CURRENT COMMENT

CURRENT COMMENT is a new department in ANESTHESIOLOGY. In it will appear invited professional and scientific correspondence, abbreviated reports of interesting cases, material of interest to anesthesiologists reprinted from varied sources, brief descriptions of apparatus and appliances, technical suggestions, and short citations of experiences with drugs and methods in anesthesiology. Contributions are urgently solicited. Editorial discretion is reserved in selecting and preparing those published. The author's name or initials will appear with all items included.

REPORT OF COMMITTEE ON STATIC ELECTRICITY *

The committee presents for adoption a revised draft of a comprehensive, informative pamphlet on static electricity. This is a revision of the progress report presented in 1937, incorporating numerous changes as a result of suggestions made, and to cover new developments in this field.

It is hoped that this report will meet the need for more complete data on static electricity for the use of industry, prepared in a way to be clear, concise, and readily understandable by the layman. It has been the endeavor of the committee in preparing this report to present it in narrative form, to avoid the use of technical language and to include numerous illustrations to make it of greatest service to plant managers, superintendents, fire inspectors and others charged with the safe operation of industrial processes.

During recent years, static electricity has been recognized as the cause of many serious fires and explosions, and resultant loss of life. Numerous careful studies have been made of various phases of the problem, the reports of which have been published in pamphlets, and articles which have appeared in various publications. However, there is still no one pamphlet which covers in a comprehensive way, the major phases of the problem of static electricity.

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1. INTRODUCTION

The term "Static" in this pamphlet is used in its commonly accepted meaning, namely, the type of electrical charge resulting from separation of materials, friction or similar cause and particularly where it constitutes a fire or explosion hazard.

The generation of static can neither be prevented nor is it practicable to attempt to do so. Its generation is not in itself a hazard. The hazard appears when static accumulates to the extent that a spark discharge may occur. Where such a spark discharge occurs in accumulations of flammable materials, it may cause a fire or explosion. Eliminating the static hazard therefore calls for preventing its accumulation rather than its generation. Humidification, grounding and neutralizing prevents the accumulation, but in no way prevents the generation of static.

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* *Editor's Note*: The above is reprinted from the April, 1941 issue of the Quarterly of the National Fire Protection Association. It consists of portions of the section on static electricity which are believed to be of interest to anesthesiologists. Permission to reprint received September 26, 1941 through E. J. Meyers, Chairman, Committee on Static Electricity, from Robert S. Moulton, Technical Secretary of the National Fire Protection Association.

Experience has shown that static is a more acute hazard in the winter than in the summer months. In winter the relative humidity indoors is low, which tends to dry all surfaces and make them poor conductors. Consequently, the static which is generated accumulates on the generating surfaces until the potential is high enough to break down the intervening air gap with a resultant spark.

In summer, however, the relative humidity is high and, as a result, all surfaces are usually covered with an invisible film of moisture which makes them relatively good conductors. This principle is used in certain industries to decrease the static hazard by intentionally increasing the relative humidity of the surrounding air. It is explained in greater detail in Section 5.—A. Humidification.

Humidification is probably the most positive means of preventing accumulations of static electricity but, in some cases, may not be feasible. Therefore, more dependence is generally placed on grounding. This subject is explained in greater detail in Section 5.—B. Bonding and Grounding, which contains many sketches showing different methods of accomplishing it.

Among the most recent developments in rubber technology, is the manufacture of conductive rubber, which differs from conventional rubber in its relatively low electrical resistance. This material can be furnished in forms suitable for flooring, matting, tubing, truck tires, table tops, belting, etc., which will drain off high voltage, low current electrical charges and prevent dangerous static discharges. The applications of this type of material have not been in service for long enough periods to warrant broad recommendations and it is suggested that where static hazards exist, the possible use of conductive rubber be carefully discussed with the rubber manufacturers in this field.

2. THEORY OF STATIC ELECTRICITY

Static electricity is commonly believed to be generated only by friction, and its original name, "frictional electricity," is still used to some extent. Experiments, however, have proven that static is generated not only by friction, but also by the bringing together and separating of unlike substances. For example: if a sheet of glass is coated with varnish and the varnish allowed to dry, the act of peeling the dried varnish coating from the sheet of glass will result in both substances being charged with static. In the case of a belt and pulley, the belief that static is generated by the slight slipping of the belt on the pulley has been disproved by substituting a loose pulley for one which is carrying a load. Under these conditions, although there is no slip between the belt and the pulley, as much static will be generated as with a pulley carrying a load.

It is not necessary to expand on any of the numerous theories which have been advanced on the generation of static, but to be content with the fact that under certain conditions it is generated and to stress the method of preventing its accumulation.

In the Section on Definitions of Hazardous Locations, numerous cases are mentioned in which the presence of static is a hazard. Static is generated in many other places when its accumulation does not constitute a hazard; such cases are not mentioned in this pamphlet.

3. PROCESSES WHERE STATIC ELECTRICITY IS A HAZARD

A. Storage and Handling of Flammable Liquids

Combustible mixtures of air and vapors of flammable liquids may be ignited by sparks of static electricity generated by the flow of the liquids themselves if they are non-conductors or poor conductors of electricity. Because of this and the fact that many flammable liquids are poor electrical conductors, it is necessary to provide special and additional forms of static protection than might otherwise be required in locations where such liquids must be handled or used in combustible atmospheres.

There is no generation of static electricity in the quiescent storage of liquids because static charges are produced only by some form of motion, such as the flow of liquids into or from tanks or other containers through pipes, hose, or even through the air, by pouring from one container into another.

One of the static charges generated tends to accumulate in or on the surface of the liquid while the opposite charge accumulates on the walls of the tank, pipe, or other liquid container. The potential difference between charges depends upon variables such as the electrical properties of the liquid and its container, the rate of liquid flow, and the distances through which charges are separated.

Other common sources of static electricity* which require static protection in places where combustible atmospheres are likely to be present include the following.

(*a*) The flow of steam, air or inert gas from any opening in a pipe or hose.
(*b*) The movement of any vehicle equipped with non-conducting tires or over a non-conducting floor.
(*c*) The movement of non-conducting power or conveyor belts.
(*d*) Other forms of motion involving changes in relative position of contacting surfaces of dissimilar substances, one or both of which may be a poor or non-conductor of electricity.

Protection Against Static Due to Other Causes

Static due to movements of trucks or other vehicles equipped with non-conducting tires may be minimized during operations on conductive floors or pavements by the use of conductors electrically interconnected to the metallic structures of vehicles and dragging upon the conducting surface of floors or pavements. Trucks and other vehicles should not be operated on non-conducting floors or pavements in spaces where combustible air-vapor mixtures are normally present unless humidification or some other special form of static protection is provided.

B. Operating Rooms

Due to the use of flammable anesthetics, precautions against static electricity in operating rooms are of great importance.

Flooring should be so constructed as to provide an electrically conductive path between any body making electrical contact with it and the building ground.

All furniture should be of metal or other electrically conductive material. Surfaces on which movable objects may be placed should be without paint, lacquer, or other insulating finish. All rubber used for casters, tires, or leg tips, or for surface finishing, should be of the conductive type or of equivalent material.

The coverings of all operating table and stretcher pads and of all pillows, cushions, and the like, should be fabricated from sheeting of conductive rubber or equivalent material.

All waterproof sheeting, such as rubber sheeting, should be made of conductive rubber or similar material.

All rubber or equivalent parts of operating room equipment, such as the masks, breathing tubes, breathing bags, and gaskets of anesthesia equipment, and all suction and pressure tubing not confined within a metallic sheathing, should be of conductive rubber or equivalent material.

All shoes should have soles of conductive rubber, conductive leather, or equivalent material.

All shoes should be tested on the wearer at least once on each day on which they may be worn.

Shoes having nails which may make contact with the floor should not be permitted.

Blankets, sheets, covers, or outer garments of wool, or containing wool, should be excluded from operating rooms.

Fabrics of silk or of synthetic textile materials such as rayon, including "sharkskin," should never be permitted in operating rooms.

Parts of hard rubber, bakelite, or any plastic material which is a non-conductor of electricity, should not be used on any equipment or instrument except when necessary as an electrical insulator on an approved device.

Where the floor does not have adequate electrical conductivity, some other suitable means should be provided for the intercoupling of those persons and objects most likely to be in the region adjoining the anesthesia machine.

4. WORKMEN HAZARDS

In some occupancies, such as those in which highly flammable solvents, or highly flammable materials are involved, the abil-

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* Note: This report does not consider the occurrence of stray electrical currents or protection against arcs due to the interruption of stray currents.

ity of the human body to become charged with static necessitates careful analysis and study.

The accumulation of such a charge on an individual is a function of the humidity of the atmosphere and the dryness of the skin of the individual. Such manifestations are hardly noticed during the warm, moist summer months, but they do appear during those periods of the year when the humidity is low.

One of the most important and easily controlled factors in regard to this hazard is in connection with the type of footwear. Where shoes are a good insulator as in the case of rubber-soled shoes, or rubbers, or rubber boots, the amount of static built up on an employee is far greater than where leather, cord or other soles are used. The leather soles absorb some of the moisture or perspiration, and thereby to some extent at least become conductors and allow the static to drain away as it is formed. Rubber cement used in some shoe fabrication may reduce the conductivity of leather soles.

In certain cases, specially made shoes, with non-sparking nails or rivets extending through the sole, are used.

Shoes with soles of electrically conductive rubber or leather have been developed which are superior to ordinary leather shoes in respect to the dissipation of static charges. (See Introduction, last paragraph.) Wool, silk or nylon stockings, or talcum powder in shoes should not be used as they may furnish sufficient insulation to nulify the value of the conductive sole. Conductive shoes in any case are of value only where there is a conductive floor surface. Wax or other non-conductive floor finish may furnish sufficient insulation to nullify the value of such grounding measures.

Certain persons are more prone to accumulate static charges than others. This is probably explained by the difference in the amount of moisture on the skin, for a person whose skin is normally very dry will have less chance of dissipating the static as it is formed than in the case of the person whose skin is normally very moist. In some industries, prospective employees are tested for skin dryness, as in the case of watch factories, where excessive skin moisture is a distinct handicap. It is possible, by keeping a careful record of the incidents involving generation of static by certain employees, to identify those employees who are prone to generate static, and, where it is a distinct hazard, to transfer them to other employment.

It is often possible for employees to pick up charges of static, which have been generated on certain equipment. It then rests in their bodies until such time as they are in close proximity to a grounded object, when it will discharge across an air-gap in the form of a spark. This, added to the static generated by the employee himself, often results in very heavy, intense sparks. It is difficult to tell when employees are thus charged unless they are tested as outlined later in this pamphlet, or until they touch a grounded object.

In some cases where employees must enter hazardous buildings where the discharge of a static spark is an acute hazard, it has been necessary to provide almost automatic means of grounding the employee prior to entering the building. Such an arrangement might consist of a short flight of steps, provided with a grounded handle, so located that the employee will normally use it to aid himself in ascending the stairs.

The following are the methods usually employed to guard against the workmen hazard:

1. Increase the relative humidity of the room to from 50% to 75%. This will permit the static to drain away from the employee's skin as it is formed.
2. Employee's footwear should be of conductive type.
3. Electrically conductive flooring, metal plates, or floor mats of conductive material should be used in and around the hazardous area, extending a sufficient distance to permit draining of any static charges from Workmen's bodies before they reach points where static sparks are dangerous.
4. All metal equipment should be electrically grounded as described in Section 5.—*B*

5. PREVENTION OF STATIC ACCUMULATIONS

A. Humidification

Unfortunately, it is not now practical to humidify all occupancies where static may be a hazard. It is necessary to conduct certain operations in atmospheres having a low relative humidity to prevent such materials as hygroscopic powders and certain finishing materials from being injured by absorption of moisture from the air. In some textile mills, relative humidity must be carefully controlled, or inferior goods will result. However, in those processes where this is not a factor, a high humidity should be maintained.

Probably one of the most common occupancies which widely employs the principle of humidification is the spreading of rubber goods. Here, high humidity does not cause blushing or affect the finish, as in the case where pyroxylin or similar finishes are used. Although few factories are provided with automatic humidifying equipment they are usually equipped with numerous steam jets which introduce moisture at a point near the application of the compound to the goods.

The exact humidity, below which it is not safe to go, is very difficult to determine, for a number of other factors enter into the problem. It is, however, known that a relative humidity of say 10 per cent or 20 per cent is entirely too low to expect the dissipation of static as it is formed, while a relative humidity of 80 per cent or 90 per cent almost precludes the possibility of static accumulations. The minimum point may be 50 per cent, or it may be 60 per cent relative humidity. However, the highest relative humidity that can be maintained without undue hardship, even up to 75 per cent, is the figure which should be set.

The exact relative humidity to be maintained must be a question for individual solution, but where humidities of 60 per cent are maintained, there is little likelihood of static accumulations.

With a relative humidity of 60 per cent in the workrooms, and low outdoor temperatures, the inside of single glass windows becomes fogged and condensation collects. Where this is objectionable it may be necessary to provide double windows, or their equivalent, and to insulate walls and ceilings.

The maximum relative humidity in the workroom which can be maintained without fogging or condensation on the inside of window panes is given below.

Outdoor Temperatures °F	Relative Humidity Single Windows	Double Windows
0°	15%	48%
10°	20%	53%
20°	27%	59%
30°	36%	66%
40°	47%	73%
50°	60%	81%
60°	78%	90%

It is important to remember that in heated buildings the air is always very dry in the winter. If the outdoor temperature is 30° F., for example, the air cannot possibly contain more than about two grains of moisture per cubic foot, this representing 100 per cent relative humidity. If this air is taken into a building and warmed to 70° F., without the addition of any moisture, the relative humidity becomes only 25 per cent. This is bad, not only from the standpoint of health, but also from the standpoint of static. Where occupancies are equipped with ventilating equipment, it is relatively easy to introduce moisture into the air-stream to increase the relative humidity. Where, however, elaborate ventilating systems are not provided, it is often necessary to introduce the moisture in the form of steam from steam jets, which are usually located at points near the generation of static. It is often possible to provide unit humidifiers so that the entire room atmosphere may be maintained at a uniformly high humidity. Humidification may be accomplished by the use of wet bagging or wet blankets hung about the room, or by periodically wetting down floors and walls. However, such methods are difficult of control. They are not generally recommended except as a temporary expedient. In connection with this, it is well to remember that a surprisingly large amount of moisture is necessary to increase the relative humidity.

The sling psychrometer is probably the most reliable type of instrument for determining the relative humidity. The advantage of this form over the stationary type lies in the facility with which tests can be made, and the accuracy of the readings obtainable, as in whirling the bulbs they are subjected to almost perfect circulation. This piece of equipment consists of a wet bulb and a dry bulb thermometer, held parallel on a member, so arranged that the thermometers can be swung quickly through the air. The wet bulb is provided with a small, tight fitting sock over the bulb so that the sock may be wet with water. When the instrument is swung in a circular motion, the wet bulb reading is lower than the dry bulb reading, due to evaporation of the moisture from the wet sock and the consequent cooling of the thermometer bulb. The difference between the wet bulb reading and the dry bulb reading is known as the temperature depression. The wet bulb thermometer is said to be depressed. The lower the relative humidity, or the less moisture in the air, the higher will be the difference between the wet bulb and the dry bulb readings. The relative humidity can be read directly from a psychrometric chart by locating the intersection of the dry bulb curve and the wet bulb curve as read on the thermometers.

Where space does not permit the use of a sling psychrometer, a rotary type is available. This consists of two thermometers mounted in such a manner that they can be rotated rapidly by turning a handle.

Most stationary instruments for relative humidity determinations are called hygrometers. These instruments, while not as accurate as the sling psychrometers, are, nevertheless, considered to be accurate enough for static humidification determinations. Some operate on the principle of the wet and dry bulb similar to the sling psychrometer. Such instruments depend upon a slight current of air in the room for their operation and they are equipped with a scale for reading the relative humidity directly.

Stationary recording hygrometers can be used to advantage in numerous places. They not only indicate the relative humidity but record it as well on a 24-hour or 32-hour chart. They can easily be arranged to shut down equipment, to start humidifiers or to give an alarm when the danger point is reached.

Stationary hygrometers of whatever type, and whether indicating or recording, should be periodically checked against readings taken with a sling psychrometer.

According to Dr. H. Sidney Newcomer, a number of explosions have occurred in hospital operating rooms with relative humidities above 65 per cent, and it has been recently shown that artificially conditioned operating rooms are more dangerous than non-conditioned rooms. This is due to removal of carbon dioxide by the air conditioning apparatus. It is the carbon dioxide in the wet atmosphere which makes it conductive.

B. Bonding and Grounding

Grounding of machinery and equipment to prevent accumulations of static electricity, involves the same general fundamental principles as those underlying the requirements of the "National Electrical Code" for grounding of electrical circuits and equipment. Grounds of relatively high resistance may be adequate to present accumulation of static charges, but considerations of mechanical strength and reliability of grounds dictate the use of substantial grounding conductors with relatively low resistance. Low resistance in grounding circuits is also evidence of good contacts not likely to be broken. The "National Electrical Code" requires that grounds for electrical circuits and equipment have a resistance of less than 25 ohms; but many industrial concerns now require less than 1 ohm resistance for grounds to prevent static accumulations. The main object is to provide a path just as short and easy as possible, from the point of generation of the static, to ground.

Protection against direct lightning strokes also requires a low resistance path to ground. Such grounding is quite similar to the grounding recommended to prevent static accumulations except that it must be capable of carrying heavy currents of electricity.

The prevention of secondary discharges in pipe lines, apparatus and equipment caused by near-by direct lightning strokes, is accomplished by grounding of the equipment. Those interested in lightning protection for either direct strokes or for secondary discharges, are referred to the "Code for Protection Against Lightning."

Grounding to prevent static accumulations involves only a very small current. However, grounding of electrical circuits and equipment; lightning protection; and grounding to prevent static accumulations each requires the application of the same fundamental principles; namely, providing a large cross sectional area, short and direct path of low resistance to ground.

It is necessary in cases where static is generated on insulating materials or non-conductors, to provide an electrical path from the point of generation to the ground wire. The ground wire itself must be of the proper size and type and the connection to the equipment must be substantial and must not introduce a high resistance at this point. The use of grounding electrodes such as water pipes, ground cones, buried copper plates, as the terminal of ground wires, and the method of connecting the wire to them, are problems requiring careful consideration. Static grounds should not be made to electrical conduit systems, gas or steam pipes, dry-pipe sprinkler systems or lightning rods. Grounding systems must be tested for electrical resistance when completed, and regularly and frequently thereafter to make sure that their original effectiveness is not impaired by such factors as corrosion, mechanical injury and loose connections.

Equipment

With metal equipment the problem is principally one of electrically interconnecting all of the metal parts and grounding them. Because metal parts of equipment are in contact with each other does not necessarily mean that they are electrically connected. Paint, rust, corrosion or merely light contact will often introduce high resistance. For a continuous electrical path, the metal parts must be clean and bright, free from paint, rust, or oil, and must be held securely in contact with substantial bolts, by brazing, or otherwise. All metal parts in or near locations where static may be generated should be electrically interconnected to prevent any condenser effect. Copper ground straps or tape is sometimes preferable to solid or stranded wire for connecting together metal parts. Ground straps or wires should be run in full view so that they may be readily seen to detect any evidences of breakage or damage.

The ground wire, or grounding conductor, is probably the most important part of a grounding system for removal of static. The No. 4 B. & S. gage wire recommended for grounding is selected for its mechanical strength rather than for its current carrying capacity. No. 4 B. & S. gage wire has a diameter of 0.2043 inches (204.3 mils). Either bare or insulated wire may be used. Where the ground wires extend through operating areas they should be protected against mechanical injury by standard conduits, or by placing behind the rugged parts of machinery. Nothing smaller than 3/4 in. conduit is recommended for the No. 4 wire, in accordance with the requirements of the National Electrical Code. Due to the choke effect in case of secondary lightning discharges an electrical connection should be made between the wire and the conduit at point where the wire enters and where it leaves the run of conduit. Where ground wires extend into the ground they should be protected to a point below the ground surface with 3/4 in. conduit.

In order to secure the shortest possible path to ground it is generally advisable to extend ground wires in a downward direction. In the case of rather high equipment, however, grounding connections may be made to wet pipe sprinkler systems installed on the ceiling above the equipment. Ohm meter readings will frequently show that such systems in their entirety are at ground potential and make excellent grounds. Where equipment which must be grounded is located on upper floors a very convenient ground is often obtained by extending the ground wires through the floor below and connecting to the wet pipe sprinkler system installed to protect the ceiling underneath. Sprinkler risers are recommended for such grounding since they are seldom out of service and are excellent paths of low resistance for static. The joints of such systems are in almost all cases well made and due to the presence of the water in the pipes the resistance across such joints is usually negligible. Dry pipe systems are not recommended for such grounding except as a last resort.

To insure low electrical resistance from the point of generation of the static to ground, it is essential that the grounding requirements of the "National Electrical Code" be met.