2°F); this must be derived from the difference between the rates of input to and exhaust from the room, after making allowance for spillover to or from adjacent areas, including leakages. As a consequence of these factors, the net air input to an operation room needed to produce the required direction of airflow through an open double door against the above temperature difference will usually be appreciably more than 45 m^3 per minute (1500 ft^3 per minute) quoted above and is more likely to be 60 m^3 per minute (2000 ft^3 per minute).

These figures emphasize the need to keep temperature differences within the operation suite to a minimum. If these can be effectively held down to no more than 0.5°C (1°F) across the doorway then the lower figure of 10 m^3 per minute per m^2 of door opening will be sufficient to maintain the desired direction of air flow and a total ventilating volume of 34 m^3 per minute (1200 cu.ft. per minute) will be satisfactory (4). Otherwise substantially greater volumes will be needed, but it should not be necessary to exceed 60 m^3 per minute (2000 ft^3 per minute).

For the airflow direction system to perform as calculated, allowance must be made for spillover of air between adjacent areas in all parts of the suite, and means of escape provided for excess air.

4.4 Removal of contaminated air

4.4.1 The main sources of air contamination inside an operation room are the human occupants. Shedding of bacteria by them is reduced by special clothing and control of movement

(4), but cannot be eliminated by any generally acceptable method. The number of organisms in the air represent a fluctuating equilibrium between bacterial liberation from sources, and removal by ventilation and sedimentation. Increasing the rate of ventilation gives diminishing returns in lowering this point of equilibrium.

4.4.2 Experience so far has suggested that if the concentration of contaminated airborne particles during a surgical operation reaches 700-1800 per m^3 (20-50 per ft^3) there is significant risk of airborne infection, and when the count is 35-180 per m^3 (1-5 per ft^3) the risk for general surgical operations is slight. Counts during operations can usually be kept below 180 per m^3 (5 per ft^3) by an air supply to the operating room of 30-60 m^3 per minute (1000-2000 ft^3/min).

4.4.3 The way in which the ventilation air is introduced into the operation room is of little bacteriological significance at these rates of flow. There are theoretical bacteriological advantages in designing for unidirectional rather than turbulent ventilation and these have been realised under experimental conditions (4) but attempts to reproduce this in functioning rooms are ineffective because of the turbulence produced by convection and staff movements (6). However, if very much higher ventilation rates are used for special purposes (see Section 4.5) the advantages of unidirectional flow could be obtained (7, 8, 9).

4.4.4 Any other room(s) in the cleanest group, Fig.1, should be ventilated to the same standards as the operation rooms, i.e. about 20-30 m^3 per minute (700-1000 cu.ft/min) should be available to maintain the designed direction of air flow through an opened single door and the rate of air change should not be less than 20 changes per hr.

Lower ventilation rates are adequate in other parts of the suite, e.g. around 15 changes/hr in the next cleanest group and 7-10 elsewhere. The net extract from rooms in the disposal zone should, however, be sufficient to maintain the desired direction of air flow through the open doorways (Fig.1).

4.5 Special requirements

4.5.1 During some types of surgical operation the patient's wound is especially liable to become infected or the consequences of infection are very serious, e.g. operations on the brain, other very long operations, those involving a transplant or implant, and those on patients whose immunological mechanism is impaired. For these operations lower air-contamination limits are probably desirable but have not yet been defined. Nor is it known whether contaminated-particle counts of less than 35 per m^3 (1 per ft^3) would be advantageous for operations not in these special groups.

Research on these matters is in progress and includes the evaluation of clean-air enclosures (10) whole-room undirectional air flow (9), and other methods of reducing the risk of infection.

4.5.2 A special requirement for ventilation of 'dirty operation rooms' is mentioned in para. 4.3.1.

4.6 Recirculation

4.6.1 There are no bacteriological objections to recirculation of air from operation suites if the requirements of Section 3 are fulfilled. However, the fresh air supply to the operation room should be at least 15 m^3 per minute (500 ft^3 per minute).

4.6.2 In recirculated air from occupied rooms, contaminated particles are more numerous and are generally smaller than in outdoor air; finer filters may therefore be needed to fulfil requirement 3.1 (11). It is suggested that the main filters in a recirculatory system should be at least 90% efficient

in the sodium-flame test in BS 3928 or in the DOP test US MIL STD 282. Filters must be exceptionally well fitted and maintained to prevent leaks around theair seatings.

4.6.3 The direction of air flow needed to fulfil requirements 3.3 must be met.

4.6.4 Where re-circulation systems are proposed the highest standards of installation and maintenance must be assured.

4.7 Bacteriological testing of the air

The numbers of airborne contaminated particles specified above and in section 3 have been given as a means of determining the ventilation requirements. Routine bacteriological testing of the air is, however, not recommended. The wide day-by-day variations in the numbers of airborne micro-organisms, especially of possible pathogens, make the results of such tests difficult to interpret. It is generally better to ensure that the specifications for volume of air supply and directions of flow are being fulfilled.

5. REQUIREMENTS IN RELATION TO ANAESTHETIC GASES

5.1 High relative humidities have been demanded to reduce the risk of anaesthetic explosions from static sparking. More recent analysis of this hazard (12) has shown that the risks are very small and are almost entirely eliminated by precautions with the anaesthetic apparatus. There seems to be no reason on grounds of safety to require high relative humidities.

5.2 Inflammable concentrations of anaesthetic gases can be found only within a few centimetres of the anaesthetic apparatus (18). Special ventilation arrangements do not seem necessary to disperse or dilute anaesthetic gases, including spillages.

5.3 There have been reports that some anaesthetics may have toxic effects on the operation room staff, especially females (13, 14).

The standard of ventilation called for on bacteriological grounds will keep the concentrations of anaesthetic gases in the room air very low. If studies, now in progress show that these are not low enough for safety, preventing the liberation of these substances into the room is likely to be the only way of eliminating the risk (15, 16).

6. COMFORT

6.1 Although humidity, air movement, and radiation affect comfort, ambient-air temperature is by far the most important environmental factor (19). Within acceptable ranges a 10% reduction in humidity is equivalent in effect to a fall in temperature of 0.5°C (1°F). Doubling the rate of air movement from e.g. about 0.1 m/sec. to 0.2 m/sec. (20/40 feet per minute), is similarly equivalent as regards comfort to a 0.5°C (1°F) fall in ambient-air temperature. Differences between mean radiant temperature and the ambient-air temperature, generally due to the heat of the operation lamp, have an effect equivalent to rather less than half the value of the difference, i.e. if the radiant temperature is 1.5°C (2.5°F) above the air temperature the sensation is equivalent to that of raising the air temperature about 0.5°C (1°F).

6.2 There is a wide variation in individual temperature preferences and there is also a substantial difference between the temperatures preferred by surgeons and by the other members of

an operation team, especially the anaesthetists.

This is illustrated by Fig.2. The conflict of preference can be resolved only by those who feel cold at the temperatures most acceptable to the surgeon, wearing warmer clothing, (there is no bacteriological objection to this). There are no clear limits which define a temperature range that will satisfy every surgeon but if the ambient-air temperature can be held down to 18°C (65°F) at 50% relative humidity and 0.15 m/sec. (25 feet per minute) air movement, with an excess radiation temperature due to the operation room lamp of about 1.5°C (2.5°F), this will be sufficiently cool for about 95% of surgeons. Similarly 21°C (70°F) will be warm enough for all but about 2% of surgeons and 24°C (75°F) is warm enough for more than 98% of anaesthetists.

6.3 Comfort specification for ventilating-plant performance

6.3.1 Temperature controls should allow for a range of setting between 15°C and 25°C (60-75°F), and be accessible to the staff of the operation suite.

6.3.2 The ambient-air temperature in the working area should not vary by more than ± 1°C (2°F) from the set value.

6.3.3 The capacity of the plant should be such that the temperature can be raised to at least 21°C (70°F) or held down to no more than 18°C (65°F) except under the most extreme weather conditions expected on the site. Both heating and cooling will be needed to achieve this in the Brisith Isles.

6.3.4 The relative humidity should be held within the range 40-60%.

6.3.5 Air movement in the working area should be between 0.1 and 0.3 m/sec (25-50 feet per minute).

6.3.6 If the main plant controls result in certain zones being over cooled, local radiant heaters should be used, outside the operation rooms.

6.4 Although high temperatures and relative humidities may be required for operations on infants, the effects of environmental conditions in the operation room on the well being of other patients are almost entirely unknown, but there is no indication that at the above temperatures and relative humidity there is likely to be excessive drying of exposed tissues.

Investigations in this field are highly desirable but until they are carried out no recommendations can be made.

7. INFORMATION FOR OPERATION SUITE STAFF

The function of the ventilating system is not necessarily apparent to all staff. A simplified plan of the suite showing air supply and extract, with the intended airflow directions through doorways should be displayed and at some convenient point. The notice should also point out that optimal conditions are obtained when doors are closed and that unnecessary opening and closing of doors, especially in the sterile zone, should be avoided, that all movement disperses airborne bacteria, and that regular maintenance and checks of the physical performance of the system are necessary to ensure continued efficient functioning.

8. SUBJECTS FOR FURTHER INVESTIGATION

Three aspects of the use of the operation suite to which ventilation is relevant but on which we have been unable to make any useful statement because of the lack of basic knowledge have been referred to in paras. 4.5.1, 5.3. and 6.4. They concern the possible use and advantages of ultra-clean ventilating systems in operation rooms, the hazards of breathing low concentrations of some anaesthetics and the effect of ambient conditions on the well being of the patient undergoing operation. We would strongly urge further work in all these areas.

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Chairman: Joint working Party
Operation Theatre Requirements
June 1972

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FIGURE 1 **OPERATION SUITE AREAS IN DESCENDING ORDER OF CLEANLINESS**

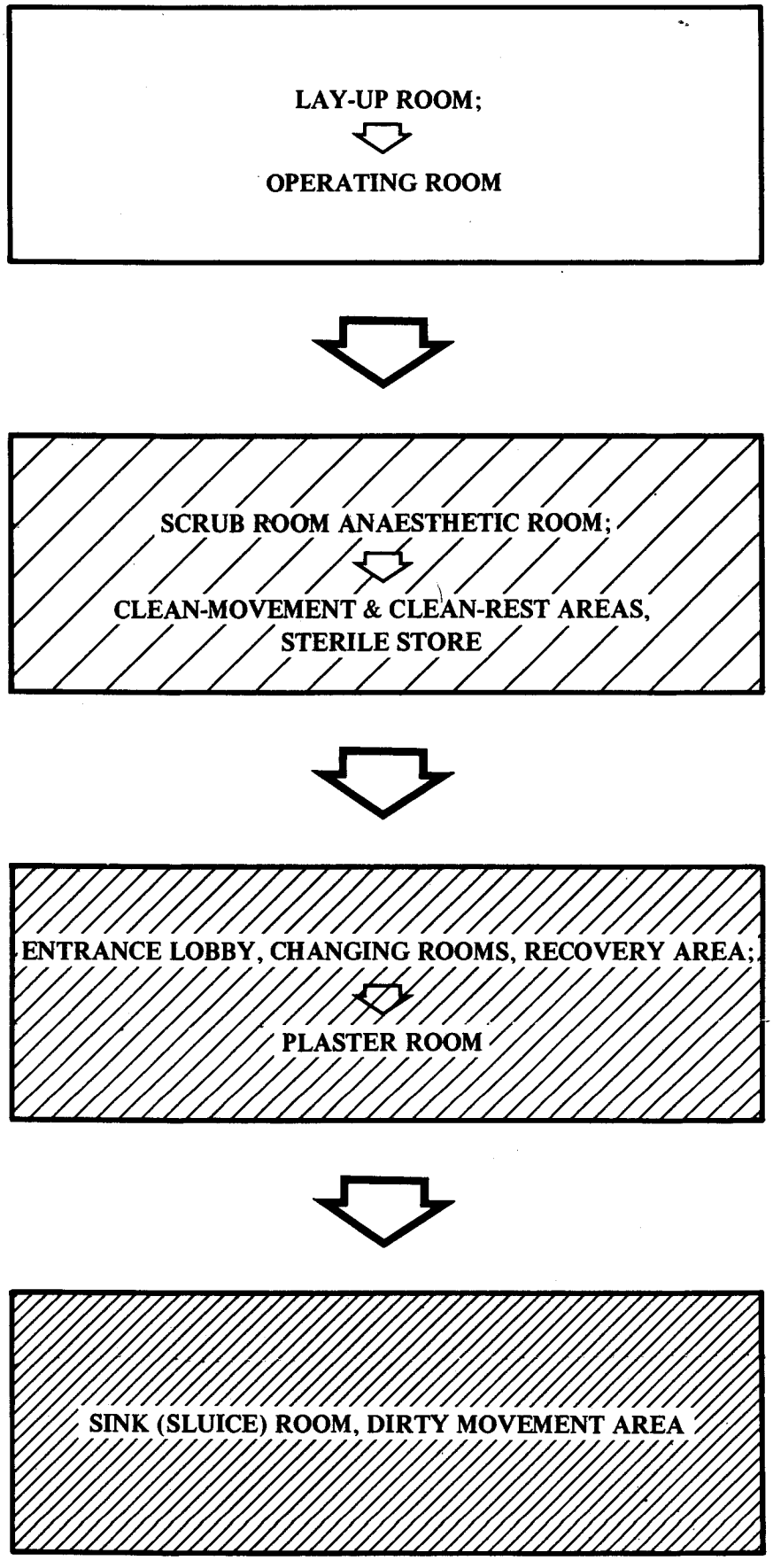
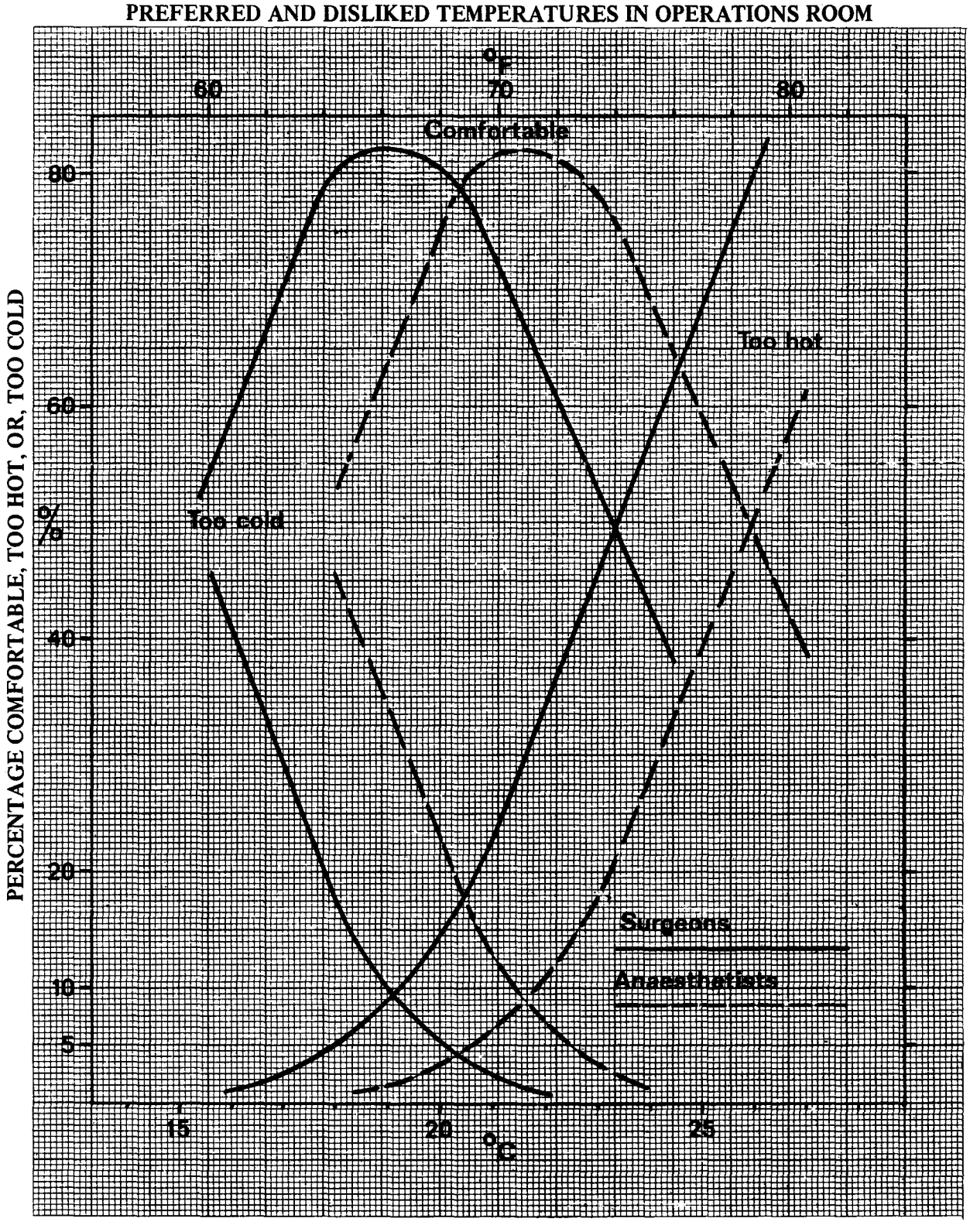


FIGURE 2



Percentage of individuals comfortable, too hot or too cold at the given ambient air temperatures. The full lines refer to the surgeons and the broken lines to anaethetists. The values apply at 50% relative humidity with 0.13 m/sec. (25 ft./min.) air movement. The figures for surgeons include the effect of excess radiation temperature, due to the operating lamp of 1.4°C (2.5°F). In the absence of any such excess radiation the temperatures for surgeons will be raised by approximately 0.5°C (1.0°F).