# CHAPTER 3

# Static Electricity



This chapter looks at hazards associated with the generation of static electricity during the handling of cargo and bunkers and during tank cleaning, dipping, ullaging and sampling. Section 3.1 introduces some basic principles of electrostatics in order to explain how objects become charged and to describe the effect of those charges on other objects in close proximity.

The risks presented by static electricity discharges are at their greatest where a flammable atmosphere may be present and there are multiple factors that may create the right environment for an electrostatic discharge, making them difficult to predict.

Although most likely during cargo loading, electrostatic discharges can happen during cargo and bunker transfer operations.

The only way to safely manage the risks from electrostatic discharge is to control the operation in line with established procedures and to follow the precautions in this chapter.

The main precaution for ships against electrostatic risks is to conduct operations with the tanks protected by IG. For tanks that are not protected by IG, section 3.2 describes, in general terms, precautions against electrostatic discharges (see chapter 12 for more detail). Section 3.3 considers other possible sources of electrostatic hazards during operations.

Some bunker fuels (e.g. low sulphur diesels) may be classified as static accumulators, and some bunker tank and piping configurations may introduce factors that could influence the generation of electrostatic risks outlined in this chapter. While the conditions may not present the same level of risk as in a cargo loading scenario, under certain circumstances the risk of electrostatic discharge (see section 3.1.4) should still be considered possible.

If some or all of the risk factors in this chapter exist, it is recommended that ship operators follow the precautions outlined. Where a possible exposure exists, a full risk assessment should be undertaken to ensure the factors influencing that electrostatic risk and the precautions necessary are considered in full.

# 3.1 Principles of electrostatics

## 3.1.1 Summary

Static electricity presents fire and explosion hazards during the handling of petroleum products and during other operations such as tank cleaning, dipping, ullaging and sampling. Certain operations can give rise to accumulations of electric charge that may be released in electrostatic discharges with enough energy to ignite flammable hydrocarbon gas/air mixtures. There is no risk of ignition unless a flammable mixture is present. Where there is a flammable mixture, three additional physical processes are involved in creating a potential electrostatic hazard:

- Charge separation.
- Charge accumulation.
- Breakdown/electrostatic discharge.

The potential for an electrostatic ignition can be minimised by managing any or all these physical processes or by eliminating the flammable atmosphere.

Electrostatic discharges can occur as a result of accumulations of charge on:

- Liquid or solid non-conductors, for example a static accumulator oil (such as kerosene) loaded into a tank, a non-conductive plastic pipe or a synthetic rope.
- Electrically insulated liquid or solid conductors, for example mists, sprays or particulate suspensions in air, or an unbonded metal rod hanging on the end of a rope.

The principles of electrostatic hazards and the precautions to be taken to manage the risks are described below. See also the guidelines published by the IEC, including the current editions of IEC TS 60079-32-1 *Explosive atmospheres – Part 32-1: Electrostatic hazards – Guidance* and the National Fire Protection Association's (NFPA) *77: Recommended Practice on Static Electricity* for more information.

## 3.1.2 Charge separation

Whenever two dissimilar materials come into contact, charge separation occurs at the interface.

The interface may be between two solids, a solid and a liquid or two liquids. At the interface, a charge of one sign (say positive) moves from material A to material B so that materials A and B become respectively negatively and positively charged.

While the materials stay in contact and immobile relative to one another, the charges are extremely close together. The voltage difference between the charges of opposite sign is then very small and no hazard exists. However, when the materials move relative to one another, the charges can be separated and the voltage difference increased.

The charges can be separated by many processes, which include but are not limited to:

- The flow of liquid petroleum through pipes.
- The flow of liquid through fine filters (less than 150 microns).
- Contaminants, such as water droplets or rust moving relative to a liquid as a result of turbulence in the liquid as it flows through pipes.
- Particles inside a pipeline (rust, sand, sediments, water and ice) travelling at high speed when cargo lines are blown with compressed air.
- The settling of a solid or an immiscible liquid through a liquid (e.g. water, rust or other particles through petroleum). This process may continue for up to 30 minutes after completion of product transfer into a tank.
- Gas bubbles rising through a liquid (e.g. air or IG introduced into a tank by the blowing of pipelines, or vapour from the liquid itself, released when pressure is dropped). This may also continue for up to 30 minutes after completion of product transfer into a tank.

- Turbulence and splashing in the early stages of transfer of a liquid into an empty tank. This can charge the liquid and can generate mist that could be charged and can increase the flammability of the vapour space above the liquid.
- The ejection of particles or droplets from a nozzle (e.g. during steaming operations or injection of IG).
- The splashing or agitation of a liquid against a solid surface (e.g. water washing operations or the sloshing of product in a part-filled tank).
- The vigorous rubbing together and subsequent separation of certain synthetic polymers (e.g. the sliding of a polypropylene (PP) rope through gloved hands).

## 3.1.3 Charge accumulation

### 3.1.3.1 General

When separated charges collect, e.g. in a tank, it is called charge accumulation. When accumulation occurs, large voltage differences and high electric fields can develop both within the material containing charge and in the neighbouring space (electric fields are just the rate of change of voltage).

High electric fields can cause electrical breakdown and discharge and high voltages can induce charge on conductors (see section 3.1.4.2). Examples of accumulation are:

- The charge on a petroleum liquid in a tank during and after filling. This generates voltages and electrostatic fields throughout the tank, both in the liquid and in the ullage space.
- The charge on a water mist formed by tank washing. This also generates voltages and electrostatic fields throughout the tank.

Charges that have been separated attempt to recombine and to neutralise each other. This process is known as charge relaxation. If one or both of the materials carrying the separated charges is a poor electrical conductor, recombination is impeded and the material can retain charge for a significant period of time. Accumulation occurs if the separation mechanism (charging process) remains active and adds more charge during this retention period. The retention period is characterised by the relaxation time of the material, which is related to its conductivity; the lower the conductivity, the longer the relaxation time. This is not to be confused with the settling time (see section 12.8.2.3).

When a material is classed as having high conductivity, its electrical conductivity is high enough that, if the material is earthed, the amount of charge required to maintain it at earth potential will flow almost instantaneously between the material and earth. If bonding rather than earthing is used, charges flow to keep the material at the same potential as the rest of the system rather than at earth potential. An earthed conductive material will remain at earth potential irrespective of any charge separation processes that act on it (see section 3.1.4.2). A charge capable of changing its potential from earth can only be passed to such a material if it is insulated from earth by a poorer conductor. The transfer of charge to or from the high conductivity material is then hindered by the resistance of the poorer conductor and charges capable of producing high voltages may accumulate. This illustrates the importance of earthing/bonding.

The important factors governing relaxation are, therefore, the electrical conductivities of:

- The separated materials (liquid or solid).
- Other materials nearby, such as the ship's internal structure.
- Additional materials that may be interposed between the materials after their separation.

Refined clean products tend to have very low conductivity and the relaxation time can be longer than a minute for these products.

### 3.1.4 Electrostatic discharge

Electrostatic discharge occurs when the electrostatic field becomes too strong and the electrical resistance of an insulating material suddenly breaks down. When breakdown occurs, the gradual flow and charge recombination associated with relaxation is replaced by sudden flow recombination that generates intense local heating (e.g. a spark) that can be a source of ignition if it occurs in a flammable atmosphere. Although all insulating media can be affected by breakdowns and electrostatic discharges, the main concern for ship operations is the prevention of discharges in air or vapour to avoid sources of ignition.

Electrostatic fields in tanks or compartments are not uniform because of tank shape and the presence of conductive internal protrusions, such as probes and structure. The field strength is enhanced around these protrusions and, consequently, that is where discharges generally occur. A discharge may occur between a protrusion and a surface or solely between a conductive protrusion and the space in its vicinity, without reaching another object.

### 3.1.4.1 Types of discharge

Electrostatic discharge can take the form of a corona, a spark, a brush discharge or a propagating brush discharge, as described below.

| | | |
|---|---|---|
| **Corona** | A diffuse discharge from a single sharp conductor that slowly releases some of the available energy. | Incapable of igniting a gas, such as propane, or a vapour such as gasoline. |
| **Spark** | An almost instantaneous discharge between two conductors at different voltages (e.g. when one is affected by the mechanisms described in section 3.1.4.2). Virtually all the stored energy arising from the voltage difference between the conductors is converted into heat that is available to ignite a flammable atmosphere.<br>Examples of a spark are discharges between:<br>• An unearthed conductive object floating on the surface of a charged liquid and the adjacent tank structure.<br>• Unearthed conductive equipment suspended in a tank and the adjacent tank structure.<br>• An earthed surface and conductive tools or materials left behind after maintenance when insulated by a rag or piece of lagging. | Sparks may be energetic enough to ignite all types of flammable mixture, including mists and dust clouds, if various requirements are met. These include:<br>• At least one of the conductors must be unbonded.<br>• A discharge gap short enough to allow the discharge to take place with the voltage difference present, but not so short that any resulting flame is quenched.<br>• There must be enough stored electrical energy to initiate combustion. |
| **Brush discharge** | A diffuse discharge from a highly charged non-conductive object to a single blunt conductor that is more rapid than corona and releases more energy.<br>Examples include discharges between:<br>• Sampling apparatus lowered into a tank and the surface of a charged petroleum liquid.<br>• An earthed conductive protrusion (e.g. fixed tank washing machine) and a charged petroleum liquid being loaded at a high rate. | Able to ignite gases and vapours but not mists or dust clouds (but beware of hybrid mixtures (dust or droplets plus vapours)). |
| **Propagating brush discharge** | A rapid, high energy discharge from a sheet of material of high resistivity and high dielectric strength with the two surfaces highly charged but of opposite polarity. The discharge is initiated by an electrical connection (short circuit) between the two surfaces (caused e.g. by breakdown through the sheet).<br>The bipolar sheet can be in free space or, as is more normal, have one surface in contact with a conducting material (normally earthed).<br>The short circuit can be achieved:<br>• By piercing the surface (mechanically or by an electrical break-through).<br>• By approaching both surfaces simultaneously with two electrodes electrically connected.<br>• When one of the surfaces is earthed, by touching the other surface with an earthed conductor.<br>Increasing the charge until the weakest point of the sheet breaks down. Industry guidelines indicate that propagating brush discharges will not occur with linings that are more than 10mm thick or those that have a breakdown potential of 4kV. On most tankers, the thickness of epoxy coatings is not generally greater than 2mm. (Typically, the dry film thickness of epoxy tank coatings is 0.15mm per coat.) It is expected that the breakdown potential of coatings will be less than 4kV. In case of doubt expert advice should be sought. | Can be highly energetic (1 joule or more) and so will readily ignite a flammable mixture. |

### 3.1.4.2 Voltages on unbonded conductors

There are two main mechanisms by which unbonded conductors can reach a high voltage by contact with a high voltage region:

1. An unbonded conductor that carries no charge is at a similar potential to its surroundings. Therefore, it is raised to a high voltage simply by being in the high voltage region (e.g. near the centre of the surface of a charged liquid or near the centre of a tank containing a charged mist).
2. A conductor that is not securely bonded may become charged by a process called induction if it loses contact with earth while in a high voltage region (e.g. this happens to a segment of a water jet from a cleaning gun as it breaks up). Charge is induced on the conductor while it is earthed and then trapped on the conductor when earth contact is lost. The trapped charge raises the conductor to a high voltage if it moves away from the high voltage region, e.g. towards a tank wall.

A conductor that is raised to a high voltage by one of the above mechanisms may give a spark that can ignite hydrocarbon/air mixtures when it approaches a bonded conductor such as a cleaning gun, the tank base or the tank wall (see section 3.1.4.1).

### 3.1.4.3 Conductivity

Materials and liquid products that are handled by ships and terminals are classified as being:

- Non-conductive.
- Semi-conductive (or dissipative).
- Conductive.

**Non-conductive materials (non-conductors)**

These materials have such low conductivities that once they have received a charge, they retain it for a very long period. Non-conductors can prevent the loss of charge from conductors by acting as insulators. Charged non-conductors can generate incendive brush discharges to nearby earthed conductors and can transfer a charge to, or induce a charge on, neighbouring insulated conductors, causing sparks.

Liquid non-conductors have conductivities of less than 50pS/m (picoSiemens/metre). Such liquids are often referred to as static accumulators.

Petroleum products, e.g. clean oils (distillates) including some low sulphur bunker fuels, frequently fall into this category with typical conductivities being below 10pS/m (relaxation times >2s). Chemical solvents and highly refined fuels can have conductivities less than 1pS/m (relaxation times >20s).

Solid non-conductors include plastics, e.g. PP, PVC, nylon and many types of rubber. Their surfaces can become more conductive if they are contaminated with dirt or moisture. Precautions to be taken when handling static accumulator oils are addressed in section 12.1.7.

**Semi-conductive materials (dissipative materials or intermediate conductors)**

If materials in the intermediate conductivity group are not insulated from earth, their conductivities are high enough to prevent accumulation of an electrostatic charge. However, their conductivities are normally low enough to inhibit production of energetic sparks (e.g. from electric power system faults).

For materials with intermediate conductivities, the risk of electrostatic discharge is small, particularly if the practices in this guide are adhered to, and the chance of the discharge becoming incendive is even smaller. However, caution should still be exercised when dealing with intermediate conductors because their conductivities are dependent upon many factors and their actual conductivity may not be known.

The liquids in this intermediate category have conductivities exceeding 50pS/m and, along with conductive liquids, they are often known as static non-accumulators. Examples of semi-conductive liquids are black oils (containing residual materials) and other liquids with a conductivity below 10,000pS/m.

The solids in this intermediate category generally include such materials as wood, cork, sisal and naturally occurring organic substances. They owe their conductivity to their ready absorption of water and they become more conductive as their surfaces are contaminated by moisture and dirt. However, when new or thoroughly cleaned and dried, their conductivities can be sufficiently low to bring them into the non-conductive range.

**Conductive materials**

Conductors are incapable of holding a charge unless insulated but, if they are insulated, charged, and an opportunity for an electrostatic discharge occurs, all the charge available is almost instantaneously released in the potentially incendive discharge.

For liquids the normal boundary from semi-conductive to conductive is set at 10,000pS/m. Crude oils have a very wide range of conductivities, only some of which are below 10,000pS/m, so they are generally classified as conductive. Most common alcohols are conductive (e.g. methanol and ethanol both have conductivities of more than 106pS/m) as are the whole range of aqueous solutions, including sea water. The human body, consisting of about 60% water, is effectively a liquid conductor.

In the case of solids, metals are conductors.

Table 3.1 provides information on the typical conductivity value and classification for a range of products:

| Product | Typical conductivity (pS/m) | Classification |
|---|---|---|
| Non-conductive | Between 0-50 | Accumulator |
| Benzene | 0.005 | |
| Xylene | 0.1 | |
| Gasoline (straight run) | 0.1 to 1 | |
| Diesel (ultra-low sulphur) | 0.1 to 2 | |
| Lube oil (base) | 0.1 to 1,000* | |
| Commercial jet fuel | 0.2 to 50 | |
| Toluene | 1 | |
| Kerosene | 1 to 50 | |
| Diesel | 1 to 100* | |
| Cyclohexane | Less than 2 | |
| Motor gasoline | 10 to 300* | |
| Semi-conductive | Between 50-10,000 | Non-accumulator |
| Fuel with anti-static additive | 50 to 300 | |
| Heavy black fuel oils | 50 to 1,000 | |
| Semi-conductive crude oil | Less than 10,000 | |
| Bitumen | More than 1,000 | |
| Conductive | More than 10,000 | Non-accumulator |
| Conductive crude oil | More than 10,000 | |
| Alcohols | More than 100,000 | |
| Ketones | 100,000 | |
| Distilled water | 1,000,000,000 | |
| Water | 100,000,000,000 | |

** Some additives used for performance improvement can increase conductivity significantly.*

**Table 3.1:** Typical conductivity of products

## 3.1.5 Electrostatic properties of gases and mists

Under normal conditions, gases are highly insulating and this has important implications with respect to mists and particulate suspensions in air and other gases. Charged mists are formed during the ejection of liquid from a nozzle. Examples include:

- Petroleum products entering an empty tank at high velocity.
- Wet steam condensing.
- Water from tank washing machines.
- Crude oil during COW.

Although the liquid may have a very high conductivity, the relaxation of the charge on the droplets is hindered by the insulating properties of the surrounding gas. Fine particles present in inert flue gas, or created during discharge of pressurised liquid $CO_2$, are frequently charged. The gradual charge relaxation, which does occur, is the result of the settling of the particles or droplets and, if the field strength is high, of corona discharge at sharp protrusions. Under certain circumstances, discharges with enough energy to ignite hydrocarbon gas/air mixtures can occur (see also section 3.3.1).

# 3.2 General precautions against electrostatic hazards

## 3.2.1 Overview

The safest way to protect from electrostatic risks is to conduct operations with tanks protected by IG.

However, if a flammable atmosphere might be present, the following measures should be taken to prevent electrostatic hazards:

- Bond metal objects to the metal structure of the tanker to eliminate the risk of spark discharges between metal objects that might be electrically insulated. This includes the metallic components of any equipment used for dipping, ullaging and sampling.
- Remove any loose conductive objects that cannot be bonded.
- Restrict the product flow to a maximum of 1m/sec at the individual tank inlets, irrespective of design, during the initial stages of product transfer into a tank, until:
  - The filling pipe and any other structure on the base of the tank has been submerged to twice the filling pipe diameter and all splashing and surface turbulence has ceased, and
  - Any water collected in the pipeline has been cleared.
- It is necessary to load at this restricted rate for a period of 30 minutes or until two pipeline volumes (i.e. from delivery tank to ship's tank) have been loaded into the receiving tank, whichever is the lesser.
- Continue to restrict the product flow to a maximum of 1m/sec at the tank inlet for the whole operation unless the product is clean. A clean product, in this context, contains less than 0.5% by volume of free water or other immiscible liquid and less than 10mg/l of suspended solids.
- Avoid splash filling by employing bottom entry using a fill pipe terminating close to the bottom of the tank.
- Not blowing lines using compressed air.

The following additional precautions should be taken against static electricity during ullaging, dipping, gauging or sampling of static accumulator oils:

- Prohibit the use of conductive (metal) ullaging, dipping, gauging or sampling equipment during product transfer into a tank and for 30 minutes after completion of operations to allow the settling of gas bubbles, water or particulate matter in the liquid and the relaxation of any electrical charge. After the 30 minute settling time, metal ullaging, dipping, gauging or sampling equipment may be used but it must be effectively bonded and securely earthed to the structure of the ship before it is introduced into the tank and must remain earthed until after removal.
- Prohibit the use of all non-conductive (non-metal) containers of more than one litre capacity for dipping, ullaging and sampling during loading and for 30 minutes after completion of product transfer into a tank.

Non-conductive (non-metal) containers of less than one litre capacity may be used for sampling in tanks at any time if they have no conducting components and if they are not rubbed prior to sampling. Cleaning, with a high conductivity proprietary cleaner or soapy water, is recommended to reduce charge generation. To prevent charging, the container should not be rubbed dry after washing.

Operations can be carried out at any time through a correctly designed and installed full depth sounding pipe. A significant charge cannot accumulate on the surface of the liquid within the sounding pipe and so waiting time is not required. Precautions to prevent the introduction of charged objects into a tank still apply and if metal equipment is used it should be bonded before being inserted into the sounding pipe.

Detailed guidance on precautions to be taken during ullaging, dipping and sampling of static accumulator oils is given in section 12.8.2. These precautions should be closely followed to avoid the hazards associated with the accumulation of an electrical charge on the cargo.

### 3.2.2 Bonding

The most important countermeasure to prevent an electrostatic hazard is to bond all metallic objects together to eliminate the risk of discharges between objects that might be charged to different voltages if they were electrically insulated. To avoid discharges from conductors to earth, it is normal practice to require bonding to earth (earthing or grounding). On ships, bonding to earth is effectively accomplished by connecting metallic objects to the metal structure of the ship, which is naturally earthed through the sea. Note that the bonding of a ship and terminal structure is not recommended, see section 17.4.4.

Some examples of objects that might be electrically insulated in hazardous situations and which should be bonded are:

- Ship/shore hose couplings and flanges, except:
  - The insulating flange or block.
  - The single length of discontinuous hose.
  - Where the hoses are Grade Ω hoses specially designed to provide electrical discontinuity (see section 18.2).
- Portable tank washing machines, portable oil spill equipment (e.g. Wilden pumps), closed cargo additive doping systems.
- Manual ullaging and sampling equipment with conducting components.
- The float of a permanently fitted ullaging device if its design does not provide an earthing path through the metal tape.

The best method of ensuring bonding and earthing will usually be a metallic connection between the conductors. Alternative means of bonding are available and have proved effective in some applications, for example semi-conductive (dissipative) pipes and O-rings rather than embedded metallic layers, for GRP pipes and their metal couplings.

Any earthing or bonding links used as a safeguard against the hazards of static electricity associated with portable equipment should be connected whenever the equipment is set up and not disconnected until after the equipment is no longer in use.

### 3.2.3 Avoiding loose conductive objects

Every effort should be made to ensure that loose conductive objects that cannot be bonded are removed from the tank. This requires careful inspection of tanks, particularly after shipyard repairs.

Objects that may be insulated during ship operations include:

- A metal object, such as a can, floating in a static accumulating liquid.
- A loose metal object while it is falling in a tank during washing operations.
- A metallic tool, lying on a piece of insulating material, left behind after maintenance.

## 3.2.4 Filters

Three classifications of filter may be used in tanker operations, coarse, fine and microfine.

**Coarse (greater than or equal to 150 microns)**

These do not generate a significant amount of charge and require no additional precautions if they are kept clean.

**Fine (less than 150 microns, greater than 30 microns)**

These can generate a significant amount of charge and require enough time for the charge to relax before the liquid reaches the tank. To allow enough time for the charge to relax, the residence time after passing through fine filters should be a minimum of 30 seconds before the product enters the tank. Flow velocity should be adjusted accordingly.

**Microfine (less than or equal to 30 microns)**

To allow enough time for the charge to relax, the residence time after passing through microfine filters must be a minimum of 100 seconds before the product enters the tank. Flow velocity should be adjusted accordingly.

## 3.2.5 Fixed equipment in tanks

Away from the (earthed) tank walls, the surface of a charged, non-conductive liquid can be at high voltage. This voltage will produce a strong electric field at the tip of any metal protrusion that is near the surface but not close to the wall even if the protrusion is earthed. Protrusions of this type may be associated with equipment mounted from the top of a tank, such as fixed washing machines or high level alarms. During the transfer of static accumulator oils into a tank, this strong electrostatic field may cause electrostatic brush discharges between the protrusion and the approaching liquid surface.

Discharges from metal protrusions of the type described above can be avoided by installing the equipment adjacent to a bulkhead or other tank structure to reduce the electrostatic field at the probe tip. Alternatively, a support can be added that runs from the lower end of the protrusion downward to the tank structure underneath, so that the rising liquid is held at earth potential as it approaches the protrusion. Another possible solution, in some cases, is to construct the probe-like device entirely of a non-conductive material.

## 3.2.6 Free fall in tanks

Ballasting or transferring product into a tank over the top (overall) delivers charged liquid to a tank that may break up into small droplets and splash into the tank. This may produce a charged mist as well as an increase in the petroleum gas concentration in the tank.

Any piping in a tank that does not lead to the bottom of the tank should be directed at the bulkhead and should not be allowed to free fall.

## 3.2.7 Water mists

The spraying of water into tanks, for example during water washing, gives rise to electrostatically charged mist. This mist is uniformly spread throughout the tank being washed.

The electrostatic levels vary widely from tank to tank, both in magnitude and in polarity.

When washing begins in a dirty tank, the charge in the mist is negative, reaches a maximum negative value, then goes back through zero and finally rises towards a positive equilibrium value. Among the many variables affecting the level and polarity of charging, the characteristics of the wash water and how clean the tank is are the most significant influences. The electrostatic charging characteristics of the water are altered by recirculation or by the addition of tank cleaning chemicals, either of which may cause very high electrostatic potentials in the mist and which are higher in large tanks than small ones. The size and number of washing machines in a tank affect the rate of change of charge, but they have little effect on the final equilibrium value.

The charged mist droplets created in the tank during washing give rise to an electrostatic field, which is characterised by a distribution of potential (voltage) throughout the tank space. The bulkheads and structure are at earth (zero) potential and the space potential increases with distance from these surfaces and is highest at points furthest from them. The field strength, or voltage gradient, in the space is greatest near the tank bulkheads and structure, particularly where there are protrusions into the tank. Around relatively sharp protrusions, if the field strength is high enough, electric breakdown occurs into the space, giving rise to a corona. Because sharp protrusions cause concentrations of field strength, a corona occurs preferentially from such points. A corona injects a charge of the opposite sign into the mist and is believed to be one of the main processes limiting the amount of charge in the mist to an equilibrium value. The corona discharges produced during tank washing are not strong enough to ignite the hydrocarbon gas/air mixtures that may be present.

Under certain circumstances, spark discharges with enough energy to ignite hydrocarbon gas/air mixtures can occur from unearthed conducting objects within, or introduced into, a tank filled with charged mist (or containing a charged liquid). For example, a metal sounding rod suspended on a rope or a piece of metal falling through the tank space.

An unearthed conductor within a tank can acquire a high potential, primarily by induction, when it comes near an earthed object or structure, particularly if the latter is in the form of a protrusion. The unearthed conductor may then discharge to earth, giving rise to a spark capable of igniting a flammable hydrocarbon gas/air mixture.

The processes by which unearthed conductors give rise to ignitions in a mist are complex and several conditions need to be met simultaneously for ignition to occur. These conditions include the size of the object, its trajectory, the electrostatic level in the tank and the geometrical configuration where the discharge takes place.

As well as solid unearthed conducting objects, an isolated slug of water produced by the washing process may act as a spark promoter and cause an ignition. High capacity, single nozzle, fixed washing machines can produce water slugs which, owing to their size, trajectory and duration before breaking up, may satisfy the criteria for producing incendive discharges. However, there is no evidence of water slugs capable of producing incendive discharges being produced by portable types of washing machine. This can be explained by the fact that, if the jet is initially fine, the length of slugs that are produced are relatively small so that they have a small capacitance and do not readily produce incendive discharges.

The tanker industry has drawn up the tank cleaning guidelines in section 12.3. These guidelines are aimed at preventing excessive charge generation in mists and at controlling the introduction of unearthed conducting objects when there is charged mist in the tank.

Charged mists, very similar to those produced during tank washing, occur from time to time in partly ballasted holds of Oil/Bulk/Ore (OBOs). Due to the design of these ships, there may be violent mist-generating impacts of the ballast against the sides of the hold when the ship rolls, even in a moderate sea. The impacts also give rise to free flying slugs of water in the tank so that, if the atmosphere of the tank is flammable, all the elements for an ignition are present. The most effective countermeasure is to have tanks either empty or fully pressed up so that violent wave motion in the tank cannot take place.

### 3.2.8 Inert Gas

Small particulate matter carried in IG produced by a boiler or IG generator can be electrostatically charged. The charge separation originates in the combustion process and the charged particles are capable of being carried through the scrubber, fan and distribution pipes into the cargo tanks. The electrostatic charge carried by the IG is usually small, but levels of charge have been observed well above those encountered from the water mists formed during washing. Because the tanks are normally in an inert condition, the possibility of electrostatic ignition should be considered only if it is necessary to inert a tank that already contains a flammable atmosphere or if a tank already inerted is likely to become flammable because the oxygen content rises as a result of ingress of air. Precautions are then required during dipping, ullaging and sampling (see section 12.8.3).

## 3.3 Other possible sources of electrostatic hazards

### 3.3.1 Discharge of carbon dioxide

During the discharge of pressurised liquid $CO_2$, the rapid cooling that takes place may form particles of solid $CO_2$ that become electrostatically charged on impact with the release nozzle. The charge can be significant and has potential for incendive sparks. Liquefied $CO_2$ should not be used for inerting purposes. It should not be injected into pumprooms that may contain flammable gas mixtures, except for the purpose of fire-extinguishing. SOLAS requires that a sign detailing this is displayed at the pumproom $CO_2$ release controls.

### 3.3.2 Clothing and footwear

Personnel who are insulated from earth by their footwear or the surface on which they are standing can become electrostatically charged, which may result in a spark. Clothing can generate more static charge through friction and increase the chance of spark generation. Personnel should avoid putting on or removing clothing when in hazardous areas.

### 3.3.3 Synthetic materials

Several items manufactured from synthetic materials are available for use on board tankers and in terminals, such as coveralls, gloves, rope, bottles, portable drip trays, ventilation hoses and oil spill response equipment.

To avoid introducing electrostatic hazards in areas where flammable atmospheres may be present, the suitability of such equipment for the intended use should be confirmed prior to use.

Consideration to suitability should also be given when ordering, purchasing and receiving such equipment on board.