MINISTRY OF HEALTH

Report of a Working Party on

ANAESTHETIC EXPLOSIONS

including

SAFETY CODE
for Equipment and Installations

LONDON
HER MAJESTY'S STATIONERY OFFICE

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Prefatory Note by the Chairman

It may be useful if in presenting the Working Party's report I briefly summarise its argument.

A. INTRODUCTION (paras. 1-3)

We recommend to the Minister not only that he should encourage certain routine measures which are in our view the best safeguards now available but also that he should seek to arrange for certain lines of enquiry to be pursued which may give us new weapons to use.

B. ANALYSIS OF PAST EXPLOSIONS (paras. 4-7)

We have obtained and analysed the histories of a number of recent explosions. Most of them were probably caused by static sparks.

C. CONCLUSIONS ON ROUTINE PRECAUTIONS (para. 8)

We believe that simple precautions of the sort many hospitals already observe as a routine would eliminate three-quarters of the explosions.

Prevention of explosions other than those caused by static discharge (paras. 9-12)

Electric equipment, etc., should be constructed and placed so as to avoid sparking or heating near the anaesthetic apparatus. We have prepared a safety code for equipment (Appendix A). The Ministry's electrical safety engineers can give further advice. The fear of a spark may lead anaesthetists to use a physiologically dangerous drug rather than an explosive one. In some cases we do not recommend this.

Prevention of explosions caused by static electrification (para. 13)

The main safeguards are the use of antistatic rubber, which should be introduced as quickly as possible ; the use of conducting footwear and outer clothing ; suitable floors (where they are not suitable they should be wetted) ; and the maintenance of high relative humidity. Further research is needed on ways of improving non-conducting floors and of raising relative humidity when it is low.

D. PREVENTION OF STATIC DISCHARGES BY IONIZING THE AIR (paras. 14-17)

An apparatus has been devised which ionizes the air so that charges are quickly dissipated. This should be further investigated.

E. SUBSTITUTES FOR EXPLOSIVE GASES (paras. 18-21)

The only complete solution of the problem would be to render the use of explosive gases unnecessary by finding non-explosive substitutes with similar properties. There are some hopeful avenues which should be explored further.

F. NOTE ON RISKS IN DENTAL DEPARTMENTS (paras. 22-25)

Precautions should be taken against accidents during dental procedures.

G. CONCLUSION (paras. 26-28)

The greatest problem in preventing explosions is how to make people in hospitals sufficiently conscious of this danger, admittedly a remote one, to take reasonable precautions. A notice warning of the danger (Appendix B) may assist.

G. STEAD.

Contents

Report

A. GENERAL

1. We were appointed in August, 1953, to consider the causes of anaesthetic explosions in hospitals and to make recommendations for their prevention.

2. The full Working Party has met four times and has co-opted Dr. Robert Forbes, of the Medical Defence Union. We have appointed a sub-committee on experiments, which has met four times and has co-opted Dr. T. H. S. Burns, of Guy's Hospital, and Dr. Ezer Griffiths, F.R.S. We have considered a report by this sub-committee.

3. In our consideration of the matters referred to us it has become clear to us that there is room for further research into many of the problems connected with anaesthetic explosions and their prevention. In this Report we set out our general conclusions on the nature of the problems and indicate where in our view further research is desirable. If the Minister finds it possible to arrange for this research to be done we recommend that we should be continued in existence : we would hope to submit further reports as the results of these researches become known to us.

B. ANALYSIS OF PAST EXPLOSIONS

4. We have obtained histories of 36 explosions occurring between the middle of 1947 and the middle of 1954. Twenty-three of these have been the subject of detailed reports by the Department's Electrical Safety Engineers, which were made available to the Working Party. Others were obtained by the courtesy of the British Oxygen Company.

5. Through the courtesy of the Department, which has undertaken a statistical enquiry in National Health Service hospitals, we have also obtained some information about the extent to which anaesthesia is now used in hospitals in this country. Accurate information will not be available until returns have been obtained over a year, but preliminary results indicate that the number of occasions on which anaesthetics are used over a year is of the order of two and three-quarter millions ; on about 860,000 of these occasions explosive anaesthetics are used. These figures do not render less unhappy the 36 accidents which have to our knowledge occurred but they help to show these in a proper perspective.

6. Following is an analysis of the explosions :

Anaesthetic Explosions, 18th June, 1947 to 29th June, 1954
Frequency of accidents—Yearly—Monthly

Year	Total	Month											
		1	2	3	4	5	6	7	8	9	10	11	12
1947 (June) ..	1						1						
1948	4	1									1	1	1
1949	3	1					1	1					
1950	1				1								
1951	5	1								1	2	1	
1952	9		2		2	1		1		1			2
1953	8	1		3	2					2			
1954 (June) ..	5	2		1	1		1						
Total ..	36	6	2	4	6	1	3	2	–	4	3	2	3

6 months. Winter (November-April) 23 (64%)
6 months. Summer (May-October) 13 (36%)

Anaesthetics used

O = oxygen
G = N_2O
E = ether
C = cyclopropane
T = trichloroethylene

Anaesthetic	Accidents	Anaesthetic	Accidents
O + C	6	O + T + G	1
O + C + G	6	O + C + E	1
O + E	8	ethyl chloride followed by O + E + G	1
O + E + G	10		
O + E + C + G	2	Open ether	1
			36

Probable Sources of Ignition

	Number	Percentage	
Static Spark	22	61·1	69·4
Static Spark or open gas burner	1	8·3	
,, ,, ,, electric heater	1		
,, ,, ,, smouldering towel	1		
Diathermy	5	14·0	
Spark in switch or cut-out	3	8·3	
Faulty valve in gas cylinder	1	8·3	
Foreign matter in valve	1		
Smoking (?)	1		
	36	100·0	

In 14 cases of explosions attributed to static electricity the values of relative humidity in the theatres were probably 20, 22, 24, 25, 25, 26, 30, 30, 30, 30, 50, 56, 58 and 60 per cent.

In 13 cases of explosions attributed to static electricity there was evidence that persons present in the theatre, or pieces of equipment, were highly insulated, such lack of earthing being due to ordinary rubber shoes and tyres, absence of chains, dirty chains and unsuitable floors.

7. One point should be noted. We believe that the 36 anaesthetic explosions of which we have obtained histories include most of the major accidents of this type which have occurred since 1947. Certainly all major accidents in the last three years, when hospitals have been calling freely on the services of the Department's Electrical Safety Engineers, are likely to have been brought to their notice. It is possible, however, that there are still some minor incidents which go unreported, and in particular that hospitals do not always bother to report explosions that have some comparatively obvious cause such as the use of diathermy with an explosive

anaesthetic. Whilst the analysis we have made of probable causes of ignition is therefore reasonably representative of major accidents, the proportion of *all* explosions caused by static electrification may be less than this analysis would suggest. It seems clear, however, that the main cause of explosions is to be found in static electricity, and that diathermy apparatus comes next in order of importance.

C. CONCLUSIONS ON ROUTINE PRECAUTIONS

8. We are impressed by the fact that almost always when an accident has occurred there has been some avoidable factor against which precautions can be taken. One of the chief difficulties to be overcome is the lack of any general consciousness of danger : we shall return to this point in paragraph 26. If every hospital would take simple precautions of the type already observed as a routine wherever any thought has been given to this matter, three-quarters of the problem of anaesthetic explosions would disappear. We will deal first with the routine precautions which should be taken to avoid explosions with a cause other than static electrification and then with the steps that should be taken to minimise the risk from static.

Prevention of explosions other than those caused by static discharge

9. Some accidents arise through sparking from a defective apparatus, or from some piece of equipment not obviously dangerous. We have prepared a safety code for apparatus used in anaesthetising locations, which we annexe as Appendix A below. We recommend that the Department should, in addition to circulating this to hospitals, try to arrange for manufacturers to observe this code in the production of all new apparatus. The range of equipment which may on occasion be used in conjunction with explosive anaesthetics is a wide one, and no safety code can cover all the possible risks.

10. Risks may depend on the siting or wiring of the apparatus, how it is maintained, and so on. We hope, therefore, that hospitals will continue to make the fullest use of the Department's Electrical Safety Engineers, whose services are available to any hospital which cares to ask for them. The detailed advice which they can give upon every point affecting safety in a particular theatre is the best way to safety. Hospitals seeking their advice should do their best to see that all the apparatus which finds its way into theatre or anaesthetic room—even articles which are the private property of an individual surgeon—is made available for inspection.

11. It is important to note that the problem presented by the use of electrical apparatus in the theatre and elsewhere is not all told in the histories of anaesthetic explosions. There are also the misadventures which occur because the anaesthetist is afraid to use an explosive anaesthetic in conjunction with such apparatus. It is usual to wish to avoid the use of explosive anaesthetics in the X-ray room, and generally there is no difficulty in finding a non-explosive alternative. There are, however, a few procedures, all of them quite short, for which the only wholly satisfactory anaesthetic is ether, and at present students are often taught to avoid ether and use some other drug which is medically unsuitable so as to avoid any risk of explosion. In our view the risk of an explosion in a modern X-ray room is easy to exaggerate : in particular we consider that the risk of a dangerous explosion where the patient is anaesthetised with open ether in the anaesthetic room and brought in unconscious is negligible. (There may, however, be special dangers of static sparking in the X-ray room by virtue of the insulated floor—see paragraph 13(c).)

12. There are other circumstances, however, in which physiological risks must be

taken because there is a very real danger of an explosion. The deaths which may be caused in this way are not strictly within our terms of reference but clearly they must be a part of our problem. Our conclusion on this part of the matter referred to us is that the great majority of explosions not attributed to static sparks are readily preventable by careful observance of the precautions discussed above. Our recommendation for the solution of the wider problem appears in paragraph 18.

Prevention of explosions caused by static electrification

13. Here we are faced with a less tangible risk. It is hard indeed to ensure that conditions are always such that a dangerous static discharge is absolutely impossible. Safety can only be a matter of degree. Nevertheless, here again most of the explosions, mysterious though they often appear to those concerned, are found on investigation to have followed some comparatively obvious departure from safe conditions : if simple precautions are taken explosions are not impossible, but they very rarely occur. It has, for example, been suggested that if woollen blankets were excluded from the operating theatre, and all non-conducting rubber in the theatre replaced by anti-static rubber or other suitable material, little more would be heard of this problem. We set out below detailed advice on such safety measures before turning to the consideration of more comprehensive solutions.

(a) *Rubber equipment.* The one factor to which the majority of these explosions can be directly attributed is the use of non-conducting rubber. Sometimes the electrostatic charge has been generated on the rubber ; sometimes the rubber has prevented the rapid dissipation of a charge produced elsewhere. By far the most dangerous explosions are those which occur in the anaesthetic apparatus itself while it is connected in a closed or partially closed circuit to the patient, so that the effects of the explosion are received internally by the patient, often with fatal consequences. Explosions of this kind are nearly always caused by electrostatic charges generated on the rubber parts of the anaesthetic apparatus.

It is therefore to be hoped that the introduction of anti-static rubber will shortly be followed by a decline in the number of explosions and above all of deaths caused by static discharges. It has been suggested that the anti-static rubber equipment at present available is not uniformly satisfactory. We have heard an account of the inquiry already being carried out by the Department on this point : this inquiry appears to us comprehensive and we do not think further advice is required from the Working Party. We do, however, recommend very strongly that as soon as the Department is satisfied that a reasonable standard has been attained hospitals should be urged to re-equip their theatres with it without delay. We do not think re-equipment should wait until existing equipment is worn out. This is not an expensive item in hospitals' budgets, and in our view the early universal introduction of anti-static rubber is the most urgent step towards the solution of the problems referred to us.

Rubber breathing equipment, rubber trolley tyres, rubber feet on the legs of aseptic furniture, rubber casings of pads and rubber sheeting should all be made of anti-static rubber. However, existing mattresses of non-conducting rubber can be made comparatively safe if they are completely enclosed in a close fitting cover of an anti-static fabric[1]. Where anti-static rubber breathing equipment is not immediately available the risk can be reduced if the rubber is wetted internally and externally before use.

[1] Among the fabrics satisfactory for anti-static purposes are cotton, linen, or viscose rayon. This does not necessarily include fabrics of these materials which have been treated to render them water-repellent.

(b) *Clothing, etc.* The chief danger here is the use of non-conducting footwear, which both increases the risk of personal electrification and also prevents any rapid discharge from the wearer to the ground. The most satisfactory forms of foot-wear for anti-static purposes are shoes or boots having anti-static rubber soles and heels or overshoes of an anti-static fabric of a type which completely enclose the normal footwear. All theatre staff should be provided with one of these types of footwear. Light canvas shoes, similar to tennis shoes but with anti-static rubber soles, are commercially available for about ten shillings. Visitors to the theatre (for example porters) should be similarly equipped; here overshoes are likely to be useful.

In addition, everybody in the theatre should wear a close-fitting gown of anti-static fabric[1] tied closely enough round the wearer to reduce the generation of charges on the clothes beneath it. Waterproof aprons should be of anti-static rubber, not of ordinary rubber or of non-conducting plastics[2].

Woollen blankets may be readily electrified in normal use and are highly dangerous in the theatre. We recommend the use of blankets of cotton or other anti-static fabric. Where woollen blankets are used while the patient is transported to the theatre suite they should never be removed quickly and should be taken out of the theatre suite before the patient is anaesthetised. Blankets fresh from the hot cupboard should never be used.

Woollen stockings and other garments worn by patients which fit closely to the body acquire a film of moisture more quickly and are not likely to be a source of danger if they are not removed in the theatre suite.

(c) *Floors*. The Department has already issued (in Appendix B of RHB (53) 55) to hospitals as interim advice certain suggestions, with which we agree, on the degree of resistance which should be aimed at for floors of anaesthetising locations and on some types of floor which are suitable. There remains the question how existing floors in theatre suites, etc., which are of highly resistant material such as rubber or cork can be made safe for the use of explosive anaesthetics. It will be evident that many of the precautions we have already suggested will be of no value if a charge which reaches the floor is still unable to dissipate further. We understand that probably between 5 and 10 per cent of the operating theatres in this country have floors which are virtually non-conducting.

In addition, almost every X-ray room in the country has a non-conducting floor, which has long been considered necessary because of the danger of electric shock from the high potentials used. We have said above, however, (paragraph 11) that we do not consider it necessary wholly to exclude explosive anaesthetics from the X-ray room, and therefore, if we are to follow the advice issued by the Department, which applies to any place where explosive anaesthetics are used, the floor should be a conducting one like those of operating theatres. We have concluded after careful consideration that this is right. If there are to be any occasions when the use of an explosive mixture in a closed or partially closed circuit will be necessary in an X-ray room the floor of choice is one of the limited conductivity recommended for other anaesthetising locations. The risk of electric shock is remote—there is certainly no record that such an accident has

[1] Among the fabrics satisfactory for anti-static purposes are cotton, linen, or viscose rayon. This does not necessarily include fabrics of these materials which have been treated to render them water-repellent.

[2] We understand that there is a prospect of satisfactory anti-static plastic materials becoming available which may also prove suitable for some of these purposes.

ever occurred with shock-proof apparatus ; while with a wholly non-conducting floor there is a real risk of a static spark.

Where a theatre, anaesthetic room, or X-ray room with a non-conducting floor is used only occasionally for procedures with explosive anaesthetics, the simplest and safest course on these occasions is to damp the floor area before anaesthetising begins. Where the floor has a non-hygroscopic surface and the effect of damping the floor itself is very temporary a damp sheet should be put down on an area sufficient to ensure that a person approaching any part of the anaesthetising equipment will tread on it before being able to touch the apparatus, including the breathing circuit.

Where explosive anaesthetics are to be used frequently some more permanent method of improving the floor is clearly desirable. At present the only complete remedy is to lay a new floor. The best and cheapest methods have been communicated to hospitals in R.H.B. (53) 55 but it remains a rather expensive undertaking. There are, however, other possibilities awaiting exploration. Among them are washing the floor down with a suitable solution, or painting it with some form of conductive coating. We understand that some of these have already been tested in the Department and results were not encouraging, but further research might well bring new and better materials to light and in our view these possibilities are worth investigating further.

We should add that wax polish should never be used on theatre floors.

(d) *Relative humidity*. The damp atmosphere of this country has prevented the problem of anaesthetic explosions reaching anything like the magnitude it has attained in America. High relative humidity is in some ways the best of all measures to reduce the dangers of a static discharge. As soon as a film of moisture has formed on an object, there is no possibility of a static charge being generated on it. With most materials (wool and plastics are among the most dangerous exceptions) this happens quite quickly in a normal English atmosphere.

Unfortunately our climate has not also the virtue of reliability. The figures given in paragraph 6 show that a high proportion of accidents occur in periods of abnormally dry weather. In a spell of abnormal dry weather in March, 1953, three accidents were reported in four days. Other accidents occur because heating and ventilating plant or some other factor keeps the air in the theatre drier than that outside. One occurred when the spray-washer in the ventilating plant was temporarily out of action. We therefore cannot place any reliance on relative humidity as a safeguard unless we are prepared to keep constant control of it. To make this possible every anaesthetising location should be equipped with some simple instrument to measure relative humidity (which need not be expensive) and some means be devised for raising the humidity there when necessary. It would be dangerous to fix on an ideal standard of relative humidity, which might give a false sense of security—electrostatic sparks can still be produced when relative humidity is in the sixties and seventies—but in our view it should be the responsibility of the Theatre Sister or some other member of the staff to inform the anaesthetist as soon as relative humidity falls below 50 per cent, as static electrification increases rapidly as the humidity drops below this value. He will then be able either to take steps to raise the humidity or to change to a non-explosive anaesthetic. A human hair hygrometer, which costs about £3, is sufficiently accurate for this purpose provided it is not moved about. It is recommended that the apparatus be checked about every three months against a wet and dry bulb type of hygrometer.

The raising of humidity is not as simple as might be imagined. Many hospitals maintain steam sterilisers in their operating theatres, in the belief that this will ensure satisfactory humidity, but even when these are working, which is not always, their effect is uncertain and may vary between different parts of the theatre. Washing down walls and floors with water has some effect, but not as much as might be expected. An ordinary spray washer might be of use for raising humidity, and there are a few special types of apparatus available for this purpose, some of which might be suitable for use in hospitals. In our view some further research should be undertaken before hospitals can be advised how best they can prevent low humidity.

D. PREVENTION OF STATIC DISCHARGES BY IONIZING THE AIR

14. We have had under consideration a piece of apparatus which it is suggested might be installed in operating theatres for the specific purpose of minimising the risk of static discharges. The apparatus is designed to ionize the air in its neighbourhood by circulating it over a radioactive thallium source. At present it is still in the experimental stage.

15. The ionization of the atmosphere cannot prevent the creation of static charges as a damp atmosphere will do : no conducting film is formed on the objects in its neighbourhood. But it has the corresponding advantage that its effect is in no way dependent on the nature of the objects it surrounds : it will dissipate charges from any surface whether conducting or otherwise, while there are some non-absorbent surfaces which will maintain a charge however high the relative humidity. Its efficacy will depend on its ability to remove charges with extreme rapidity, as a charge sufficient to cause sparking may be built up in a fraction of a second. This requires further investigation, but there is no reason to doubt that it will be possible to produce a machine which would dissipate at any rate the great majority of static charges.

16. If put into production the machine should cost something like £60 and the radioactive thallium should need replacing, at a cost of about £20, not more frequently than every four years.

17. Further investigation is required both into the machine's efficiency as an anti-static device and into the possibility of harmful effects of breathing ionized air, and we commend this research to the Minister.

E. SUBSTITUTES FOR EXPLOSIVE GASES

18. We have said above (paragraph 12) in considering the dangers of using explosive anaesthetics in the presence of electrical equipment, that the only complete answer to the problems which these explosions present to the anaesthetist would be one which freed him from the necessity of using medically unsuitable drugs to avoid them. Since the use of electrical instruments in surgery is here to stay, this can only be done by offering the anaesthetist a sufficient range of medically suitable non-explosive gases. This is equally the only complete answer to the problem of static explosions, since it is virtually impossible to design conditions in which a dangerous static discharge will never occur. Various possible avenues of research to this end have been brought to our attention.

19. First, there is the use of fluorine-substituted compounds analagous to existing anaesthetics. Work done several years ago by Professor Stacey at Birmingham

suggested that compounds could be found which retained the anaesthetic properties of the originals but were non-inflammable, but this has unfortunately never been followed up.

20. Secondly, we learn that within the last few months a so-called "snuffer" for petrol has been found : in other words, a substance which when added to petrol renders it non-inflammable. It is, in our view, worth immediate investigation whether this or another substance will perform the same function for ether and other explosive gases.

21. Thirdly, there are a few references in the literature to the anaesthetic properties of the inert gas Xenon. This again deserves investigation.

F. NOTE ON RISKS IN DENTAL DEPARTMENTS

22. At the request of the Ministry's Standing Dental Advisory Committee, we have considered explosive risks from anaesthetics used in dentistry. To the best of our knowledge no explosions have occurred during ordinary dental procedures in recent years, but risks similar to those already mentioned are present. The most commonly used anaesthetising agents for dental operations are nitrous oxide and oxygen sometimes mixed with trichloroethylene, ethylchloride, ether or other material. The use of cyclopropane and divinyl ether in dental operations, the latter especially for children, has become increasingly popular. Both of these agents are highly explosive and, in view of the spark risks enumerated below, their use should be conditioned by the precautions described in Appendix A.

23. Possible sources of ignition are :

(i) Sparking on commutators or internal switching devices of motors, particularly drills and dental engines and suction pumps (which may also aspirate an explosive anaesthetic gas from the patient's mouth), and on switches of speed regulators, portable lighting units and small lighting appliances such as illuminated dental mouth mirrors.

(ii) Heat or sparking produced in the operation of electrical equipment such as fires, heaters, cautery appliances, chisels, small surgical lamps (over-running), low voltage transformers (particularly when wrongly designed) : also heat from open flames such as gas burners.

NOTE : The most easily ignitable anaesthetic gas mixture may be ignited at a temperature below that of visible red heat.

(iii) Sparking on flexible cables, wiring, connections, and plugs and on switches controlling lighting and power supplies.

(iv) A spark-discharge by static electricity, resulting from the electrification of highly insulating materials such as ordinary rubber in the form of anaesthetic breathing equipment and the rubber flooring commonly employed in dental surgeries, etc.; also from plastic materials in the form of instrument trays, illuminator panels on X-ray viewing units and upholstery on dental chairs, etc.

(v) Heat or frictional sparking on dental burrs and drills.

24. In addition attention has recently been drawn to the fact that sparks may be thrown off when a forceps fractures the enamel of a tooth. Investigation has shown that such sparks are capable of igniting anaesthetic mixtures. The probability of ignition is a function of the oxygen content of the mixture and dilution with nitrogen so that the oxygen is not above 25 per cent effectively excludes this hazard ; this modification is easy to carry out and does not detract from the efficacy of the anaesthetic technique.

25. The general remarks we have made about precautions to be taken with explosive

mixtures are applicable here as elsewhere, as are the comprehensive electrical safety precautions described in Appendix A.

G. CONCLUSION

I. Dissemination of advice

26. In recommending the above measures for preventing anaesthetic explosions we should add a further word on the difficulties of securing their general adoption in hospitals.

Though the problem referred to us is a very real one we do not wish to exaggerate its importance, and for this reason we have sought to be moderate in our recommendations. We appreciate that hospital authorities would rightly hesitate to adopt measures which conflicted with clinical requirements, or even clinical convenience, or which involved heavy expenditure. Nevertheless it is important that there should be a more general awareness of this danger and a realisation that since 1947 three patients have died and a number of people have sustained injuries as a result of anaesthetic explosions. There are thus no grounds for complacency. Anaesthetists should not need to be reminded that they must not smoke at their work, nor hospital authorities that they must not site gas burners near any locations where inflammable anaesthetics are used. (Some guidance on this matter is included in Appendix A.) But they do, and until some consciousness of the danger can be engendered there is little to be gained by refinements in the recommended technique. It is not easy to suggest a remedy. For the majority, even of those who spend their lives in theatres, explosions will remain something they read about in the newspapers. We consider that the best means of creating an awareness of the risks involved in the use of explosive anaesthetics would be for the Minister when circulating advice to hospital authorities, to provide for use in every anaesthetising location a notice setting out clearly the main points involved (somewhat on the lines of that prepared in 1943 by the Institution of Electrical Engineers). We append a draft for such a notice (Appendix B). In drafting it our prime consideration has been simplicity and comprehensibility, since in our view somewhat rough and ready rules universally followed are to be preferred here to comprehensive precautions which those concerned do not always bother to put into practice.

27. It will of course be for the Minister to decide, if he accepts generally the advice contained in this Report, whether he should pass it on at once to hospital authorities or whether he should hold it up until we are able to submit further reports on some or all of the four matters on which we have recommended that further research should be undertaken. These recommendations are collected below.

II. Proposals for research

28. Following are the four matters which we have proposed in the body of our Report should be the subject of further research.

(a) Means of increasing the conductivity of existing non-conductive floors in anaesthetising locations (paragraphs 13 (c)).

(b) Means of adjusting the relative humidity of anaesthetising locations (paragraph 13 (d)).

(c) The efficiency and safety of ionizing the air as a means of preventing static discharges (paragraphs 14-17).

(d) The use of new non-explosive drugs as anaesthetics (paragraphs 18-21).

We recommend that the Minister should ask the appropriate body or bodies to consider research into these matters.

APPENDIX A

SAFETY CODE

for Equipment and Installations used in conjunction with Explosive Anaesthetics

PREFACE AND SUMMARY

THIS code has been prepared by the Working Party on Anaesthetic Explosions appointed by the Minister of Health primarily as a guide

(a) for hospital engineers in the installation and care of electrical equipment in places where explosive anaesthetics are to be used, and

(b) for hospital supplies officers or pharmacists in the ordering of such equipment;

but some of its recommendations are of concern to other members of hospital staff as well.

It is to be read in conjunction with the Working Party's Report.

The following summary indicates the scope of the code and where points have been included which are of wider concern this has been noted in the summary.

It is suggested that when new equipment is ordered supplies officers should where possible specify to the manufacturer that the relevant paragraphs of the code are to be complied with.

I. INTRODUCTION

1. These notes are intended to give guidance to persons who are responsible for the functioning, installation, maintenance, or purchasing of equipment in hospitals with the object of reducing the risk of igniting inflammable anaesthetics in operating theatres and other anaesthetising locations. It is also hoped that they will be of assistance to manufacturers. Consideration has also been given to the reduction of associated risks such as the risk of electric shock arising from the use of apparatus connected to mains electricity and the risk of burns or electric shock when using surgical diathermy apparatus.

It is recognised that in some instances safeguards that can be readily incorporated during manufacture may be impracticable for existing equipment ; where this is so, alternative safeguards have been specified.

It is recommended that the code be given its widest application in respect of new installations and equipment or when major alterations are being made. With existing installations and equipment the code should be applied as far as is practicable and as far as resources permit, particularly in busy anaesthetising locations. Where, however, inflammable anaesthetics are rarely used and their use is restricted to short periods it is suggested that precautionary measures against the ignition of inflammable anaesthetics could reasonably be limited to any obvious risks, which should include any applicable to the anaesthetic apparatus.

The highest degree of safety can only be achieved with the co-operation of all concerned, but the provision of the most suitable equipment together with good maintenance can do much to ease the minds of the medical staff on safety matters and allow them greater freedom of action. It should be the aim to provide equipment which is most suitable for its functional use combined with the highest degree of safety practicable.

II. DEFINITIONS

2. The following definitions have been adopted for the purpose of this code :

(a) *Totally enclosed construction.* Enclosures without openings and with well fitting jointed surfaces to restrict the movement of gases through the enclosure, but with the joints not sufficiently sealed to be gas tight.

(b) *Gas-Tight Enclosure.* As in (a) above but constructed as far as is practicable to prevent the passage of gas through the enclosure and to be capable of remaining reasonably gas-tight (for practical purposes) after repeated servicing.

(c) *Flameproof Enclosure.* An enclosure which will withstand without injury any explosion (of the gas mixture in use) which may occur within it under conditions that may arise in practice, and will prevent the transmission of flame sufficiently to avoid the ignition of the gas mixture which may be present in the surrounding atmosphere.

(d) *Sparking.* Arcing or sparking produced by intentional making or breaking of current-carrying conductors or by fault conditions, or due to static electricity.

(e) *Incendive Spark.* A spark capable of igniting any mixture of the gases in use.

(f) *Ignition Temperature.* The minimum temperature which will ignite any mixture of specified gases.

(g) *Intrinsically Safe Circuits.* Circuits in which any sparking that may occur, either in normal working or under fault conditions, is of such low incendivity as to be incapable of causing an explosion of the gases constituting the risk.

(h) *Earth-free Circuit.* Current-carrying conductors having no physical connection with an earthing source.

(i) *Electrostatic materials.* Those capable of readily generating static electricity during normal movements.

(j) *Anti-static.* Having sufficient electrical conductivity to prevent the production or retention of significant electrostatic potentials.

(k) *Equipment.* Includes apparatus, furniture and all equipment, fixed or portable.

(l) *Portable Equipment.* Any apparatus capable of being moved including transportable (wheeled) equipment.

(m) *Low Voltage Equipment.* For the purpose of this code, this is a relative term referring to equipment operating at 15 volts or less.

III. NOTES ON RISKS

3. *Inflammable Anaesthetics*

The main inflammable anaesthetics in use at present are ether, cyclopropane and ethyl chloride. Mixed with air, oxygen or nitrous oxide these anaesthetics may be violently explosive. The minimum temperature which will ignite a mixture of these gases is approximately 355°F (180°C).

Trichloroethylene is not inflammable in air at any temperatures or pressures likely to be encountered during anaesthetising procedures. If, however, trichloroethylene vapour is mixed with air enriched with oxygen (33% oxygen), or with pure oxygen, at a temperature exceeding 78°F (25·5°C), an inflammable mixture may be formed, the ignition temperature in oxygen being 786°F (419°C). The minimum quantity of trichloroethylene that will form an explosive mixture in these circumstances is 10·3% and it should be noted that this represents a strength which is greater than is normally necessary for anaesthetic purposes.

It is not considered that trichloroethylene mixtures could be ignited by electrostatic spark discharges, but it may in certain circumstances be possible to ignite them with diathermy or cautery, e.g. if used in the mouth.

4. *Extent of Risk*

Experience to date suggests that the risk of an explosion during the administration of inflammable anaesthetics is confined almost entirely to the use of anaesthetic apparatus in which the inflammable agents are confined, that is, where a closed or partially closed breathing circuit is employed. Leakage of the inflammable agents into free air may cause the surrounding atmosphere to become inflammable but it is unlikely to be explosive unless a considerable quantity of inflammable gas is liberated, as for example by spillage. It should be clearly understood, however, that ignitions occurring external to anaesthetic apparatus may travel through the leakage aperture into the confined breathing circuit and cause an explosion. Experience suggests that most explosions occur in this manner.

The risk of an explosion is considerably lessened when inflammable anaesthetics are administered by open methods, and no instance is known of an injury resulting from an ignition during the administration of inflammable anaesthetics using open techniques.

Inflammable anaesthetics are heavier than air and consequently there is a greater risk of an inflammable concentration existing at lower levels.

5. *Zone of Risk*

Experience suggests that the risk of igniting an inflammable gas mixture by a sparking source is confined to the area immediately surrounding the anaesthetic apparatus or container. On the other hand, open flame or hot surfaces can ignite very weak inflammable gas mixtures so that the area of risk is greatly extended with these forms of heating.

For the purpose of this safety code the zone of risk is defined as :

Spark Risks. Between floor level and a height of 4′ 6″ above floor level for a horizontal radius of 4′ from any part of the anaesthetic apparatus or container.

Note : As anaesthetic apparatus is normally portable, all fixed equipment installed less than 4′ 6″ above floor level in an operating theatre, anaesthetic room, or similar anaesthetising location, should be regarded as being within the spark risk zone, and equipment installed more than 4′ 6″ above floor level in these locations should be regarded as being above the spark risk zone. The main purpose in defining the horizontal extent of the spark zone is to indicate the spacing necessary to secure reasonable safety when any electrical equipment is used which does not conform to the safety recommendations in respect of spark risks.

Flame and Hot Surface (exceeding 300°F (149°C) Risks. The safe distance for these risks will be influenced largely by the ventilating arrangements. Where there is no mechanical ventilation, the zone of risk should be regarded as being between floor level and a height of 4′ 6″ above floor level for a horizontal distance of 20 ft., the horizontal distance being the shortest air passage between the source of ignition and the anaesthetic apparatus. Doors between the anaesthetising position and the ignition risk should not be regarded as a reliable safeguard as they may be open.

Note : Adequate mechanical ventilation will greatly reduce the ignition risk if the air movement is such that any inflammable gases escaping at the anaesthetising location will be carried away from any open flame or similar ignition risk. However, too much reliance should not be placed on mechanical ventilating arrangements for this purpose because of the possibility that the ventilating equipment may at times be out of use. The use of ventilating arrangements whereby the air movement is from the anaesthetising location towards an open flame ignition risk should be avoided.

6. *Spark Risks*

Sparking may occur during the normal functioning of equipment as, for example, with brush gear of electric motors, switch contacts, socket-outlets, diathermy apparatus, etc. There is also a spark risk associated with fault conditions on almost all electric apparatus, e.g. faulty connections and short circuits.

7. *Hot Surfaces*

Apparatus having surfaces which are open to atmosphere and which may attain a temperature capable of igniting inflammable anaesthetics, e.g. electric space heaters, sterilisers, lamps and lighting fittings, and electric cautery apparatus, may be a source of risk.

8. *Electrostatic Risks*

Certain materials can be readily electrified by normal movements during use and if the electrostatic charges generated are of sufficient magnitude considerable differences of potential may exist and cause equalising spark discharges to occur. The generation of large electrostatic charges is associated with materials having high electrically insulating properties. In addition to the risk of a spark discharge direct from the material generating the charge, electrical conductors brought within the field of the charged object may become charged. Sparking may then occur when electrical conductors at different potentials are brought into close proximity.

9. *Open Flames*

The risk associated with gas burners, spirit stoves and other equipment employing open flames is obvious and it is recommended that the use of such equipment should be avoided altogether in operating theatre suites and similar locations if safer means of heating can be provided without undue expense. The use of highly inflammable liquids for anaesthetic and cleaning purposes in these locations and the possibility of spillage greatly increases the fire and ignition risks with open flame equipment. (See also paragraph 48.)

10. *Spontaneous Ignition*

It has been suggested that ether peroxides formed by the oxidation of ether over a period of time, and in particular when ether is exposed to bright light, may cause spontaneous combustion. No instance is known of an explosion being directly attributed to this cause. Frequent emptying and cleaning of ether containers on anaesthetic apparatus and special attention to the storage of this anaesthetic should provide an effective safeguard against any risk from this source.

IV. GENERAL PRECAUTIONS

11. This code is principally concerned with safeguards that are associated with the construction, installation and maintenance of equipment. The references to the extent and zones of risk are intended to give guidance where segregation is relied upon as an alternative safeguard.

Safeguards concerning anaesthetising procedures are outside the scope of this code.

12 *Anti-static Precautions*

(a) *General.* The framework, enclosures, etc., of all equipment should be constructed of metal or other material having suitable anti-static properties so as to be electrically continuous throughout and should have an electrically conductive path to the floor. Shelves and other surfaces on which movable objects may be placed should be free from paint or other electrically insulating finish. Special attention should be given to the continuity of metal parts on anaesthetic apparatus, e.g. framework, manifold, metal connectors.

(b) *Rubber Equipment and Components**. Rubber and similar equipment, e.g. tyres, mattresses, pads, furniture feet, buffers, tubing and belting, should have anti-static properties and be in effective electrical contact with any metal work to which it is attached. The permissive limits of electrical resistance for anti-

* Including thermoplastic products used as an alternative to those made of rubber.

static rubber components when tested by the appropriate method given in paragraph 53 are as follows :

Each anti-static rubber item (except those mentioned below)	50,000 ohms— 10 megohms when new. 50,000 ohms—100 megohms after being in service.
Soles and heels of footwear	75,000 ohms— 10 megohms when new. 75,000 ohms—100 megohms after being in service.
Castor tyres	10,000 ohms— 10 megohms when new. 10,000 ohms—100 megohms after being in service.
Tubing other than breathing tubing which constitutes the main connection between anaesthetic apparatus and the patient. Short tubing connections Facepieces Breathing bags Bellows Head harness * Airways * Endotracheal tubes Buffers Belting	No lower limit—up to 10 megohms when new. up to 100 megohms after being in service.

(c) *Marking.* Each anti-static rubber item of equipment and each detachable component should bear individually a conspicuous and indelible lemon coloured marking, together with the word "anti-static," where practicable. Anti-static rubber tubing which may be cut in shorter lengths after manufacture should have an indelible lemon coloured line at least one-eighth inch in width or some similar marking throughout its length. In addition to the anti-static marking it is important that rubber tubing on anaesthetic apparatus used for connecting gas cylinders, etc., should bear a conspicuous and permanent coloured marking appropriate to the gas for which it is to be used, in accordance with the approved colour code.

13. *General Fire Precautions*

Equipment should be constructed of fire-resisting materials as far as is practicable.

14. *Compliance with British Standards*

Equipment should be constructed to comply in all respects with British Standards in so far as they are applicable.

The following British Standards include references to equipment which may be used in association with inflammable anaesthetics :

B.S. 1938—Instrument Tables, Anaesthetists' Trolleys and Dressings' Trolleys for use in Hospitals.
B.S. 1962—Patients' Trolleys (Fixed Top) for indoor use in Hospitals.
B.S. 2057—Patients' Trolleys (Tilting Top) for indoor use in Hospitals.
B.S. 2097—Maternity Cribs (Metal) on Tubular Metal Frames for use in Hospitals.
B.S. 2050—Resistance of conductive and anti-static rubber products.
B.S. 2506—Anti-static Rubber Footwear for hospital use.

V. DESIGN AND CONSTRUCTION OF ELECTRICAL APPARATUS—BASIC PRINCIPLES

15. Three basic principles are described below for the design and construction of electrical apparatus which might otherwise constitute a spark risk if used in association with inflammable anaesthetics.

* These items are normally moistened when in use, consequently it is less important for them to have permanent anti-static properties. However, it is considered desirable that they are made of materials having permanent anti-static properties, provided this can be achieved without significantly affecting the essential properties required for their clinical use.

16. *Gas-Tight Enclosures*

The enclosure should be constructed to prevent ingress of the surrounding atmosphere. Jointed surfaces should have adequate surface area and a gasket or suitable jointing compound should be used to render the joints gas-tight. Diametrical clearances should be as small as is practicable and of adequate depth to render them as gas-tight as practicable. The enclosure should have an adequate heat-dissipating surface to prevent undue temperature rise.

Metal gauze will not prevent the passage of flame with the gases under consideration and is not therefore suitable for the enclosure of any electrical apparatus liable to constitute an ignition risk.

> NOTE: Flameproof enclosures for electrical apparatus are used in industrial locations where the surrounding atmosphere may contain certain prescribed gases. The specified gases for which flame-proof enclosures are suitable do not include cyclopropane or ether when used with oxygen; therefore flameproof enclosures are not a complete safeguard for the risks under consideration. Moreover, conditions in anaesthetising locations differ from those normally met in industry in that inflammable anaesthetic gases are used intermittently. This means that electrical apparatus in these locations will not normally be exposed to an inflammable atmosphere for long periods, a fact which considerably lessens the possibility of inflammable gases penetrating into an enclosure which has been rendered reasonably gas-tight. Where flameproof type enclosures are used it is recommended that they be rendered reasonably gas-tight by sealing the jointed surfaces.

17. *Pressurised Enclosures*

Where use of gas-tight enclosures presents difficulties as, for example, with large apparatus incorporating numerous controls, the spark risk may be reduced by maintaining a positive pressure within the enclosure by means of a piped air supply drawn from outside the zone of risk. With this arrangement the electric supply to the apparatus should be controlled by means of a pressure sensitive switch located within the enclosure and arranged so that the supply cannot be switched "on" or remain "on" unless there is a positive air pressure within the enclosure. The air pressure necessary for this purpose will depend on the sensitivity of the pressure switch and may be of the order of $\frac{1}{4}$-$\frac{1}{2}$ lb. per square inch.

18. *Intrinsically Safe Circuits*

In general the spark ignition risk increases with voltage and is greater with alternating current than with direct current. The presence of inductance in the circuit also increases the spark risk.

Current limitation, e.g. by means of a suitable resistor, can render circuits intrinsically safe inasmuch as any sparking occurring under normal or fault conditions would be non-incendive. This precautionary measure can only be applied to low energy consuming circuits such as those used with endoscopic instruments or circuits incorporating sensitive relays or thermionic valves.

The table overleaf gives the values of resistance which are necessary to render circuits intrinsically safe under all conditions and include a safety factor. The resistors should be non-inductive (for practical purposes) and be connected as near to the energy source as possible to safeguard against any short circuit that may occur.

TABLE 1

Direct Current		Alternating Current	
Volts	Minimum Safe Limiting Resistance	Volts	Minimum Safe Limiting Resistance
0–2	0·25 ohms	0–2	1·25 ohms
2–4	1·24 ,,	2–4	6·00 ,,
4–6	3·25 ,,	4–6	14·00 ,,
6–8	7·00 ,,	6–8	25·00 ,,
8–12	27·00 ,,	8–13·5	54·00 ,,

Primary cell battery units allow the safe use of more energy than other energy sources and with most battery units a portion of the voltage regulating resistance can be used as the current limiting resistance by providing a stop for the contact arm in a position that ensures the required value of resistance is always in circuit. On new apparatus it is considered preferable that a separate current limiting resistor be provided.

Intrinsically safe circuits are particularly suitable for energising endoscopic and similar instruments having closely spaced contacts at different potentials, because of the increased risk of a short circuit on such instruments.

In some instances the values of limiting resistance quoted in Table 1 may reduce the amount of useful energy in the circuit to a value which prevents the proper and reliable functioning of apparatus, e.g. relay operated control circuits. In these instances it will be necessary to reduce the value of the current limiting resistor and to regard the load resistance as part of the current limiting resistance. Where this is so, provided the total resistance in circuit, i.e. load and limiting resistance, is not less than the value of current limiting resistance specified for the maximum voltage in use and the circuit is reasonably non-inductive, sparking at switch contacts and at other points where the circuit is interrupted would be non-incendive, but the circuit would not be fully safeguarded against sparking and other risks associated with short circuit conditions. In these circumstances adequate alternative precautionary measures should be taken to reduce the risk of short circuits, e.g. by the use of heavy quality cables, adequate spacing of contacts at different potentials, etc.

VI. DESIGN CONSIDERATIONS AND PRECAUTIONARY MEASURES—COMPONENTS

19. *Electric Motors*

Electric motors should comply with the following:

NEW MOTORS:

(a) motors incorporating no switch contacts or other mechanisms liable to spark in normal use should be of a totally enclosed induction type, i.e. the frame should have no ventilating openings and the jointed surfaces should be closely butted together. The cable entry point should be sealed with a well-fitting grommet or screwed gland;

(b) motors incorporating switch contacts, e.g. a centrifugally operated switch for controlling the starting winding and/or the on/off switch controlling the electric supply to the motor, should be rendered as gas-tight as is practicable. Jointed surfaces should have adequate surface area and a suitable jointing compound used to render the joints gas-tight. Diametrical and other bearing surfaces should also be of adequate surface area, to render the bearings reasonably gas-tight. The construction of the motor should be such that the omission or fracture of a screw or bolt used in the assembly will not destroy the gas-tightness of the enclosure.

EXISTING MOTORS:

(c) induction type motors incorporating switch contacts may be regarded as satisfactory if they are totally enclosed and reasonably gas-tight, i.e. the jointed surfaces are tightly bolted together, the frame having no ventilating openings and the cable entry sealed with a well-fitting grommet.

(d) open frame induction motors housing switch contacts are considered unsatisfactory. To render these safe the switch contacts inside the motor should be disconnected and a relay switch of gas-tight construction, or its equivalent, provided. (It will normally be necessary for this switch to be located outside the motor frame.) The switch and its enclosure should comply with paragraph 26.

GENERAL:

D.C. and other commutator motors are unsatisfactory unless they can be rendered effectively gas-tight. (Note. It is not usually satisfactory to seal existing ventilating openings in motor frames owing to the possibility of overheating.)

Motors should be capable of withstanding without damage the maximum temperature rise which will be experienced in normal service, particularly where totally enclosed or gas-tight motors are housed in totally enclosed apparatus.

Condensers used in conjunction with electric motors should be of robust gas-tight construction and their terminal connections fully protected.

20. *Terminal Connections*

Terminal connections should be of adequate size and designed to prevent conductors becoming loose or frayed, particularly on alternating current circuits, e.g. by the use of lock nuts, spring washers or soldered tags. All terminal conductors, including those of low voltage equipment, should be completely enclosed or shielded with an insulating material or earthed metalwork to prevent inadvertent contact with other conductors or with persons.

21. *Cable Connections on Apparatus*

Flexible cable connections which form part of electrical apparatus should have at least 23 stranded conductors and be liberally rated as regards their current carrying capacity. The cables should be secured at frequent intervals where practicable and grommets or other protection should be provided where cables pass through openings in enclosures, etc.

Cable connections should have an outer covering of tough rubber, p.v.c., asbestos, or equivalent and be of circular cross-section. The insulation on cables should be capable of withstanding the temperature to which it may be subjected during use without undue deterioration.

22. *Earthing*

Unless otherwise specified, e.g. where special arrangements are made for earth-free working, the exposed metal work and other non-current-carrying metal parts on all electrical apparatus should have an effective earthing connection. On portable apparatus the earthing conductor should be incorporated in the flexible cable used for connecting the apparatus to the energy source so as to ensure that the exposed metal work is earthed when the plug is inserted into any corresponding socket-outlet. The cross-sectional area of the earthing conductor should be not less than that of the current-carrying conductors.

23. *Plug and Socket Connectors*

MAINS VOLTAGE:

It is considered preferable that the use of plug and socket connectors on apparatus and in flexible connections be avoided particularly on new apparatus. Where plug and socket connectors are necessary they should incorporate the following:

(a) an earthing connection arranged to ensure that the connection to the earthing source is always completed with the other electrical connections (except where used with earth-free apparatus—see paragraphs 30 and 40);

(b) a positive locating device to render them non-reversible and ensure that correct polarity is maintained;

(c) means to prevent easy and inadvertent disconnection which may cause sparking;

(d) adequate shielding of live conductors to prevent accidental contact therewith or short circuit.

GENERAL:

All plug and socket connectors should have the socket portion connected to the supply.

24. *Fuses*

It is preferable that sub-circuit and other fuses be installed outside the zone of risk. Any fuses installed within the zone, and fuses on portable equipment, should be housed in gas-tight enclosures of incombustible construction. Special attention should be given to the correct fusing of circuits supplying portable equipment in hazardous locations, to ensure rapid interruption of the supply in the event of a fault occurring.

25. *Belts*

Transmission belts should have anti-static properties to the requirements of B.S. 2050 and be adequately guarded.

26. *Switches*

Switches on equipment which may be used in the spark risk zone should be arranged so that the switch contacts are in a gas-tight enclosure. They should be of robust construction and be capable of withstanding the following tests without becoming unserviceable:

(a) withstand a test voltage (R.M.S. 50 cycles) of at least four times the maximum voltage rating, applied between the contacts with the switch in the off position for one minute.

(b) withstand a current 100% in excess of the current rating for 30 minutes.

(c) make and break a current overload 100% in excess of the current rating ten times in succession at one minute intervals.

(d) make and break their rated current at the rated voltage 10,000 times at regular intervals of 10 seconds per cycle of operation.

Switches having glass enclosures, e.g. mercury switches and their terminal connections, should be housed in metal enclosures to provide adequate protection against mechanical damage, etc. Where such switches are incorporated in portable apparatus the enclosure should be of reasonably gas-tight construction with the cable entry sealed with a well-fitting grommet, or by other appropriate means.

Footswitches should be of gas-tight construction. The use of a moulded rubber casing with a vulcanised cable entry and metal access plate has been found convenient for forming a gas-tight enclosure for footswitches used in conjunction with portable apparatus, and for reducing the electric shock risk.

The tests should be made with the outer enclosures in position.

27. *Transformers*

Transformers should be of the double wound type and if the primary and secondary windings overlap an earthed screen should be provided between the windings.

The output circuits of low voltage transformers, e.g. those to be used for energising endoscopes, should be earth-free and only one set of output terminals should be provided for each output circuit; multiple secondary windings should not be interconnected. Special attention should be given to effective separation and insulation between live conductors at mains voltage and those at lower voltage, particularly where rheostats are incorporated in the apparatus.

To reduce the spark and electric shock risks it is recommended that the maximum output voltage of low-voltage transformers should be as low as is practicable and the following maximum voltages are recommended for :

Endoscopic instruments ..	4 volts
Surgeons headlamps	6 volts

There may be special surgical techniques which require higher voltage lamps but in general it is recommended that the voltage be kept as low as possible. Where it is necessary to obtain a greater light output it is preferable from the electrical safety aspect to use a lamp having a higher current rating rather than higher voltage. Where a higher voltage is used the output terminals of the supply should be arranged so that they cannot be used with other apparatus requiring a lower voltage.

The maximum output voltage should be indelibly indicated on or near output terminals.

Transformer terminal connections should comply with paragraph 20.

All non-current-carrying metal work should be connected so that it is at earth potential when in use. (See also paragraph 45.)

28. *Voltage Adjustment*

The direct connection of low voltage equipment to mains electricity through a resistance unit greatly increases the electric shock and spark ignition risks and any apparatus which operates at a potential lower than that of the mains and which is required to be energised with mains electricity should be supplied from a transformer (see paragraph 27) or other equipment giving equal protection. Resistance units should not be used for reducing the input voltage to apparatus.

Where facilities are provided to enable the input circuit of apparatus to be adjusted for different mains potentials the connections should be enclosed within the apparatus and arranged to prevent inadvertent misadjustment. Where single pole plugs and sockets or similar exposed connections are provided on existing apparatus they should be removed and more permanent internal connections substituted.

29. *Drawer and Cupboard Space*

Any drawer, cupboard space or compartment incorporated into electrical apparatus (e.g. electro-surgical tables) should be formed with incombustible materials and the internal partitioning should be adequate to prevent accidental contact between stored materials and internal live connections.

VII. DESIGN CONSIDERATIONS AND PRECAUTIONARY MEASURES—APPARATUS

30. *Electrically operated Surgical Saws and Drills*

The motors of electrically operated surgical saws and similar equipment normally incorporate a commutator and brush gear which is likely to spark in use and there is also a spark risk associated with the switch or speed controller normally used in conjunction with the motor. Where, as is usual, the apparatus is connected to mains electricity, there is also a risk of electric shock, particularly where part of the metalwork of the machines makes direct contact with the patient. Having regard to the inherent risks associated with electrically operated tools it is considered preferable from the safety aspect to use pneumatically operated equipment.

Where for surgical reasons electrically operated machines are preferred the motors and any speed controller or switching mechanism should be as far as is practicable of gas-tight construction.

Where the apparatus is energised with mains electricity, special precautions are necessary to reduce the risk of electric shock. The normal precautionary measures include earthing the exposed metalwork of the apparatus, and frequent testing of the earthing connections is advisable to ensure that they are effective. In particular it is desirable that the earthing connections are checked immediately prior to use. This may present difficulties where it is necessary for the exposed metalwork to be sterile ; also, despite regular servicing, there is the possibility of a fault developing during use. Because, therefore, of the difficulties associated with the maintenance of earthing connections on electrically operated surgical tools, it is considered preferable that they be energised from an earth-free output circuit of a mains isolating transformer. Where earth-free working is adopted the earthing connection to the appliance should be omitted (see paragraphs 40 and 45). When this is arranged it is essential on grounds of safety that the appliance should not be operated from any socket-outlet other than those connected to an earth-free circuit. Special attention should be given to periodical insulation tests between the current carrying conductors and the exposed metalwork on earth-free apparatus (see paragraph 52). (For flexible cables and plug and socket connectors see paragraphs 21 and 23.)

31. *Surgical Diathermy*

The inherent risk associated with the use of diathermy apparatus in the presence of inflammable anaesthetics is well known. There are, however, many occasions when despite the ignition risk it is necessary to use surgical diathermy, and for this reason, the apparatus should be designed to reduce the ignition risk to a minimum. It is considered preferable that transformers, oscillatory equipment, switch gear, etc., be housed in a single gas-tight enclosure. Alternatively the various components which constitute a spark risk, including any spark gaps, fuses and switches, should be housed in separate gas-tight enclosures (see paragraph 16). Any footswitch used with the equipment should be of gas-tight construction (see paragraph 26).

In addition to the spark risk there is a risk of electric shock and burns associated with the use of diathermy apparatus unless proper precautions are taken. To reduce these risks the plate-electrode terminal should be so connected that it is at earth potential when in use, preferably by means of a rigid connection to the metal framework of the apparatus which in turn should be connected to an earth lead in the flexible cable supplying the apparatus. This will ensure that the plate-electrode terminal is earthed when the mains plug is inserted into the socket-outlet. The earthed output terminal on the apparatus should be indelibly marked "P" and should also differ from the active electrode terminal(s) in a manner that will prevent the plate-electrode being connected to the active electrode terminal.

New apparatus should incorporate a test unit to enable the effectiveness of the earthing of the plate-electrode to be tested before it is applied to the patient. This could consist of a special insulated terminal point and a small indicator lamp energised from a 2·5 volt transformer winding and arranged to give an indication when the plate-electrode makes contact with the terminal, if the earthing is satisfactory. With such an arrangement the lamp resistance would be sufficient to render the circuit intrinsically safe. Where diathermy apparatus does not incorporate these facilities it is recommended that a separate test unit be provided (for details of test units see paragraph 50).

32. *Endoscopic Instruments, Surgeons' Headlamps and other small lamps*

It is recommended that the following voltages be standardised:

Endoscopic instruments	2·5 volts or 3·5 volts
Surgeons' Headlamps and other small lamps ..	6 volts

There may be special surgical techniques requiring the use of higher voltage lamps (see paragraph 27).

It is considered preferable that the metal framework of the appliance should not form part of the electrical circuit. Exposed metalwork at different potentials should be avoided (see paragraph 51).

33. *Electric Sterilisers*

Where electric sterilisers are to be installed within the zone of risk, the heating elements and any thermostats, switches, etc., provided for use in conjunction with them should be of sealed gas-tight construction. The use of non-sealed heating elements clamped outside the water compartment is not considered satisfactory.

Electrically heated sterilisers should incorporate a thermal safety device which disconnects the heating elements from the energy source in the event of overheating, e.g. due to lack of water.

34. *Suction Apparatus*

It is considered preferable that suction apparatus be permanently installed with the main suction unit outside the anaesthetising location, piped suction points being provided in the anaesthetising area as required. Such an arrangement, in addition to reducing the ignition risk, has the advantage of providing additional working space in the anaesthetising area.

In general non-electrically operated suction apparatus, e.g. the steam ejector type, is to be preferred from the safety aspect. Oxygen operated apparatus, however, has the drawback that if it is used in association with inflammable anaesthetics highly inflammable gas mixtures may be discharged from the exhaust outlet (e.g. when the suction is used in the mouth), while the continuous discharge of oxygen from the apparatus may result in the surrounding atmosphere being appreciably oxygen enriched and thereby increase the general fire risk. It would therefore be

metalwork should not be less than 250,000 ohms when tested with a 500 V. insulation tester.

36. *X-ray Apparatus*

The application of safety measures to reduce the ignition risk with X-ray apparatus presents a special problem because of the numerous possible sources of sparking associated with the apparatus. Experience to date suggests that the risk of an explosion arising from the use of X-ray apparatus in association with inflammable anaesthetics is very slight and there is no knowledge of an incident being caused by X-ray apparatus in this country. In particular the risk is considered to be very remote when a small quantity of ether is administered in X-ray rooms by open methods and it is understood that this practice has been in operation in some hospitals for a number of years without incident. Where portable or mobile X-ray apparatus is used in operating theatres whilst inflammable anaesthetics are being administered the control panel and any other part of the apparatus incorporating sparking contacts or other ignition risks should be located as far as is practicable from the anaesthetic equipment.

VIII. INSTALLATIONS

37. The electric installations in anaesthetising locations should comply with the Regulations for the Electrical Equipment of Buildings issued by the Institution of Electrical Engineers and with the following :

38. *Electric Wiring*

All electric wiring should be permanently installed as far as is practicable and preferably be concealed. The permanent installation should consist of wiring enclosed in screw-jointed conduit, mineral insulated metal-clad cable, or a wiring system giving equivalent protection. Lead-sheathed cables are not regarded as a suitable form of wiring.

Special attention should be given to the earthing of exposed metalwork enclosing electric wiring and connections to sterilising apparatus, and such metalwork should be electrically continuous with nearby water and steam piping in addition to being earthed in the normal manner.

Where flexible metallic conduit is used and forms part of an earthed metal conduit system, a separate earth-continuity conductor should be installed with the tubing and connected to it at each end.

The wiring to heating appliances, e.g. sterilisers and space heaters, should be capable of withstanding the working temperature without undue deterioration. Asbestos covered cables should be used where necessary.

The wiring of primary and emergency lighting circuits should be separated as far as is practicable to reduce the risk of a fault affecting both systems, particularly with pendant lighting fittings which are subject to movement in use.

39. *Flexible Wiring*

Flexible cable connections should only be used where it is not practicable to use permanently installed wiring and should be as short as possible and free from joints. Terminations should be adequately gripped and shrouded as necessary to prevent undue wear of, or strain on, connections, and reduce the risk of short circuit. The cables should have at least 23 conductors and be liberally rated for the connected load. The outer covering should be of tough rubber, p.v.c. or equivalent and should be of round cross-section. Any metallic outer covering should be an integral part of the cable. The use of flexible metallic conduits in conjunction with flexible cable connections to portable apparatus is not recommended, as in practice it is found that these may be damaged in service and in turn cause damage to the flexible cable without it being known.

40. *Switches and Socket-Outlets*

Only essential switch-gear should be installed within the zone of risk. Unless incorporated in an intrinsically safe circuit any switches installed in this zone should comply with paragraph 26.

It is considered preferable that switch units controlling heating apparatus incorporate a pilot lamp arranged to indicate when the current is "on."

Totally enclosed ceiling type switches installed above the zone of risk are considered to meet the safety requirements.

All switches and socket-outlets and their connections should be totally enclosed in incombustible material and adequate measures should be taken to prevent the ingress of moisture. It is preferable that wall-mounted switches and socket-outlets be recessed into walls and have cover plates flush with the wall surface.

All socket-outlets installed within the zone of risk other than those used with intrinsically safe circuits (see paragraph 18) should incorporate an interlocking device to prevent the plug being withdrawn while it is energised.

Socket-outlets energised at potentials exceeding 15 volts, unless incorporated in an earth-free circuit, should have an earthing connection which is made or broken with the line conductors.

Socket-outlets energised from an earth-free secondary circuit of a mains isolating transformer (see paragraph 30) may be of a standard type with an earthing contact and an interlocking device, but should incorporate a double-pole switch to control both line conductors of the earth-free supply. They may be used to supply earthed or earth-free appliances, but for the latter use the flexible cable connection to the apparatus should have no earthing conductor (two conductors only). Socket-outlets connected to an earth-free supply should be conspicuously marked to enable them to be readily distinguished from those connected to the normal earthed supply.

Socket-outlets which are likely to be used regularly with electric heating pads or blankets and other non-luminous type electric heaters should incorporate a pilot lamp arranged to indicate when the current is switched on.

An adequate number of socket-outlets should be provided to obviate any need for multiple adaptors, the use of which is considered to be unsatisfactory in hazardous locations as they increase the spark risk and may prevent the proper fusing of sub-circuits.

It is recommended that all socket-outlets connected direct to the mains are energised with one type of current only and preferably alternating current. Where it is necessary to have alternating current and direct current supplies a different type of socket-outlet should be used for each supply to prevent plugs being inadvertently interchanged between the two systems. For the same reason a different type of socket-outlet should be used to supply voltages lower than the standard mains potential.

Where socket-outlets are wall-mounted they should be positioned to reduce the lengths of flexible cable connections to the apparatus to a practicable minimum and to minimise the possibility of damage due to the movement of trolleys, etc., e.g. anaesthetic apparatus or patients' trolleys. Where the socket-outlets are of a safe type and are wall-mounted a height of approximately 1′ 6″ is suggested so that the trailing cables will cause less hindrance to the movement of staff, etc. Socket-outlets should not be installed at floor level because of the possibility of damage from water. In some hospitals the use of a rigid overhead fixture located near the operating table has been found a convenient means of installing socket-outlets. If the fixture (which may contain several socket-outlets) is carefully sited the use of long trailing flexible cables can be avoided. A minimum height of 6′ 3″ above floor level is suggested for such a fixture.

The use of portable socket-outlets on extension leads should be avoided.

Plugs incorporating fuses should not be used within the spark risk zone.

41. *Low Voltage Equipment for Surgeons' Headlamps, etc.*

It is considered preferable that the wiring to low voltage sockets used for energising headlamps, etc., be permanently installed as far as practicable. The use of two-pin sockets suspended on t.r.s. flexible cable from the ceiling with the socket about 6′ 3″ above floor level has been found convenient. If sockets are provided in different positions to suit the working arrangements and are carefully sited, the use of long trailing flexible leads can be avoided and any sparking at the socket at this height would not be a serious ignition risk. This arrangement also prevents undue stress on flexible cables and connections, e.g. where headlamps are attached to the surgeon.

42. *Lighting Fittings*

Portable lighting fittings which may be used within the zone of risk, and lighting fittings installed above the zone, should be totally enclosed to provide adequate mechanical protection to the lamp and to prevent hot particles falling into the zone in the event of lamp breakage, except that it is not considered essential that fluorescent type lamps installed well above the zone of risk need be further enclosed.

Chokes, condensers and other control gear associated with lighting fittings should preferably be installed outside the zone of risk. If installed above the zone of risk they should be totally enclosed in incombustible housings.

Any slip-rings incorporated in lighting fittings installed over the zone of risk should be totally enclosed in incombustible housings. Any slip-rings forming part of portable lighting fittings should be housed in gas-tight enclosures.

Voltage dropping resistances including dimmers unless of gas-tight construction should not be incorporated in lighting fittings used within the zone of risk. Where such equipment is necessary it is recommended that it should be permanently installed outside the zone, e.g. on the wall of the room at least 4′ 6″ above floor level. Where used in conjunction with portable lighting fittings it is recommended that a suitable socket-outlet be provided on or near the resistance unit for connecting the portable lighting fittings.

Adequate precautions should be taken on portable lighting fittings to prevent the insulation of cables being unduly twisted, strained or pinched. Such precautions are the provision of mechanical stops to prevent excessive movement of adjustable arms or radial joints. The apparatus should have adequate stability to reduce the risk of overturning.

Where lampholders are not attached directly to earthed metalwork, it is considered preferable that they are of an all insulated type.

NOTE: It is recommended that 24 volt lamps be used for main operating theatre type lighting fittings. The use of this low voltage, in addition to reducing the electric shock risk, results in an increased light output and reduces the heating effect compared with a similar wattage lamp at mains voltage.

43. *Emergency Lighting*

Failure of the normal lighting in operating suites, etc., increases the risk of an accident, and if inflammable anaesthetics are in use any improvised arrangements made during a failure of the normal lighting may increase the ignition risk. It is therefore advisable that a reliable and safe form of emergency lighting is available for use. It is recommended that operating suites in regular use for major surgery should have permanently installed emergency lighting and the advantages of automatic operation will be obvious. For other types of anaesthetising locations portable emergency lighting units incorporating secondary batteries may suffice.

Emergency lighting systems should safeguard against any failure that is likely to involve the normal lighting, e.g. lamp failure where the main lighting fittings incorporate a single lamp only, sub-circuit failure where the main lighting is supplied from a single sub-circuit, and mains failure unless adequate lighting is available from a completely independent supply, e.g. site generators.

Battery operated emergency lighting systems should incorporate a device to prevent the emergency lighting coming into operation when the normal lighting is not in use and thereby prevent unnecessarily discharging the batteries.

Where the main lighting fitting incorporates a single lamp, automatic change-over is best effected by means of switch-relay unit comprising a double-pole switch, one pole controlling the primary lighting and the other controlling the emergency lamps, and a series type relay to open circuit the emergency supply whilst current is flowing in the primary lighting circuit. Where the primary and emergency lighting circuits are energised at the same voltage it may only be necessary to change over the supply in the event of a failure of the normal supply. Where, however, there is only a single lamp in the main lighting fitting, it is advisable that additional emergency lamps be provided to safeguard against a lamp failure.

Portable emergency lighting units should comply with paragraph 26 (Switches) and paragraph 42 (Lighting Fittings). Where a self-contained battery is provided it is recommended that an alkaline type battery be used in preference to the lead acid type, which may give off a corrosive gas.

Where battery charging facilities are incorporated in portable emergency lighting equipment the charging apparatus should be constructed to comply with this safety code.

44. *Electric Space Heaters*

The customary means of heating operating theatres is by hot water or steam. The use of electric heaters, e.g. as supplementary heating, may have advantages in some instances.

Electric heaters should be of a totally enclosed type and unless of gas-tight construction the operating temperature of the heating element should not exceed 300°F (149°C). With electric heaters there is the risk of rapid and dangerous overheating occurring if materials such as blankets or towels are draped over the heat dissipating surfaces. The difference between hot water or steam radiators and electric radiators in this respect appears not to be widely appreciated. To reduce this risk, electric heaters located at a low level where they are liable to be so covered should be equipped with a high temperature thermal cut-out which should be additional to any normal thermostatic control. The thermal cut-out should have a manual reset and be enclosed in a gas-tight enclosure, and should prevent the temperature of any exposed surface exceeding 250°F (121°C).

Liquid filled radiators equipped as above and with gas-tight enclosures throughout meet safety requirements.

Heaters should be fixed in position and wiring to them should be permanently installed.

Tapped conduit entries on gas-tight heaters should have adequate depth to enable a gas-tight joint to be made. Any switches on electric heaters installed within the zone of risk should comply with the requirements of paragraph 26.

The ignition risk with electric heaters which are not hermetically sealed and have heating elements which operate at a temperature exceeding 300°F (149°C) will be reduced if they are installed at a high level. This precautionary measure will also reduce the risk mentioned above in respect of heaters which have been draped with fabrics. Such heaters, however, should be of a totally enclosed type.

Where electric heaters are installed in ventilation ducts an excess temperature cut-out should be provided to limit the operating temperature of the heater to 250°F (121°C). The cut-out should be installed immediately above or close to the heater so as to operate rapidly in the event of over-heating. No electric wiring or electric heater connections should be situated in ventilation ducts.

45. *Transformers*

It is considered preferable that transformers together with any voltage controlling equipment should be permanently installed outside the spark risk zone, e.g. behind a panel on the wall of the operating theatre at least 4′ 6″ above floor level. Where portable they should be housed in a gas-tight enclosure.

Low-voltage transformers may be used without overload protection devices in the secondary circuit but other transformers including those for energising earth-free circuits should incorporate fuses or other approved overload protection device in each line conductor of the output circuit, in addition to the normal primary circuit protection. (See also paragraph 27.)

46. *Electric Dryers and Clippers*

Because of the inherent ignition risks associated with these appliances and the difficulty of incorporating appropriate precautionary measures their use should be avoided within the zone of risk.

47. *Current Conversion Apparatus*

Portable A.C. to D.C. conversion apparatus should not be used within the spark risk zone. Where it is necessary to use such apparatus it should be installed outside the zone of risk and the output wiring permanently installed as far as is practicable.

48. *Open Flame Equipment*

Equipment employing open flames should not be installed within the zone of risk (see paragraph 5). Where open flame equipment is installed near anaesthetising locations it is recommended that low level mechanical extract ventilation be provided in the anaesthetising location on the side remote from the gas burners to ensure that the movement of air carrying anaesthetic gases is away from the burners.

49. *Ventilation*

Mechanical ventilation contributes to reducing the risk of anaesthetic explosions by the constant dilution of anaesthetic gases present in the air in anaesthetising locations. If the appropriate apparatus is embodied, as is frequently done for busy and important operating theatres, it is also a convenient method for humidifying the atmosphere, which is a contribution towards a reduction of the static electrical risks. Ventilation is not in any way, however, a substitute for the other safeguards recommended in this Code. Where mechanical ventilation is provided it should always be used while anaesthetising is in progress.

It is important that a ventilating plant, or ventilating apparatus, should not cause an objectionable level of noise in the operating theatre ; nor should it cause draughts, otherwise it may not be used.

Normally, the following air changes are recommended :

Mechanical extract ventilation only—a minimum of 5 air changes per hour.

Mechanical input (warmed) with extract plant—8-10 air changes per hour.

It is recommended that the input openings be located not less than 6 feet above floor level and extract openings not more than 3 feet above floor level.

It is, on medical grounds, essential that any system of ventilation shall not result in air being drawn into the operating theatre from spaces which are potentially contaminated such as corridors outside the operating suite. For this reason, with mechanical input and extract systems of ventilation the air input quantity should be in excess of that extracted and with mechanical extract only systems ample fresh air inlets should be provided.

Humidification of the input air is desirable for anti-static purposes, but humidity alone is not sufficiently reliable for completely eliminating risk. Relative humidities between 55% and 60% are suggested as a contributory precautionary measure against electrostatic risks and to provide comfortable environmental conditions. Facilities should be provided with humidifying plants for controlling humidity at the required level, either by automatic devices or manually from the operating theatre.

Ventilation motors and control gear installed within the spark risk zone should comply with paragraphs 19 and 26.

IX. PRECAUTIONS DURING USE OF APPARATUS

50. *Precautions against Diathermy Burns*

The two main causes of diathermy burns are : (1) incorrect application of the plate-electrode, resulting in high electrical resistance at the point of application ; (2) operating the plate-electrode at potentials above earth and allowing the patient to come into contact with earthed or partially earthed metalwork.

Precautionary measures to ensure good electrical contact between the plate-electrode and the patient, together with an effective earthing connection to the plate-electrode, should largely eliminate the risk of diathermy burns. It is recommended that the plate-electrode be earthed via the metal casing or general metalwork of the diathermy apparatus and an earthing conductor in the flexible cable used for connecting the apparatus to the mains, in preference to the use of a separate earthing lead. The following precautionary measures are suggested :

(a) the terminal connection on the plate-electrode should be examined and the effectiveness of the earthing connections tested before it is applied to the patient.

NOTE : A simple test will enable the effectiveness of the earthing connection to the plate-electrode, etc., to be checked before use. Figure 1 gives the schematic diagram of a suitable test unit. With such an arrangement the electrical resistance of the lamp constitutes the current limiting resistance and renders the test circuit intrinsically safe and suitable for use, therefore, within the spark risk zone.

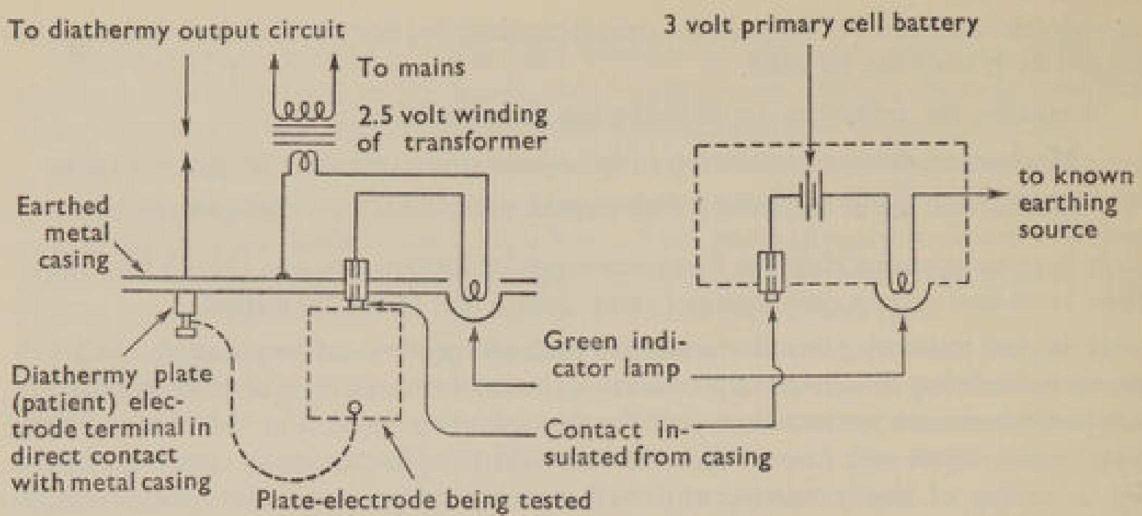

Plate-Electrode Earth Test Unit Incorporated in Diathermy Apparatus FIG. 1 *Separate Earth Test Unit*

(b) At least two plate-electrodes of adequate size should be provided for each diathermy apparatus. Where a saline pad or contact cream is used in conjunction with the plate-electrode it is recommended that the plate-electrode should have a surface area of at least 30 square inches (one side) and should be sufficiently flexible to enable it to be easily shaped to the contour of the body, (e.g. lead 1/32" thick). Where the patient is laid directly on to the plate-electrode and no electrolyte is used, a plate having a surface area of 150 square inches (one side) is recommended.

(c) The electrodes should be flattened periodically and be discarded when cracking occurs or the surface becomes hardened with use.

(d) Where a saline pad is used in conjunction with the plate-electrode the saline should have a strength of between 15% and 20% and the pad should be applied as wet as is practicable. (Normal strength saline has insufficient electrical conductivity for this purpose.) Where a contact cream is used as an alternative to a saline pad, the cream should be removed from the pad after each application to prevent a film of dried cream forming, as this may considerably impair electrical contact.

(e) To ensure effective electrical contact with the patient, subcutaneous bone areas should be avoided and steps taken to ensure that the contact surface of the pad is kept in contact with the patient but is not so tight as to cause the electrolyte to be squeezed out of the pad or blood to be squeezed from the tissue under the pad. In this connection the use of elastic or rubber bandage may be found advantageous.

(f) When diathermy apparatus is likely to be used for a long time on a patient, or when heavy currents are to be used, two separate plate-electrodes should be applied to the patient to reduce the current density at the contact surfaces, the two plate-electrodes being connected together with a flexible cable connection between the terminals.

(g) All exposed metalwork (other than the working surface) of "active" diathermy electrodes which are used for cavity work should be adequately insulated. It should be noted that intimate contact between exposed metalwork and tissue, e.g. when working in a cavity, can cause comparatively large circuit losses and thereby considerably increase the current density at the plate-electrode with consequent increase in the burn risk.

51. *Endoscopes*

When two or more endoscopic instruments are used at the same time each should be energised from a completely separate low-voltage supply, e.g. separate primary battery units or separate earth-free output circuits of a transformer. The use of a common low-voltage supply may result in differences of potential between the exposed metalwork of the instruments and give rise to sparking and increase the electric shock risk. In this connection it should be noted that comparatively small potentials can cause serious electric shocks in certain circumstances, as, for example, where contact is made direct on to the tissue (i.e. without skin resistance).

X. MAINTENANCE

52. *Electrical Equipment Generally*

There should be a routine of regular and periodic inspection and testing of all electrical equipment in operating theatres and similar situations, by persons competent and qualified to undertake the work, to ensure as far as possible its reliability in operation, and that its safety features are in good order. The frequency of inspections and tests will depend a great deal on the extent to which the equipment is used, its condition and the hazards it presents in use. Portable apparatus, for example, is usually subjected to more handling and rough usage and wear than is fixed equipment and needs more attention. It is not possible, therefore, to make specific recommendations in this respect, but it is considered that inspection should be made weekly of equipment in daily use and of all equipment at not longer intervals than one month, except that with portable X-ray apparatus and other equipment which is serviced by manufacturers or other outside specialists, a longer interval between servicing may be considered satisfactory. The periodical inspections and tests are, of course, additional to any superficial inspections and simple tests which may be carried out by theatre staff as indicated elsewhere in this Code e.g. testing the earth-continuity of the patient's H.F. circuit (paragraph 50(a)).

Inspections and tests made on equipment should include the following :

(a) Earth continuity testing of the exposed metalwork of all electrical apparatus arranged for use with mains electricity (except any earth-free apparatus—see paragraphs 30 and 40) and all exposed metalwork associated with the electrical installation. It is recommended that the tests be made with a heavy current (10 amperes) loop type earth continuity tester and be so applied that the test current traverses the whole of the earthing path from the exposed metalwork of the appliance to the main earthing connection, and returns by means of the neutral conductor of the supply network. As there will be a small standing potential on the neutral conductor of the supply network the test should be made with reversed polarities and the mean impedance determined. This should not exceed 1 ohm.

(b) Insulation resistance tests between the current-carrying conductors and the non-current-carrying metalwork of electrical appliances constructed for use with mains electricity, using a 500 v. D.C. ohmmeter. This test will also indicate whether circuits required to be earth-free are in fact earth-free.

(c) Tests to ensure that all single pole mains-fed switches including footswitches and those controlling socket-outlets are connected in the non-earthed conductor of the supply.

(d) Inspection of the condition of terminals, plug tops, socket-outlets and switches, and the functioning of switches, especially any interlocking features and of all flexible cables and their terminals, particularly at the point of entry to plugs and appliances and those used on or in close proximity to a patient and anaesthetic equipment.

(e) The condition of equipment enclosures, particularly gas-tight enclosures, to ensure that safety features are not impaired.

(f) The condition of fixed wiring and the general lighting and any special lighting including the functioning of any emergency lighting equipment.

(g) The condition of fixed or portable batteries for emergency lighting and for energising endoscopes, etc.

(h) A check on electric suction apparatus to ensure that (i) the rubber tubing and other connections on the exhaust outlet of the pump are secure and free from leaks, and (ii) the overflow cut-out functions satisfactorily.

Such routine inspections will also be useful in that they will tend to prevent the introduction of unsafe equipment and to discourage unsafe practices of the kind to which reference is made in this Code.

It is recommended that privately owned electrical equipment brought into hazardous situations also should be included in the foregoing arrangements.

The testing instruments necessary for the use of the electrician in carrying out maintenance as described above are :

A Universal multi-range testing instrument.
A circuit testing ohmmeter.
A 500 volt insulation tester (which is also useful for checking the effectiveness of certain of the anti-static precautions recommended).
A loop type heavy current earth tester.
A sensitive neon test probe.

This equipment is no less essential for the proper maintenance of the general electrical installations, plant and apparatus in hospitals.

It is desirable that there should be a list of all electrical equipment in use and that each item should be identifiable by a suitable durable marking so that the keeping of accurate records of inspections and tests is facilitated.

Sufficient spare parts should be held if maintenance is to be carried out properly, particularly of those items of equipment which are in frequent use.

53. *Anti-static Components*

There may be a tendency for electrical resistance of anti-static rubber products to increase whilst in service ; therefore periodical tests (say three monthly) should be made. The permissive maximum resistance for products in service, when determined by the following test method, is 100 megohms. Items having resistance values exceeding 100 megohms are deemed to have lost their anti-static properties and should be withdrawn from service.

Apply water to two areas (a and b) each of approximately 1 square inch in the positions set out below for the particular item under test. Using a 500 volt D.C. insulation tester, apply clean metal electrodes to these areas to make effective electrical contact with them and measure the resistance. In general the test areas should be located on surfaces such that the results represent the electrical resistance of the discharge path.

Item	*Position of Test Area* (a)	(b)	*Remarks*
Footwear.	Inside the sole or heel.	On undersole.	The test surfaces should be chosen to ensure that the electrical conductivity is measured between a surface which is in intimate contact with the wearer and the under surface of the sole and heel.
Corrugated and other anti-static rubber tubing.	Inside surface at one end.	Outside surface at other end.	A second test should be made from the other inside surface to the outside surface at the opposite end. For lengths of tubing exceeding 6 feet the electrodes should be applied to the outside surface at approximately 6 feet spacings throughout the length of the tubing as necessary.
Breathing bag (with loop and neck).	Inside surface of the neck.	On the loop.	
Breathing bag (with two necks).	Inside surface of one end.	Outside surface at the other neck.	A second test should be made from the inside surface of the other neck to the outside surface at the opposite end.
Anaesthetic mask and face pad.	Inside surface of neck.	Flexible surface which makes contact with the face.	
Sheeting and items made of sheeting, including aprons.	On the same surface with approximately 2 in. dry distance between wetted areas.		Tests should be made on both sides of the material.
Cellular rubber pads.	On the top side.	On the under side.	Electrodes should be opposite.
Furniture feet.	Surface at bottom of cavity.	Surface normally in contact with floor.	
Buffers.	Top contact surface.	Bottom contact surface.	On small buffers it may be necessary to use wetted areas of less than 1 sq. in.
Castors.	Castor tyres should be placed on a wet metal plate and the resistance measured between the hub of the wheel and the plate. When testing a castor fitted to a trolley, etc., the other castors of the trolley should be suitably insulated from the floor and the resistance measured between the metal plate and the framework of the trolley.		

54. *Ventilation Equipment*

Paragraph 49 refers to the contribution made by proper ventilating and humidifying arrangements to reducing the explosion risk. Such equipment requires regular inspection and maintenance having regard to its type and the manufacturers' instructions. Particular attention should be given to filters, strainers and spray nozzles which may become choked.

APPENDIX B

MINISTRY OF HEALTH

FIRES AND EXPLOSIONS IN OPERATING THEATRES AND ANAESTHETIC ROOMS

WARNING NOTICE

Inflammable anaesthetic agents such as ether, cyclopropane and ethyl chloride when mixed with air, oxygen or nitrous oxide may form explosive mixtures, and the ignition of such anaesthetic vapours has resulted in explosions which have been attended by serious consequences. The chief causes of such ignitions are:—

(a) Electrostatic spark discharge. This is more likely to occur during dry atmospheric conditions and in particular during the early part of a session when conditions tend to be driest.

(b) Sparking at electrical contacts, diathermy electrodes, etc.

(c) Use of apparatus incorporating hot surfaces, e.g. cautery, electric heaters, overheated lamps.

(d) Gas or spirit burners.

Whenever an explosive mixture is in use the surgeon and the theatre sister should be aware of the fact.

PRECAUTIONS AND RECOMMENDATIONS

1. ANTI-STATIC PRECAUTIONS

The best means of reducing electrostatic risks is to eliminate the use of materials which readily electrify in normal use. **The chief sources of static electricity are insulating rubber, plastics, wool, nylon and acetate rayon.** Experience suggests that non-conducting rubber breathing equipment on anaesthetic apparatus constitutes the greatest risk. Materials which are anti-static for practical purposes are available, e.g. anti-static rubber, anti-static rubber-proofed fabrics, linen, cotton and viscose rayon, and should be used whenever possible instead of the electrostatic materials.

Recommended anti-static precautionary measures:—

(*a*) Rubberised anaesthetic **breathing equipment and rubber tubing** used with suction apparatus, etc., should have permanent anti-static properties or be damped internally and externally before use, preferably with water containing a wetting agent such as soap or a detergent.

(*b*) **Operating tables, anaesthetic apparatus, patients' and other trolleys, stools, etc.,** should be in effective electrical contact with the floor, preferably by means of metal or anti-static rubber-tyred castors or feet. Where these are not provided the apparatus should be equipped with an effective type of trailing chain, e.g. a looped type with a long floor-contact surface. The metal work of anaesthetic and other apparatus should be electrically continuous, and top surfaces and shelves should be free from paint or other insulating finish.

(*c*) **Rubber pads** on operating tables, trolleys or stools should have permanent anti-static properties or be completely enclosed in an anti-static fabric, e.g. cotton, linen or viscose rayon.

(*d*) **All persons entering an anaesthetising location should wear anti-static footwear and a reasonably close-fitting outer garment of an anti-static fabric.** Anti-static rubber-soled footwear is considered preferable. Leather-soled footwear provides reasonable protection but other types should be enclosed in overboots of an anti-static fabric.

(*e*) Terrazzo, quarry tile and similar **floors** having a cement base are usually satisfactory for anti-static purposes. Floors of ordinary rubber or p.v.c., linoleum, asphalt, or wood are electrically insulating and are unsuitable for anti-static purposes when dry. Moisture applied to the surface of such floors will render them temporarily anti-static: **it is advisable to damp them immediately prior to the use of inflammable anaesthetics** either by the direct application of water containing a wetting agent such as a detergent or soap or by laying a damp sheet on the floor. The damp area should extend around the anaesthetic apparatus sufficiently to prevent persons touching any part of the apparatus unless they are standing on the wetted area or sheet.

2. ELECTRICAL APPARATUS

(*a*) **Switch contacts** and other parts of apparatus capable of producing an incendive spark should be housed in a gas-tight enclosure or spaced at least 6 feet horizontally from any anaesthetic apparatus.

(*b*) The maximum **voltage** of circuits used for energising endoscopes, etc. should be as **low** as is practicable and not appreciably higher than the rated voltage of the lamps. The provision of a special current limiting resistance in the circuit will greatly reduce the spark and overheating risks. **Dry-cell batteries** are safer than mains transformers for operating endoscopes.

(*c*) **Electrically operated suction apparatus** should have no sparking contacts which are open to atmosphere, and the exhaust outlet from the pump should terminate outside any enclosure housing the apparatus.

(*d*) From the electrical safety aspect **surgical tools** operated by means of compressed air are considered preferable to electrically operated tools, because of the inherent spark and electric shock risks associated with the latter.

(*e*) Flexible **cables** should be free from joints, frequently inspected, and renewed when damaged or showing signs of deterioration.

(*f*) The risks associated with **diathermy and cautery apparatus** are obvious. Before these are used following the administration of inflammable anaesthetics a non-inflammable gas should be passed through the breathing circuit until no explosive residue remains either in the apparatus or in the patient's lungs. The ether bottle should be removed and if it must be replaced it should be washed out and left uncorked. It is not sufficient to rely on the closure of the ether tap as this may not be gastight.

3. OPEN FLAMES AND HEATED SURFACES

Apparatus incorporating open flame burners or heated surfaces which may operate at temperatures of 350°F. or more can constitute an ignition risk if located within 20 feet of an anaesthetising position. Doors between the anaesthetising position and the ignition risk should not be regarded as a reliable safeguard, as they may be left open.

NOTES—Spirit lotions, etc. It should be noted that the use of spirit, spirit lotions and other similar solutions which are frequently employed for cleansing the patient's skin, etc., involves dangers similar to those mentioned above.

Additional information on the risks referred to above, together with recommended precautions against associated risks, are contained in "Safety Code for Equipment used in conjunction with Explosive Anaesthetics" (see HM (56) 50).

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