CURRENT COMMENT

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RECOMMENDED SAFE PRACTICE FOR THE USE OF COMBUSTIBLE ANESTHETICS IN HOSPITAL OPERATING ROOMS *

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GENERAL INTRODUCTION

The purpose of the following recommended specifications for certain features of the construction and arrangement of operating rooms, delivery rooms, and other places for surgical treatment, and for the performance, installation, maintenance and use of equipment therein is to reduce the hazard of electric shock from the electric power and lighting circuits and the hazard of igniting flammable mixtures of gases. Studies of these hazards by many investigators, over many years, lead to the conclusion that the greatest degree of safety possible with our present knowledge can be secured only by a coordinated treatment of all significant factors rather than by the

* *Editor's Note.* Because of its interest to anesthesiologists, the above is reprinted from the April, 1941 issue of the Quarterly of the National Fire Protection Association. This is the major portion of a report which was prepared by a special conference committee (the personnel of which is listed) to the Committee on Gases of the National Fire Protection Association. Inasmuch as the report was adopted *tentatively* it is open for discussion and *possible change* until such time as the National Fire Protection Association deems it worthy of final adoption as an Association standard. No recommendation for any change in its status will be made prior to the convention of the National Fire Protection Association in May, 1942. Permission to reprint received June 5, 1941 from H. E. Newell, Chairman, Committee on Gases.

application of individual and unrelated safeguards. In some cases certain of the suggestions here presented are effective, or even permissible, only when carried out in conjunction with other recommendations.

In preparing these safe practice recommendations it has been recognized that the behavior of materials and of mechanical agents can be relied upon with greater assurance than can the behavior of human beings. Consequently it has been the aim to follow a plan which will require the minimum of conscious human effort in its daily application. On the other hand it must be emphasized that the most adequate physical safeguards can not eliminate the necessity for continuous and intelligent vigilance but can only make such vigilance effective.

It must further be pointed out that all details of operating room arrangement or equipment are by no means covered by the specifications here presented, although they do cover the major factors contributing to the hazards of electric shock and of the ignition of flammable gases. There remain other details concerning which it appears unwise at the present time to formulate rigorous recommendations.

These recommendations outline in some detail ways and means for eliminating or correcting conditions which experience and investigation have shown to contribute to the hazards in question. In applying them it is necessary to understand fully the nature of these contributory conditions and their relations to the hazards. In any given situation intelligent judgment must be used in order to meet the particular conditions there existing most reasonably and effectively.

It is not the intention that these recommendations shall, in any way, supersede the accepted standards of the National Electrical Code. All recommendations here presented which have to do with electrical equipment are in strict conformity with the November, 1940, edition of this Code. An attempt has been made to emphasize those standards which are of particular significance in connection with electrical wiring and equipment used in operating rooms and to present them in such form that they may be most useful to those concerned with this specific problem.

NATURE OF HAZARDS

Combustible Gases

The use of the ether compounds or of the hydrocarbon gases as anesthetics is attended by considerable risk because of the fact that these agents form flammable mixtures with air, oxygen, or nitrous oxide. In many cases these mixtures are violently explosive. Fatal accidents have been of not infrequent occurrence.

The use of closed rebreathing systems for the administration of these anesthetic agents normally tends to restrict the region likely to be hazardous. To secure a reasonable measure of protection, however, it has been found necessary, with minor exceptions, to apply safeguards throughout any room in which these agents may be used. Definitions for hazardous locations are given under the section Definitions of Hazardous Locations.

The actual extent and duration of a hazardous condition resulting from any use of flammable anesthetic agents may, in practice, be reduced by suitable ventilation. Recommended specifications covering certain important details of such ventilation are given in the section on Ventilation.

Spontaneous Ignition

A possible method of ignition is by spontaneous oxidation. Under certain conditions, as when oxidizing and reducing gases are permitted to mix under high pressure, explosions due to this cause may be of terrific violence and are a serious hazard. Precautionary measures for reducing this hazard, as well as other precautions to be observed in the storing and handling of anesthetic gases, are suggested in the section Storage and Handling of Gases.

Electrical Systems

If a connection between two points of the electrical system which are at different electrical potentials includes the body of a person, he is likely to suffer an electric shock. If a connection between two points of the electrical system which are at different electrical potentials is made by metallic conductors, there is likely to be a spark or an arc or intense heating of one or more of the metallic conductors. In the majority of cases, situations presenting one of these hazards also present the other and safeguards against one are often effective against the other. There are, however, situations for which the safeguards are conflicting; hence, it is necessary to consider both hazards in recommending precautionary measures for either.

The most common hazardous electrical contacts are between the two sides of the low voltage distribution circuits. The potential difference in these cases is ordinarily 110 volts although it may, in some installations, be as high as 220 volts. A shock resulting from such contact is likely to be of sufficient severity to be extremely hazardous in an operating room. Less common hazardous contacts are between either side of the high voltage distribution circuits and some metallic object in contact with some other portion of the electrical power system. Present methods of installation make such contacts extremely unlikely. When they do occur, however, the potential differences encountered may be of sufficient magnitude to be exceptionally dangerous. Shocks from such contacts are generally fatal.

The conventional protection against both of these situations is to ground one side of the low voltage distribution system and to enclose the conductors within a grounded metallic sheath, or conduit. The current-carrying portions of all electrical equipment are likewise enclosed, as far as possible, within grounded metallic housings. In this way all exposed conducting portions of electrical equipment are maintained at ground potential. Consequently, simultaneous contacts with conducting bodies are likely, in most cases, to involve points at the same electrical potential. Should the ungrounded side of any grounded circuit come into contact with an exposed conductor, the ground connection of the latter would result in a short circuit and thus remove the potential from the line by opening the fuse or other overcurrent device. The possibility of shock is thus further reduced.

A short circuit resulting from contact between the ungrounded side of the electrical system and any grounded conductor, while reducing the shock hazard, introduces the possibility of a spark or arc and hence of the ignition of any flammable gases which may be present. To reduce this hazard without, at the same time, impairing the safeguards against electric shock, the use of an ungrounded branch distribution system, as specified in the section on Electrical Wiring and Equipment, is recommended. In this arrangement the protection against electric shock is as complete as in more conventional arrangements. In order for a short circuit to occur with this arrangement, however, it would be necessary for two defects, involving both sides of the circuit, to exist simultaneously in the electrical wiring or equipment. As a further safeguard a ground contact indicator is recommended which would give immediate warning of the existence of either of these two defects, thus making it possible to correct one before the occurrence of the other.

Other recommendations for the installation and maintenance of electrical equipment in hazardous locations and in places where electric shocks are particularly to be avoided are given in the section on Electrical Wiring and Equipment.

Electrostatic Spark Discharges

Statistics indicate that the ignition of flammable gases by electrostatic spark discharge is a hazard of approximately the same frequency of occurrence as ignition by the electrical system. Electrostatic charges can set up dangerous potential differences only in the presence of materials which are electrically non-conducting, i.e. insulators, which act as barriers to the free movement of such charges and hence prevent the equalization of potential differences. A spark discharge can take place only when there is no other path of greater conductivity available by which this equalization may be effected. A reduction of the hazard, therefore, may be accomplished by the proper selection, use, and maintenance of materials. The specifications recommended in the section on Reduction of Electrostatic Hazard cover points of major importance in this connection.

Inasmuch as these specifications recommend the effective grounding of persons and objects, there are situations in which they might result in an increased probability of hazardous contact with the electrical system. This possibility can and should be avoided by the thorough grounding of all protective metallic housings or enclosures of electrical circuits and equipment as recommended in the section on Electrical Wiring and Equipment.

It has been suggested that the electrical interconnection of conductive bodies, such as is brought about by grounding, may increase the amount of energy liberated by any electrostatic spark discharge resulting from the presence of bodies not included by the interconnection. It is the purpose of the specifications recommended in the section on Electrical Wiring and Equipment and the section on Reduction of Electrostatic Hazard to provide grounding, and hence interconnection, which is sufficiently effective to prevent completely the entrance of such bodies into hazardous locations.

Flames and Hot Bodies

A very obvious and, hence, less frequent cause of the ignition of flammable gases is by open flame or hot body. The most effective safeguard against this source of ignition is a continuous consciousness on the part of the operating room personnel of the danger inherent in the use of flammable anesthetics.

DEFINITIONS OF HAZARDOUS LOCATIONS

Hazardous Locations

A room in which any of the hydrocarbon anesthetic gases or any of the ether compounds are stored or used is to be considered a *hazardous location.* The hazardous condition may be considered as extending for a horizontal distance of 10 feet and to a height of 7 feet above the floor outside of any door opening into such a room.

An exception may be made in the case of a room ventilated as specified in the following section; in such rooms the hazardous condition may be considered as extending to a height of 7 feet above the floor.

Locations of Limited Hazard

Any corridor or room through which a patient is moved during the progress of anesthesia, or through which anesthesia equipment is moved while in an operating condition, is to be considered a *location of limited hazard.* In such locations hazards due to permanently installed electrical equipment should be considered as being the same as for non-hazardous locations: hazards due to electrostatic charges should be considered as being the same as for hazardous locations.

VENTILATION

Method of Ventilation

All hazardous locations, as defined in the previous section, should be ventilated by mechanical means. Air should be brought into the room by ducts opening not less than 6 feet from the floor and removed from the room by ducts opening not more than 3 feet from the floor.

Amount of Ventilation

There should be a change of air of not less than 20 cubic feet per person per minute, but in no case should there be less than 12 changes of air per hour.

Arrangement of Equipment

The preferable location for the circulating fans or blowers is in the inlet ducts.* Regardless of location, fans should be of a type approved for use in explosive atmospheres. Motors should be of a type approved for use in explosive atmospheres and should be installed outside the ducts.

Temperature and Humidity

The temperature and humidity maintained in operating rooms should be chosen on the basis of the well being of patient and personnel. High humidity will reduce the hazard of electrostatic spark discharge under certain conditions but is not sufficiently reliable for their complete elimination.

Windows

Windows in hazardous locations should be kept closed.

STORAGE AND HANDLING OF GASES

The recommendations presented in this section are, in general, taken from pre-

* Vapors in the inlet ducts are less likely to be flammable than those in the outlet ducts. The use of fans in the inlet ducts also maintains a positive pressure in the operating room thus tending to lessen air-borne infection brought in from corridors and other adjoining locations.

viously published good practice requirements and safety codes. They have been modified, where necessary, to bring the several sources into agreement with each other and with other sections of these recommendations. They include and are in conformity with the recommended good practice requirements adopted by the National Fire Protection Association and by the National Board of Fire Underwriters and with the recommendations of the National Safety Council and of the American Hospital Association.

Specifications for Cylinders

All cylinders containing compressed gases, such as anesthetic gases, oxygen, or other gases used for medicinal purposes, whether these gases be flammable or not, should be in accordance with the regulations of the Interstate Commerce Commission with respect to construction, testing, and fittings.

Marking of Cylinders

All cylinders containing compressed gases should be clearly marked with the name of the gas contained therein.

All cylinders containing compressed gases should, in addition to showing the name of the gas, show conspicuously a color indicating the nature of the gas contained therein. Recommendations and regulations of the Interstate Commerce Commission and of the National Bureau of Standards regarding suitable conventions for such color coding should be followed.

Storage of Containers

All cylinders containing compressed gases, and all cans containing volatile liquids should be stored in dry locations ventilated as recommended in the previous section. Under no circumstances should these cylinders be stored in the operating room. If stored in an adjoining room there should be a blank wall between such room and the operating room. In all cases the storage of compressed gases and of flammable liquids should be in strict accordance with the provisions of State law and of municipal ordinances.

Location of Containers

Cylinders containing compressed gases, or cans containing volatile liquids should be kept away from radiators, steam pipes, and like sources of heat. Cylinders containing reducing gases, such as ethylene or cyclopropane, and cans containing flammable liquids, such as ether, should be kept out of proximity to cylinders containing oxidizing gases, such as oxygen or nitrous oxide. Flammable materials, such as wood and fabrics, should not be stored or kept near cylinders containing oxygen.

Coverings

Cylinders containing compressed gases, cans containing volatile liquids, and anesthetic administering equipment not in active use should never be covered with fabric or other covering at any time.

Special Care of Oxygen Cylinders

Great care must be exercised with cylinders containing compressed oxygen to prevent any accumulation of grease or oil on either the cylinder or any of the fittings attached thereto. Such cylinders and fittings should never be wiped or rubbed with any cloth, waste, or similar material likely to contain oil or grease.

Regulators and Valves

Suitable approved regulators or other gas flow control devices should be used in conjunction with any cylinder containing gas used for medicinal purposes.

Cylinder Connections

No equipment should be used for coupling cylinders containing compressed gases which might permit the inter-mixing of gases, either through defects in the mechanism or through error in manipulation, in any portion of the high pressure side of any system in which these gases may flow. It is particularly important that the intermixing of oxidizing and reducing gases under pressure be scrupulously avoided as such mixing inevitably results in spontaneous combustion and explosions of terrific violence.

Filling of Cylinders

Compressed gas should never be transferred from one storage cylinder to another on the hospital premises.

Piping Systems for Gases

Systems for the distribution of gases should, except as noted below, employ standard, full weight iron-pipe-size brass pipe with substantial brass fittings, or approved seamless drawn well annealed copper, brass, or other non-ferrous tubing with approved fittings, protected against mechanical injury in a manner satisfactory to the authorities having jurisdiction. In all piping systems proper allowance should be made for expansion and contraction, jarring, and vibration. Brass used for such piping should have a copper content of not less than 83 per cent. Long runs of piping should be avoided and cylinders should be located as close as feasible to points of consumption.

An exception may be made in the case of nitrous oxide, for the distribution of which iron or steel tubing may be used.

An exception should be made in the case of ethylene, for the distribution of which iron or steel tubing should be used.

Where threaded joints or fittings are used threads should be in accordance with the American Pipe Thread Standard. All joints should be sweated with solder.

Where anesthetic or other gases used for medicinal purposes are piped from building to building, pipes should preferably be placed in a separate tile duct used for no other purpose. If tunnels containing other piping are used for this purpose the anesthetic or other gases should be segregated in a special basket type metal duct for this use exclusively, having screened sides, top and bottom, and conspicuously labeled at frequent intervals, "DANGEROUS GASES." Such tunnels should be well lighted and ventilated.

All piping should be tested and proven tight at one and one half times the maximum working pressure, but never at less than 100 pounds per square inch. Before being placed in service such piping should be thoroughly blown out to insure freedom from foreign materials.

Identification of Pipe Lines

All oxygen pipe lines should be painted one color, preferably green, and all anesthetic gas lines a different color. Where more than one anesthetic gas is piped, the lines distributing the different anesthetics should be painted distinctive colors.

A chart identifying the various gases according to colors employed should be prominently displayed.

Manifolding Anesthetic Cylinders to Headers

Headers should be constructed of double extra heavy piping, preferably brass or bronze, not exceeding one and one quarter inch nominal pipe size. Fittings in header, if used, should be extra heavy. Headers should be provided with shut-off valves at each point where a cylinder is to be connected.

Leads from header valves to cylinder valves should be constructed of steel tubing or an approved composition pipe, and should be capable of withstanding a pressure of 1000 pounds per square inch.

The discharge opening from the header should be equipped with an approved regulator.

Manifold systems should be capable of withstanding a test pressure of one and one half times the charging pressure.

A preferred arrangement from the safety standpoint is to so set the manifold regulators that when one side of the manifold is exhausted, the other side will automatically function.

A method which eliminates the need of a header and which has been successfully used in practice, is to connect two cylinders to the piping system and so set the regulator of the second cylinder that when the first is empty, the second cylinder will automatically come into service.

Oxygen Manifolds

Oxygen manifolds or headers should be constructed of bronze of such weight as to insure suitability for the purpose. All sections of the header should be freed of foreign material and combustible matter before assembly.

Fittings for header should be of substantial design and may be threaded and soldered to header or threaded using litharge and glycerine only.

The leads or connections attaching cylinders to header should be constructed of annealed brass, bronze or copper, of suitable strength.

High pressure headers, fittings and leads should be capable of withstanding a pressure of 3600 pounds per square inch.

Headers, fittings and leads after assembly should be washed out with carbon tetrachloride or other suitable grease solvent and blown out by low pressure oxygen.

It is recommended that oxygen headers or manifolds be purchased from, and installed by, reliable manufacturers familiar with the proper shop practice with reference to their construction and installation.

Emergency Shut-off Valves

In addition to the shut-off valves within the operating room, a shut-off valve should be provided outside thereof in each flammable gas and oxygen line, so located as to be accessible at all times for use in an emergency. These valves should be so arranged that shutting off the supply of gas to any one operating room will not affect the others. Valves should be of approved type and mounted on a pedestal or otherwise properly safeguarded against mechanical injury.

General Precautions

As defined in the section on Definitions of Hazardous Locations, places where compressed flammable gases or flammable liquids are stored are considered as hazardous locations. The recommendations covering electrical wiring in hazardous locations and recommendations for the reduction of the electrostatic hazard should, therefore, be rigorously observed.

(*To be continued in the November issue.*)

TECHNICAL SUGGESTIONS

Anesthesia machines are usually constructed so that the cylinders, hanging in place, are in close approximation. As the apparatus is moved about in the surgery, the cylinders frequently knock against each other. Their loud clang is a familiar sound to all anesthetists.

To prevent two cylinders from noisily striking each other, a simple bumper device has been found useful. A portion of firm rubber tubing, one-half inch in diameter, is made into a ring by sewing the ends together with wire or stout cord. The diameter of this doughnut-like ring must be slightly less than that of the cylinder on which it is to be used. The ring is placed some three inches from the bottom of the cylinder where its own elasticity will hold it in place. It will be found an efficient aid in maintaining the quiet so essential in the properly conducted surgery.

D. H. B.

For intravenous anesthesia a piece of small caliber rubber tubing several inches long, with glass needle adapter at one end and stopcock at the other, may be used to connect the syringe with the intravenous needle. If an antecubital vein is used, the syringe is fastened to the wrist with adhesive tape or lies on the arm board. When the vein has been punctured the needle is securely fastened in position with adhesive tape. There are two advantages of this method. First, the needle will remain in the vein indefinitely because the weight of the syringe does not drag on it, and second, the stopcock prevents blood from entering and plugging the needle.

P. D. W.

Anesthetists, wishing to insert endotracheal tubes under direct vision, frequently find it necessary to exert considerable force on the laryngoscope in order to expose the larynx. To their embarrassment this frequently results in damage to the upper incisors which are used as a fulcrum. Such accidents can be prevented through the use of either of these coverings: 1. A gauze square is folded, eight layers thick, to one inch by three inch size. To one edge is applied an adhesive strip. The gauze can be placed over the teeth, the adhesive being stuck to the upper lip or to the nose to keep it in place. 2. A piece of lead plate, one-sixteenth inch thick, one inch by two inches in size, may be shaped to fit the upper teeth before anesthesia is begun. This forms a solid surface over which the blade of the laryngoscope may slide without fear of injury to the teeth.

D. H. B.

When exposure of the vocal cords is difficult, one or both of the following methods may be helpful: 1. The anesthetist may hook his thumb inside the mandible and pull it anteriorly. The floor of the mouth moves forward with it, thus furnishing more room for the laryngoscope. 2. With his free hand the anesthetist may bring the larynx into view by making pressure in a posterior direction over the thyroid cartilage immediately below the tip of the laryngoscope. An assistant should maintain this pressure while the anesthetist inserts the airway.

P. D. W.