BRITISH STANDARD

BS 5958-2:
1991

Code of practice for

Control of undesirable static electricity —

Part 2: Recommendations for particular industrial situations

Committees responsible for this British Standard

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British Textile Technology Group
Chief and Assistant Chief Fire Officers' Association
ERA Technology Ltd.
Engineering Equipment and Materials Users' Association
General Council of British Shipping
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Contents

Foreword

This Part of BS 5958 was prepared under the direction of the General Electrotechnical Standards Policy Committee. It replaces BS 5958-2:1983 which is withdrawn.

This edition introduces technical changes to bring the standard up-to-date but it does not reflect a full review of the standard, which will be undertaken in due course.

Static electricity occurs commonly in industry and in daily life, and can be a source of danger as well as discomfort or inconvenience. The main hazard is that of explosions and fires initiated by electrostatic discharges, but shocks to personnel can also, on occasion, cause accidents. In addition, static electricity introduces operational problems during manufacturing and handling processes, e.g. by causing articles to adhere to each other or to attract dust. It is generated in many operations, including the flow of liquids or powders, the production of sprays and the contact and separation of solids. It therefore gives rise to problems in a wide range of industries, e.g. chemicals, pharmaceuticals, petroleum and textiles.

The purpose of this Part of BS 5958 is to provide recommendations for the control of static electricity. In some cases static electricity is an integral part of a process, e.g. paint spraying, but more often it is an unwelcome side effect and it is with the latter that this Part of BS 5958 is concerned.

It is very seldom that an electrostatic hazard occurs in isolation. Precautions against static electricity should therefore be consistent with those taken to avoid other hazards that may be present, such as ignitions due to other causes, and toxicity. It is important that all sources of risk in a system of work are considered and that a balanced basis of safety covering all risks be considered. In particular, care should be exercised in the provision of earthing systems where they may interfere with other protective systems, e.g. cathodic protection or intrinsically safe electrical equipment.

Although lightning is a form of static electricity, it is not intended that this Part of BS 5958 be used to obtain guidance on the protection of structures against lightning. For this purpose, reference should be made to BS 6651.

BS 5958 is in two Parts. BS 5958-1 provides basic information on the generation of undesirable static electricity in solids, liquids and gases, and also on persons, and describes how the charges produced give rise to discharges which may cause ignitions or electric shocks. It gives the methods available for minimizing such generation and for safely dissipating the charges produced. It also deals with the principles of earthing and bonding as applied to avoid static electricity hazards. An appendix gives guidance on the means of measuring or estimating the parameters that need to be taken into account when deciding upon the action to be taken to control static electricity.

This Part of BS 5958 provides simple recommendations for controlling static electricity in a variety of specific operations, the justification for which should be sought in BS 5958-1. Static phenomena are encountered so widely that it is not possible to cover all cases. This edition of BS 5958 includes new clauses on pneumatic conveying systems, flexible intermediate bulk containers, vacuum filters, flakers and centrifuge operations. If adequate guidance is not found in this Part of BS 5958, BS 5958-1 should be consulted. If there is still doubt, expert advice should be sought; research on the subject continues and new information is still coming to light.

This Part of BS 5958 does not provide recommendations for the control of static electricity in the transport, handling, storage or testing of electrostatic sensitive electronic devices (ESD) or circuits. Reference should be made to BS 5783:1987 for this purpose.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 34, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

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1 Scope

This Part of BS 5958 deals with static electricity problems which are encountered in particular situations during the handling of different types of materials including liquids, powders, gases, sprays, explosives and electro-explosive devices. In each case, the source and nature of the electrostatic hazards and/or nuisances are identified and specific recommendations are then given for dealing with them. The static electricity problems that can occur with personnel and their clothing are also described and the precautions are given for avoiding these problems.

NOTE The titles of the publications referred to in this standard are listed on the inside back cover.

2 Definitions

For the purposes of this Part of BS 5958, the definitions given in BS 5958-1 apply.

3 Fixed metal tanks for the storage of liquids

3.1 General

Static electricity hazards can arise in various operations connected with fixed storage tanks for liquids, including filling, gauging and sampling. Charge on the liquid may be generated within the tank, due, for example, to splashing or free fall, and/or in the pipeline system feeding the tank. Charging may also be associated with personnel undertaking tasks on the tank, such as gauging or sampling, and with cleaning operations.

An ignition hazard is created when charge is retained in the liquid, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist or foam. To avoid these hazards the recommendations given in **3.2** to **3.8** inclusive should be followed.

3.2 Earthing

3.2.1 The tank and its associated pipework and fittings should all be in good electrical contact with each other and with earth, so that the resistance to earth is at all points less than 10 Ω. Electrical continuity checks should be made before the equipment is brought into use, and subsequently where maintenance or modification could affect electrical continuity (see clause **13** of BS 5958-1:1991).

3.2.2 New tanks or tanks that have been out of service for repairs should be inspected prior to the initial fill for any potential floating objects, such as cans, that could form insulated conductors. Such objects should be removed.

3.2.3 It should be ensured that personnel working on the tanks do not present an ignition risk (see **31.3.1**).

3.3 Tank filling

3.3.1 Splash filling into a tank where a flammable atmosphere may exist should be avoided, in order to prevent the formation of a charged mist. This can be achieved either by bottom entry or by the use of a fill pipe reaching to the bottom of the tank without actually touching it.

3.3.2 For liquids with conductivity up to and including 50 pS/m the inlet should be designed to minimize turbulence and the agitation of any heavier immiscible liquid or sediment on the tank bottom.

3.3.3 Entrained air or other gas should be avoided in liquids with conductivities up to and including 50 pS/m if there is any possibility of immiscible liquid or sediment on the tank bottom.

3.3.4 For liquids with conductivity up to and including 50 pS/m the linear flow velocity in the pipe entering the tank should not exceed 1 m/s until the inlet has been covered and should be maintained at 1 m/s if a second immiscible phase is present; an example is water suspended in oil. A precise value for the safe maximum linear velocity in the absence of a second phase in large tanks has not been established. However, experience indicates that the limitations on flow rates imposed by the present designs of pipeline systems have been adequate to maintain safe operations. There is no evidence that flow velocities up to and including 7 m/s are hazardous. For storage tanks of the order of size of road/rail tanks the safe maximum linear velocity should be calculated by the procedure given in **7.3.3**.

3.3.5 For liquids with conductivity greater than 50 pS/m, the recommendations of **3.3.2**, **3.3.3** and **3.3.4** can be disregarded. An antistatic additive may be used to raise the conductivity of a low conductivity liquid above 50 pS/m, provided that it is compatible with the intended use of the liquid.

3.4 Filters

Fine particle filters installed in the pipeline system upstream of the tank can produce a significant amount of charge. It is recommended that the methods for dealing with the charge given in clause **16** be followed.

3.5 Gauging and sampling

The introduction into a tank of equipment for gauging and sampling may produce additional static electricity hazards. It is recommended that the procedures given in clause **6** be followed.

3.6 Tank cleaning

Tank cleaning operations may give rise to static electricity hazards. It is recommended that the procedures given in clause **14** be followed.

3.7 Floating roof tanks

When a liquid with conductivity up to and including 50 pS/m is pumped into a metal tank with a floating roof, precautions for earthing (see **3.2**), filling (see **3.3**), fine particle filters (see clause **16**) and gauging and sampling (see clause **6**) are applicable until the floating roof is buoyant. Thereafter, only the earthing, gauging and sampling precautions are necessary.

3.8 Floating blankets

3.8.1 Floating blankets in tanks used for storing liquids with conductivities up to and including 50 pS/m should be fabricated from metal, from non-conducting material entirely coated with antistatic material or from antistatic material. The blanket should be adequately earthed. Tanks with such blankets should be treated as if the blanket were a floating roof (see **3.7**).

3.8.2 Conducting floating spheres or balls intended to suppress evaporation loss should not be used with liquids having a conductivity up to and including 50 pS/m. Non-conducting spheres should not be used with liquid at any conductivity level if there is any possibility of the presence of a flammable atmosphere.

4 Fixed non-metallic tanks for the storage of liquids, sited partially or wholly above ground

4.1 General

The charging processes and static electricity hazards associated with fixed metal storage tanks (see **3.1**) are also encountered with non-metallic tanks. If tanks are made from high resistivity materials charge may also be generated and retained on the material itself by the liquid handling operations or by internal or external rubbing. This presents additional hazards, especially if there are insulated metal components, such as bolts, flanges and valves, or if the surface is contaminated with isolated areas of conductive material, such as water or grease.

As in metal tanks, an ignition hazard is created when charge is retained on the liquid, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist or foam. The risk of an internal discharge from the liquid surface, for example during gauging, is enhanced with tanks of high resistivity material because the dissipation of charge from the liquid is impeded and because the distribution of the field within the tank results in a greater field strength at the surface than in a metal tank. In addition, there is increased risk outside the tank if it is situated in a hazardous area, owing to the possibility of charge on the tank itself, even when a non-flammable liquid is being handled.

Recommendations for avoiding electrostatic hazards are given in **4.2**, **4.3** and **4.4**. They should be considered in conjunction with measures to deal with risks from other sources, e.g. the general fire risk associated with the storage of large quantities of flammable liquids in non-metallic containers and mechanical strength limitations on larger containers.

4.2 Tanks made of high resistivity materials

4.2.1 The use of large storage tanks completely fabricated from high resistivity materials, such as synthetic polymers and glass reinforced plastics having a volume resistivity greater than $10^8\ \Omega\cdot m$ and/or a surface resistivity greater than $10^{10}\ \Omega$ is not recommended. The exception is when it can be shown that the liquid handling operations do not produce dangerous levels of static electricity and that no charge generating processes exist outside the tank.

Specialist advice should be sought before installing tanks of high resistivity materials.

4.2.2 If such a tank is installed, rubbing of its surface, e.g. in cleaning operations, should be avoided when a flammable atmosphere may be present.

4.3 Tanks made from conductive non-metallic materials

Storage tanks made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) present no electrostatic hazards additional to those existing for metal tanks, provided that they are earthed and the precautions for metal tanks are fully implemented (see clause **3**). Such tanks should be permanently marked as “Antistatic material” or “Conducting material”.

4.4 High resistivity tanks incorporating conducting elements

4.4.1 Electrostatic hazards in the use of tanks made from high resistivity materials can be minimized by the incorporation, on or just below the surface throughout the material, of a permanent robust conducting element, for example a metal grid, connected to earth (see **10.3.6** of BS 5958-1:1991). Such tanks are supplied by specialist manufacturers who will usually advise on their suitability for specific applications.

4.4.2 The recommendations for metal storage tanks in **3.2** to **3.6** inclusive apply also to tanks incorporating conducting elements. To facilitate the earthing of personnel walking on a tank, a conducting walkway should be provided.

4.4.3 The liquid in the tank should be in direct contact with earth. If the conducting element covers the inner surface of the tank this provides the necessary earth connection. If the conducting element is not in contact with the liquid an earthed metal plate should be provided in the base of the tank with an area given by:

$A = 0.04\, v$

where

A is the area of the metal plate (in m^2);

v is the volume of the tank (in m^3).

Experiments have demonstrated that this relationship is satisfactory for tanks with capacities up to and including 5 m^3 provided that the liquid is at no point more than 2 m from the earthed plate. For larger tanks, specialist advice should be sought but there appears to be no reason why the same relationship should not be valid.

4.4.4 Although rubbing may generate sufficient charge on the tank surface to give an incendive discharge, the probability that this will occur in normal practice is low. Nevertheless vigorous rubbing of the surface, e.g. in cleaning operations, should be avoided when a flammable atmosphere may be present.

5 Fixed non-metallic tanks for the storage of liquids, sited completely below ground

5.1 General

Tanks fabricated from non-metallic materials which are partly or completely above ground are considered in clause **4**. The major differences when the tank is buried are in respect of tanks of high resistivity materials having a volume resistivity greater than $10^8\ \Omega$ m and/or a surface resistivity greater than $10^{10}\ \Omega$. When buried, such tanks cannot be charged by external movement or rubbing. Also, the proximity of the earth all around the tank increases the electrical capacitance of its contents and therefore increases the amount of charge required to produce the break-down field strength inside the tank. The liquid may however be insulated from earth and the possibility of an incendive discharge from its surface cannot be wholly excluded. Precautions against this source of ignition need to be taken in the presence of a flammable atmosphere. If the liquid is conducting (conductivity greater than 50 pS/m) the charge on it will dissipate safely to earth provided the liquid is in contact with an earthed surface; suitable earthed contact can be, e.g. a metal run-off valve or metal dip leg on or near the base of the tank. If no such contact is present an earthed metal plate, a few square centimetres in area, should be fixed to the base of the tank in contact with the liquid. Additional contacts with earth may be needed for low conductivity liquids depending on the size of the container and the conductivity of the liquid. In such circumstances expert advice should be sought.

Recommendations for avoiding electrostatic hazards are given in **5.2** and **5.3**. They should be considered in conjunction with measures to deal with risks from other sources, e.g. the general fire risk associated with the storage of large quantities of flammable liquids in non-metallic containers and mechanical strength limitations on larger containers.

5.2 Tanks made of high resistivity materials

5.2.1 Large storage tanks made entirely of high resistivity materials and sited below ground should be individually designed for each specific application. Such tanks are normally supplied by specialist manufacturers and the necessary risk assessment is usually carried out in consultation with the supplier. The degree of safety derived from the presence of earth around the tank depends on the maximum charge that can be produced and on the thickness of the tank wall. To confirm the safety of the installation, it is necessary to show that the maximum charge produced in filling the tank does not produce a field strength at which a discharge can occur.

5.2.2 The whole of the outer surface of the tank, including the roof, should be in contact with the earth.

5.2.3 The liquid in the tank should be in direct contact with earth by means of an earthed metal plate in the base of the tank with an area given by:

$$A = 0.04\ v$$

where

A is the area of the metal place (in m^2);

v is the volume of the tank (in m^3).

This relationship is satisfactory for tanks with capacities up to 5 m^3, provided that the liquid is at no point more than 2 m from the earthed plate.

For larger tanks specialist advice should be sought.

5.2.4 Provided that the design of the tank is in accordance with **5.2.1**, **5.2.2** and **5.2.3**, the recommendations for metal storage tanks in **3.2** to **3.6** inclusive apply, except that the tank itself cannot be earthed.

5.3 Tanks made of conductive non-metallic materials

Buried storage tanks made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) present no electrostatic hazards additional to those existing for metal tanks, provided that they are earthed and the precautions for metal tanks are fully implemented (see clause **3**). Such tanks should be permanently marked as "Antistatic material" or "Conducting material".

6 Gauging and sampling of tanks

6.1 General

There are static electricity hazards in the gauging and sampling of storage tanks and tanker cargo tanks. Electrostatic charge may be present on the liquid in the tank, either because it is being pumped or because it is being subjected to agitation, e.g. in a mixing operation (see clause **10**). Charge may also be generated on the gauging or sampling equipment or on the personnel using the equipment.

An ignition hazard is created if such charges are generated in the presence of a flammable vapour/air mixture, mist or foam. An incendive discharge may occur between the liquid and the gauging or sampling equipment as they approach each other, or between the equipment, or the personnel handling it, and the rim of the manhole or dip hatch through which the operation is taking place. To avoid these hazards the recommendations in **6.2**, **6.3** and **6.4** should be followed.

6.2 Materials of construction, earthing and bonding

6.2.1 All metallic parts of gauging or sampling equipment should be connected to the tank, or if the tank is constructed of high resistivity material, directly to earth. For this purpose the connections may be metallic, giving a resistance to earth at all points less than 10 Ω, or they may be of higher resistivity material, provided that the resistance to earth is low enough to relax any charge on the metal components (see clause **13** of BS 5958-1:1991). Thus the tape or cord may be of metal or of a natural fibre such as sisal or manila. A metal chain should not be used.

6.2.2 A high resistivity (synthetic polymer) cord or dip stick is not acceptable, unless it can be shown that a hazardous level of charge will not be generated. However, it is considered that small sampling containers of high resistivity materials are on balance safer than similar metal containers (see **12.5**).

6.2.3 Gauging and sampling equipment may be constructed entirely of natural or other materials, such as wood or natural fibres, the resistivities of which are such that they are unlikely to accumulate electrostatic charges or to give rise to discharges. Such equipment should be earthed.

6.2.4 Ensure that personnel engaged in gauging or sampling operations do not present an ignition risk (see **31.3.1**). The problems this may present on board ships are mentioned in **13.2.4**.

6.3 Precautions with systems containing conductive components

6.3.1 Gauging and sampling should not be carried out while any charge generating operation is going on in a tank containing a flammable vapour/air mixture, mist or foam. These operations include the pumping into a tank of liquids with conductivities up to and including 50 pS/m and many cleaning procedures.

6.3.2 If a liquid with conductivity up to and including 50 pS/m and containing a separate water phase has been pumped into a tank or has been involved in a mixing operation in a tank, the tank should not be gauged or sampled until at least 30 min has elapsed after completion of the operation, unless it can be shown that charge relaxation is complete in a shorter period.

6.3.3 If a liquid with conductivity up to and including 50 pS/m but without a separate water phase has been pumped into a tank, the tank should not be gauged or sampled immediately after the cessation of the operation. A period of, say, 10 min should be allowed to elapse before gauging or sampling.

6.3.4 After a mixing operation involving a liquid with conductivity up to and including 50 pS/m, gauging or sampling should not take place while there is any settling of the components of the mixture.

6.3.5 If the liquid, or liquids, being pumped or mixed all have conductivities greater than 50 pS/m, gauging and sampling can take place at any time.

6.3.6 After a cleaning operation, gauging and sampling should be delayed until any charged mist generated has settled. This may take several hours.

6.3.7 The recommendations in **6.3.1** to **6.3.6** inclusive need not be followed with fixed gauging equipment, or if the gauging takes place in a fixed, earthed dip pipe extending to the bottom of the tank.

6.4 Precautions in adverse weather conditions

Gauging and sampling of flammable liquids should not be undertaken during thunderstorms, snowstorms or hailstorms or where there is reason to believe that disturbed atmospheric electrical conditions could occur.

7 Metal road/rail tanks for liquids

7.1 General

Various liquid handling operations associated with road/rail vehicles can give rise to ignition risks due to static electricity; examples are loading, gauging and sampling. Charge on the liquid may be generated within the vehicle tank and/or in the pipeline system feeding the tank. Charging may also be associated with personnel undertaking tasks on the tank, such as gauging or sampling, or with cleaning operations. Charging arising in the equipment when transferring liquid to or from the vehicle is considered in clause **9**.

An ignition hazard is created when charge is retained in the liquid, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist or foam. The flammable atmosphere in the tank may be due to the liquid currently being handled or to liquid carried in a previous load (switch loading operations). To avoid these hazards the recommendations given in **7.2** to **7.6** inclusive should be followed.

7.2 Earthing

7.2.1 The tank and its associated metal pipework and fittings should all be in good electrical contact with each other and with the main metal structure of the vehicle. During loading, the vehicle should be earthed directly or connected to the earthed loading gantry so that the resistance to earth is at all points less than 10 Ω. Electrical continuity checks should be made on the vehicle before it is brought into use, and subsequently where maintenance or modification could affect electrical continuity (see clause **13** of BS 5958-1:1991).

7.2.2 The tanks or compartments of new vehicles or of vehicles that have been out of service for repairs should be inspected, prior to the initial loading, for any potential floating objects, such as cans, which could form insulated conductors. Such objects should be removed.

7.2.3 It should be ensured that personnel working on the vehicles do not present an ignition risk (see **31.3.1**).

7.3 Loading

7.3.1 Splash filling into a tank where a flammable atmosphere may exist should be avoided. This can be achieved either by bottom entry with a deflector or, if top loading is used, by the use of a fill pipe reaching to the bottom of the tank. Where filling is carried out through an open manhole or filling hatch not provided with an internal fill pipe, the hose or loading arm nozzle should be inserted slowly to the bottom of the tank.

7.3.2 Entrained air or other gas should be avoided in liquids with conductivities up to and including 50 pS/m if there is any possibility of immiscible liquid or sediment on the tank bottom.

7.3.3 For liquids with conductivities up to and including 50 pS/m, the linear flow velocity in a pipe used for top loading should not exceed 1 m/s if a second immiscible phase is present; an example is water suspended in oil.

In the absence of a second phase, charge generation increases with increasing flow velocity. The maximum linear flow velocity for top loading may be expressed in terms of a velocity, u (in m/s), of the liquid flowing in a pipe section. The velocity u is the lower of those given by the expressions:

$$u \leq 7$$

$$ud \leq N$$

where

d is the diameter of the pipe section (in m);

N is a constant with a value of 0.5 m^2/s for liquid conductivities above 5 pS/m. The value of N which should be applied for liquid conductivities up to and including 5 pS/m is a matter for debate; values of 0.38 m^2/s and 0.5 m^2/s have been accepted, there being only a very small degree of risk with either level. In the United Kingdom 0.5 m^2/s is used.

These expressions should be applied to the smallest diameter pipe section upstream of the tank or compartment being filled, except when the length of the section is less than 10 m and it is only one pipe size smaller than the next larger diameter pipe (i.e. its diameter is not less than 67 % of that of the larger). If both these conditions are satisfied the velocity u should be derived from the next larger size pipe.

If the length of the tank or compartment into which the single phase liquid is flowing is less than 2 m the velocity u in the pipe section to which it applies determines the maximum flow rate in the system. if the tank or compartment length, L, is between 2 m and 4.5 m the limiting velocity, u, may be increased by a factor $\sqrt{L/2}$, while if the length L is greater than 4.5 m the limiting velocity should be $1.5u$, provided that the maximum of 7 m/s is not exceeded.

Bottom loading generates higher potentials at the liquid surface than top loading because of the absence of the earthed fill pipe. Therefore unless an equivalent earthed fitting, such as a dip tube, standpipe or baffle plate, is mounted centrally in the tank, reaching from top to bottom, it is recommended that the flow rates for bottom loading should be 25 % below those for top loading, calculated as above.

The flow rate established by the above procedure may be exceeded for a particular system and liquids if many years of experience with that system and liquids has demonstrated that it is safe to do so.

7.3.4 For liquids with conductivity greater than 50 pS/m the recommendations of **7.3.2** and **7.3.3** can be disregarded. An antistatic additive may be used to raise the conductivity of a low conductivity liquid above 50 pS/m, provided that it is compatible with the intended use of the liquid.

7.4 Filters

Fine particle filters installed in the pipeline system upstream of the vehicle can produce a significant amount of charge. It is recommended that the methods for dealing with the charge given in clause **16** be followed.

7.5 Gauging and sampling

The introduction of equipment into a tank for gauging and sampling may produce additional static electricity hazards. It is recommended that the procedures given in clause **6** be followed.

7.6 Tank cleaning with high pressure water jets or steam

These cleaning operations may give rise to static electricity hazards. It is recommended that the procedures given in clause **14** be followed.

8 Non-metallic road/rail tanks for liquids

8.1 General

The charging processes and static electricity hazards associated with metal road/rail tanks (see **7.1**) are also encountered with non-metallic road/rail tanks. If tanks are made from high resistivity materials charge may also be generated and retained on the material itself by liquid handling operations or by internal or external rubbing. This presents additional hazards especially if there are insulated metal components, such as bolts, flanges or valves, or if the surface is contaminated with isolated areas of conductive material, such as water or grease.

As with metal tanks an ignition hazard is created when charge is retained on the liquid, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist or foam. The risk of an internal discharge from the liquid surface, e.g. during dipping, is enhanced with high resistivity tanks both because the dissipation of charge from the liquid is impeded and because there is a greater field strength at the liquid surface. There is increased risk external to the tank if it is situated in a hazardous area, or is moved into such an area, owing to the possibility of charge on the tank itself, even when a non-flammable liquid is being handled. Also personnel working on the tank may be insulated from earth.

Recommendations for avoiding electrostatic hazards are given in **8.2**, **8.3** and **8.4**. They should be considered in conjunction with measures to deal with risks from other sources, e.g. the general fire risk associated with the carriage of large quantities of flammable liquids in non-metallic containers and mechanical strength limitations on larger containers. In applying these recommendations it will be necessary to bear in mind relevant national and international transport regulations.

8.2 Tanks made of high resistivity materials

8.2.1 The carriage of flammable liquids is not recommended in road/rail tanks completely fabricated from high resistivity materials, such as synthetic polymers and glass reinforced plastics having a volume resistivity greater than $10^8\ \Omega\cdot m$ and/or a surface resistivity greater than $10^{10}\ \Omega$.

8.2.2 Such tanks can be used for the carriage of non-flammable liquids, provided that the vehicle is not in, or does not move into, an area where there may be a flammable atmosphere.

8.3 Tanks made from conductive non-metallic materials

Road/rail tanks made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) present no electrostatic hazards additional to those existing for metal tanks, provided that they are earthed and the precautions for metal tanks are fully implemented (see clause **7**). Such tanks should be permanently marked as "Antistatic material" or "Conducting material".

8.4 High resistivity tanks incorporating conducting elements

8.4.1 Electrostatic hazards in the use of tanks made from high resistivity materials can be minimized by the incorporation, on or just below the surface throughout the material, of a permanent robust conducting element, e.g. a metal grid, connected to earth (see **10.3.6** of BS 5958-1:1991). It is essential to maintain the integrity of the earthing. This may be achieved by incorporating an earthing check as part of the planned regular maintenance procedure. Such tanks are supplied by specialist manufacturers who will usually advise on their suitability for specific applications.

8.4.2 The recommendations for metal road/rail tanks in **7.2** to **7.6** inclusive apply also to tanks incorporating conducting elements. To facilitate the earthing of personnel working on a tank a conducting walkway should be provided.

8.4.3 The liquid in the tank should be in direct contact with earth. If the conducting element is not in contact with the liquid an earthed metal plate should be provided in the base of the tank, as recommended in **4.4.3**.

8.4.4 Although rubbing may generate sufficient charge on the tank surface to give an incendive discharge, the probability that this will occur in normal practice is low. Nevertheless, vigorous rubbing of the surface, e.g. in cleaning operations, should be avoided when a flammable atmosphere may be present.

9 Installation for the transfer of liquids to and from road/rail vehicles

9.1 General

Transfers between installations and road/rail vehicles are frequently carried out by means of fixed standpipes and/or flexible hoses, and the operations can give rise to static electricity hazards. Additional ignition risks may be encountered when hose connections are made or broken due to sparking from stray currents flowing in the hose string. Where these can occur reference should be made to appropriate industry codes of practice[1].

Three types of hose are in common use in the petroleum industry. Constructional details and electrical specifications are given in BS 1435, BS 3158, BS 4089, BS 5173-104.1 and BS 5173-104.2 and BS 5842. In summary the three types of hose are as follows.

[1] e.g. Institute of Petroleum. Model Code of Safe Practice, Electrical. Part 1, 1965.

a) *Conductive hose.* This is made of material of high electrical resistivity with an embedded reinforcing wire and/or enshrouding wire braid or armouring incorporated during manufacture. These conducting components are bonded to the metal fittings permanently attached to the ends of the hose, so that when several lengths are coupled together there is a continous low resistance electrical path along the entire run of the hose. It is essential that the integrity of earthing of all components be maintained at all times.

b) *Semi-conductive hose.* Part of the material of which this hose is made, usually its outer layer, has a conductivity high enough to disperse static electricity but low enough to restrict stray currents to safe limits, and this layer is in contact with the end fittings. The hose may have a metal reinforcing wire and/or enshrouding braid or armouring, but this is not in contact with the end fittings.

c) *Non-conductive hose.* This is made of material of high electrical resistivity without incorporated conducting wire or braid, and is incapable of dispersing static electricity.

The recommendations given in **9.2** to **9.5** are intended to guard against external electrostatic sparks when transferring flammable liquids, including loading into a road or rail tank with a flammable atmosphere due to a previous load (switch loading operations). Charging of the liquid, giving rise to hazards within such tanks, is dealt with in clauses **7** and **8**. If at the end of the operation the pipe line is to be drained off then the recommendations in c) of **19.8.3** should be followed.

9.2 Earthing: the installation

9.2.1 All metal parts of the installation should be in good electrical contact with each other and with earth, so that the resistance to earth is at all points less than 10 Ω. Electrical continuity checks should be made before the equipment is brought into use, and subsequently where maintenance or modification could affect continuity (see clause **13** of BS 5958-1:1991). Swivel joints in standpipes and metal loading arms should be electrically continuous.

9.2.2 Whenever there is a possibility of a flammable atmosphere within or outside the vehicle tank, conductive or semi-conductive hose should be used. Non-conductive hose may itself become charged and if two or more such hoses are joined by metallic flanges these flanges may be capable of producing incendive sparks unless each is provided with a bonding cable to earth.

9.2.3 The resistance between the flanges of each length of conductive or semi-conductive hose should be checked with sufficient frequency to ensure that its conductive properties are being maintained.

9.2.4 It should be ensured that personnel working on the installation do not present an ignition risk (see **31.3.1**).

9.3 Earthing: road tankers

9.3.1 Before the loading of such a vehicle is commenced, before any pipe connections are made and before any man lids are opened, its tank should be bonded to the appropriate earth point and the bond should remain in position throughout the operation. Automatic monitors are available to check the effectiveness of the earthing system.

9.3.2 In general, when a delivery is made from a road tanker to a storage tank, e.g. at a petroleum spirit filling station, the hose couplings to both the vehicle and the receiving tank will ensure adequate electrical continuity and earthing provided that this continuity is regularly monitored.

9.3.3 Liquefied petroleum gas road tankers, however, should be earthed during both loading and discharging by being bonded to a suitable earth point. The bond should remain in position until the operation has been completed.

9.4 Earthing: rail tankers

9.4.1 Both rails of railway tracks where loading or unloading takes place should be bonded permanently to each other and to the earthed gantry or pipeline. The railcar itself is earthed by contact between its wheels and the rails. A separate flexible bonding cable between the tank and the pipeline is therefore not required unless doubt exists concerning the electrical continuity between the tank and the running gear. If a bonding cable is used, the recommendations given in **9.3.3** should be followed. If a railcar detector system requiring a resistance between the rails is in use, the value of the resistance should not be of such a magnitude as to prevent the safe dissipation of charge.

9.4.2 If an insulating flange is installed in a loading line to prevent the passage of stray currents, the filling nozzle should be bonded to the railcar by a flexible cable to ensure that the hose assembly downstream of the insulating flange is earthed. This connection should be made before the operation commences and should remain in place until it is complete.

9.5 Fuelling of motor vehicles

External bonding of the vehicle to earth is not needed provided the fuelling installation complies with the requirements of the Health and Safety Booklet HS (G) 41[2] and BS 7117.

10 Liquid/liquid and solid/liquid blending and mixing

10.1 General

The mixing together of liquids or of liquids and solid particulate matter can give rise to static electricity ignition risks. Charge may be generated when the mechanical energy of the mixing process is expended in systems containing one or more low conductivity liquids. It is then retained on the continuous liquid phase, on suspended liquid or solid particulate matter, or on any insulated metallic object. If a flammable vapour/air mixture, mist or foam is present there is an ignition hazard and to avoid this the recommendations in **10.2** to **10.5** inclusive should be followed.

10.2 Earthing

10.2.1 All metallic parts of the equipment should be connected together and earthed, so that the resistance to earth at all points is less than 10 Ω. If steam is used for inerting, the nozzle of the steam hose should be earthed by an independent bonding wire, rather than relying on the conductivity of the hose itself.

10.2.2 If a blending vessel has an internal insulating lining, e.g. glass, ceramic or plastic, relaxation of charge on the contents should be promoted by the provision of internal earthing, e.g. the mounting of earthed metal strips or plates on or near the bottom of the vessel. This precaution may not be necessary if the lining is thin enough to permit charge dissipation or to avoid a dangerous surface potential (see **10.2.4** of BS 5958-1:1991).

10.2.3 It should be ensured that personnel working in the vicinity of a blending vessel do not present an ignition risk (see **31.3.1**).

10.3 In-line blending

10.3.1 In this method, mixing takes place within a pipe into which the various constituents are pumped at prescribed rates. There is therefore no vapour space in which a flammable mixture can occur, and hence no ignition risk where the mixing is taking place.

10.3.2 The recommendations in clauses **3**, **4**, **5**, **7**, **8** and **13** should be adopted, as appropriate, to avoid ignition hazards in the receiving tank arising from charge generated in the mixing operation or in subsequent flow to the tank.

10.4 Blending in vessels or tanks

10.4.1 The mixing of liquids to produce a single phase of low conductivity is not considered to be unduly dangerous, provided that the normal precautions appropriate to liquid handling operations are taken (see clause **3**).

10.4.2 If the resultant mixture contains dispersed liquid or solid particulate matter it is advisable to minimize the generation of static electricity by increasing the conductivities of low conductivity liquids in the system by means of antistatic additives, provided that they are compatible with the intended use of the mixture.

10.4.3 If the phases in a mixture are all liquids it is usually sufficient to raise the conductivity of the continuous phase above 50 pS/m.

10.4.4 If one or more of the dispersed phases is a solid the conductivity of the continuous phase may need to be much greater than 50 pS/m, and it may in addition be necessary to restrict the power input of the stirrer. As an example, in one operation a conductivity of 1 000 pS/m was required with a power input limited to 0.37 kW/m^3 of the suspension[3]. Each case should be considered on its merits, taking expert advice if necessary.

10.4.5 The gauging and sampling of wholly liquid systems should be carried out in accordance with the recommendations of clause **6**. If there is a dispersed solid phase the precautions will depend upon the specific mixture and no general advice can be given.

10.4.6 As an alternative to raising liquid conductivities, the vapour space in the blending vessel can be inerted. Restriction of the power output is then not required. The use of inerting agents should be in accordance with the recommendations of clause **25**.

10.5 Jet mixing

10.5.1 The jet mixing of liquids with conductivities greater than 50 pS/m is not hazardous provided that the jet does not break the liquid surface and that the liquid and all metal parts of the equipment are earthed.

[2] Health and Safety Booklet HS (G)41. *Petrol filling station, construction and operation.* Published by the Health and Safety Executive and available from HMSO.

[3] Vos, B.,Douwes, C., Ramackers, L. and Van de Weerd, J.M. Electrostatic charging of suspensions during agitation. In: Buschman, C.H. (ed) *Proceedings of the first international symposium on loss prevention and safety promotion in the process industries* arranged by the Royal Institute of Engineers in the Netherlands and the Royal Netherlands Chemical Society). Published by Elsevier. Paper No. 34, 381-384.

10.5.2 If a liquid has a low conductivity, an antistatic additive may be used to raise the conductivity above 50 pS/m, provided that it is compatible with the intended use of the mixture.

10.5.3 As an alternative to raising liquid conductivities, the vapour space in the tank can be inerted. The use of inerting agents should be in accordance with the recommendations of clause **25**.

10.5.4 If a liquid has a low conductivity and neither the use of an antistatic additive nor inerting is possible, the hazard will depend upon circumstances and expert advice may be needed to control the surface potential of the liquid in the tank. Factors to be considered include:

a) the proximity of internal projections in the tank to the liquid surface; an excessive field strength could occur in the vapour space due to charges in the incoming liquid being carried up to the surface by the jet;

b) the presence of a separate phase (usually water) at the bottom of the tank;

c) whether the tank is being filled whilst the mixing is taking place;

d) the time that has elapsed since the completion of a filling operation.

10.5.5 Gauging and sampling should be carried out in accordance with the recommendations of clause **6**.

11 Small metal containers for liquids

11.1 General

This clause is concerned with metal containers that are easily portable or movable, rather than with such equipment as fixed storage tanks or road/rail vehicle tanks. Charge may be generated during the filling or emptying of such containers or during cleaning operations and an ignition hazard is created when charge is retained in the liquid, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist of foam. The flammable atmosphere may be due to the liquid currently being handled or to the previous contents of the container or it may be the result of conducting the operation in a hazardous area.

To avoid these hazards the recommendations given in **11.2** to **11.5** should be followed. In applying these recommendations it will be necessary to bear in mind relevant national and international transport regulations.

11.2 Earthing

11.2.1 During both filling and emptying, the container and all metallic parts of the system, such as funnels and nozzels, should be bonded together and/or earthed (see **13.3.1** of BS 5958-1:1991). Care should be taken to ensure that a metal funnel is not insulated from the container by a plastics bush. It is preferable to avoid the use of plastics funnels; if they are used, particular care is needed to ensure that they do not lead to the insulation of any metal component.

11.2.2 It should be ensured that personnel engaged in filling, emptying or cleaning operations do not present an ignition risk (see **31.3.1**).

11.3 Filling

11.3.1 For liquids with a conductivity less than 50 pS/m the linear flow velocity in the pipe entering the container should not exceed 1 m/s if a second immiscible phase is present; an example is water suspended in oil. In the absence of a second phase, the limitations on flow rates imposed by present designs of filling stations, coupled with the avoidance of insulated conductors, have been adequate to maintain safe operations in containers up to 200 L.

11.3.2 For liquids with a conductivity greater than 50 pS/m the recommendations of **11.3.1** can be disregarded. An antistatic additive may be used to raise the conductivity of a low conductivity liquid above 50 pS/m, provided that it is compatible with the intended use of the liquid.

11.3.3 Particular care is required in the filling of liquefied petroleum gas containers to ensure that earthing is effective at all times, e.g. as follows.

a) All the metal-work of buildings plant and equipment should be electrically continuous and earthed. It may be advisable to use a common earthing system, within which the resistance to earth should not exceed 10 Ω at any point.

b) Weighing machine platforms should be electrically continuous with the weighing machine bases which should be connected to the earthing system.

c) The conveyor track should be electrically continuous and earthed.

d) If a fan ducting system is used it should be electrically continuous and earthed. At a joint where high resistivity material has been used a flexible bond should be provided between adjacent lengths of metal ducting.

e) Filling hoses should be semi-conductive or of an approved type (see **9.1**).

11.4 Filters

Fine particle filters installed in the filling system upstream of the container can produce a significant amount of charge. This charge should be dealt with by the methods given in clause **16**.

11.5 Cleaning

The container, the cleaning equipment and personnel carrying out the operation should all be earthed if there is any possibility of the presence of a flammable atmosphere within or outside the container.

12 Small non-metallic containers for liquids

12.1 General

This clause is concerned with non-metallic containers that are easily portable or movable, rather than with such equipment as fixed storage tanks or road/rail vehicle tanks. The charging processes and static electricity hazards associated with metal containers are also encountered with non-metallic containers. The great majority of these containers, however, are made from high resistivity materials having a volume resistivity greater than 10^8 Ω·m and/or a surface resistivity greater than 10^{10} Ω and it is then necessary to consider the charge that may be generated and retained on the material itself by liquid handling or by internal or external rubbing. This presents additional hazards, especially if there are insulated conducting components, such as metal closures, or if the surface is contaminated by isolated areas of conductive material such as water or grease.

As with metal containers, an ignition hazard is created when charge is retained on the liquid contents, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist or foam. The risk of an internal discharge from the liquid surface is enhanced with high resistivity containers both because the dissipation of charge from the liquid is impeded and because the field within the container is intensified at the liquid surface. There is increased risk external to the container if it is situated in a hazardous area, or is moved into such an area, owing to the possibility of charge on the container itself, even when a non-flammable liquid is being handled.

Recommendations for avoiding electrostatic hazards are given in **12.2** to **12.6**. In applying these recommendations it will be necessary to bear in mind relevant national and international transport regulations. In the case of high resistivity containers the precautions are considered in terms of the hazardous zones defined in **2.12** of BS 5958-1:1991.

12.2 Containers made of high resistivity materials in non-hazardous areas

If a non-flammable liquid is being handled in an area where there is no possibility of a flammable atmosphere from another source, there is no ignition hazard and precautions against static electricity are not required.

12.3 Containers made of high resistivity materials in Zone 2 areas

12.3.1 The container can be considered to be safe in a Zone 2 area if a non-flammable liquid is being handled and the possibility of a flammable atmosphere from another source during normal operations is unlikely. The precautions in **12.3.2** to **12.3.6** should then be sufficient to avoid an ignition.

12.3.2 All conducting components, particularly metal funnels, should be earthed, metal caps and conductive labels should be avoided. Any adjacent metal objects should be earthed, e.g. metal trolleys with insulating wheels.

12.3.3 During filling operations, the liquid should be in good contact with earth by means of an earthed metal fill pipe reaching to the bottom of the container. During emptying operations the appropriate precautions should also be applied to the receiving vessel.

12.3.4 The liquid flow rate during filling operations should be not greater than that recommended for an equivalent metal container (see **11.3.1**).

12.3.5 Rubbing of the external surface of the container should be avoided, together with any other potential charging process, such as steam impingement.

12.3.6 It should be ensured that personnel in the vicinity of the container do not present an ignition risk (see **31.3.1**).

12.4 Containers made of high resistivity materials in Zone 1 areas

12.4.1 The container can be considered to be in a Zone 1 area if a flammable liquid is being handled, or if a non-flammable liquid is being handled and there is a possibility of the presence of a flammable atmosphere from another source during normal operations.

12.4.2 Containers of high resistivity materials should only be used in Zone 1 areas if it can be shown that the electrostatic ignition risk is acceptable. This requires a balance to be struck between the electrostatic risk and the protection afforded by a high resistivity container in other respects, such as corrosion resistance or advantageous behaviour in flame engulfment conditions; specialist guidance may be needed in reaching a decision. In general, the lower the conductivity of the liquid, the greater is the electrostatic risk. Also, as the volume of the container increases, both the electrostatic ignition risk and the scale of the ensuing fire increase.

12.4.3 When a high conductivity liquid is being handled, the precautions given in **12.3.2** to **12.3.6** are adequate in filling and emptying operations. If it can be established that charging of the container itself can be kept to a low level it is permissible to use container sizes up to the maximum specified in International Regulations for the Transport of Dangerous Goods.

12.4.4 When a low conductivity liquid is being handled and the precautions in **12.3.2** to **12.3.6** are applied, a small electrostatic charge may remain but it is common practice to use high resistivity containers with capacities up to 5 L. Larger containers should be used only after specialist consultation.

12.5 Containers made of high resistivity materials in Zone 0 areas

In areas where a flammable atmosphere is present continuously, or for long periods, the use of high resistivity containers is not in general recommended, irrespective of the size of the container. There are exceptions, e.g. small sampling containers of high resistivity materials for use in storage tanks are considered on balance to be safer than similar metal containers. Expert advice should be sought to assess such cases.

12.6 Containers made of conductive non-metallic materials

Small containers made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) present no electrostatic hazards additional to those existing for metal containers, provided that they are earthed and the precautions for metal containers are fully implemented (see clause **11**). Such containers should be permanently marked as "Antistatic material" or "Conducting material".

13 Ships (tankers) and barges

13.1 General

Various liquid handling operations associated with tankers and barges (both referred to subsequently as "ships") can give rise to ignition risks due to static electricity; examples are loading, gauging and sampling. Charge on the liquid may be generated within a tank and/or in the pipeline system feeding the tank. Charging may also be associated with personnel undertaking tasks on a tank, such as gauging or sampling, or with cleaning operations.

An ignition hazard is created when charge is retained in the liquid, on insulated conductors or on personnel in the presence of a flammable vapour/air mixture, mist or foam. The flammable atmosphere in the tank may be due to the liquid currently being handled or to liquid carried in a previous cargo. To avoid such hazards the recommendations given in **13.2** to **13.6** should be followed.

Certain sizes of tankers carrying crude oil or petroleum products having a flash point less than 60 °C or other liquids having a similar fire hazard have to be provided with an inert gas system[4]. This recommendation does not apply to chemical tankers having a valid Certificate of Fitness for the Carriage of Dangerous Chemicals in Bulk.

13.2 Earthing

13.2.1 Ships of metal construction are inherently earthed because they float in water. All metal fittings, pipework and associated equipment should be earthed to the ship (see clause **13** of BS 5958-1:1991). Electrical continuity checks should be made to establish that all metal parts of equipment such as valves and ullage devices are properly earthed to the ship. These checks should take place before the ship is brought into use, and subsequently where maintenance modification or deterioration could affect continuity.

13.2.2 The ship-shore loading line is normally conducting. It is customary to include in the line an insulating flange or a single length of non-conducting hose to prevent any hazards arising from stray currents due to any potential difference between ship and shore. All metal on the shore side of such a flange or hose length should be electrically continuous to the jetty earthing system and all metal on the seaward side should be electrically continuous to the ship.

A separate bonding cable between ship and shore is not required to avoid static electricity hazards.

[4] The International Maritime Organization. *Inert gas systems for ships carrying petroleum products in bulk.* 1982

13.2.3 Tanks in new ships or tanks that have been out of service for repairs should be inspected, prior to the initial fill, for any potential floating objects, such as cans, which could form insulated conductors. Such objects should be removed.

13.2.4 It should be ensured that personnel working in the vicinity of cargo tanks do not present an ignition risk (see **31.3.1**). This may be difficult on board ship and it is advisable, therefore, to minimize the occurrence of flammable atmospheres, for example by using a closed gauging system and avoiding open hatches. If a flammable mixture is possible, every effort should be made to prevent personnel from becoming charged, e.g. by close attention to the materials used in dip tapes. In many cases the marine environment is probably an alleviating factor.

13.3 Loading

13.3.1 Splash filling into a tank where a flammable atmosphere may exist should be avoided, in order to prevent the formation of a charged mist. This can be achieved by bottom entry or by the use of a fill pipe reaching to the bottom of the tank.

13.3.2 For liquids with conductivity up to and including 50 pS/m the bottom entry or fill pipe should be designed to minimize turbulence and the agitation of any heavier immiscible liquid or sediment on the tank bottom.

13.3.3 Entrained air or other gas should be avoided in liquids with conductivities up to and including 50 pS/m if there is any possibility of immiscible liquid or sediment on the tank bottom.

13.3.4 For liquids with conductivity up to and including 50 pS/m the linear flow velocity in the pipe entering the tank should not exceed 1 m/s until the inlet has been covered, and maintained at 1 m/s if a second immiscible phase is present; an example is water suspended in oil. A precise value for the safe maximum linear flow velocity in the absence of a second phase has not been established.

However, experience indicates that the limitations on flow rate imposed by the present designs of pipeline systems have been adequate to maintain safe operations. There is no evidence that flow velocities up to and including 7 m/s are hazardous.

13.3.5 For liquids of conductivity greater than 50 pS/m the recommendations of **13.3.2**, **13.3.3** and **13.3.4** can be disregarded. An antistatic additive may be used to raise the conductivity of a low conductivity liquid above 50 pS/m, provided that it is compatible with the intended use of the liquid.

13.4 Filters

Fine particle filters installed in the pipeline system upstream of the cargo tank can produce a significant amount of charge. It is recommended that the methods for dealing with the charge given in clause **16** be followed.

13.5 Gauging and sampling

The introduction of equipment into a tank for gauging and sampling may produce additional static electricity hazards. It is recommended that the procedures given in clause **6** be followed.

13.6 Tank cleaning

Tank cleaning by high pressure jets is recognized to be a potential static electricity hazard. Reference should be made to clause **14**

14 Tank cleaning with high pressure water jets or steam

14.1 General

The techniques for cleaning metal tanks cover a very wide range, including the use of water, solvent jets and the impingement of steam. Flammable atmospheres of vapour, mist or foam may be produced from the contents of the tank or by the cleaning solvent or by the disturbance of the residual layers on the tank walls. The spraying of water, solvents or steam can generate large amounts of static electricity. In some cases the cleaning liquid is recycled and this may lead to two immiscible phases, e.g. oil in water suspensions or the cleaning water may contain detergent. These two conditions can significantly increase charge generation. If high levels of charge are retained on isolated conductors, slugs of liquid, mist or foam then the cleaning operation becomes hazardous. Advice on the avoidance of hazardous electrostatic discharge is given in **14.2**, **14.3** and **14.4**.

The recommendations given are concerned with the cleaning of tanks that are electrically conducting. The cleaning of non-conducting plastic or fibre glass tanks or tanks lined with insulating materials is not included. Specialist advice should be sought in such cases.

14.2 General precautions

14.2.1 *Earthing*

All conducting components in the cleaning system should be earthed (see clause **13** of BS 5958-1:1991).

14.2.2 *Personnel*

It should be ensured that personnel working on the tank do not present an ignition risk (see **31.3.1**).

14.2.3 ***High resistivity materials***

The effects of high resistivity materials, such as synthetic plastics, in either the cleaning system or the tank structure should be carefully assessed before use where a flammable vapour/air mixture, mist or foam may be encountered (see clause **10** of BS 5958-1:1991).

14.2.4 ***Gauging and sampling***

The introduction of equipment into a tank for such operations as gauging should be avoided as far as possible during tank cleaning. If gauging is considered to be essential, the recommendations in clause **6** should be rigorously followed.

14.3 Additional safety measures

14.3.1 ***General***

Earthing will remove one hazard but there may remain hazards arising from the electrostatic charge generated in the tank space. Risks from this can be eliminated either by control of flammable atmosphere or by restricting the space potential. Methods of achieving safety will depend on the industry concerned.

In the shipping industry, the cleaning of chemical tankers has been studied in detail. Guidance for the safe washing of tankers is given in the shipping codes[5)].

In the chemical industry, only limited experiments have been reported. The guidance for safe washing of tankers depends on tank size and the type of cleaning equipment used. Safe operating conditions which have been established experimentally are given in **14.3.2** and **14.3.3**.

14.3.2 ***Safe operating conditions for cleaning with high pressure water jets***

Experimental work[6)] has established that, in addition to the recommendations in **14.2**, the following conditions should be adhered to in order to eliminate the risk of ignition from electrostatic discharge:

a) the volume of the metal tank should be less than 3 000 m^3;

b) water throughput per nozzle should not exceed 17.5 m^3/h (4.86 L/s);

c) total combined water throughput of all nozzles into the tank should be less than 110 m^3/h (30.56 L/s);

d) the tank should be kept drained during washing; washing should be stopped to clear any build up of wash water;

e) recirculated wash water should not be used;

f) chemical additives should not be used;

g) wash water may be heated, but should not be above 60 °C.

If all the above conditions cannot be fulfilled then the cleaning of metal tanks with water jet should take place only under inert atmospheres, or it should be shown that there is no ignition hazard from electrostatic discharge.

14.3.3 ***Safe operating conditions for cleaning with high pressure solvent jets***

Experimental work[7)] has established that, in addition to the recommendations in **14.2** the following conditions should be adhered to in order to eliminate the risk of ignition from electrostatic discharge:

a) for most tank shapes in general use the volume of the metal tank should not exceed 5 m^3 or the tank diameter should not exceed 3 m;

b) maximum solvent throughput should be less than 1 L/s and the feed pressure should be less than 50 bar[8)];

c) the tank should be kept drained during cleaning;

d) the insoluble contents in the washing solvent should be less than 1 % by weight.

The above conditions have been established experimentally under relatively small tank volume and low liquid throughput conditions. It may be possible to establish other safe conditions for larger tank volume and higher liquid throughput.

If the above conditions cannot be fulfilled then the cleaning of metal tanks with high pressure solvent jets should be carried out only under inert atmospheres or it should be shown that there is no ignition hazard from electrostatic discharge.

[5)] International Chamber of Shipping and Oil Companies. International Marine Forum. *The International Safety Guide for Oil Tankers and Terminals. 1978.*
International Chamber of Shipping. *ICS Tanker Safety Guide (Chemical).*
International Maritime Organizations. *Crude Oil Washing Systems. 1982.*

[6)] Jones, M.R.O and Bond, J. *Electrostatic hazards associated with marine tanker operations – criteria of safety in tank cleaning operations.* Vol.63 November 1985. Chemical Engineering Research and Development.

[7)] Post, L.et.al. *The avoidance of ignition hazards due to electrostatic charges occurring during the spraying of liquids under high pressure.* Journal of Electrostatics, 23 (1989).

[8)] 1 bar = 10^5 N/m^2 = 10^5Pa.

14.4 Safe operating conditions for cleaning with wet steam

Wet steam presents a source of very high charge generation. Safety should therefore be based on the removal of the flammable atmospheres before steaming, unless it can be shown that dangerous potentials will not be produced in the particular operation.

15 Aircraft fuelling

15.1 General

Aircraft are most frequently fuelled by means of mobile fuellers or by hydrant systems feeding the aircraft system through mobile dispensers. Fuel transfers are made through flexible hoses and ignition hazards due to static electricity may arise during the operations. Charge may be generated on the fuel in the system feeding the aircraft or in the aircraft tank, which is normally of metal construction. In addition, charge accumulates on the aircraft itself during flight and, if insulated, it can, in some atmospheric conditions, become charged whilst on the ground.

Although not an electrostatic hazard, the possibility exists of sparking when making or breaking hose connections. Sparks are due to stray currents arising from, for example, electrical power installations or cathodic protection systems. Precautions against static electricity ignitions need therefore to be consistent with the avoidance of stray current sparking.

Recommendations for avoiding static electricity hazards are given in **15.2**, **15.3** and **15.4**. They assume the presence in the fuelling system of a fine particle filter and/or a water separator.

15.2 Hoses

15.2.1 Flexible hoses should preferably be of the semi-conductive type (see **9.1**) so as to facilitate the disperson of static electricity while limiting stray current flow. If conductive hose is used in a hydrant system, an insulating flange should be installed at the end of the-hydrant riser. The use of non-conducting hoses should be limited to situations where a flammable atmopshere is not likely to be present and where charging of the outer surface is unlikely, for example where the hose lies on the ground.

15.2.2 The resistance between the end flanges of each length of conductive or semi-conductive hose should be checked with sufficient frequency to ensure that its conductive properties are being maintained.

15.3 Earthing and bonding

15.3.1 All the metallic parts within each fuelling vehicle should be in good electrical contact with each other, so that the resistance between any two points on each unit is less than 10 Ω. Similar electrical continuity should exist within the hydrant system and also within each hydrant dispenser.

15.3.2 It is recommended that fuelling vehicles and hydrant dispensers have antistatic tyres. Aircraft are normally equipped with such tyres.

15.3.3 Although the aircraft should be earthed through its tyres, additional earthing is sometimes provided by means of a bonding cable between the aircraft and an earthing point in the concrete apron. This connection should be made only to an earthing rod provided for the purpose; on no account should hydrant pits or pit valves be used owing to the possibility of stray current sparking.

The connection should be direct from the aircraft to the earthing rod and independent of the fuelling vehicle or hydrant dispenser.

15.3.4 A bonding connection should be made between the aircraft and the fuelling vehicle or hydrant dispenser before any fuel system connections are made and should remain in position until the operation has been completed and all fuel system connections have been broken. For this purpose the fuelling vehicle or dispenser should carry a cable firmly connected to the vehicle, and this connection should be tested with sufficient frequency to ensure that its resistance remains below 10 Ω (see clause **13** of BS 5958-1:1991).

15.3.5 Bonding connections on the aircraft should be firm and made to unpainted metal parts. Where possible bonding lugs should be used and equipment such as pitot head tubes, aerials and propellers should be avoided.

15.3.6 There should be a direct bond between the aircraft fuelling orifice and the metallic end of the fuelling hose. With underwing fuelling the necessary connection is achieved by the metal-to-metal contact between the hose end coupling and the aircraft fuelling adaptor. With overwing fuelling the hose nozzle should be bonded to the aircraft by a separate cable before the filler cap is removed and the bond should remain in position until the operation has been completed and the filler cap replaced.

With some light aircraft, bonding may not be possible because of the absence of a bonding lug near the fuelling orifice, and a semi-conductive hose is then strongly recommended.

15.3.7 Some overwing operations may require the use of a funnel. This should be metallic and should be bonded both to the fuelling nozzle and to the aircraft before the aircraft filler cap is removed.

15.3.8 Earthing and bonding procedures similar to the above apply also to fuel deliveries to aircraft from drums and other containers.

15.3.9 It should be ensured that personnel do not present an ignition risk (see **31.3.1**).

15.4 Fuelling rate

During the fuelling of aircraft, liquid velocities in the delivery system or the aircraft fuel manifolds often exceed the levels recommended for road/rail vehicles (see **7.3.3**). However, aircraft tanks have large horizontal areas and little depth and this reduces the hazard of the fuelling operation. The majority of aircraft fuels contain an antistatic additive and, where this is known to be present, flow rates up to 7 m/s are acceptable. Where no additive is used the recommendations of the Civil Aviation Authority[9)] should be followed.

16 Fine particle filters and water separators

16.1 General

The presence of a fine particles filter and/or a water separator in a pipeline system can greatly increase electrostatic charge generation in a liquid, because the very large surface area of the filter or separator medium promotes extensive charge separation as the liquid passes through it. Typical charge densities in the liquid leaving such a device can be in the range 10 $\mu C/m^3$ to 5 000 $\mu C/m^3$, that is up to several orders of magnitude greater than those encountered in pipelines. Coarse strainers and gauzes do not normally cause any significant charge generation.

If a flammable vapour/air mixture, mist or foam is present in the tank downstream of the filter or water separator, there is an ignition hazard and, to supplement the recommendations for tanks given in clauses **3**, **4**, **5**, **7**, **8** and **13**, the measures in **16.2** to **16.6** should be adopted.

16.2 Earthing

16.2.1 All metallic parts of fine particle filters and water separators should be connected to each other and to earth, so that the resistance to earth at all points is less than 10 Ω. (See clause **13** of BS 5958-1:1991.)

16.2.2 It should be ensured that personnel do not present an ignition risk (see **31.3.1**).

16.3 Charge relaxation

The charge generated in the fine particle filter or water separator can be dissipated by the provision of sufficient residence time between the device and the receiving tank. This may be achieved by including in the line between them a metal relaxation chamber; in some cases there may be sufficient residence time in the pipeline, which should be of metal construction and earthed, without the need for a special chamber.

For liquids with conductivities down to 2 pS/m the residence time should be 3τ, where τ is the relaxation time of the liquid (in s), and for less conductive liquids it should be 100 s. The relaxation time is given by the equation:

$$\tau = \frac{\epsilon\epsilon_0}{\gamma} \times 10^{12}$$

where

- ϵ is the relative permittivity of the liquid
- ϵ_0 is the permittivity of free space (8.85×10^{-12} F/m);
- γ is the conductivity of the liquid (in pS/m).

Thus, for a liquid with a relative permittivity of about 2, the residence time in seconds is about $50/\gamma$.

Disadvantages of the relaxation procedure are as follows:

a) the range of conductivities needs to be known at the design stage;

b) low conductivity liquids require large relaxation chambers;

c) these chambers have always to be kept completely full during pumping operations, to avoid the ignition hazard which would occur in the vapour space above the liquid.

16.4 The use of antistatic additives

The residence time required downstream of a fine particle filter or water separator may be reduced by using an antistatic additive to increase the conductivity of the liquid, provided that it is compatible with the intended use of the liquid.

[9)] Civil Aviation Authority. *Aircraft fuelling: fire prevention and safety measures for the fuelling of aeroplanes and helicopters.* London CAP 74.

16.5 The use of floating tanks or floating blankets

If the use of a relaxation chamber or an antistatic additive is not possible, liquid may be pumped directly from a fine particle filter or water separator into a floating roof tank, or into a fixed roof tank equipped with an earthed conducting floating blanket. The precautions given in **3.7** and **3.8** should be adopted. Until the floating roof or blanket is buoyant the flowrate should be low enough to allow relaxation before the liquid enters the tank. Thereafter, the flow rate can be increased to that normally acceptable for the tank.

16.6 Filling and emptying

Fine particle filters and water separators should be filled and emptied slowly, and on no account should they be emptied by means of compressed air.

17 Metal containers and tanks for the storage and transport of liquids, with a fixed internal non-metallic coating

17.1 General

The charging processes and static electricity hazards associated with metal containers (see **3.1**) still apply when the container has a fixed internal non-metallic coating. If the coating is made from high resistivity material, charge may also be generated and retained on the coating itself by the liquid handling operations or by internal rubbing.

An ignition hazard is created when charge is retained on the liquid, on insulated conductors, on the coating itself or on personnel in the presence of a flammable vapour/air mixture, mist or foam. The risk of a discharge from the liquid surface, for example during gauging, depends upon the rate of charge input, the volume of the container, the conductivity of the liquid and the thickness and conductivity of the coating.

Recommendations for avoiding electrostatic hazards are given in **17.2** and **17.3**. They should be considered in conjunction with measures to deal with other hazards that may arise in the storage and transport of flammable liquids.

17.2 Containers with an internal high resistivity coating

17.2.1 There should be good contact between the container and the coating.

17.2.2 Provided that the precautions recommended for the equivalent uncoated container are applied (see clauses **3**, **7**, **11** and **13**), internal coatings, such as paint, with a thickness less than 2 mm are unlikely to create hazards additional to those normally expected in an uncoated container, except where there are rapid repeat fillings.

17.2.3 For layers thicker than about 2 mm, or where there is a possibility of rapid repeat fillings, the precautions for an equivalent uncoated container should be supplemented by providing a conducting path between the liquid contents and earth. For conducting liquids this path can be, e.g. an earthed metal fill pipe or dip pipe extending almost to the bottom of the container but not touching it. Additional earthing may be needed for low conductivity liquids, depending on the type and thickness of the coating, the size of the container and the conductivity of the liquid. The conductivity level at which additional earthing is likely to be needed is not definitely established, but it should not be necessary if the conductivity exceeds 50 pS/m for storage tanks or 1 000 pS/m for tanks in which blending is taking place.

17.2.4 The inner, coated surface should not be rubbed in the presence of a flammable vapour/air mixture, mist or foam. This is important when cleaning a container that has held a flammable liquid. Flammable solvents should not be used for cleaning the inside of a container.

17.3 Containers with an internal conductive coating

Coating made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) are acceptable provided that the precautions recommended for equivalent uncoated metal containers are applied (see clauses **3**, **7**, **11** and **13**).

18 Metal containers for liquids with outer non-metallic coatings or jackets

18.1 General

The charging processes and static electricity hazards associated with metal containers (see **3.1**) are still encountered when the container has a non-metallic coating on its outer surface. If the coating is made from high resistivity material, charge may also be generated and retained on the coating itself when subjected to processes producing high charging rates, e.g. excessive rubbing. In some designs of container the high resistivity coating supports metallic components not in contact with the main metal container and these can be a source of discharges if not earthed. However, the presence of the coating in close contact with the metal provides a system of relatively high capacitance and a large amount of charge is required on such components to raise their potentials sufficiently to give rise to incendive discharges. Personnel walking on such high resistivity coatings may also be insulated from earth.

An ignition hazard is created when charge is retained on the liquid, on insulated conductors, on the coating itself or on personnel, in the presence of a flammable vapour/air mixture, mist or foam. Recommendations for avoiding electrostatic hazards are given in **18.2**, **18.3** and **18.4** They should be considered in conjunction with measures to deal with other hazards that may arise in the storage and transport of flammable liquids.

18.2 Containers with an outer high resistivity coating

18.2.1 The metal container and any metallic components in the vicinity, including those mounted on the high resistivity coating, should be earthed.

18.2.2 It should be ensured that personnel do not present an ignition risk (see **31.3.1**. Where appropriate, conducting walkways should be provided.

18.2.3 The full range of precautions recommended for an equivalent uncoated container should be applied.

18.2.4 In most situations coatings, such as paint, with a thickness less than 2 mm are unlikely to create hazards additional to those expected with an uncoated container, provided that all the precautions for the uncoated container are applied. In processes where the rate of external charge generation is very high, e.g. electrostatic spraying, there is a possibility of a propagating brush discharge (see **5.5** of BS 5958-1:1991).

18.2.5 For coatings thicker than 2 mm the hazard depends on such variables as the external charge generating mechanism and the thickness and resistivity of the coating and each situation should be considered on its merits, taking expert advice if necessary. In processes where the rate of external charge generation is very high, e.g. electrostatic spraying, there is a possibility of a propagating brush discharge (see **5.5** of BS 5958-1:1991).

18.3 Containers with an outer high resistivity coating protected by an earthed conducting sheath

A container on which an outer coating of high resistivity material is completely covered by a permanent earthed sheath of conducting material is acceptable, irrespective of the thickness of the high resistivity coating. The inner metallic container should be earthed and all the precautions recommended for an equivalent uncoated container should be applied.

18.4 Containers with an outer conductive coating

Coatings made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) are acceptable provided that the precautions recommended for equivalent uncoated metal containers are applied.

19 Pipelines for liquids and gases

19.1 General

When a liquid flows in a pipe, charge separation occurs between the liquid and the internal surface of the pipe, producing electrostatic charges on both the liquid and the pipe. In the case of a pure gas, or a mixture of pure gases, flowing through a pipe there is no generation of static electricity. However, in practice, gases often contain solid or liquid particulate matter and charge can then be generated where these particles impinge on the walls of the pipe or on obstructions such as orifices or valves.

The extent to which the charges are retained depends upon the resistivity of the pipe material and upon the conductivity of the pipe contents, in the case of liquids. High resistivity pipes may have metallic components, such as flanges or valves, and these may retain charge if they are not earthed.

In addition to charge generation within the pipe by liquid or gas flow, charging processes, such as rubbing or steam impingement, can lead to the accumulation of charge on the outer surface of a high resistivity pipeline and on any insulated metal components in the line.

Potentials high enough to cause incendive discharges can be generated by the flow of both flammable and non-flammable liquids and gases. If such discharges do occur the hazard external to the pipeline depends upon the presence of a flammable atmosphere adjacent to the pipe, which may be due to leakage from the pipe itself if its contents are flammable, or to flammable gas or vapour from some other source. Also, if the liquid or gas in the pipe is flammable, there may be an internal ignition risk if air enters the system and produces a flammable mixture within the pipe.

It should be noted that the use of plastics pipelines with flammable liquids or gases may be restricted by requirements imposed by the general fire risk.

To avoid the ignition hazards that may arise in various situations, the recommendations given in **19.2** to **19.8** should be followed.

It should be noted that these refer to pipeline flow situations and additional precautions may be necessary if the line contains any elements, such as fine filters, capable of high charge generation.

19.2 Avoidance of a flammable atmosphere

When a flammable atmosphere external to a pipe is due to a leak of flammable gas or liquid from the pipe, the escape should be stopped as soon as possible by closing valves or, in the case of a flexible non-metallic pipe, by the application of mechanical clamps on either side of the leak. If the presence of a flammable atmosphere is considered possible, personnel should be earthed. (See **31.3.1**.)

19.3 Metallic and conductive non-metallic pipes above ground

All parts of the pipeline should be earthed, including any metal cladding or netting reinforcement of coatings. The criterion for satisfactory earthing is that the resistance to earth at any point should not exceed 10^8 Ω, although a resistance not exceeding 10 Ω should be obtainable in a wholly metallic system (see **13.2.2** and **13.3.4** of BS 5958-1:1991).

19.4 High resistivity pipes above ground

19.4.1 All metallic components in the pipeline system, including any metal cladding or netting reinforcement of coatings, should be earthed with a maximum reistance to earth of 10^8 Ω (see **13.2.2** of BS 5958-1:1991).

19.4.2 The transfer of gases and low conductivity liquids (conductivity up to and including 1 000 pS/m) through high resistivity pipes is not, in general, recommended in Zones 0, 1 and 2 hazardous areas (see **2.12** of BS 5958-1:1991). If the use of such a pipeline in these circumstances is considered to be essential, the electrostatic hazard should be carefully evaluated, using expert advice if necessary.

19.4.3 When a high conductivity liquid (conductivity above 1 000 pS/m) flows in a high resistivity pipe it prevents the accumulation on the inner surface of the pipe of sufficient charge to cause a hazardous field outside the pipe, provided that the liquid is in contact with earth at some point, e.g. in an earthed metal tank or valve. The presence of high resistivity pipelines carrying high conductivity liquids is therefore acceptable in Zones 0 and 1 hazardous areas if the liquid is earthed in this way, if all metallic components are earthed and if there are no external sources of electrostatic charge generation, such as rubbing or steam impingement. They are also acceptable in Zone 2 areas with the same provisions, except that external sources of electrostatic generation can be tolerated if it can be shown that the consequent ignition risk is low, that is, comparable with the ignition risk from Zone 2 electrical equipment.

19.5 Buried pipelines

19.5.1 When a pipe is buried its whole external surface is in contact with the earth. The passage of electrified liquid through a pipe can cause high field strengths to develop through the pipe wall. Under certain combinations of liquids and pipe resistivities electrostatic discharge may puncture the pipe wall, release the flammable liquid and possibly cause ignition. The risk of ignition will depend on the extent of the flammable atmosphere produced around the pipe.

This is a complex phenomenon and specialist advice should be sought.

19.5.2 When a metallic or conductive pipeline is exposed by excavation it remains in contact with earth at both ends of the excavation and it requires no further earthing.

19.5.3 When a high resistivity pipeline is exposed by excavation any metallic components in the excavated section of pipe should be earthed if there is any possibility of the presence of a flammable atmosphere.

19.5.4 For all types of buried pipeline, when exposed by excavation adjacent conductors should be earthed if the presence of a flammable atmosphere is suspected. It is very hazardous to make the earthing connection to an insulated conductor while flammable gas or vapour is present.

19.6 Ignition hazard within a pipeline

If a flammable mixture occurs in a pipeline due to the inadvertent ingress of air the risk of an electrostatic ignition may be very high, depending on circumstances, and flow should be stopped until the risk has been evaluated. Intentional pumping of a flammable mixture should never be attempted without taking expert advice.

19.7 Valves

It is important when using ball valves in such systems that they are fitted with antistatic devices as specified in **8.11** of BS 5351:1986.

19.8 Metal pipes and components lined with high resistivity internal coating

19.8.1 *General*

The flow of flammable liquid through a pipe could generate flammable atmosphere within the pipe at some time during the start or at the end of the operation. The flow of liquid through pipes lined with a high resistivity internal coating will give rise to charge generation on the lining and the liquid. Ignition hazards may arise from electrostatic discharges resulting from charge accumulation on the liquid or the lining.

19.8.2 *Conducting liquid*

There is no electrostatic hazard with the flow of conducting (conductivity greater than 1 000 pS/m) liquid, provided the liquid is in contact with an earth at some point and the outer metal pipe is earthed.

19.8.3 *Non-conducting liquid*

When the liquid is non conducting (conductivity less than 1 000 pS/m), charge can be retained on the liquid and the lining even when the liquid is in contact with the earth. Recommendations in a) to c) below should be followed to eliminate the risk of electrostatic discharge.

a) *Initial filling of pipe.* Flammable atmosphere may be present within the pipe at the start of the filling operation. However, it takes a long time to develop hazardous potentials and provided the flow velocity is maintained within safe limits (see **3.3.4**) there is no electrostatic ignition hazard.

b) *Full pipe.* There will be no flammable atmosphere present within the pipe when the liquid completely fills the pipe. There is no fire hazard from electrostatic discharge in this situation.

c) *Draining of pipe.* The flow of non-conducting liquid (conductivity less than 1 000 pS/m) can result in charge generation and accumulation on the lining and the liquid. High levels of charge on the lining can cause energetic discharges producing pinholes through the lining. The pinholes will expose earthed metal pipe. Incendive discharges across the surface of the lining to the exposed metal pipe could result. A potential fire hazard would exist in the presence of a flammable atmosphere within the pipe. Therefore, it is necessary to ensure that charge has dissipated to a safe level before draining the pipe. The charge can dissipate through the lining and the liquid. The hazard from electrostatic discharge can be removed by ensuring that the draining of the pipe does not commence until time t_1, or t_2, whichever is the shorter, has elapsed.

Time t_1 (in s) can be established from the following equation:

$$t_1 = 3\rho\ \epsilon_1\ \epsilon_0$$

where

ρ is the volume resistivity of the lining (in Ω·m);

ϵ_1 is the dielectric constant of the lining (in Ω·m);

ϵ_0 is the permittivity of free space (8.85×10^{-12} F/m).

Time t_2 (in s) can be established using the following equation:

$$t_2 = \left(\frac{L^2}{dr}\right)\left(\frac{\epsilon_1}{\epsilon_2}\right)\tau_2$$

where

L is the distance between the earth points in contact with the liquid along the pipe (in m);

r is the pipe radius (in m);

d is the pipe lining thickness (in m);

ϵ_2 is the dielectric constant of the liquid;

τ_2 is the relaxation time of the liquid (in s);

$$\tau_2 = \frac{\epsilon_2\ \epsilon_0}{\sigma}$$ where σ is the conductivity of the liquid (in pS/m).

When the above conditions are satisfied the liquid can be drained off safely provided the flow velocity is maintained within recommended values. (See **3.3.4.**)

If these conditions cannot be met then metal pipes with high resistivity internal linings should not be used with low conductivity flammable liquids unless it can be demonstrated that there is no hazard from electrostatic discharge.

20 Pneumatic conveying systems

Pneumatic conveying of powdered materials through pipe work produces electrostatic charges on the powder and the conveying pipe. (See clause **9** of BS 5958-1:1991.) In the presence of a flammable atmosphere (dust cloud and/or solvent vapour) electrostatic discharges from the dust cloud or pipe may present a hazard. The following recommendations are made for the safe operation of metal pneumatic conveying systems.

a) All metal parts of the conveying system should be earthed.

b) For earthed metal pipes of diameter less than 1 m there is no hazard of ignition from electrostatic discharges originating from the dust cloud within the pipe provided the flammable atmosphere (dust cloud and/or solvent vapour) has minimum ignition energy greater than 0.2 mJ.

c) For earthed metal pipes of diameter greater than 1 m and for powders with minimum ignition energy greater than 25 mJ, there is no hazard of ignition from electrostatic discharges within the pipe.

d) For earthed metal pipes of diameter greater than 1 m, the conveying of powders in the presence of a flammable atmosphere with a minimum ignition energy of less than 25 mJ is not recommended, unless it can be demonstrated that no electrostatic ignition hazard exists.

NOTE Recommendations for powder collecting hoppers are covered in clause **21**.

21 Containers for powders

21.1 General

With few exceptions, all particles, including chips and granules, readily become charged during transport through pipes and ducts. This is especially true when the particles remain well separated from each other, as in pneumatic transport. When the highly charged particles are bulked in a container, discharges may occur between the powder and the container (see **9.2** of BS 5958-1:1991) and these could constitute an ignition hazard if a flammable vapour/air mixture or a powder suspension in air is present. If a system contains only granules (particle size greater than 200 µm) then their size precludes the formation of an ignitable dust cloud. The potentially most hazardous situations occur when granules and fine powder are intermixed. Electrostatic effects associated with granules are not yet fully understood. This clause is concerned with powders having particle sizes up to 200 µm. Other discharges may also occur involving the container or personnel in its vicinity and these also present ignition hazards. In the case of a container of high resistivity material the discharges from the powder to the container may lead to polarization across the thickness of the container wall and to the risk of a propagating brush discharge if an earthed conductor or person approaches the inner or outer surface (see **10.2.3** of BS 5958-1:1991). Such a discharge is not only highly incendive but can cause severe physiological shock. High resistivity containers can also be charged externally by rubbing or by other charge generating mechanisms, such as steam impingement; these charges may constitute an ignition hazard.

To avoid these hazards the recommendations given in **21.2** and **21.3** should be followed. The specific case of a removable liner in a container is included in clause **23**.

The phenomena are complex and in many instances it may be appropriate to take expert advice.

21.2 Metallic and conductive non-metallic containers

21.2.1 The container and any metallic equipment in the vicinity, including the fill pipe, if present, should be earthed.

21.2.2 For containers with capacities up to and including 65 m^3 in the presence of flammable mixtures of materials with minimum ignition energies greater than 25 mJ, earthing of equipment should provide adequate protection. However, if a flammable atmosphere with a minimum ignition energy less than 100 mJ could occur, e.g. dust dispersed into an atmosphere, personnel should also be earthed (see **31.3.1**).

21.2.3 For containers of capacities up to and including 65 m^3 where a flammable mixture could occur of any material with a minimum ignition energy up to and including 25 mJ, protective measures additional to the earthing of equipment and personnel should be considered to deal with discharges from the dust cloud or the bulked powder, although practice has shown that such additional precautions are seldom needed in the absence of flammable vapours. If it is found that incendive discharges are possible, the protective measures that may be used include the reduction of the quantity of charge on the incoming powder, e.g. by neutralization using ionized air, or the installation of some form of explosion protection such as inerting air, purging, explosion suppression or explosion venting.

21.2.4 For containers with capacities exceeding 65 m^3 and containing a flammable atmosphere there is an as yet unknown probability of an incendive discharge from the charged powder suspension in air. In addition to the earthing of equipment and personnel, consideration should be given to installing some form of explosion protection as mentioned in **21.2.3** unless it can be shown that discharges from both the suspended and the bulked powder will not occur.

21.3 Containers of high resistivity materials

21.3.1 The recommendations given in **21.3.2** to **21.3.9** inclusive apply to containers fabricated from materials having a volume resistivity greater than 10^8 Ω·m and/or a surface resistivity greater than 10^{10} Ω.

21.3.2 If the contents of the container are solvent-wet and can produce a flammable atmosphere the advice given in **12.4** and **12.5** for flammable liquids in high resistivity containers should be followed.

21.3.3 Any metallic equipment in the vicinity of the container, including the fill pipe, if present, should be earthed.

21.3.4 For dry powders in containers with capacities up to and including 5 m^3, in the presence of flammable mixtures of materials with minimum ignition energies greater than 25 mJ, earthing of metallic equipment should provide adequate protection. It should also be established that the rate of charge input with the powder is insufficient to promote propagating brush discharges. If a suspension in air of a powder with a minimum ignition energy less than 100 mJ could occur personnel should also be earthed (see **31.3.1**).

21.3.5 For dry powders in containers with capacities up to and including 5 m^3, where a vapour/air mixture or dust suspension could occur of any material with a minimum ignition energy up to and including 25 mJ, protective measures additional to the earthing of equipment and personnel should be considered to deal with discharges from the bulked powder, if it cannot be shown that the quantity of charge present is insufficient to cause incendive discharges. These protective measures include the reduction of charge on the incoming powder, e.g. by neutralization using ionized air, or the installation of some form of explosion protection, such as inerting, air purging, explosion suppression or explosion venting.

21.3.6 For dry powders in containers with capacities up to and including 5 m^3, where propagating brush discharges, giving rise to physiological shock, are possible, one or more earthed rods may be inserted into the container to assist relaxation of charge from the powder.

Precautions as given in **21.3.5** are still recommended if a vapour/air mixture or dust suspension could occur of any material with a minimum ignition energy up to and including 25 mJ.

The possibility of a propagating brush discharge can be reduced by prebulking the incoming powder in an earthed metal hopper. The precautions given in **21.2** should be applied to the hopper.

21.3.7 For containers with capacities exceeding 5 m^3 there is an as yet unknown probability of an incendive discharge from the charged powder suspension in air. In addition to the earthing of equipment and personnel, consideration should therefore be given to installing some form of explosion protection, as mentioned in **21.3.5**, unless it can be shown that discharges from both the suspended and the bulked powder will not occur. The insertion of earthed rods should also be considered if there is any risk of physiological shock to personnel owing to propagating brush discharges.

21.3.8 If the container and its contents are in, or are moved into, an area where a flammable atmosphere could be present, rubbing of the surface of the container should be avoided, together with any other charging process such as steam impingement.

21.3.9 Powder should not be emptied from a high resistivity container in the presence of a flammable atmosphere. When the powder itself is liable to produce a sensitive dust cloud (minimum ignition energy less than 25 mJ) then, ideally, high resistivity containers should not be used unless it can be shown that the charge levels developed during pouring do not produce incendive discharges.

22 Flexible intermediate bulk containers

22.1 General

Flexible intermediate bulk containers (FIBCs) are used in industry for storage and transport of powdered materials. They are typically constructed from polypropylene fabric (or any similar strong and heavy duty material) and some FIBCs have conducting threads woven into the fabric.

Electrostatic charge is generated during the filling and emptying of FIBC. Charge may accumulate on the powder, conducting elements of the fabric from which FIBC is constructed. Electrostatic hazard may arise in the presence of a flammable atmosphere when the accumulated charge is released in the form of an incendive electrostatic discharge.

It is not possible to make recommendations for the safe use of all the different types of FIBCs available. Data is available only on a limited number of different types of FIBCs and recommendations for their safe use are given in **22.2** to **22.8**. For FIBCs where no or insufficient data are available it is recommended that expert advice be sought.

22.2 FIBC constructed from conducting fabric

Recommendations for metallic and conductive non-metallic containers (see **21.2**) also apply to these FIBCs. It is essential that all conducting components be earthed.

22.3 FIBC constructed from non-conducting fabric

These are safe to use in the absence of flammable vapours for powders with minimum ignition energy greater than 25 mJ provided all auxiliary conducting components are earthed. Such FIBCs should not be used in the presence of a flammable vapour. Expert advice should be sought when they are used for plastics granules.

22.4 FIBC constructed from non-conducting fabric containing woven earthed conducting filaments

The recommendations for the safe use of metal container (see clause **21**) also apply to these FIBCs provided the metal filaments or threads are spaced less than 20 mm apart and are interconnected and earthed.

22.5 Two fixed layered FIBC with outer layer constructed of non-conducting fabric and the inner containing earthed conducting elements, filaments or threads

Recommendations given in **22.4** also apply.

22.6 FIBC constructed from non-conducting fabric containing woven unearthed conducting filaments or threads

There are insufficient data available at present to make recommendations for the safe use of such FIBCs. It is therefore recommended that expert advice be sought for their safe use in flammable atmosphere.

22.7 Two loose layered FIBC with outer containing conducting elements and the inner constructed of non-conducting fabric

There are insufficient data available at present to make recommendations for the safe use of such FIBCs. It is therefore recommended that expert advice be sought for their safe use in flammable atmosphere.

22.8 Two loose layered FIBC with outer constructed from non-conducting fabrics and the inner constructed from conducting plastic

There are insufficient data available at present to make recommendations for the safe use of such FIBCs. It is therefore recommended that expert advice be sought for their safe use in flammable atmospheres.

23 Removable non-metallic liners in containers for solvent wet materials or dry powders

23.1 General

In some operations, particularly the handling of solvent wet or dry powders in drums, it is convenient to use an inner liner, such as a plastics bag, as a precaution against contamination. If made of high resistivity material, such a liner can be charged during filling and emptying. Dangerous potentials can be generated if the liner is removed from the container, because of the separation of charges which then occurs. In some processes, e.g. when filling the container with a highly charged high resistivity powder, there is a possibility of a propagating brush discharge from the liner (see **5.5** of BS 5958-1:1991). In addition to these consequences of charging the liner, it may also insulate the material being handled from earth, even though the conducting outer container is earthed.

The discharges that may occur in operations with high resistivity liners can give rise to an ignition hazard if a flammable vapour/air mixture is present. Sensitive dust clouds may in principle be ignited and the possibility of such ignition should be assessed for dust clouds of minimum ignition energy less than 25 mJ. A propagating brush discharge would be much more incendive and could also cause serious physiological shock. Recommendations for avoiding these hazards are given in **23.2** and **23.3**.

23.2 Liners of conductive materials in metal or conductive containers

23.2.1 If a non-metallic liner is used in circumstances where there may be an ignition hazard, or where propagating brush discharges giving rise to physiological shock are possible, it is strongly recommended that the liner be conductive with a surface resistivity not exceeding 10^{11} Ω.

23.2.2 All the precautions recommended for the equivalent unlined container should be applied (see **21.2**).

23.3 Liners of high resistivity materials in metal or conductive containers

Liners with surface resistivities greater than 10^{11} Ω should be used only if they are essential, e.g. reasons of chemical compatibility between the liner and the material being handled. The ignition risk and the possibility of physiological shock from propagating brush discharges depends very much on the thickness and resistivity of the liner, the handling procedure, the electrical properties of the material being handled and the nature of any flammable mixture that may be present. Each situation should be considered on its merits, taking expert advice if necessary.

23.4 Liners in high resistivity containers

The precautions required are the same as those for the handling of powders in high resistivity containers in the absence of a liner (see **21.3**). The use of conductive liners within high resistivity containers is not generally recommended because of the danger that they will remain electrically isolated and contribute towards an ignition hazard. Conductive liners should therefore only be used with high resistivity containers if the liner is effectively earthed.

23.5 Removal of liner

An essential precaution in almost all situations is that the liner should not be removed from the container, e.g. to shake out any residue, if there is a possibility of the presence of a flammable vapour/air mixture or a sensitive dust cloud.

24 Manual addition of powders to flammable liquids

24.1 General

A significant number of fires/explosions during the manual addition of powder from drums (metal or plastics) and sacks (paper or plastics) to flammable liquids have been attributed to electrostatic discharges. Electrostatic charge is generated by the pouring of the powder down any chute into the receiving vessel. If this charge is permitted to accumulate then potentials can be developed on the container being emptied, any liner in this container, the receiving vessel, loading chute, powder stream, vessel contents and personnel carrying out the operation.

For reasons of general fire and toxicity risk, the flammable vapour should be contained within the receiving vessel and the formation of dust clouds around the loading point should be strictly controlled. In the precautions given in **24.2** to **24.7** it has been assumed that flammable vapour and dust clouds will be formed only within the receiving vessel and the immediate vicinity of the entry point.

The elimination of flammable atmospheres can provide one basis for safe operation. However, it is important to appreciate that the addition of powder into the reaction vessel will also permit air to enter. The atmosphere may become flammable. It is essential to ensure that a non-flammable atmosphere be maintained, and if necessary the level of oxygen in the vessel should be monitored. Alternatively the recommendations given in **24.2** to **24.7** should be followed to avoid electrostatic ignition.

24.2 Container being emptied

24.2.1 ***Metal, paper and conductive non-metallic containers***

These should be earthed (see clause **13** of BS 5958-1:1991) prior to being emptied and remain earthed when in the presence of a flammable atmosphere. In the case of a paper sack the use of an earth clip may not be very practicable and the sack can be earthed by contact with the earthed plant.

24.2.2 ***High resistivity non-metallic containers***

In areas where a flammable atmosphere is present the use of high resistivity containers is not, in general, recommended except in situations in which the flammable atmosphere does not come into contact with the container. Sensitive dust clouds may in principle be ignited and the possibility of such an ignition should be assessed for dust clouds of materials of minimum ignition energy less than 25 mJ.

24.3 Liner

The precautions in **23.3**, **23.4** and **23.5** should be applied.

24.4 Receiving vessel/loading chute

24.4.1 ***Metal and conductive non-metallic items***

These should be earthed (see clause **13** of BS 5958-1:1991).

24.4.2 ***High resistivity items***

In general, the use of receiving vessels and loading chutes fabricated completely from high resistivity materials is not recommended (see **4.2**).

24.5 Powder stream

The conditions under which an incendive discharge could be released by the electrostatically charged powder stream as it enters the receiver cannot be precisely defined. Available evidence suggests that, with two possible exceptions, this does not present an ignition risk. The exceptions are:

a) if the length of the charge chute exceeds 3 m; or

b) if high resistivity powders are involved.

In both situations the risk is considered to be low in the majority of operations but it is recommended that expert advice be sought when these conditions exist.

24.6 Vessel contents

24.6.1 *Liquid conductivity greater than* 50 pS/m

There is no hazard provided that the liquid is in contact with earth. In an uncoated metal receiver the earthing system for the receiver provides the necessary earth path. If the liquid is insulated from earth by a lining then a special earth point should be provided near to the base of the receiver.

24.6.2 *Liquid conductivity less than* 50 pS/m

A dangerous level of charge may be retained on the liquid. The degree of risk depends on the conductivity of the liquid and the levels of charge generated during the loading operation. Ideally the liquid should be made conducting by the use of a suitable antistatic additive. If this cannot be done then expert advice should be sought to establish a safe procedure.

24.7 Earthing

It should be ensured that personnel do not present an ignition risk (see **31.3.1**).

25 Release of gases and vapours

25.1 General

Gas issuing under pressure from an orifice very frequently carries with it liquid or solid particulate matter. This may be a condensed phase of the gas itself, such as carbon dioxide snow or water droplets in wet steam, or it may be a different material, such as rust or dirt or atomized paint. Charge separation occurs at the orifice and equal and opposite charges are produced on the orifice and on the particulate material. Any unearthed object in or near the cloud of particles can then acquire a charge from it. The charges on the orifice, if insulated from earth, and on other unearthed objects may be hazardous if a flammable mixture of any kind is present, and there may also be a risk of physiological shock to personnel.

To avoid these hazards the recommendations given in **25.2** to **25.5** should be followed.

25.2 Deliberate release of compressed gas

25.2.1 In processes where a gas containing particulate matter is deliberately released, as in compressed air grit blasting, the equipment itself and adjacent metal objects should be earthed. It should be ensured that personnel working in the area do not present an ignition risk (see **31.3.1**).

25.2.2 Such processes should not be carried out in the presence of flammable gases or vapours until it has been established that incendive discharges do not occur from the particulate suspension.

25.3 Accidental leakage of compressed gas

Hazardous charges may be produced when either flammable or non-flammable gases are released accidentally, if they carry liquid or solid particulate matter. Wherever a leak could occur the containing vessel or pipe and any adjacent conducting objects should be earthed if there is any possibility of the presence of a flammable atmosphere, due either to the leakage or to other causes. Earthing is also required if a charged object could be moved into an area where a flammable atmosphere is present. It should be ensured that personnel going into the area of such leaks, for example to effect repairs, do not present an ignition risk (see **31.3.1**).

25.4 Fire extinguishers

25.4.1 Some types of pressurized fire extinguisher, particularly those using carbon dioxide, can generate highly charged clouds. If there is a fire this is of little importance. However, if such equipment is situated where a flammable atmosphere could be present the container and the associated pipework should be earthed. In the absence of fire, the system should not be operated for testing, demonstration or inerting until it has been ascertained that flammable mixtures are absent from the area.

25.4.2 The use of a hand-held extinguisher may cause charging of the operator if he is not earthed, with a consequent risk of minor physiological shock. Nozzles are being developed to minimize this risk.

25.5 Inerting

25.5.1 The precautionary inerting of vessels containing flammable gas mixtures or dust suspensions should be done only with gases that do not contain particulate matter and that do not condense to a liquid or solid phase when released at high pressure, e.g. clean dry nitrogen, unless it can be shown that a hazardous potential will not be reached.

25.5.2 Wet steam should not be used for inerting a vessel containing a flammable mixture of any kind. Dry steam is acceptable provided that all condensed water is removed from the lines prior to the inerting operation.

25.5.3 Whatever substance is used for inerting, it is advisable to introduce it slowly through a large orifice, to minimize the pick-up of dirt and scale from the lines and to avoid raising dust or spray by direct impingment after the gas has entered the vessel.

26 Spraying of paints and powders

26.1 General

The clouds of droplets or particles produced by paint or powder spraying are frequently highly charged. Both the spraying equipment and any object within range of the spray may become charged. There may then be a risk of physiological shock, and there will be an ignition hazard if the cloud of droplets or particles is flammable.

These problems are normally present with airless and electrostatic processes but the level of charging with air-atomizsed spraying equipment is usually not high enough to cause concern. However, if sparking or electric shocks are encountered, air-atomised equipment should be submitted to the same precautions as other types of spraying equipment. These precautions are given in **26.2**, **26.3** and **26.4**.

It is emphasized that spraying operations often involve the production of flammable atmospheres and the prevention of electrostatic hazards should not be considered in isolation. Precautions against a wider range of hazards are available in other publications (see BS 6742).

26.2 Earthing

The spraying equipment and all metallic objects in the vicinity of a paint or powder cloud should be earthed (see clause **13** of BS 5958-1:1991). It should be ensured that personnel operating the equipment do not present an ignition risk (see **31.3.1**).

It is very important to earth the object being sprayed and it should be remembered that deposits laid down during spraying may tend to destroy the earth connection. This problem may be overcome by the design of jigs and/or by the provision of automatic earth checking devices.

26.3 Spraying of high resistivity objects

Objects made from high resistivity materials should not be sprayed with electrostatically charged paints. There is much less hazard with powder spraying but the degree of hazard should be checked.

26.4 Plastics spray cabinets

Spray cabinets of high resistivity materials should not be used in the spraying of flammable paints, and they should be used with powders only if it can be shown that there is no ignition risk. Cabinets of conductive material are acceptable with all types of spray, provided that they are earthed.

27 Rigid plastics sheeting, walls and screens

27.1 General

Rigid plastics sheeting for wall cladding, internal room screens, etc. (referred to subsequently as sheeting) does not readily accumulate electrostatic charge in normal use. However, sheeting made from high resistivity materials can become charged by rubbing of the surface and by other generating processes, such as paint spraying or steam impingement. In such situations there is a possible ignition hazard if a flammable atmosphere is present. Generally, the items being considered form part of a building and severe restraints are then placed on the occurrence of flammable atmospheres.

To avoid these ignition hazards the recommendations given in **27.2**, **27.3** and **27.4** should be followed.

In the case of sheeting of high resistivity materials, precautions are considered in terms of the hazardous zones defined in Part 1 (see **2.12** of BS 5958-1:1991).

27.2 Sheeting made from conductive materials

There is no electrostatic ignition hazard in connection with sheeting made from conductive non-metallic materials (see **10.3.2** of BS 5958-1:1991) provided that it is earthed. The resistance between every point on the surface and earth should not exceed $10^8\ \Omega$, as measured by the test procedure described in **A.7** of BS 5958-1:1991.

27.3 Sheeting made from high resistivity materials

27.3.1 In Zone 0 areas the use of sheeting made from high resistivity materials is not recommended.

27.3.2 In Zone 1 and Zone 2 areas such sheeting is acceptable provided that the charge generation from any source is small and gives rise to an acceptably low ignition risk, equivalent to that from Zone 2 electrical equipment. In many cases it will be obvious that no significant charge generation will occur. If there is any doubt it is recommended that expert advice should be sought before high resistivity sheeting is used in Zone 1 and Zone 2 areas.

27.3.3 In Zone 1 and Zone 2 areas any metallic component mounted on the sheeting should be earthed and precautions should be taken to see that isolated conducting areas are not produced by deposits on the surface, if it is considered that either could accumulate a dangerous level of charge.

27.4 Sheeting incorporating conducting elements

27.4.1 The electrostatic hazard from high resistivity materials is minimized in some types of sheeting by the incorporation in them of a conducting grid or support (usually metallic) or a plastics laminate, throughout the area of the sheet (see **10.3.6** of BS 5958-1:1991).

27.4.2 The conducting element and any metallic components mounted on the sheeting should be earthed.

27.4.3 Although rubbing may generate sufficient charge on the surface to give an incendive discharge, the probability that this will occur in normal practice is low. Where processes with a very high rate of charge generation, such as electrostatic spraying, occur, this type of sheeting should not be used if there is any possibility of the presence of a flammable atmosphere.

28 Processing of flexible sheet or film materials

28.1 General

High resistivity sheet and film materials, including many papers, plastics and textiles, readily acquire electrostatic charge during manufacture and conversion processes. Mere contact with a metal roller generally leaves charge on the surface of the material; the metal takes the complementary charge, which rapidly dissipates provided that the machinery is properly earthed. The major problems caused by charges on sheets and films are ignitions of flammable atmospheres, physiological shock, handling difficulties, and dirt and dust attraction.

Examples of these problems are as follows:

a) accumulation of charged material on wind-up reels, causing shocks to personnel at reel change;

b) charging of unearthed metal parts by passage of film over guides and rollers, leading to spark discharges liable to ignite volatile solvents; personnel may also become charged by induction as well as by charge transfer from the film material;

c) disruption of stacking by mutual repulsion of charged sheets;

d) clinging of thin films to metal rollers, etc.;

e) quality degradation by attraction of dirt and dust to charged surfaces during coating.

To avoid such problems the recommendations in **28.2** and **28.3** should be followed, as appropriate.

28.2 Earthing

28.2.1 All metallic parts of machinery should be earthed. If a flammable atmosphere may be present, non-metallic components, such as rollers, conveying tapes and trays or containers for sheets and cut-offs, should be conductive and, where possible, should have a resistance to earth less than 10^6 Ω. Nevertheless, it should be noted that earthing of metal rollers does not prevent the charging of the high resistivity sheet or film itself.

28.2.2 It should be ensured that personnel working on or passing near the machinery do not present an ignition risk (see **31.3.1**).

28.3 Control of charge on the material

28.3.1 The operating conditions of the machinery should be chosen to minimize electrostatic charging. Thus, excessive running speeds and, very importantly, sticking rollers should be avoided. Any friction between a sheet and its conveying and guiding system should be reduced by reducing the area of contact as much as possible, e.g. by using corrugated surfaces. The pressure between rollers of drive nips should be kept as low as is consistent with preventing any slip.

28.3.2 Hydrophylic materials, e.g. cellulosics, including cotton and paper, should have the highest moisture content compatible with process efficiency.

28.3.3 It may be possible to increase the conductivity of some sheet or film materials by the use of antistatic additives. As most antistatic agents depend on water absorption to enhance their ionic conduction, low relative humidity should be avoided when they are employed. In some circumstances it may be acceptable to use a conducting composite, e.g. containing carbon black, where conduction is independent of humidity.

28.3.4 High charges are often imparted to sheet or film materials either deliberately, e.g. in electrostatic "pinning" to enhance grip between the material and a roller or base plate, or as a side effect of an electrical process, e.g. in electrical discharge ("corona") treatment which is commonly used to improve adhesion to plastics. It is then essential to neutralize these charges as soon as possible, and especially before the material passes forward to a printing or coating unit where any flammable solvent is used.

28.3.5 Neutralization of charge on the surface of sheet or film materials may be readily accomplished by means of a static eliminator based on air ionization (see **10.3.4** of BS 5958-1:1991). The choice of eliminator depends mainly on the application concerned, but in many cases a simple passive type is all that is necessary to prevent incendive discharges taking place. Where a passive eliminator will not work, e.g. in the confines of metal machinery, a high-voltage eliminator should be tried. For efficient working of any eliminator it is necessary to site the eliminator opposite "free web" as far away from earthed metalwork as possible, so as not to detract from the self-field of the charge being neutralized to the eliminator. Performance is critically dependent on distance from the film; too far away and neutralization is incomplete, too near and overcompensation occurs. The final setting (usually in the range 10 mm to 50 mm) is best obtained with the aid of a field meter to test for charge left on the film. Eliminators should be used singly; it is neither necessary nor desirable to have eliminators facing both sides of the film in order to achieve neutralization. It is, however, preferable to have the single eliminator facing that side of the film which carries the charge. Special eliminators are available for fast production lines and for the changing geometry of stacking and reeling operations.

29 Explosives manufacture, handling and storage

29.1 General

For the purposes of this clause, explosives are materials defined as such in the Explosives Acts 1875 and 1923, etc. Static electricity accumulated on insulated conductors or personnel may cause the ignition of explosives with possibly severe or even catastrophic results. There are various types of explosives (solid powder or liquid) and they may be encountered in many forms, such as bulk, bagged, plastics, pelletted, compacted, moulded or filled into metal or plastics containers. Before handling or processing explosives, consideration should be given to the specific recommendations given in **29.2** to **29.4**, but in addition reference should be made to those clauses of this Part of BS 5958 that are relevant to the particular operations to be performed.

The energy required in a spark to cause ignition of an explosive varies with the type of explosive and its physical state. In general, primary explosives are much more sensitive than propellants or high explosives, while pyrotechnics exhibit a wide range of sensitivity.

The extent of the precautions that should be applied depends upon the minimum spark energy for ignition, and explosives may be divided into three classes depending upon this minimum spark energy. It is essential to understand that the minimum spark energy for ignition of explosives is measured by means of a specialized test carried out by the Explosives Inspectorate. It is not the minimum ignition energy test described in **A.6** of BS 5958-1:1991, which should never be used with explosives.

The three classes of explosives and the precautions that should be adopted for them are given in **29.2**, **29.3** and **29.4**. The recommendations are based upon information published by the Ministry of Defence[10] and there should be no deviation from them without taking expert advice. Specialized earthing techniques are used in the explosives industry for sensitive or very sensitive explosives; information may be obtained from the Explosives Inspectorate.

29.2 Comparatively insensitive explosives

29.2.1 These materials have a minimum spark energy for ignition greater than 450 mJ and the first degree precautions given in **29.2.2** are sufficient when they are handled.

29.2.2 All large conducting objects, such as fixed plant and equipment and pneumatic systems, should be earthed. Where the earthing is by means of metallic conductors the resistance to earth should be less than 10 Ω. Conductive or antistatic non-metallic materials may also be used for earthing. (See clause **13** or BS 5958-1:1991.)

29.3 Very sensitive explosives

29.3.1 The minimum spark energy for ignition of these materials is up to and including 1 mJ and the full second degree precautions given in **29.3.2** to **29.3.7** inclusive are required.

29.3.2 All equipment, including movable and portable items, should be earthed. High resistivity materials should be rigorously excluded.

[10] Ministry of Defence. Sensitiveness Collaboration Committee. *Manual of Test, Explosives Hazards Assessment*. Publication No. 3.

29.3.3 All personnel should be earthed by means of conducting floors and footwear (see clause **31**). A personnel resistance monitor (**A.8** of BS 5958-1:1991) should be installed at every entrance to any area where such footwear is required. When handling compositions having ignition energies of less than 100 μJ, consideration should be given to the installation of personnel resistance monitors at the individual work stations.

29.3.4 Outer clothing should not be made from high resistivity materials. Clothing should in no circumstances be removed in the area where the explosive is being handled (see clause **32**).

29.3.5 Metallic objects which could act as spark promoters should be avoided, for example rings on personnel, conductive tools or wires.

29.3.6 The relative humidity of the atmosphere should not be less than 65 %.

29.3.7 Care should be taken to prevent a number of small capacitances working together to give a much larger capacitance.

29.4 Sensitive explosives

29.4.1 These are materials with sensitiveness between those dealt with in **29.2** and **29.3**, and have minimum spark energies for ignition greater than 1 mJ and up to and including 450 mJ.

29.4.2 Depending on the properties of the particular explosive and the way in which it is handled, some relaxation of the full second degree precautions given in **29.3** may be acceptable. Specialist advice should be sought to determine the level of precautions applicable to each specific case.

30 Handling of electro-explosive devices

30.1 General

Electro-explosive devices such as electric detonators may inadvertently be ignited by a discharge of static electricity, either through the fusehead or between the metal case and the fusehead. Many electro-explosive devices can be more sensitive to electrostatic energy in this latter configuration. The static electricity may accumulate on insulated personnel as a result of their movements, and personnel and items of equipment may become charged during dust or dry sand storms. Charge may also be generated during the pneumatic loading of bore holes with granular blasting explosives.

Precautions to avoid the hazard are given in **30.2** to **30.5** inclusive and they should be observed at all times when electro-explosive devices are being handled, that is during storage, issue and use.

It should be recognized that there are other sources of hazard when handling electro-explosive devices and appropriate manuals should be consulted for these, for example the pick-up of energy from sources of electromagnetic radiation (see BS 6656 and BS 6657), testing for continuity of the firing circuit, and procedures for the custody of the exploder key or the exploder.

30.2 Earthing

30.2.1 Personnel should have an adequately conducting path to earth, for example by wearing leather soled footwear, and preferably they should wear cotton type clothing. However, in some environments, for example mines, continuous earthing of personnel may not be feasible, and it is recommended that the procedures in **30.3** and **30.4** should therefore always be followed.

30.2.2 All conducting equipment in the area, such as rails and piping, and all machinery should be earthed. It should be noted that other codes of practice may also require conductors to be bonded to each other to avoid any difference in potential between them which might cause a current to flow through lead wires making contact with them.

30.2.3 If a granular type explosive is being loaded pneumatically into a bore hole, the loading equipment should be earthed. The hose should be semi-conductive and should be connected to earth. Specialized codes of practice exist on this subject and should be consulted.

30.3 Precautions during storage and issue

Electro-explosive devices are received from the manufacturer with the leads folded and wrapped and the bare ends twisted together. If the bare ends are found to be unconnected, the operative should earth himself and reconnect them. If the possibility of significant electro-magnetic fields (see BS 6656 and BS 6657) exists then care will need to be taken to ensure that such procedures do not create a radio frequency ignition hazard. These devices should not be packaged or transported in insulating materials, e.g. polyethylene bags or polystyrene foam packs; the use of metallic or conducting packs is advised for this purpose and these may also provide some protection against any radio frequency hazard.

30.4 Precautions during use

30.4.1 When the firing cable has been laid out the bare wires at each end should be connected to each other and to a suitable earth, such as a metal rod driven into the ground, which should be wetted if very dry. This cable and all other leads should be kept separate from conductors in the area, such as rails and piping.

30.4.2 A check should be made to see that the device leads are connected together. After connecting them if necessary (see **30.3**), they should be earthed to the earth rod or other suitable earth at the firing end. The device leads can then be uncoiled and laid along the ground.

30.4.3 The operative should then make sure that he is earthed before he handles the metal case of the device prior to connecting it to the firing cable.

This is to prevent a discharge from the metal case to the fusehead. The use of insulating or similar self-adhesive tapes near electro-explosive devices is not advisable and should be completely avoided near devices having no-fire energies less than 100 μJ. If used at all, the piece of tape should be removed from the reel before use. Under no circumstances should tape be wound from the reel in the proximity of these devices.

30.4.4 The charge may then be inserted into the bore hole. The device leads and the firing cable wires at the firing end should then be disconnected from earth and connected to each other so that the device is in series with the cable. During this process the operative automatically earths himself on touching the leads prior to disconnection. It is recommended that the device be connected to the firing cable at the firing end before it is inserted into the charge. The operative should earth himself immediately before handling the device case or its leads.

30.4.5 The operative should then retire to the other end of the firing cable. When he is ready to fire he should disconnect the cable leads at the exploder end from earth and connect them to the terminals of the exploder.

30.5 Precautions in adverse weather conditions

Electro-explosive devices should not be used on the approach of and during thunderstorms or during dust or dry sand storms.

31 Earthing of personnel

31.1 General

The human body has a low enough volume resistivity to act as a conductor and if insulated from earth it can accumulate electrostatic charge. The charge may be produced by contact electrification, for example by walking across an insulating floor, or by touching charged equipment or materials. It may also arise by induction due to charge on the clothing or adjacent charged objects (see **12.1** of BS 5958-1:1991).

A troublesome consequence of the electrostatic potential on charged personnel is that it can be high enough to cause damage to electrostatic sensitive devices, such as semiconductors, when these are being handled or assembled (see BS 5783).

A discharge from a charged person can occur on touching any metallic object and a shock may be felt which, although not physically harmful, can be unpleasant. Involuntary reaction, however, can lead to accidents. If a flammable mixture of any kind is present with an ignition energy less than about 100 mJ the discharge may cause ignition (see **12.2.1** of BS 5958-1:1991).

In many situations the resistance of the footwear and flooring is fortuitously low enough to provide adequate earthing. The precautions that should be applied, using special equipment and materials if necessary, are given in **31.2** to **31.5**.

31.2 Precautions in the absence of flammable mixtures

31.2.1 Uncomfortable shocks due to discharges from personnel may be avoided by wearing footwear and using flooring materials such that the total resistance between the body and earth is less than $5 \times 10^9\ \Omega$. Floors of bare concrete, wood or cork are likely to be satisfactory for this purpose, provided that they are kept clean and are not covered by an insulating floor covering. Where a risk of exposure to mains voltage cannot be excluded the resistance to earth should be not less than $5 \times 10^4\ \Omega$.

31.2.2 Disconcerting shocks are experienced by individuals walking on highly insulating floor coverings, usually carpets. Such shocks can be avoided by increasing the conductivity of the floor covering.

31.3 Precautions in the presence of flammable vapours and powders

31.3.1 Where a person may come into contact with a flammable vapour or dust of minimum ignition energy up to and including 100 mJ, it is recommended that he be earthed. This can be achieved by the use of suitable antistatic or conducting footwear and floors (see BS 1870-1, BS 2050 and BS 7193). It is emphasized that conducting footwear should only be used where it is compatible with the substance being processed and in situations where there is no risk of exposure to dangerous electric shock in the event of apparatus becoming defective when operating at voltages of up to 250 V to earth.

31.3.2 The resistance of footwear may increase in use due to continuous flexing and it may decrease because of permeation of perspiration through or around the insole. Both antistatic and conductive footwear should be discarded if their resistance rises above 10^8 Ω. Where a risk of exposure to mains voltage cannot be excluded the footwear should be discarded if its resistance falls below 5×10^4 Ω. The resistance of the footwear while being worn can be measured by means of a personnel resistance monitor of the type described in **A.8** of BS 5958-1:1991.

31.3.3 The electrical requirements for conducting and antistatic flooring materials are given in BS 2050. The properties required for conducting floors after laying are given in BS 3187 which, however, does not deal with antistatic floors, although the test methods in BS 3187 are applicable to both types of floor. It is emphasized that conducting floors should only be installed where there is no danger of exposure to mains voltage. The flooring should not raise the total resistance between the person and earth above 10^8 Ω. Deposits of insulating contaminants on the floor, such as oil or high resistivity powder, should be removed. Where there is any doubt about the resistance between the person and earth it may be measured by means of a suitably modified personnel resistance monitor of the type described in **A.8** of BS 5958-1:1991.

31.3.4 If the flammable mixture is confined to a limited area, for example near a vessel containing a flammable liquid, it may be sufficient to render only a small area of the floor conductive. One method is to provide an earthed metal plate for the person to stand on.

31.4 Precautions for highly sensitive materials

31.4.1 In areas where materials, such as some explosives or oxygen enriched flammable mixtures, are present conducting footwear as described in BS 1870-1, BS 2050 and BS 7193 should be worn. It is emphasized that conducting footwear should be used only where there is no danger of exposure to mains voltage. The footwear should be discarded when its resistance rises above 10^6 Ω.

31.4.2 The flooring should not raise the total resistance between the person and earth above 10^6 Ω. Special requirements for hospitals are described in BS 2050. The floor should be cleaned frequently to ensure the absence of insulating contaminants, such as oil or high resistivity powder. A regular check should be made on the resistance between the person and earth by means of a suitably modified personnel resistance monitor of the type described in **A.7** of BS 5958-1:1991.

31.5 The handling of electrostatic sensitive devices

The special precautions that should be applied in the handling and assembly of electrostatic sensitive devices are given in BS 5783.

32 Hazards from clothing

32.1 General

Clothing on the body can readily acquire an electrostatic charge when, e.g. it rubs or presses against an external surface. Also, if an outer garment is removed, charge may be produced on the remaining clothing and on the garment that has been removed. The charged clothing on the body induces a similar charge on the body which will remain for some time if the person is insulated from earth by the footwear or the floor. Discharges may occur between the body, or the clothing on the body, or the clothing removed from the body and any conductor with which they happen to make contact. The charge on the body can be eliminated by earthing (see clause **31**) but in some circumstances charge can still remain on the clothing. Discharges from the clothing may be sufficient to cause ignitions and the voltage may be high enough to damage electrostatic sensitive devices, such as semiconductors, when they are being handled.

Precautions to avoid hazards due to the clothing are given in **32.2** to **32.6** inclusive which should be read in conjunction with **31.3**.

32.2 Precautions with materials with minimum ignition energies greater than 0.2 mJ

Any garment, including those made from high resistivity materials, such as some synthetic fibres and coated fabrics, may be worn in the presence of mixtures in air of vapours, powders or dusts with minimum ignition energies greater than 0.2 mJ, provided that the resistance between the person and earth complies with **31.3**.

32.3 Precautions for highly sensitive flammable materials

32.3.1 Where materials with minimum ignition energies up to and including 0.2 mJ may be present, such as some explosives and oxygen enriched flammable mixtures, the resistance between the person and earth should comply with **31.4**.

32.3.2 Garments should not be worn in these situations if their surface resistivity is greater than 5×10^{10} Ω. Natural fibres, such as cotton, flax or linen, meet this requirement provided that the relative humidity is moderately high, say 65 % or more, and the temperature is about 20 °C. Many synthetic fibres and coated fabrics should be used only if they have been treated as described in **32.3.3** to reduce their surface resistivities below 5×10^{10} Ω. There are special requirements for hospitals which are described in BS 2050. The surface resistivities of garment materials may be measured using the method given in **A.9** of BS 5958-1:1991 with specimens conditioned at the minimum relative humidity expected in the working environment.

32.3.3 The simplest and most widely used method of reducing the electrostatic charge on fabrics is to apply an antistatic finish which reduces the surface resistivity. Some of these finishes are effective on a range of different fibres, while others are specific to only a few types of fibre. Most antistatic finishes function for only a limited period and they should therefore be applied at regular intervals, at least every time the garment is washed. Because the majority depend upon moisture from the atmosphere they are most effective in humid conditions.

32.3.4 Good antistatic properties can be achieved by introducing a small proportion of highly conducting fibres into fabrics. Such materials have the advantage over the antistatic finishes described in **32.3.3** that they are resistant to repeated washings and are effective in warm, dry conditions.

32.4 Removal of clothing

Garments should not normally be removed in the presence of a flammable vapour/air mixture, powder or dust.

32.5 Gloves

When gloves satisfying other safety requirements are used for handling metallic or conductive objects in the presence of a flammable mixture of any kind, either the gloves should be of conductive or antistatic material or the objects should be earthed, for example by means of an earthed clip lead. The resistance between each object and earth should not exceed 10^8 Ω for mixtures in air of materials with minimum ignition energies greater than 0.2 mJ, and 10^6 Ω for those with minimum ignition energies up to and including 0.2 mJ.

32.6 Handling of electrostatic sensitive devices

The special precautions that should be applied in the handling and assembly of electrostatic sensitive devices are given in BS 5783.

33 Vacuum filter

33.1 General

The process involves the separation of solid and liquid phases from a slurry by vacuum. The filtrate is pulled through leaving a moist cake on the filter bed. The cake is sometimes washed with a solvent before it is removed manually with a scoop or shovel. The processes of filtration, washing and scooping may give rise to generation of static electricity that can be a potential source of ignition in the presence of a flammable solvent vapour. Clauses **33.2** and **33.3** consider these three processes and recommendations are made for the elimination of electrostatic ignition hazards when there is the possibility of existence of a flammable atmosphere. Other sources of ignition should also be considered, e.g. thermal decomposition.

33.2 Filtration and washing

If all components are fabricated from conducting materials there is no electrostatic ignition risk during the filtration and washing processes provided all such parts are earthed. If the filter contains non-conducting, high resistivity components, earthing alone may not remove the electrostatic hazard and each situation should be individually assessed.

33.3 Scooping/digging out process

33.3.1 *All conducting components*

33.3.1.1 *General*

The solvent is considered conducting when its conductivity is 50 pS/m or greater. The filter cloth and cake are considered conducting when their surface resistivity is 10^{10} Ω or less. Low resistivity may be a property of cloth or cake or may be achieved when these items are wetted with a conducting solvent. Precautions relating to filter bed, scoop/shovel and an operator are given in **33.3.1.2** to **33.3.1.4**.

33.3.1.2 *Filter bed*

There is no risk of incendive discharges from the filter bed when solvent, cake, filter cloth and filter cloth support are conducting and earthed.

33.3.1.3 *Scoop/shovel*

An earthed conducting scoop/shovel should be used.

33.3.1.4 *Operator*

The operator should wear antistatic or conducting footwear (see **31.3.1**) and should be grounded by standing on an earthed conducting floor or earthed metal plate. If gloves are worn, these should also be conducting or antistatic.

33.3.2 ***Non-conducting cake or filter or liquids***

33.3.2.1 *Filter bed*

An incendive discharge may arise when the cake or filter cloth is non-conducting. Safety should be based on explosion prevention and protection.

The use of a non-conducting liquid with conducting cake and earthed conducting filter cloth does not give rise to an electrostatic ignition risk.

The use of a conducting filtrate or wash will render the cake and filter conducting and prevent incendive discharges from the bed provided all conducting parts are earthed. A non-conducting liquid may be made conducting by using suitable additives.

33.3.2.2 *Scoop/shovel*

An earthed conducting scoop/shovel should be used.

33.3.2.3 *Operator*

The operator should wear antistatic or conducting footwear (see **31.3.1**) and should be grounded by standing on an earthed conducting floor or earthed metal plate. If gloves are worn, these should also be conducting or antistatic.

34 Centrifuge operation

34.1 General

The process involves the separation of solid and liquid phases from a slurry by centrifugal forces. The filtrate is pulled through leaving a cake on the filter cloth of a spinning basket. The cake is sometimes washed with a solvent before being ploughed off or dug off. Even after ploughing, a heel may need to be manually dug out.

The processes of filtration, washing and digging out may give rise to the generation of static electricity which can be a potential source of ignition in the presence of a flammable atmosphere. The recommendations given in **3.2**, **3.3** and **3.4** should be implemented to eliminate the electrostatic ignition hazard. Other sources of ignition should also be considered, e.g. bearing failure, frictional sparking, and overheating.

It is common practice to operate centrifuges with inert gas protection during filtration and washing where low flash-point solvents are in use, and this eliminates the need for precautions against electrostatic hazards other than the earthing of conductors.

Clause **34** considers the precautions against electrostatic hazards in the centrifuge operation. Consideration should also be given to the electrostatic hazard that might arise during the flow of liquids into and out of the centrifuge (see clauses **3**, **4**, **11**, **12**, **16**, **17** and **19**).

34.2 Filtration and washing

If all component materials, liquids, cake and filter are conducting, there is no electrostatic ignition risk during the filtration and washing processes provided all such parts are earthed. If the centrifuge contains non-conducting materials, earthing alone may not remove the electrostatic hazard and each situation should be individually assessed.

34.3 Scooping/digging out process

34.3.1 ***All conducting components***

34.3.1.1 *General*

The solvent is considered conducting when its conductivity is 1 000 pS/m or greater. The filter cloth and cake are considered conducting when their surface resistivity is 10^{10} Ω or less. Low resistivity may be a property of cloth or cake or may be achieved when they are wetted with a conducting solvent. Precautions relating to filter bed, scoop/shovel and an operator are given in **34.3.1.2** to **34.3.1.4**.

34.3.1.2 *Filter bed*

There is no electrostatic risk from the filter bed when solvent, cake, filter cloth and centrifuge basket are conducting and earthed.

34.3.1.3 *Scoop/shovel*

An earthed conducting scoop/shovel should be used.

34.3.1.4 *Operator*

The operator should wear antistatic or conducting footwear (see **31.3.1**) and should be grounded by standing on an earthed conducting floor or earthed conducting plate. If gloves are worn, these should also be conducting or antistatic.

34.3.2 ***Non-conducting cake or filter or liquids***

34.3.2.1 *Filter bed*

An electrostatic ignition hazard may arise when cake or filter cloth is non-conducting. Safety should be based on explosion prevention and protection.

The use of a non-conducting liquid with conducting cake and earthed conducting filter cloth does not give rise to an electrostatic ignition risk.

The use of a conducting filtrate or wash will render the cake and filter conducting and prevent incendive discharges from the bed provided all conducting parts are earthed. A non-conducting liquid may be made conducting by using suitable additives.

34.3.2.2 *Scoop/shovel*

An earthed conducting scoop/shovel should be used.

34.3.2.3 *Operator*

The operator should wear antistatic or conducting footwear (see **31.3.1**) and should be grounded by standing on an earthed conducting floor or earthed conducting plate. If gloves are worn, these should also be conducting or antistatic.

35 Flaker

35.1 General

The flaking process involves the rotation of a cooled metal drum passing through a molten material. A thin layer of solid forms on the drum which is removed with a sharp knife. The film breaks up into flakes and falls into a collection hopper placed directly below the scraping point.

In the flaking operation the bulk of the material is in the form of flakes but the process may have associated with it some fine dust or flammable vapour. Where this occurs consideration should be given to the hazards from static electricity.

This process can generate electrostatic charges on the drum, knife, flakes, dust and collecting hopper. An electrostatic ignition hazard may arise from drum, knife, flakes, film at the point of flaking and collecting hopper in the presence of a flammable atmosphere. Recommendations given in **3.2**, **3.3** and **3.4** inclusive should be followed to avoid an electrostatic ignition.

35.2 Elimination of hazard from isolated conductors

All conducting parts including drum, knife and the collecting hopper should be securely earthed. This will eliminate the risk of electrostatic discharges from conductors.

35.3 Elimination of hazard from flakes

35.3.1 The bulking of electrostatically charged flakes with resistivity less than 10^9 Ω m in a conductive, unlined, earthed hopper will not accumulate significant charge. There will be no risk of electrostatic discharges under these circumstances.

35.3.2 The bulking of electrostatically charged flakes having resistivity greater than 10^9 Ω m could present an ignition risk. Under these circumstances it is recommended that explosion prevention and protection should be provided, unless it can be demonstrated that no electrostatic hazard exists and no other sources of ignition are present, e.g. friction.

35.4 Elimination of hazard from discharges from drum/flake interface

Electrostatic discharges can occur at the point of separation of flake from the drum. The igniting power of such discharges is not known at present.

It is recommended that when the minimum ignition energy of the flammable atmosphere is less than 25 mJ, then explosion prevention and protection should be considered.

There is no electrostatic hazard when the minimum ignition energy of the flammable atmosphere is greater than 25 mJ.

36 Dust collectors

36.1 General

The movement of dust particles through ducts can lead to particles bcoming electrostatically charged. An electrostatic ignition risk may arise from accumulated charge on unearthed metal parts, filter bags and the powder itself.

Explosive dust concentrations are often present, particularly during filter cleaning and shaking. As the dust collector is subject to various ignition sources that cannot be completely eliminated, e.g. burning material, frictional heating, the primary basis for safety is the provision of appropriate explosion protection, e.g. explosion relief vents.

Clause **36.2** is concerned with the control of electrostatic ignition source. When dust collectors are fitted with explosion protection the implementation of the following clauses minimizes the electrostatic ignition hazard.

36.2 Precautions for explosion-protected dust collectors

36.2.1 ***Metal components***

The risk of electrostatic sparks from isolated conductors should be removed by ensuring good earthing of all metal parts of the dust collector.

36.2.2 ***Filter bags***

Normally the use of antistatic filter bags with explosion protected dust collectors is not required because of the low risk of ignition. In situations where flammable vapour atmospheres are present, the risk can be further reduced by the use of antistatic or conducting filter bags. It is essential that when antistatic or conductive bags are used the conducting elements, e.g. metal filaments, fibres, yarns be earthed.

Publication(s) referred to

BS 1435, *Rubber hose assemblies for oil suction and discharge services.*

BS 1870, *Safety footwear.*

BS1870-1, *Specification for safety footwear other than all-rubber and all-plastics moulded types.*

BS 2050, *Specification for electrical resistance of conducting and antistatic products made from flexible polymeric material.*

BS 3158, *Specification for rubber hoses and hose assemblies for aircraft ground fuelling and defuelling.*

BS 3187, *Specification for electrically conducting rubber flooring.*

BS 4089, *Specification for hoses and hose assemblies for liquefied petroleum gas.*

BS 5173, *Methods of test for rubber and plastics hoses and hose assemblies.*

BS 5173-104.1, *Measurement of electrical resistance of hoses and hose assemblies.*

BS 5173-104.2, *Measurement of electrical continuity and discontinuity of hoses and hose assemblies.*

BS 5351, *Specification for steel ball valves for the petroleum, petrochemical and allied industries.*

BS 5783, *Code Of practice for handling of electrostatic sensitive devices.*

BS 5842, *Specification for thermoplastic hose assemblies for dock, road and tanker use.*

BS 5958, *Code of practice for control of undesirable static electricity.*

BS 5958-1, *General considerations.*

BS 6651, *Code of practice for protection of structures against lightning.*

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