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National Fire Codes®

A Compilation of NFPA Codes, Standards, Recommended Practices, Manuals and Guides

Volume 8

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National Fire Protection Association
Batterymarch Park, Quincy, MA 02269

NATIONAL FIRE PROTECTION ASSOCIATION

Batterymarch Park, Quincy, MA 02269

The National Fire Protection Association was organized in 1896 to promote the science and improve the methods of fire protection and prevention, to obtain and circulate information on these subjects and to secure the cooperation of its members in establishing proper safeguards against loss of life and property by fire. The Association is an international, charitable, technical and educational organization. Its membership includes over one hundred and fifty national and regional societies and associations and over thirty-two thousand individuals, corporations, and organizations. Anyone interested may become a member; membership information is available on request.

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National Fire Codes

The *National Fire Codes* are annual compilations of the Codes, Standards, Recommended Practices, Manuals, Guides and Model Laws prepared by Technical Committees organized under NFPA sponsorship in accordance with the published procedures of the Association. Only those documents which have been adopted by the Association are included in the *National Fire Codes*.

The Board of Directors of the Association appoints persons from those vitally interested, qualified, and active in the areas with which the Committees are concerned so as to achieve a fair balance of affected interests. All service on these NFPA Technical Committees is contributed voluntarily in support of the Association's program for firesafety. While these procedures assure the highest degree of care, neither the National Fire Protection Association, its members, nor those participating in its activities accept any liability resulting from compliance with the provisions given herein, for any restrictions imposed on materials or processes, or for the completeness of the text. Users should realize that complete reliance for firesafety can never rest exclusively on any single safeguard.

The committees responsible for the various texts published herein are given in the introductory sections preceding each. Current committee lists are published in the NFPA *Yearbook,* which may be obtained from the Association. Official records of the adoption of each standard will be found in the NFPA *Technical Committee Reports,* the *Technical Committee Documentation* and *Fire Journal,* a bimonthly membership publication of the Association.

Volumes 1 through 6 contain documents which have been judged suitable for legal adoption and enforcement (Codes and Standards).

Volumes 7 and 8 contain Recommended Practices, Manuals and Guides which are generally referred to as good engineering practices. Also included in these volumes are such documents as model laws and enabling acts which will be found to be particularly helpful to enforcing agencies.

Many of the documents have been approved by the American National Standards Institute as American National Standards. Most of the documents contained in these volumes are also published by the Association in separate pamphlet form.

Users of this document should consult applicable Federal, State and local laws and regulations. NFPA does not, by the publication of this document, intend to urge action which is not in compliance with applicable laws and this document may not be construed as doing so.

Policy adopted by NFPA Board of Directors on December 3, 1982

The Board of Directors reaffirms that the National Fire Protection Association recognizes that the toxicity of the products of combustion is an important factor in the loss of life from fire. NFPA has dealt with that subject in its technical committee documents for many years.

There is a concern that the growing use of synthetic materials may produce more or additional toxic products of combustion in a fire environment. The Board has, therefore, asked all NFPA technical committees to review the documents for which they are responsible to be sure that the documents respond to this current concern. To assist the committees in meeting this request, the Board has appointed an advisory committee to provide specific guidance to the technical committees on questions relating to assessing the hazards of the products of combustion.

Official NFPA Definitions

Extracted from the *Regulations Governing Committee Projects*

Section 2. Terms and Definitions.

2-2 Definitions. Where the following terms, commonly found in the Association Committee Documents, are used or defined in the body of the text of a Standard, Code, Recommended Practice, Manual or Guide, they shall be consistent with the intent of these meanings, but these "definitions" may be altered by a Committee to fit the individual needs of the Document. Such altered definition shall be clear and unambiguous in the context in which it is used.

Approved: means "acceptable to the authority having jurisdiction."

NOTE: The National Fire Protection Association does not approve, inspect or certify any installations, procedures, equipment or materials; nor does it approve or evaluate testing laboratories. In determining the acceptability of installations or procedures, equipment or materials, the authority having jurisdiction may base acceptance on compliance with NFPA or other appropriate standards. In the absence of such standards, said authority may require evidence of proper installation, procedure or use. The authority having jurisdiction may also refer to the listings or labeling practices of an organization concerned with product evaluations which is in a position to determine compliance with appropriate standards for the current production of listed items.

Authority Having Jurisdiction: The "authority having jurisdiction" is the organization, office, or individual responsible for "approving" equipment, an installation, or a procedure.

NOTE: The phrase "authority having jurisdiction" is used in NFPA Documents in a broad manner since jurisdictions and "approval" agencies vary as do their responsibilities. Where public safety is primary, the "authority having jurisdiction" may be a federal, state, local, or other regional department or individual such as a fire chief, fire marshal, chief of a fire prevention bureau, labor department, health department, building official, electrical inspector, or others having statutory authority. For insurance purposes, an insurance inspection department rating bureau, or other insurance company representative may be the "authority having jurisdiction." In many circumstances, the property owner or his designated agent assumes the role of the "authority having jurisdiction"; at government installations, the commanding officer or departmental official may be the "authority having jurisdiction."

Code: A Document containing only mandatory provisions using the word "shall" to indicate requirements and in a form generally suitable for adoption into law. Explanatory material may be included only in the form of "fine print" notes, in footnotes, or in an appendix.

Labeled: Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed: Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The authority having jurisdiction should utilize the system employed by the listing organization to identify a listed product.

Manual or Guide: A Document which is informative in nature and does not contain requirements.

Recommended Practice: A Document containing only advisory provisions (using the word "should" to indicate recommendations) in the body of the text.

Shall: Indicates a mandatory requirement.

Should: Indicates a recommendation or that which is advised but not required.

Standard: A Document containing only mandatory provisions using the word "shall" to indicate requirements. Explanatory material may be included only in the form of "fine print" notes, in footnotes, or in an appendix.

Notes and footnotes are informatory only and are not mandatory.

NOTICE

All questions or other communications relating to documents in this volume should be sent only to NFPA Headquarters, addressed to the attention of the Committee responsible for the document.

For information on obtaining Formal Interpretations of the documents, proposing Tentative Interim Amendments, proposing amendments for Committee consideration, and on matters relating to the content of the document, write to the Secretary, Standards Council, National Fire Protection Association, Batterymarch Park, Quincy, MA 02269.

A statement, written or oral, that is not processed in accordance with Section 16 of the Regulations Governing Committee Projects shall not be considered the official position of NFPA or any of its Committees and shall not be considered to be, nor be relied upon as, a Formal Interpretation.

VOLUME 8

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Recommended Practice on
Static Electricity

NFPA 77-1983

1983 Edition of NFPA 77

This edition of NFPA 77, *Recommended Practice on Static Electricity*, was prepared by the Technical Committee on Static Electricity, and acted on by the National Fire Protection Association, Inc. on November 17, 1982, at its Fall Meeting in Philadelphia. It was issued by the Standards Council on December 7, 1982 with an effective date of December 27, 1982, and supersedes all previous editions.

The 1983 edition of this document has been approved by the American National Standards Institute.

Origin and Development of NFPA 77

NFPA committee activity in this field was initiated in 1936 and a progress report was presented to the Association in 1937. A revised text was tentatively adopted in 1941 and, with further revisions, was finally adopted in 1946.

Revised editions have subsequently been adopted by the Association in 1950, 1961, 1966, 1972, 1977, and 1982.

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This list represents the membership at the time the Committee was balloted on the text of this edition. Since that time, changes in the membership may have occurred.

NOTE: Membership on a Committee shall not in and of itself constitute an endorsement of the Association or any document developed by the Committee on which the member serves.

Contents

Recommended Practice on

Static Electricity

NFPA 77-1983

Chapter 1 General

1-1 Purpose.

1-1.1 The purpose of this recommended practice is to assist in reducing the fire hazard of static electricity by presenting a discussion of the nature and origin of static charges, the general methods of mitigation and recommendations in certain specific operations for its dissipation.

1-1.2 Static electricity is often the ignition source for an ignitable mixture, an operating problem in industry or an annoyance to some individuals.

1-2 Scope.

1-2.1 This publication covers methods for the control of static electricity for the purpose of eliminating or mitigating its fire hazard, except as provided in 1-2.2 and 1-2.3 below.

1-2.2 The prevention and control of static electricity in hospital operating rooms or in areas where flammable anesthetics are administered are not covered by this publication but are covered in NFPA 56A, *Standard for the Use of Inhalation Anesthetics.*

1-2.3 Lightning is not covered by this publication but is covered in NFPA 78, *Lightning Protection Code.*

1-3 Definitions. (*See also Appendix A.*)

Approved. Acceptable to the "authority having jurisdiction."

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Bonding. The process of connecting two or more conductive objects together by means of a conductor.

Ignitable Mixture. A vapor-air, gas-air, dust-air mixture or combinations of these mixtures which can be ignited by a static spark.

Grounding (Earthing). The process of connecting one or more conductive objects to the ground, and is a specific form of bonding. The words Bonded or Grounded, as they are used in the text, must be understood to mean either that a bond or ground as defined has been deliberately applied, or that an electrically conductive path having a resistance adequately low for the intended purpose (usually 10^6 ohms or less) is inherently present by the nature of the installation.

Labeled. Equipment or materials to which has been attached a label, symbol or other identifying mark of an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

Listed. Equipment or materials included in a list published by an organization acceptable to the "authority having jurisdiction" and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials and whose listing states either that the equipment or material meets appropriate standards or has been tested and found suitable for use in a specified manner.

NOTE: The means for identifying listed equipment may vary for each organization concerned with product evaluation, some of which do not recognize equipment as listed unless it is also labeled. The "authority having jurisdiction" should utilize the system employed by the listing organization to identify a listed product.

Should. Indicates a recommendation or that which is advised but not required.

Static Spark. An impulsive discharge of electricity across a gap between two points not in contact.

1-4 Introduction.

1-4.1 The term "static electricity," as used in this publication, means electrification of materials through physical contact and separation, and the various effects that result from the positive and negative charges so formed—particularly where they constitute a fire or explosion hazard. The generation of static electricity cannot be prevented, absolutely, because its intrinsic origins are present at every interface.

1-4.2 The development of electrical charges may not be in itself a potential fire or explosion hazard. There must be a discharge or sudden recombination of separated positive and negative charges. In order for static to be a source of ignition, four conditions must be fulfilled:

(a) There must first of all be an effective means of static generation,

(b) There must be a means of accumulating the separate charges and maintaining a suitable difference of electrical potential,

(c) There must be a spark discharge of adequate energy, and

(d) The spark must occur in an ignitable mixture.

1-4.3 The accumulation of static charges may be prevented under many circumstances by grounding or bonding, by humidification, or by ionization. These means and their functions are discussed in Chapter 3.

1-4.4 Common sources of static electricity include:

(a) Pulverized materials passing through chutes or pneumatic conveyors,

(b) Steam, air, or gas flowing from any opening in a pipe or hose, when the steam is wet or the air or gas stream contains particulate matter,

(c) Nonconductive power or conveyor belts in motion,

(d) Moving vehicles, and

(e) Motions of all sorts that involve changes in relative position of contacting surfaces, usually of dissimilar liquids or solids.

1-4.5 The object of most static-corrective measures is to provide a means whereby charges separated by whatever cause may recombine harmlessly before sparking potentials are attained, or to avoid spark gaps where harmful discharges could occur.

1-4.6 If hazardous static conditions cannot be avoided in certain operations, means must be taken to assure that there are no ignitable mixtures at points where sparks may occur.

1-5 General.

1-5.1 To the average person the words "static electricity" may mean either a noise in the radio receiver which interferes with good reception or the electric shock experienced when touching a metal object after walking across a carpeted floor or sliding across the plastic seat cover in an automobile. Some people also have experienced mysterious crackling noises and a tendency for some of their clothing to cling or stick tightly together when wool, silk, or synthetic fiber garments are worn. Nearly everyone recognizes that these phenomena occur mainly when the atmosphere is very dry. To most people they are simply an annoyance.

1-5.2 The word "electricity" is derived from the ancient Greek word "elektron" — meaning amber — for it was with this substance that the phenomenon of electrification was first observed. For centuries "electricity" had no other meaning than the property exhibited by some substances, after being rubbed with a material like silk or wool, of being able to attract or repel lightweight objects. Stronger electrification accompanied by luminous effects and small sparks was first observed about 300 years ago by von Guericke. In comparatively recent times, when the properties of flowing electricity were discovered, the word "static" came into use as a means of distinguishing the old from the new. The implication that such electricity is always at rest is erroneous; it is when it ceases to rest that it causes the most concern.

1-5.3 For the sake of simplicity, one may imagine electricity to be a weightless and indestructible fluid which can move freely through some substances, such as metals, that are called "conductors," but can flow with difficulty or not at all through or over the surface of a class of substances called "nonconductors" or "insulators." This latter group includes: gases, glass, rubber, amber, resin, sulfur, paraffin, and most dry petroleum oils and many plastic materials. When electricity is present on the surface of a nonconductive body, where it is trapped or prevented from escaping, it is called static electricity. Electricity on a conducting body which is in contact only with nonconductors is also prevented from escaping and is therefore nonmobile or "static." In either case, the body on which this electricity is evident is said to be "charged."

1-5.4 The charge may be either positive (+) or negative (-). At one time it was thought that the two charges were two kinds of electricity and that in a neutral (uncharged) body they were present in exactly equal amounts. Now it is known that there is actually only one kind of electricity, although it is described by many adjectives. It is manifested when some force has abnormally separated a few of its positive and negative constituents. These entities are components of all atoms, the outer electrons (-) and the inner (nuclear) protons (+). Curiously, a surface that has an excess or deficiency of one electron in every 100,000 atoms is very strongly charged.

1-5.5 It is true, however, that in a neutral or uncharged body the two entities are present in exactly equal amounts. Work is required to separate positive and negative charges. Electricity, therefore, is sometimes referred to as a form of energy produced by expenditure of energy in some other form, such as mechanical, chemical, or thermal. Likewise, when electrical energy (a better term) is expended, its equivalent appears in one of these other forms.

1-5.6 Electrons are free to move from one molecule to another in conductors but the proton, in the nucleus of the atom, cannot move appreciably unless the atom moves. Therefore, in solids, only the electrons are mobile; in gases and liquids both are free to move.

1-5.7 The stable structure of the atom shows that unlike charges attract; and, conversely, like charges repel. It follows that a separated charge will be self-repellent and will reside only on the surface of a charged body. If the body were a perfect insulator or perfectly insulated, the charge would remain indefinitely. However, there are no perfect insulators and isolated charges soon leak away to join their counterparts and thus bring about neutralization, the normal state (*see also Section 3-3*).

1-5.8 Static electricity then is the set of phenomena associated with the appearance of an electric charge on the surface of an insulator or insulated conductive body. It is "generated" usually by the expenditure of mechanical work, although we must remember that in this sense generated means "liberated" or made alive — electricity cannot be created. Somewhere, possibly "grounded" but as close as conditions will allow, there will be an exactly equal opposite charge — its counterpart. This concept is extremely important.

1-6 Generation and Storage.

1-6.1 Like charges repel each other and unlike charges attract. The charge on the surface of an insulator can thus attract an equal and opposite charge on the nearest surface of any conducting body close to it. A companion charge of opposite polarity will be repelled to the more remote side. This is the process called induction. The charge on the near side is said to be "bound"; the repelled charge on the opposite side is "free," and may be dissipated by momentarily providing a path to earth. If the conducting body is now moved away from the originally charged body, the bound charge is now freed and will redistribute itself over the whole surface of the conducting body. In turn, it can be released in the form of a spark.

1-6.2 Whereas a spark from the surface of an insulator can release a charge from only a small area, all the charge on the conducting body can be released in a single spark. Thus, in many situations, induced charges are far more dangerous than the initially separated ones upon which they are dependent.

1-6.3 In effect, a metal plate in close proximity to a charged surface can be considered one plate of a capacitor, and its ability to store energy is described as its capacitance. When a potential difference is applied between the two plates of a capacitor, electricity can be stored. In some instances one of the plates is the earth, the insulating medium is the air, and the other plate is some body or object insulated from the earth to which the charge has been transferred by induction or otherwise. When a conducting path is made available, the stored energy is released (the capacitor is discharged) possibly producing a spark. The energy so stored and released by the spark is related to the capacitance (C) and the voltage (V) in accordance with the following:

$$\text{Energy} = \frac{C\,(V)^2}{2}$$

(See Appendix A for a discussion of terms.)

1-6.4 If the object close to the highly charged nonconductor is itself a nonconductor, it will be polarized, that is, its constituent molecules will be oriented to some degree in the direction of the lines of force since their electrons have no true migratory freedom. Because of their polarizable nature, insulators and nonconductors are often called dielectrics. Their presence as separating media enhance the accumulation of charge.

1-7 Ignition Energy.

1-7.1 The ability of a spark to produce ignition is governed largely by its energy, which will be some fraction of the total stored energy.

1-7.2 Tests have shown that saturated hydrocarbon gases and vapors require approximately 0.25 millijoule of discharge energy for spark ignition of optimum mixtures with air. Unsaturated hydrocarbons may have lower minimum ignition energies. (See Table 1-7.2) It has been shown further that sparks arising from potential differences of less than 1500 volts are unlikely to be hazardous in saturated hydrocarbon gases because of the short gap and heat loss to the terminals.

Table 1-7.2 Approximate Minimum Ignition Energy

	millijoule
methane	0.29
propane	0.25
cyclopropane	0.18
ethylene	0.08
acetylene	0.017
hydrogen	0.017

1-7.3 Tests have shown that dusts and fibers require discharge energy of one or two magnitudes greater than gases and vapors for spark ignition of optimum mixtures with air.

1-8 Summary.

1-8.1 In summarizing, static electricity will be manifest only where highly insulated bodies or surfaces are found. If a body is "charged" with static electricity, there will always be an equal and opposite charge produced. If a hazard is suspected, the situation should be analyzed to determine the location of both charges and to see what conductive paths are available between them.

1-8.2 Tests of the high-resistance paths should be made with an applied potential of 500 volts or more, in order that a minor interruption (paint or grease-film or airgap) will be broken down and a correct reading of the instrument obtained.

1-8.3 Resistances as high as 10,000 megohms will provide an adequate leakage path in many cases; when charges are generated rapidly, however, a resistance as low as 1 megohm (10^6 ohms) might be required.

1-8.4 Where bonds are applied, they should connect the bodies on which the two opposite charges are expected to be found.

Chapter 2 The Hazards of Static Electricity

2-1 Static Electricity as an Ignition Source.

2-1.1 Flammable and Combustible Liquids. Static is generated when liquids move in contact with other materials. This occurs commonly in operations such as flowing through pipes, and in mixing, pouring, pumping, filtering or agitating. Under certain conditions, particularly with liquid hydrocarbons, static may accumulate in the liquid. If the accumulation is sufficient, a static spark may occur. If the spark occurs in the presence of a flammable vapor-air mixture, an ignition may result. Therefore, steps should be taken to prevent the simultaneous occurrence of the two conditions.

2-1.2 Gases. When flowing gas is contaminated with metallic oxides or scale particles, etc., or with liquid particles or spray, electrification may result. A stream of such particle-containing gas directed against a conductive object will charge the latter unless the object is grounded or bonded to the discharge pipe. If the accumulation is sufficient, a static spark may occur. If the spark occurs in the presence of a flammable vapor-air mixture, an ignition may result. Where a static spark and a flammable vapor-air mixture may occur simultaneously, suitable preventive measures are required to avoid ignition.

2-1.3 Dusts and Fibers. Generation of static charge is commonly observed during handling and processing of dusts and fibers in industry. There are recorded instances where ignition of a combustible dust cloud or layer is attributed to the static electrical discharge. In all instances in which static electricity has been authentically established as the cause of ignition, the spark occurred between an insulated conductor and ground. It has not been verified experimentally that a dust cloud can be ignited by static discharge within itself.

2-2 Personnel Hazards of Static Electricity.

2-2.1 The Human Body. The human body is an electrical conductor and in dry atmospheres frequently accumulates a static charge resulting in voltages as high as several thousand volts. This charge is generated by contact of the shoes with floor coverings, or by participation in various manufacturing operations.

2-2.2 Clothing.

2-2.2.1 Under many conditions, the shoes and clothing of workers can be conductive enough to drain away static charges as fast as they are generated.

2-2.2.2 Although silk and some synthetic fibers are excellent insulators, and undergarments made from them exhibit static phenomena, there is no conclusive evidence to indicate that wearing such undergarments constitutes a hazard.

2-2.2.3 Outergarments, on the other hand, can build up considerable static charges when moved away from the body, or removed entirely. Under many conditions this effect constitutes little hazard. However, for some materials and/or low humidity conditions an electrostatic ignition source may exist.

2-2.2.4 The removal of outer garments is particularly dangerous in work areas such as hospital operating rooms, explosive manufacturing facilities and similar occupancies where there may be flammable or explosive atmospheres which are ignitable with low electrical energy. Outergarments used in these areas should be suitable for the work area. NFPA 56A, *Standard for the Use of Inhalation Anesthetics*, provides information on test methods for evaluating the antistatic performance of wearing apparel.

2-2.2.5 In liquid oxygen filling plants, vapor from cooled gas may permeate the employee's clothing, rendering it flammable. A static charge accumulating on the person can cause ignition. This can be prevented by the use of conductive footwear and conductive floors.

2-2.3 Hazardous Occupancies. Where ignitable mixtures exist there is a possible ignition potential from the charged human body, and means to prevent accumulation of static charge on the human body may be necessary. Steps to prevent such accumulations may include:

(a) Avoid the wearing of rubbers, rubber boots, rubber-soled shoes, and nonconductive synthetic-soled shoes.

(b) Providing conductive floors and conductive footwear.

2-2.4 Discomfort and Injury. Static shock can result in discomfort and, under some circumstances, injury to workers due to involuntary reaction. The discharge in itself is not dangerous to humans, but it may cause an involuntary reaction which results in a fall or entanglement with moving machinery. If charge accumulation cannot be avoided, and there are no flammable gases or vapor present, consideration should be given to the various methods by which contact with metal parts can be eliminated. Such methods would include, among others, the use of nonmetallic hand rails, insulated doorknobs and other nonconducting shields.

2-3 Process Hazards of Static Electricity.

2-3.1 Mixing and Blending Operations.

2-3.1.1 Mixing, grinding, screening or blending operations with solid nonconductive materials as well as the pneumatic conveying of finely divided nonconductive materials can generate static electricity. The degree of static hazard is influenced by the ability of the materials to generate and hold a charge and on the capacitance of insulated conductive parts of the machines and ducts to accumulate sufficient charge to cause an incendive discharge. (*See Section 7-4.*)

2-3.1.2 Flammable liquids are mixed in churns or autoclaves with various pigments, resins or similar materials in the manufacture of paints, varnishes, lacquers, printing inks and similar products. This process can be a severe fire and explosion hazard depending upon the flashpoint of the solvents, the amount involved, method of handling, the amount of ventilation and other factors. Static electricity is a potential ignition source and can be guarded against. (*See Chapter 4.*)

2-3.2 Cotton Gins. When the static charge on the cotton is of sufficient magnitude, the cotton will ball up in the gin stands and equipment. This results in a production problem and frictional heat in the equipment. Experience has shown that the amount of energy released by sparks due to static accumulations has not been of sufficient magnitude to ignite loose lint, dust or cotton.

2-3.3 Coating, Spreading, and Impregnating. In each of these operations the material to be processed usually is unwound from a roll at the feed end of the machine, it passes over a series of rollers under a spreader or doctor knife where the coating material is applied, or through an impregnating tank between squeeze rolls and then under a doctor knife, then over a steam table or through a drying oven, and is finally wound up on a reel or laminated on skids. Static charges are often produced in each of these operations. If flammable liquids are employed, the static electricity may be a source of ignition.

2-3.4 Belts. Some types of belts frequently exhibit static generation, which may or may not warrant corrective measures depending on circumstances. (*See Section 7-1.*)

2-3.5 Drycleaning. Commercial drycleaning operations are in closed machines except for spotting operations. The operations employed — immersing fabrics, some of them highly insulating, in various solvents which are themselves good insulators and good generators of static electricity, stirring and agitating them, and removing them from the solvent bath — are all likely to produce static charges on the insulating surfaces of the materials involved. If flammable liquids are employed the static electricity may be a source of ignition. (*See NFPA 32, Drycleaning Plants.*)

2-3.6 Printing and Lithographing.

2-3.6.1 In the printing and lithographing industries static electricity is a frequent, annoying, and often expensive source of trouble from the production standpoint. Where flammable inks and solvents are used in the process, static may create a fire or explosion hazard. (*See Section 7-3.*)

2-3.6.2 In practice, sheets charged with static electricity have an attraction for other objects which often causes difficulty in controlling the sheets or webs and sometimes results in tearing of the webs. It may also cause an increase in offset due to more intimate contact of the surfaces of the sheet in the delivery pile or from the attraction of the ink to the underside of the overlying sheets. The printed image may also be damaged by the attraction of dust particles and loose paper fibers to the paper.

2-3.7 Spray Finishing. The application of paint, varnishes, enamels, lacquers, and other finishes by spray finishing equipment may cause a static charge to accumulate on the object being sprayed and the spray gun. If flammable liquids are employed, the static electricity may be a source of ignition. (*See NFPA 33, Spray Application Using Flammable and Combustible Materials.*)

2-3.8 Steam Jets. Wet steam escaping into the atmosphere can generate static electricity which can accumulate on any insulated object in the area. If flammable vapor-air mixtures are likely to be present, the discharge of static electricity may become a source of ignition. (*See Section 7-6.*)

2-3.9 Explosive Manufacturing. Primary explosives, mercury fulminate and tetryl for example, if in the form of a dust, are readily detonated by static spark discharge. Steps necessary to prevent accidents from static electricity in explosive manufacturing operations and storage areas vary considerably with the static sensitivity of the material being handled.

Chapter 3 Control of Ignition Hazards

3-1 Static Control. Ignition hazards from static electricity can be eliminated by removing the ignitable mixture from the area where static may be discharged as sparks, controlling the amount or speed of charge generation, or relaxing a charge after it has been generated.

3-2 Control of Static Generation. Since static is generated whenever two dissimilar materials are in relative motion to each other, a slowing down of this motion will reduce the rate of the generation of static electricity. For example, a low conductivity material flowing through pipes, ducts, filters and the like will generate static electricity. If the material flows at a low enough rate, a hazardous level of static will not be generated. Frequently this means of static control is not commercially acceptable because of slower production.

3-3 Charge Relaxation (Dissipation).

3-3.1 Bonding and Grounding.

3-3.1.1 A conductive object may be grounded directly or by bonding it to another conductive object that is already connected to the ground. Some objects are inherently bonded or inherently grounded by their contact with the ground. Examples are underground piping or large storage tanks resting on the ground.

3-3.1.2 Bonding is done to minimize potential differences between conductive objects. Likewise, grounding is done to minimize potential differences between objects and the ground.

3-3.1.3 The minimum size of wire is dictated by mechanical strength rather than by current-carrying capacity. Flexible conductors should be used for bonds that are to be connected and disconnected frequently. To prevent the accumulation of static electricity the resistance need not be less than 1 megohm and in most cases may be even higher. To protect electrical power circuits the resistance must be low enough to ensure operation of the fuse or circuit breaker under fault conditions. Any ground that is adequate for power circuits or lightning protection is more than adequate for protection against static electricity.

3-3.1.4 Conductors may be insulated or uninsulated. Some prefer uninsulated conductors so that defects can be easily spotted by visual inspections. If insulated, the conductor should be checked for continuity at regular intervals, depending on experience.

3-3.1.5 Connections may be made with pressure-type ground clamps, brazing, welding, battery-type clamps, magnetic or other special clamps which provide metal-to-metal contact. (*See Figures 1, 2, and 4.*)

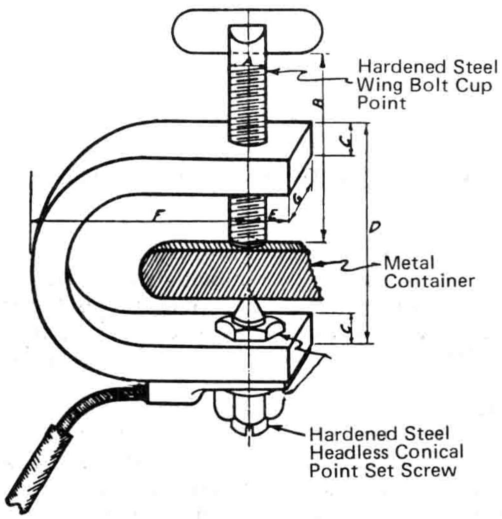

Figure 1 Typical Pressure-type Ground Clamp.

3-3.1.6 The resistance between a grounded object and the soil is made up of the resistance of the ground wire itself and the resistance of the ground electrode (ground rod) to the soil. Most of the resistance in any ground connection is in the contact of the ground electrode with the soil. The ground resistance is quite variable as it depends upon the area of contact, the resistivity of the soil, and the amount of moisture.

3-3.2 Humidification.

3-3.2.1 It is a matter of common experience that manifestations of static electricity — e.g., the sparks which an individual may experience on walking across a rug — are more intense in periods of dry weather than they are when a moist atmosphere prevails. From such experience has arisen the erroneous popular belief that static generation is controlled by weather. Actually, the generating mechanism is not influenced by weather, but weather does have a marked effect on whether a generated charge leaks away so fast that no observable accumulation results, or whether it can build up to produce the commonly recognized sensory manifestations.

3-3.2.2 In Chapter 1, materials were loosely described as "conductors," as distinguished from "nonconductors" or "insulators," and it was stated that, since there is no perfect insulator, isolated charges of static electricity eventually dissipate. Anything which could be relied upon to impart conductivity to an insulating body would thus become a means of dissipating static charges.

3-3.2.3 Most of the commonly encountered insulating materials, such as fabric, wood, paper, films, concrete or masonry, contain a certain amount of moisture in equilibrium with the air in the surrounding atmosphere. This moisture content varies, depending on weather, and to a large measure controls the conductivity of the material, and hence its ability to prevent the escape of static electricity. The conductivity of these materials is controlled, not by the absolute water content of the air, but by its relative humidity. This figure, as ordinarily recorded in weather reports and comfort charts, is the ratio of the partial pressure of the moisture in the atmosphere to the partial pressure of water at the prevailing atmosphere temperature. Under conditions of high relative humidity — 50 percent or higher — the materials in question will reach equilibrium conditions containing enough moisture to make the conductivity adequate to prevent static accumulations.

3-3.2.3.1 At the opposite extreme, with relative humidities of 30 percent or less, these same materials may dry out and become good insulators and static manifestations become noticeable. There is no definite boundary line between these two conditions.

3-3.2.4 It should be emphasized that the conductivity of these materials is a function of relative humidity. At any constant moisture content, the relative humidity of an atmosphere decreases as the temperature is raised and vice versa. In cold weather, the absolute humidity of the outdoor atmosphere may be low, even though the relative humidity may be high. When this same air is brought indoors and heated, the relative humidity becomes very low. As an example, a saturated atmosphere at an outdoor temperature of 30°F (-1°C) would have a relative humidity of only a little over 20 percent if heated up to a room temperature of 70°F (21°C). This phenomenon is responsible for the previously mentioned common belief that static generation is always more intense during winter weather. The static problem is usually more severe during this period because static charges on a material have less opportunity to dissipate when relative humidities are low.

3-3.2.5 Humidifying the atmosphere has proved to be a solution to static problems in some special circumstances, as where static has resulted in the adhesion or repulsion of sheets of paper, layers of floss, fibers, and the like. It is usually stated that a relative humidity of about 50 percent or higher will avoid such difficulties.

3-3.2.5.1 Unfortunately, it is not practical to humidify all occupancies in which static might be a hazard. It is necessary to conduct some operations in an atmosphere having a low relative humidity to avoid deleterious effects on the materials handled. High humidity can also cause intolerable comfort conditions in operations where the dry bulb temperature is high. On the other hand, a high humidity may advantageously affect the handling properties of some materials, thus providing an additional advantage.

3-3.2.5.2 In some cases localized humidification produced by directing a steam jet onto critical areas may provide satisfactory results without the need for increasing the humidity in the whole room (*see 7-2.6 and Section 7-6*).

3-3.2.6 It does not follow that humidification is a cure for all static problems. Some insulators are not susceptible to moisture absorption from the air, and high humidity will not noticeably decrease the resistivity. Notable examples are the uncontaminated surfaces of some plastics and the surface of petroleum liquids. Such surfaces are capable of accumulating static charges even though the atmosphere may have relative humidity of up to 100 percent.

3-3.2.7 In summary, humidification may be a cure for static problems where the surfaces on which the static electricity accumulates are those materials which can absorb moisture and which are not abnormally heated. For heated surfaces, and for static on the surface of oils and some other liquid and solid insulating materials, high humidity will not provide a means for draining off static charges, and some other solution must be sought.

3-3.3 Increasing Conductivity.

3-3.3.1 Electrostatic charges may accumulate on the surfaces of low conductivity materials. By increasing the conductivity, i.e., lowering the resistivity, these charges can be relaxed before they can accumulate to a hazardous level.

3-3.3.2 In solid material, it may be possible to add a conductive material to increase the conductivity. For instance, carbon black has been added to some plastics to increase their conductivity.

3-3.3.3 In liquid fuels, conductivity additives have been used for controlling charge accumulation. These are polar materials, blended into fuels, usually at low concentrations. Conductivity levels greater than 50 picoseimens/meter (pS/m)* at use temperature are generally considered nonhazardous.

3-3.3.3.1 The effect of conductivity additives decreases with decreasing temperature. It is important that enough additive be used to assure satisfactory conductivity at the lowest product use temperature.

3-3.3.3.2 It is important to note that conductivity additives do not prevent the generation of static electricity. They allow rapid charge relaxation, i.e., the recombining with charges of opposite polarity. The use of conductivity additives must be in conjunction with bonding and grounding to provide a complete electrical path for charge relaxation.

3-3.4 Ionization.

3-3.4.1 General. Under certain circumstances air may become sufficiently conducting to dissipate static charges. In the use of all static eliminators, one must consider certain engineering problems such as environmental conditions (dust, temperature, etc.), and positioning of the device in relation to the stock, machine parts, and personnel.

3-3.4.2 Inductive Neutralizer (Static Comb).

3-3.4.2.1 A static charge on a conductive body is free to flow, and on a spherical body in space it will distribute itself uniformly over the surface. If the body is not spherical, the self-repulsion of the charge will make it concentrate on the surfaces having the least radius of curvature.

3-3.4.2.2 If the body is surrounded by air (or other gas) and the radius of curvature is reduced to almost zero, as with a sharp needle point, the charge concentration on the point can produce ionization of the air, rendering it conductive. Whereas a surface of large diameter can receive and hold a high voltage, the equivalent surface equipped with a sharp needle point can hold only a small charge before the leakage rate equals the rate of generation.

3-3.4.2.3 A "static comb" is a metal bar equipped with a series of needle points. Another variation is a metal wire surrounded with metallic tinsel.

3-3.4.2.4 If a grounded "static comb" is brought close to an insulated charged body (or a charged insulating surface), ionization of the air at the points will provide enough conductivity to make the charge speedily leak away or be "neutralized." This principle is sometimes employed to remove the charge from power belts (*see Section 7-1*), fabrics (*see Section 7-2*), and paper (*see Section 7-3*). (*See Figure 6.*)

3-3.4.3 Electrical Neutralizer.

3-3.4.3.1 The electrical neutralizer is a line-powered high voltage device which is an effective means for removing static charges from materials like cotton, wool, silk, or paper in process, manufacturing, or printing. It produces a conducting ionized atmosphere in the vicinity of the charged surfaces. The charges thereby leak away to some adjacent grounded conducting body.

3-3.4.3.2 Electrical neutralizers should not be used where flammable vapors, gases, or dust may be present unless approved specifically for such locations.

3-3.4.4 Radioactive Neutralizer.

3-3.4.4.1 Another method for dissipating static electricity involves the ionization of air by radioactive material. Such installations require no redesign of existing equipment. The fabrication and distribution of radioactive neutralizers are licensed by the US Nuclear Regulatory Commission (or Agreement State Licensing Agency) which is responsible for the health and safety of the general population.

3-3.4.4.2 Radioactive substances are not of themselves a potential ignition source; hence, the location of such sources for purposes of static dissipation need not be restricted on the basis of possible flammability of the surrounding atmosphere. However, if the radiation source is some sort of line-powered device, the location of the equipment must be restricted in the same manner as for any other electrical device, in accordance with NFPA 70, *National Electrical Code®*.

3-3.4.5 Open Flame. Ionization of the air can also be obtained by an open flame (*see 7-3.4.6*).

* 1pS/m = $1 \times 10^{-12} \simeq {}^{-1}\ m^{-1}$