Cenelectrex®

Grounding & Bonding Applications

Controlling Static Electricity in Hazardous Areas

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Effective Control of Static Electricity through Grounding and Bonding

Static electricity or the build up of electrostatic charge is present all around us. In everyday life, a static spark is seen as a nuisance: in a flammable atmosphere, its effect can be catastrophic. Many plant fires and personnel injuries can be directly linked to a static spark igniting a vapour, gas or dust atmosphere. There are, however, various protective measures that can be adopted across industry to control this ever-present threat to people, plant and processes.

When implementing safety measures in potentially explosive atmospheres, there are many issues to consider. Eliminating potential ignition sources is the best starting point, both in terms of good engineering design and general operating procedures. However, in any type of flammable atmosphere there may be hidden dangers present, in the form of “isolated conductors”. These are conductive objects which are either inherently or accidentally insulated from ground, so as to prevent any static electricity generated from safely dissipating, thus resulting in accumulation of charge on the object. These isolated conductors include metal flanges, fittings or valves in pipework systems; portable drums, containers or vessels; road tankers, rail cars and even people ! Isolated conductors are probably the most likely source of static ignition incidents in industry.

To understand the extent of the danger and how it may be controlled, the fundamentals of static electricity, and how it is manifested must be considered. In any industrial process where there is movement, the coming together and separation of materials will generate static. This could be liquid flowing through a pipe, powder dropping down a chute, a mixing process, or a person walking across a floor. The extent of the charge generation current is usually very low, typically no greater than 0.1 mA. If the object or piece of plant is in good enough contact with earth, this charge will be lost as it is generated. However, if the object is insulated from ground, the charge will start to accumulate.

Paints, coatings, gaskets, seals and other non-conductive materials can all be sufficiently insulating to prevent safe static dissipation. Static charge can quickly build up to a very high potential, sometimes with voltages in excess of 30kV. Depending on the capacitance of the object, this may result in significant levels of energy available for discharge, well above the minimum ignition energy (MIE) of the surrounding flammable atmosphere.

Typical MIEs vary according to whether the flammable atmosphere comprises vapour, dust or gas, but many commonly used solvents have MIEs of well below 1 millijoule (see Tables A & B). If the isolated conductor then comes into proximity with another object at a lower potential, much of this energy could be released in the form of an incendive spark. Of course, in order for an ignition of the flammable atmosphere to occur, there would also need to be a suitable concentration of fuel (vapour, dust or gas) in the air; but for the purposes of safe plant design, the very fact that there is an identified flammable atmosphere should suggest that ignition is possible or likely.

Table A: Potential energy on typical plant items

Object	Capacitance (pF)	Stored energy at 10kV (mJ)	Stored energy at 30kV (mJ)
Road Tanker	5000	250	2250
Person	200	10	90
Steel Bucket	20	1	9
100mm Flange	10	0.5	4.5

Table B: Minimum ignition energy of vapours & powders

Liquid vapour	MIE (mJ)	Powder cloud	MIE (mJ)
Propanol	0.65	Wheat Flour	50
Ethyl Acetate	0.46	Sugar	30
Methane	0.28	Aluminium	10
Hexane	0.24	Epoxy Resin	9
Methanol	0.14	Zirconium	5
Carbon Disulphide	0.01	Some Pharmaceutical Intermediates	1

data source: UK IchemE

The problems associated with isolated conductors can be remedied by effective grounding (also known as “earthing”) and bonding. “Grounding” may be defined as linking the conductive object to a known “grounding point” via a mechanically strong and electrically conducting cable, thereby giving it zero (or ground) potential. “Bonding” (or equipotential bonding) may be described as linking together adjacent conductive objects so as to equalise the potential between them. At some point

these linked items are also grounded, ensuring that everything is at zero (or ground) potential. In the case of fixed installations such as pipework, storage tanks etc, this is relatively simple to implement. However, it is more difficult in the case of mobile / portable objects such as drums, IBC's (intermediate bulk containers) and tankers. In these instances, purpose-designed temporary grounding and bonding devices should be used, with strict procedures in place, to ensure they are always connected prior to starting the process. This will prevent any static charge accumulation.

In the case of people, static dissipative (anti-static) footwear and gloves may be worn to ensure that the person is continually “grounded”. Testing devices are available to ensure that footwear conforms to the relevant standard (eg. EN345 or the Cenelec 50404 level in Europe or ANSI Z41 SD Type II in the USA). When a working area is designed, it is important to ensure that the floor has a suitable level of conductivity, as static dissipative footwear will be rendered ineffective if the wearer is walking on an insulating floor or floor covering. If the flammable atmosphere has a very low MIE, static dissipative clothing may also be required.

Even when the appropriate static safety equipment has been specified, there are some further concerns that must be addressed by all those responsible for operations within potentially explosive atmospheres. In operational terms, attaching a grounding clamp to a plant item is always a “physical” action. Even if the operators diligently carry out their duties as detailed in company safety procedures, they can never be sure that the clamp has made a low enough resistance contact with the conductive object to enable any static generated to be safely dissipated to ground.

The fact remains that many conductive objects that are capable of accumulating high levels of static charge also have insulating layers on their surfaces that may prevent the necessary low resistance contact. This may be caused by the paint or coating on drums, tankers and other mobile plant, or may be the result of product build-up caused by normal working conditions (for instance where insulating liquids, powders and other materials are part of the process). Many grounding and bonding clamps show very high resistance readings when clamped onto conductive objects with insulating surfaces. Worse still, if a company tries to reduce costs by using standard welding clamps or lightweight alligator clips for static grounding in place of purpose designed and approved clamps, these devices have an even higher failure rate.

To solve this problem, Intrinsically Safe, self-testing grounding clamps may be specified. From an operator's point of view, these devices are used in exactly the same way as conventional grounding clamps. Where they differ is in the way that they reassure the operator that the clamp has not only been physically attached, but is also performing it's intended function of safely dissipating any static electricity that is generated. These clamps employ active electronic monitoring circuits that are powered from an internal low energy battery. The circuit is only completed when the clamp achieves a low resistance contact onto the object to be grounded, and the operator receives visual confirmation of this via an indicator (usually a flashing LED). The self-testing grounding clamp also monitors cable condition back to the designated grounding point, and will also fail to register a permissive signal if the cable has worked loose or is broken.

Table C:

In order to be used in Europe in a potentially explosive atmosphere, equipment must conform to the ATEX 95 “equipment “ directive (94/9/EC). This applies both to electrical AND, more recently, mechanical devices. The appropriate equipment category and marking will depend on the hazardous area Zone that the item is intended to be used in.

Hazardous Area Zone	Equipment Group	Equipment Category	Marking under ATEX 95 G = Gas or Vapour, D = Dust
Zone 0 - Gas or Vapour Zone 20 - Dust	II	1	CE Ex II 1 G (and / or) D
Zone 1 - Gas or Vapour Zone 21 - Dust	II	2	CE Ex II 2 G (and / or) D
Zone 2 - Gas or Vapour Zone 22 - Dust	II	3	CE Ex II 3 G (and / or) D

Note: the above categories are for surface industries (Group II). Mining comes under Equipment Group I. The hazardous area zones approximate to the equipment categories as shown.

To move to an even higher level of security, earth monitoring systems may also be used that not only give visual verification to the operator, but also provide interlock switching contacts that may be linked to process pumps, valves, alarms or control systems. This means that the process cannot be started until the conductive object has been safely grounded and if at any time during the operation the condition changes (due to a clamp being accidentally removed, etc), the system automatically switches to non-permissive and shuts down the process. These systems are generally fed from a mains power supply, and employ approved Intrinsically Safe circuits to limit the monitoring energy to safe levels. Static earth monitoring and Interlock systems are typically used in ultra safety-critical applications such as loading / unloading road tankers and IBCs, mixing processes, fluid bed drying operations and wherever there is a high likelihood of static charge accumulation in very low minimum ignition energy (MIE) flammable atmospheres.

Static ground verification clamps and interlock systems tend also to have an important beneficial effect on the operators using them. As they build an "additional" check into the operation, they help reinforce the static safety procedures of the company; in short the operator is more likely to observe the correct procedures as he or she is kept aware of the need to control static electricity properly on a daily basis.

In all situations, it is important to make regular, periodic tests of the control measures used, checking clamp and cable condition and the all-important connection back to the grounding point (bus bar). Resistance testers or multi-meters may be used to perform this function but, of course, these will need to be approved Intrinsically Safe instruments if working when a potentially explosive atmosphere may be present. Recording of test results is a positive way of ensuring that standards are maintained. The frequency of testing will depend on the nature of the operation and the type of control measures in place: generally, non-monitored devices will need to be tested more frequently than self-testing clamps or interlocked equipment.

In addition to these engineered static safety controls, due consideration should also be given to all plant and packaging materials used within the hazardous area. Today, specialised "non-metallic static dissipative" materials are increasingly being used for making drums, flexible containers, linings, and hoses, in applications not suited to traditional materials such as steel. Such materials are safe to use in flammable atmospheres, provided that they are treated in the same way as conductive items and appropriately grounded during static-generating operations. It is important to note that insulating plastics, such as those used in certain IBCs and bags, may pose a serious static-ignition risk. These materials cannot be safely earthed and it is not recommended to use them where a flammable atmosphere is likely to be present.

It should also be noted that charge can build up on the actual materials being processed (liquids, powders, gases), so it is necessary to make sure that these are in sufficient contact with grounded, conductive piping, vessels and plant, thus providing a safe discharge path. Conductive materials in good contact with a ground path will not retain significant levels of charge. However, as many of these materials are highly resistive, it may be necessary to consider using anti-static additives in liquids and building in periods of rest into processes to allow the charge time to "decay", particularly in the case of powders.

In conclusion, the dangers of static electricity in hazardous areas demand a "holistic" approach to plant, process and personnel safety, as any control measures are only as good as the weakest link in the chain. As the speed and scale of modern manufacturing techniques increase, and the range of materials used and processed grows, this basic approach to safety will be even more important.

Static Grounding Safety Summary

1. Always use correctly approved and specified, purpose designed grounding and bonding clamps, cables and devices.

2. Check all grounding application characteristics and consider positive verification and interlock systems for places where further safety and security is required.

3. Ensure all operators working in hazardous areas understand the risk of static ignition and follow correct company safety procedures.

4. Ensure that a proper maintenance programme is followed for grounding and bonding measures.

More detailed information on this subject may be found in the following publications:

Cenelec CLC/TR 50404 Electrostatics - Code of practice for the avoidance of hazards due to static electricity. June 2003 (Europe).

National Fire Protection Association NFPA77 Recommended practice on static electricity. 2000 edition (United States).

British Standard BS5958 Part 2 - Code of practice for control of undesirable static electricity. Last updated 1991 (United Kingdom).

Note: this guidance assumes that qualified personnel have carried out appropriate risk assessments and hazardous area zoning work. For European companies, this would form part of their compliance with the ATEX 137 Directive (99/92/EC). Please note that any advice offered is intended to make a contribution towards effective static control practice and it is drawn from the publications mentioned above and other related materials. However it should not be regarded as an exhaustive list of solutions for particular problems, and it is always the responsibility of the operating company to verify the efficiency and effectiveness of any static control measures employed.

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Cenelectrex Application (CA) Drawings

The following 12 pages contain application drawings showing how to achieve a reliable ground connection to a variety of moveable plant items commonly found in the chemical, pharmaceutical and food processing industries.

Most of these applications require the availability of a recognised or dedicated grounding point or network. This normally takes the form of bars that run along the walls and are connected to a number of grounding rods, pits or grids, driven into the ground. The grounding devices can then be connected to this site grounding network in order to provide an interface between it and the moveable plant item. It is important to ensure that the manufacturer's instructions are followed precisely when installing earthing and bonding devices and systems.

CA01 to CA04 feature non-monitored clamps and cables, which rely on their design and mechanical strength to achieve a low resistance connection between the plant item and earth. The European and American codes of practice make the following references to the use of such devices:

CLC/TR 50404 (Europe)
11.4.1 - Cables for earthing movable items should be equipped with a strong clamp capable of penetrating through paint or rust layers. Earthing devices…..should be robust.

NFPA77 (USA)
6.4.1.4 - Where wire conductors are used, the minimum size of the bonding or grounding wire is dictated by mechanical strength, not by its current carrying capacity. Stranded or braided wires should be used for bonding wires that that will be connected and disconnected frequently.

CA05 to CA08 illustrate the use of self-testing clamps and cables which give an indication to confirm that the resistance between the plant item and the grounding point is less than 10 ohms. Such devices may be used for more safety-critical applications, or where a build up of dirt or product may hinder the reliability of the connection to the plant item. The codes of practice state that where the bonding / grounding system and plant are all metal:

NFPA77 (USA)
6.4.1.3 - resistance in continuous paths will typically be less than 10 ohms. Greater resistance usually indicates the metal path is not continuous, usually because of loose connections or corrosion.

NFPA77-2007 (USA)
6.8.4 - In bonding and grounding installations that are prone to corrosion, movement, or insulating surface coatings, self-testing bonding clamps and systems can be used to continuously test the resistance to ground and verify acceptable results.

CLC/TR 50404 (Europe)
11.2.2 - resistance (with an upper limit) in the range 10 ohms to 100 ohms is often specified for convenience in monitoring.

CA09 to CA12 highlight the use of ground monitoring systems which may be interlocked to items such as pumps, valves, mixers or process control equipment. In these applications, the process cannot commence unless the ground connection is correctly fitted to the plant item and can be monitored at the specified resistance. The codes of practice support the use of interlocked ground monitoring equipment for the most safety-critical applications. In the case of road tankers:

CLC/TR 50404 (Europe)
5.4.4.1.2 - It is recommended that interlocks should be provided to prevent loading when the grounding cable is not connected.

NFPA77 (USA)
Table 7.6 Recommended Loading Precautions - all bonding and grounding should be in place prior to starting operations. Ground indicators, often interlocked, with the filling system, are frequently used to ensure bonding is in place.

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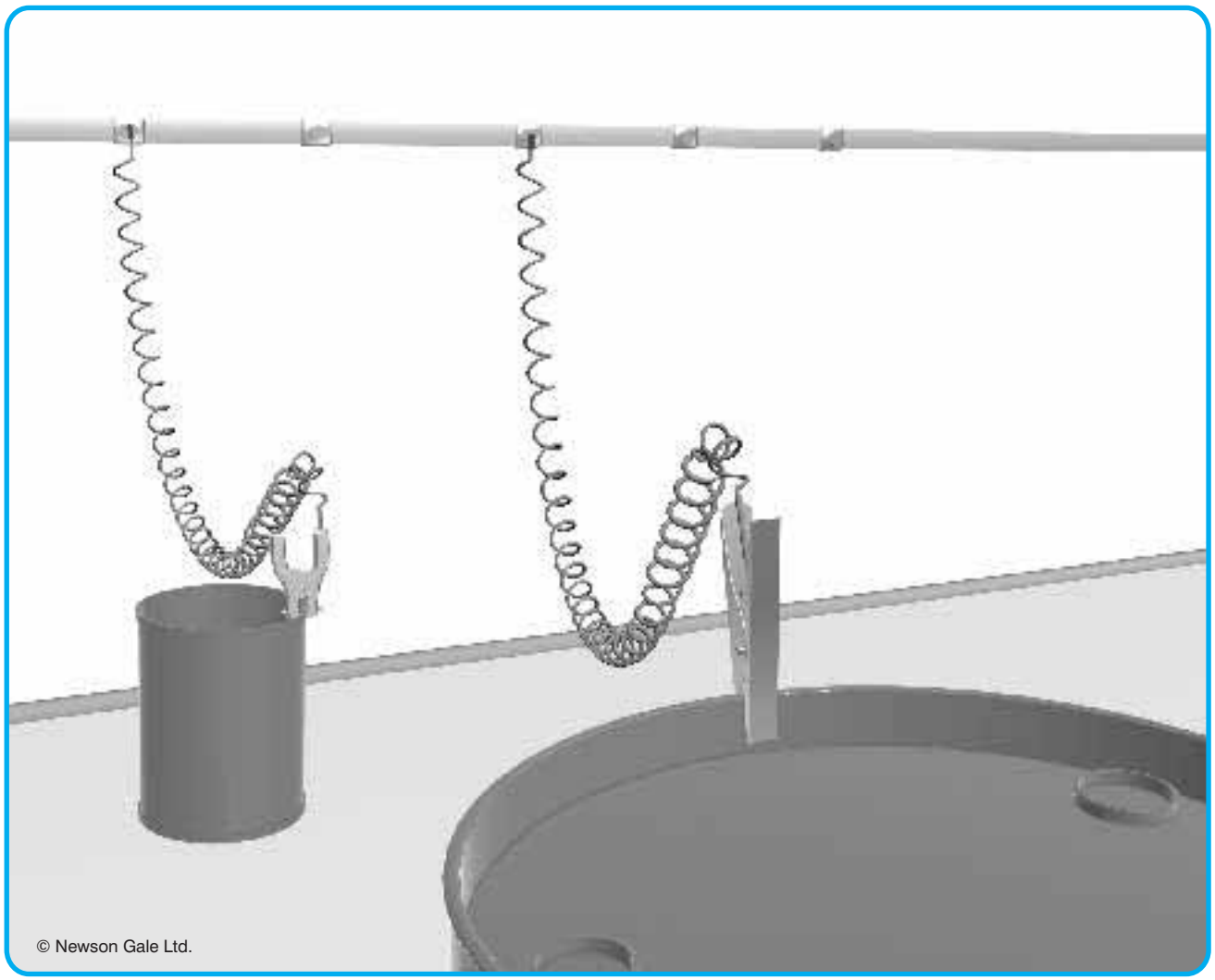
REB Plier clamp & 3m cable
VESX41/G09

Cling-On clamp & 5m cable
VESX10

CA01 - Grounding of drums & containers

using purpose designed grounding clamps and cables



Movable metal items may be connected to ground via the bonding bar using the type of clamps and cables illustrated. The clamp should be designed to grip the container securely and to bite through any paint or rust layers. As a mechanical device, it should be approved for use in the appropriate Potentially Explosive Atmosphere zone. Cable cores and connections should be strong enough to avoid damage from repeated movement as the clamp is brought to and from the container.

CLC/TR 50404 states that: There are items of equipment such as drums, funnels and trolleys, which cannot be permanently connected to earth through the main plant structure….To allow for this suitable temporary grounding connections should be used (11.3.1.2).

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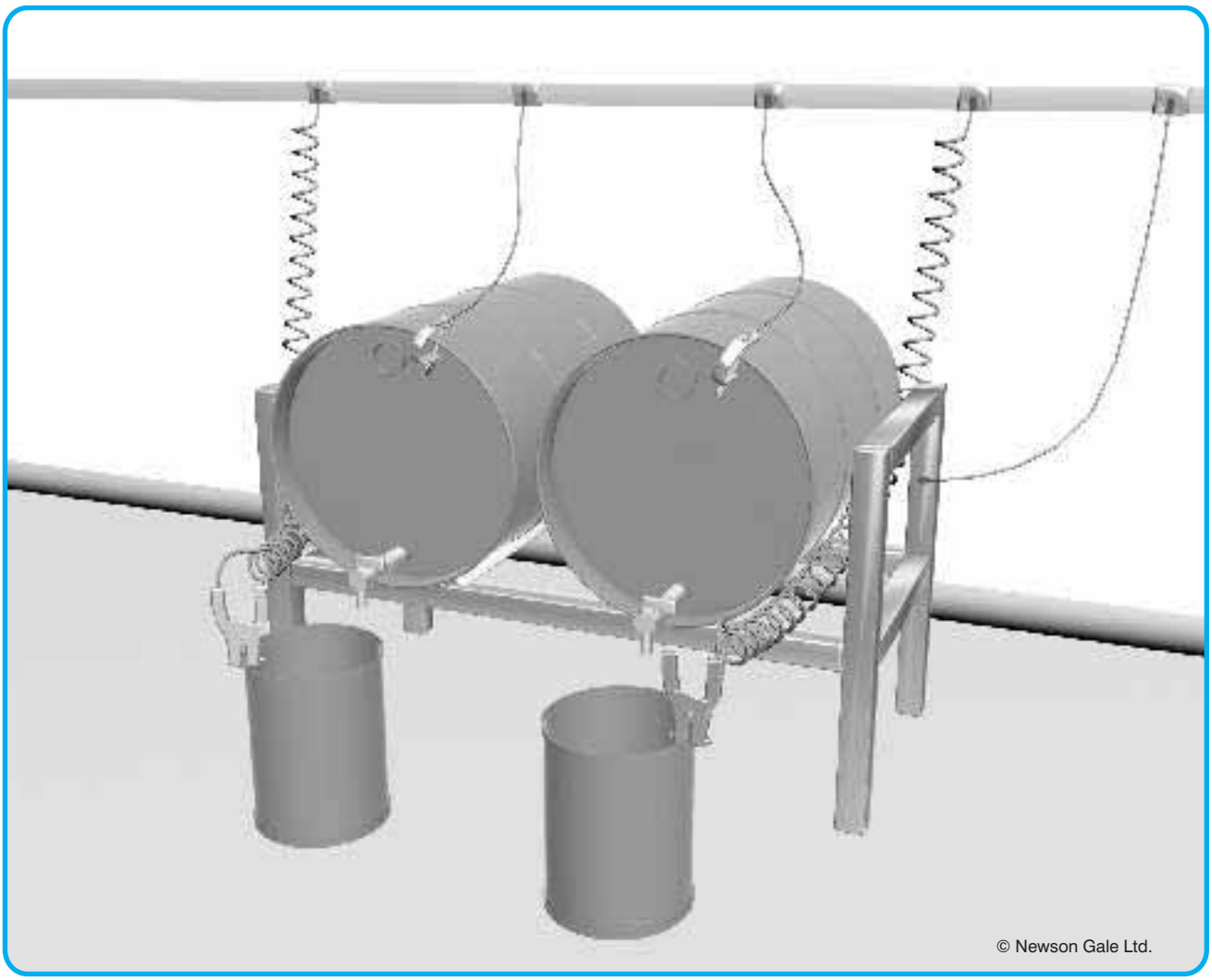
CA02 - Grounding of drums & containers with storage rack

REB Plier clamp & 5m cable
VESX41/G03

C clamp & straight cable
VESC41/G30

using purpose designed grounding clamps and cables



When product transfer occurs, it is important to ensure that the containers involved are at ground potential. This can be achieved by grounding them using clamps and cables which go back to a common grounding bar, as shown. An alternative method is shown in CA03.

NFPA77 states that: Bonding should be done with a clamp having hardened steel points that will penetrate paint, corrosion products and accumulated material using either screw force or a strong spring. (7.13.3).

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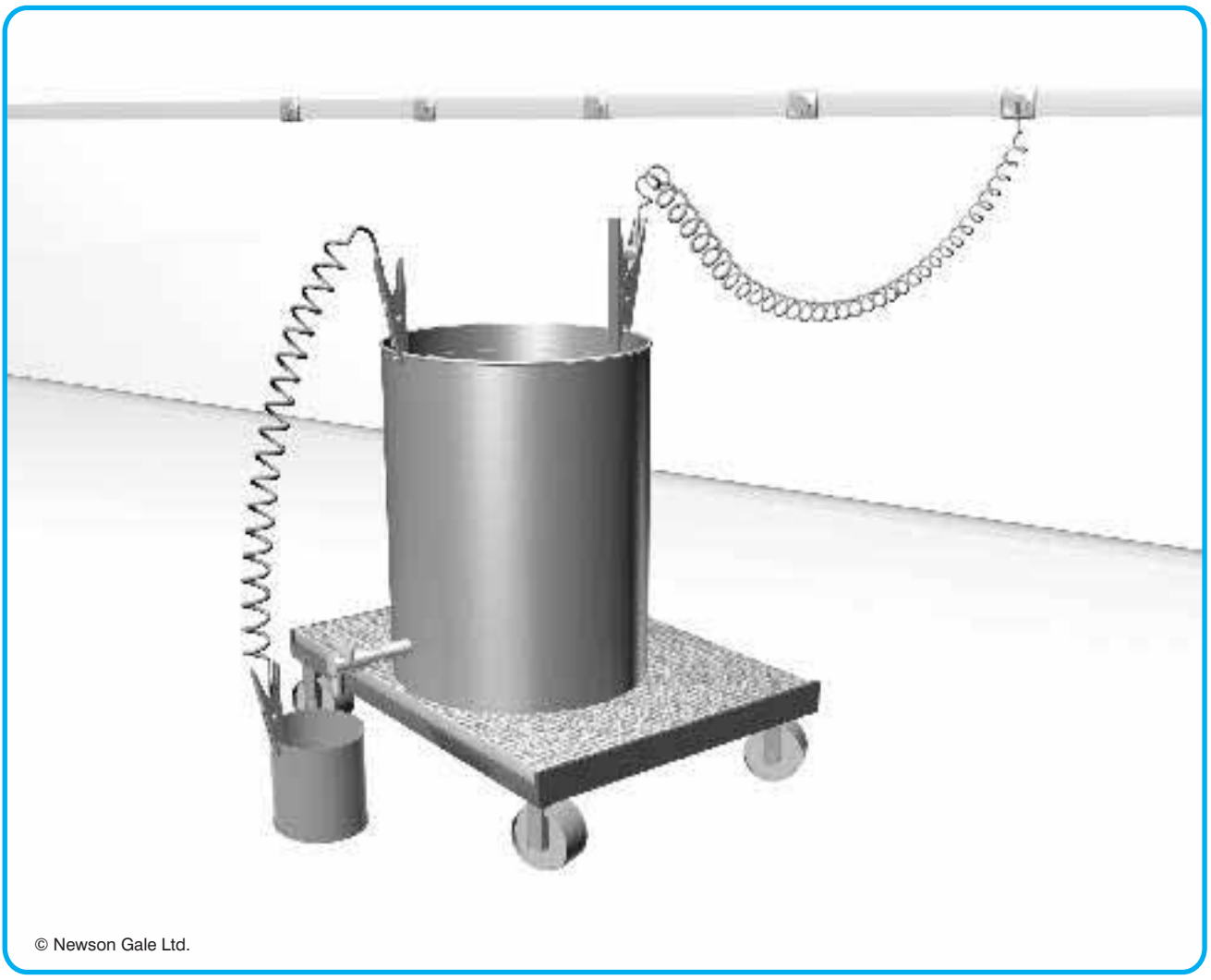
CA03 - Grounding of mobile vessels & small containers

Pair of stainless steel medium duty clamps & 3m cable
VESX02/G09/X02

Stainless steel heavy duty clamp & 5m cable
VESX90/G03

using purpose designed grounding clamps and cables



Ground potential may be achieved on two vessels by connecting the main one to the grounding point and bonding the secondary container to the first, as shown. Stainless steel clamps are recommended for pharmaceutical / clean room applications or where high corrosion resistance is required.

NFPA77 states that: When being filled, metal containers and associated fill equipment should be bonded together and grounded. (7.13.3).

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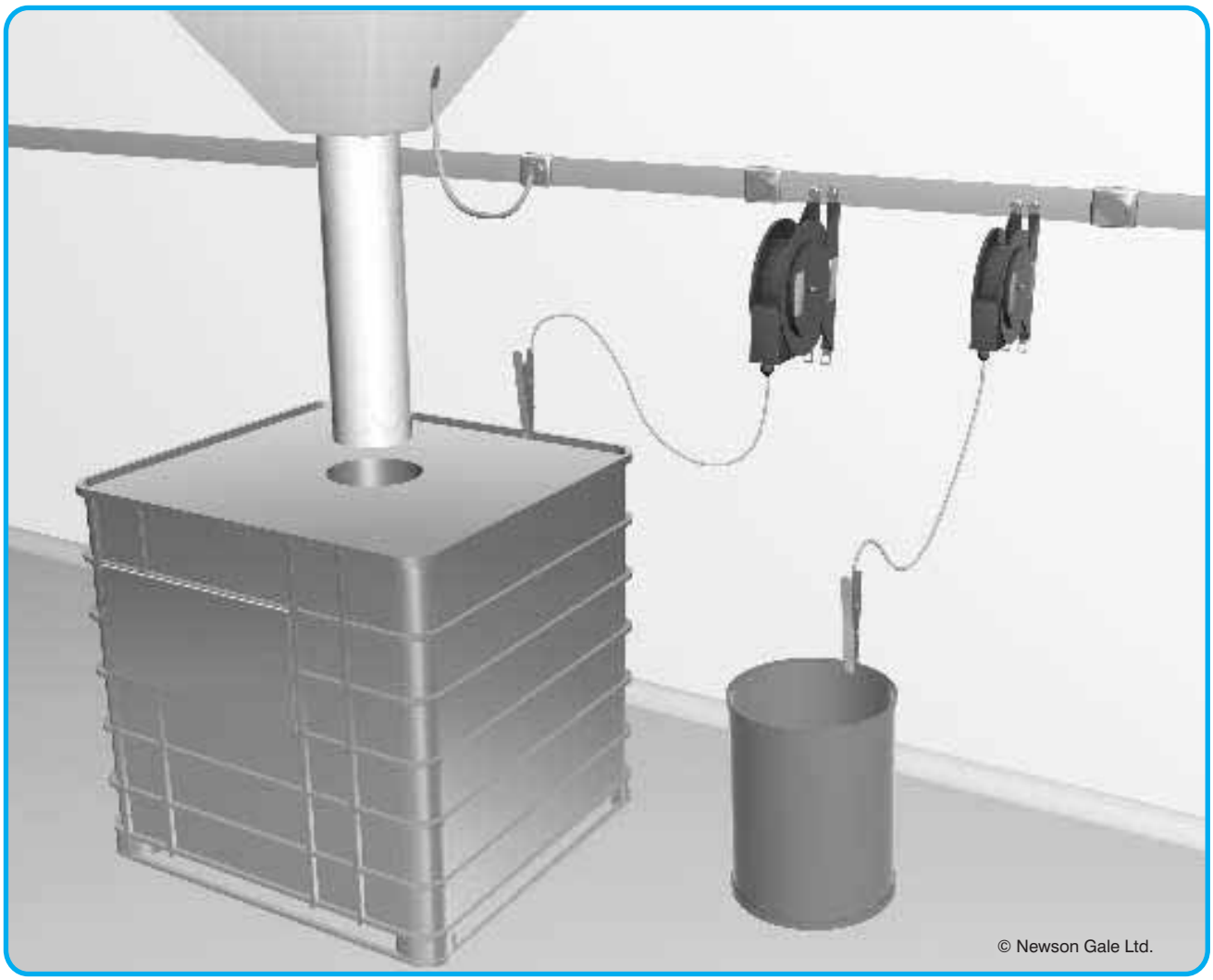
Cling-On clamp & 15m reel
VESX34

Cling-On clamp & 7.6m reel
VESX07

CA04 - Grounding of IBCs & containers

using purpose designed grounding clamps and reels



As an alternative to spiral cables, self-retracting cable reels are a popular method of providing a reliable bond from the grounding bar to an IBC (intermediate bulk container) or other container. The choice between spiral cables or retractable reels is down to practicality, convenience and user preference, as both are equally effective grounding devices.

BS5958 states that: During both filling and emptying, the container and all metallic parts of the system, such as funnels and nozzles, should be bonded together and / or grounded (11.2.1).

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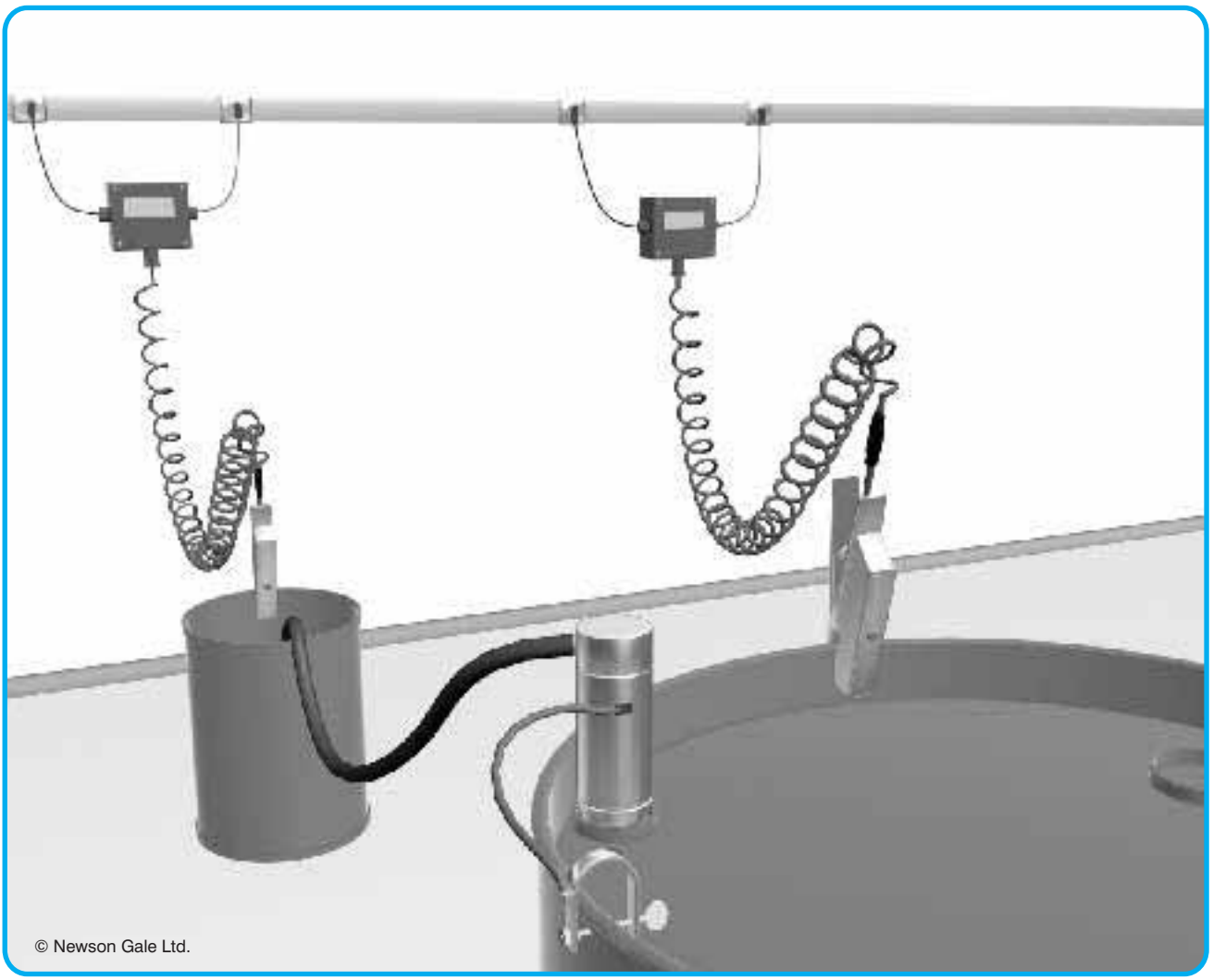
Bond-Rite clamp & 5m cable
VESC52

C clamp & straight cable
VESC41/G30

CA05 - Grounding of drums & containers

using self-testing clamps and cables



For complete reassurance that a suitable low resistance connection has been achieved, self-testing clamps with built-in LED indicator are recommended for safety-critical operations, such as product transfer. Being operated by an internal battery, they are ideal where simple installation is desirable and an interlock is not required.

By confirming the reliability and condition of connections via the flashing LED, self-testing clamps enable the user to conform with CLC/TR 50404 which states that: What is most important…..is that all connections are reliable…..and not subject to deterioration (11.2.2).

NFPA77-2007 (USA)
6.8.4 - In bonding and grounding installations that are prone to corrosion, movement, or insulating surface coatings, self-testing bonding clamps and systems can be used to continuously test the resistance to ground and verify acceptable results.

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Bond-Rite clamp & 15m reel
VESC50/M34

Bond-Rite clamp & 7.6m reel
VESM50/M07

CA06 - Grounding of a road tanker

using a self-testing clamp and reel

A road tanker is often the largest potentially isolated conductor which is brought on site and if incorrectly grounded, may pose a significant ignition risk.

When filling and emptying road tankers, both CLC/TR 50404 and NFPA77 recommend that fully interlocked static grounding systems are used (see CA09 page 14). However in cases where an interlock is not possible, a self-testing clamp provides operator feedback via the built-in LED, ensuring that a low resistance connection has been made through paint or rust etc to the metalwork of the tanker chassis.

NFPA77-2007 (USA)
6.8.4 - In bonding and grounding installations that are prone to corrosion, movement, or insulating surface coatings, self-testing bonding clamps and systems can be used to continuously test the resistance to ground and verify acceptable results. BS5958 states that: During loading the vehicle should be grounded…..so that the resistance to earth is at all points less than 10 ohms (7.2.1).

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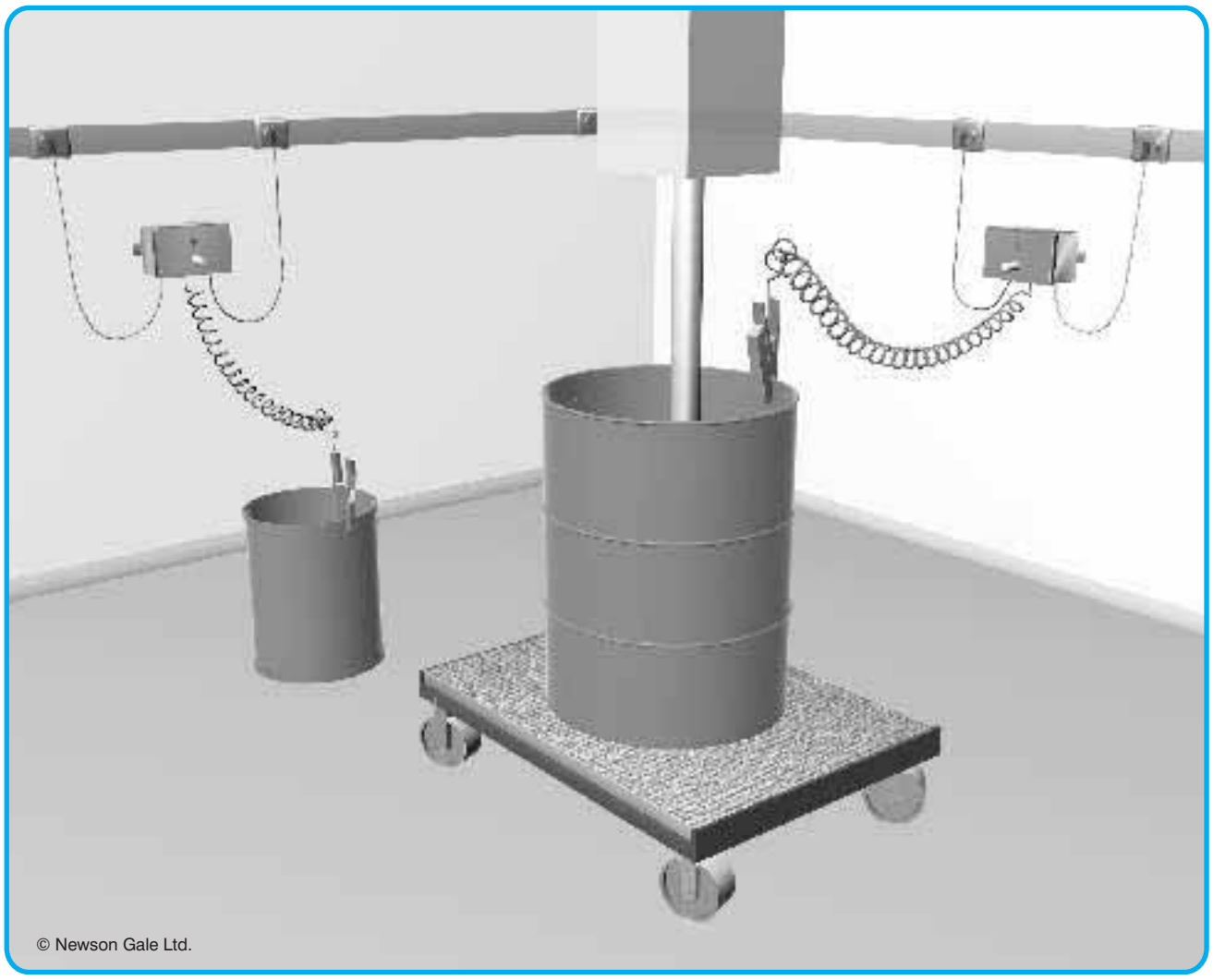
CA07 - Grounding of mobile vessels & small containers

using self-testing clamps and cables

Bond-Rite REMOTE with stainless steel clamp VESC63

Bond-Rite REMOTE with REB-IP Plier clamp VESC61



In some applications, such as those found in the paints and coatings industry, the benefits of a self-testing clamp are clear, enabling the operator to ensure that it has penetrated through accumulated layers of product. However, it is possible that the LED may become obscured by such product. In these situations, a self-testing clamp with “remote” indicator LED and battery, mounted on the wall, may provide a solution.

A second benefit is that other, smaller clamps may be used with the monitoring unit, as dictated by the application.

NFPA77-2007 (USA) 6.8.4 - In bonding and grounding installations that are prone to corrosion, movement, or insulating surface coatings, self-testing bonding clamps and systems can be used to continuously test the resistance to ground and verify acceptable results.

BS5958 states that when mixing and blending: 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 ohms. (10.2.1).

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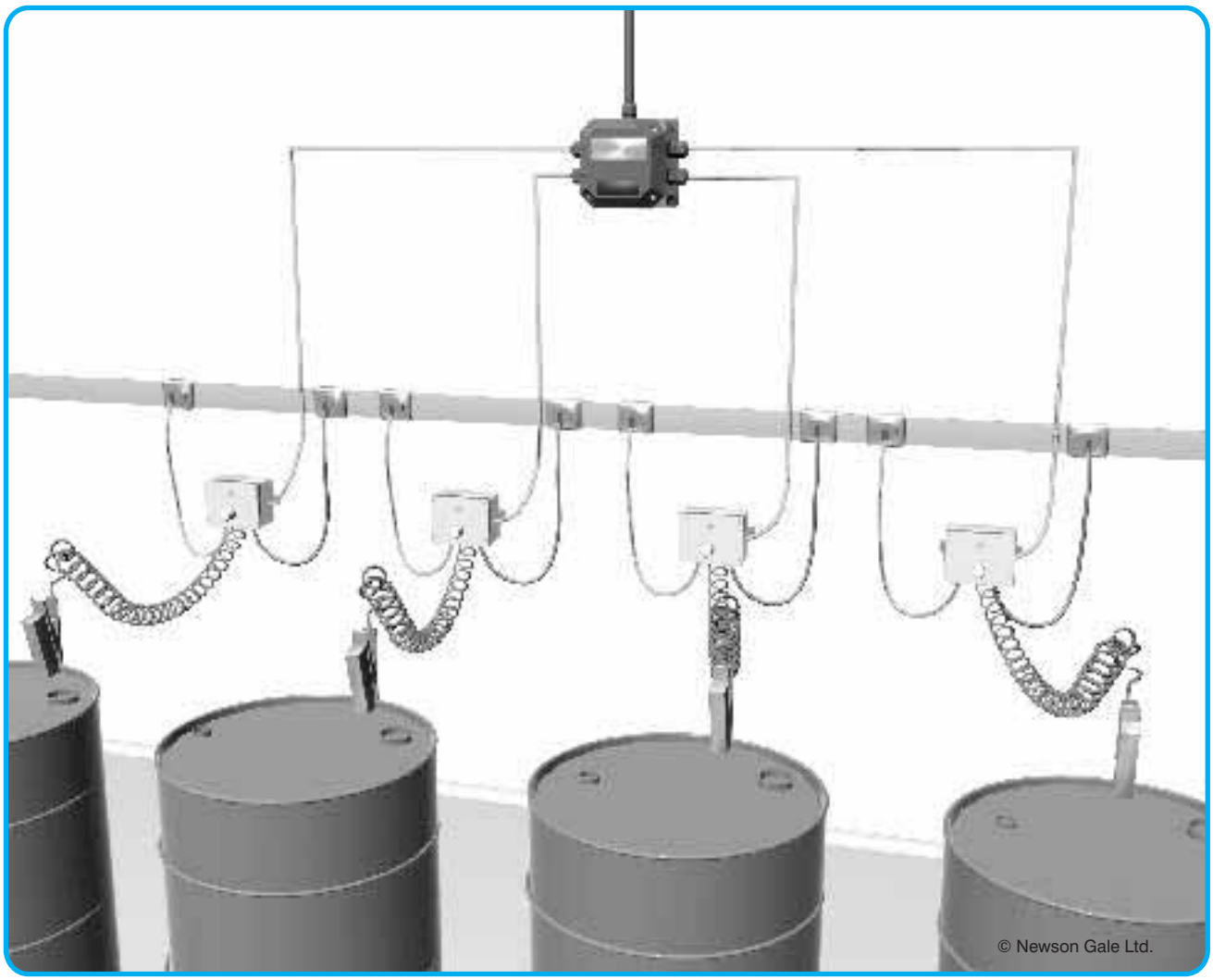
CA08 - Grounding of drums in a drum store or processing room

Bond-Rite REMOTE (EP)
with stainless steel clamp
VESC63 / EP

B-RR (EP) Power Supply Unit
& Multi-way Junction box
VESC90 & VESM63

using mains powered self-testing clamps and cables



Battery-powered self-testing clamps are suitable where they are not expected to be attached to plant items for prolonged periods. If continuous monitoring is required, such as in a drum store where product is regularly tapped-off from the drums, mains Externally Powered self-testing clamps with “remote” indicator LEDs are recommended.

NFPA77-2007 (USA) 6.8.4 - In bonding and grounding installations that are prone to corrosion, movement, or insulating surface coatings, self-testing bonding clamps and systems can be used to continuously test the resistance to ground and verify acceptable results.

CLC/TR 50404 states that: Cables for grounding movable items should be equipped with a strong clamp capable of penetrating through paint or rust layers (11.4.1). 10 ohms….is often specified for convenience in monitoring (11.2.2).

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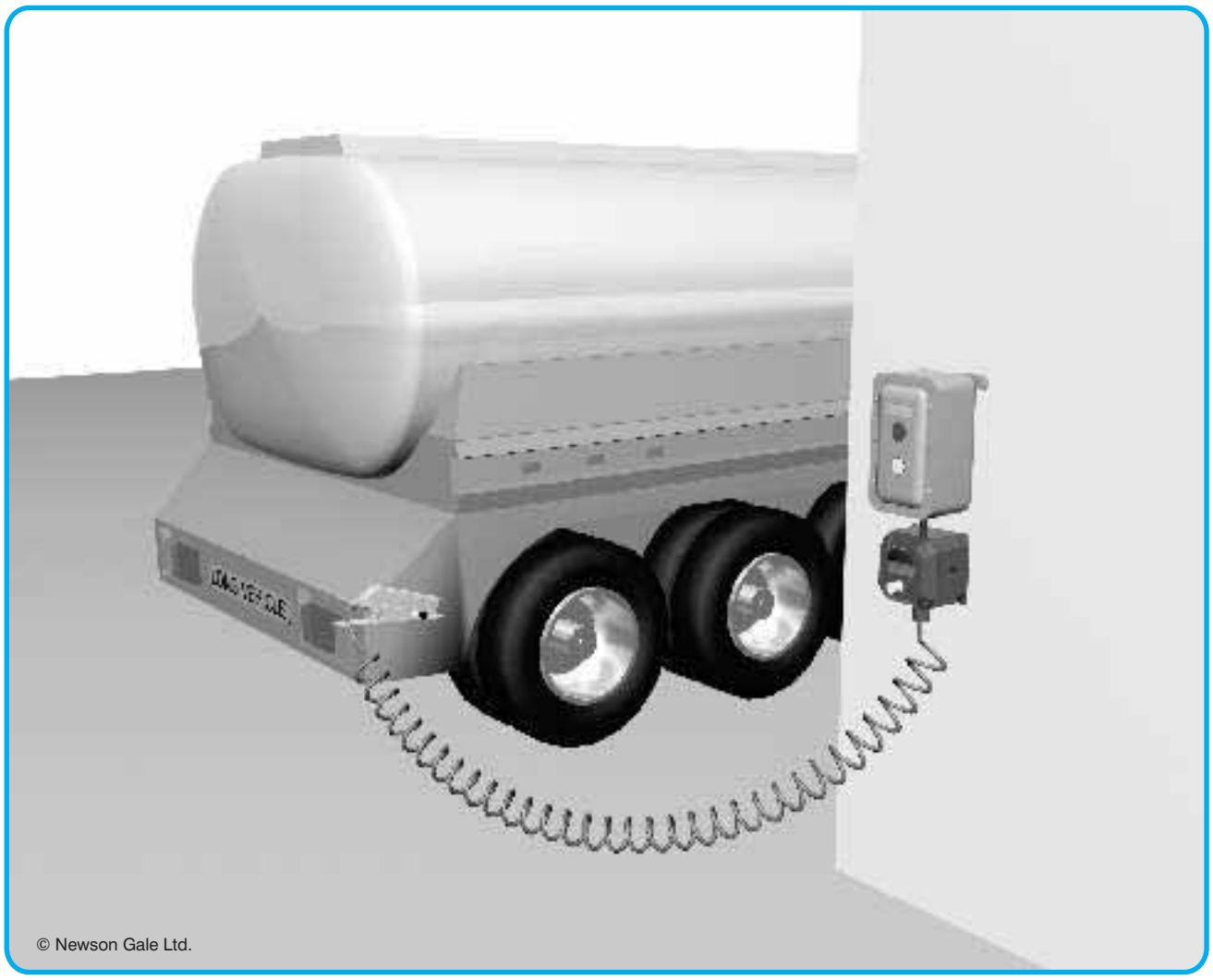
Earth-Rite PLUS Dual Mode
IIB T5 with tanker recognition
EMUE90

Earth-Rite PLUS Dual Mode
IIC T6 with tanker recognition
EMUE92

CA09 - Grounding of a road tanker

using a tanker ground monitoring / interlock system



Owing to the high electro-static ignition risk associated with an ungrounded road tanker, many sites opt to follow the Cenelec Code of practice recommendations and provide interlocked ground monitoring systems to prevent product transfer if the grounding cable is not connected.

A system with a capacitance check feature will actually recognise whether the clamp has been attached to a road tanker or simply to other metalwork, in order to prevent misuse. Such a system will also ensure that the following procedure is followed:

CLC/TR 50404 states that: A grounding cable should be connected to the tanker before any operation (eg. opening man lids, connecting pipes) is carried out. It is recommended that interlocks should be provided to prevent loading when the grounding cable is not connected. (5.4.4.1.2).

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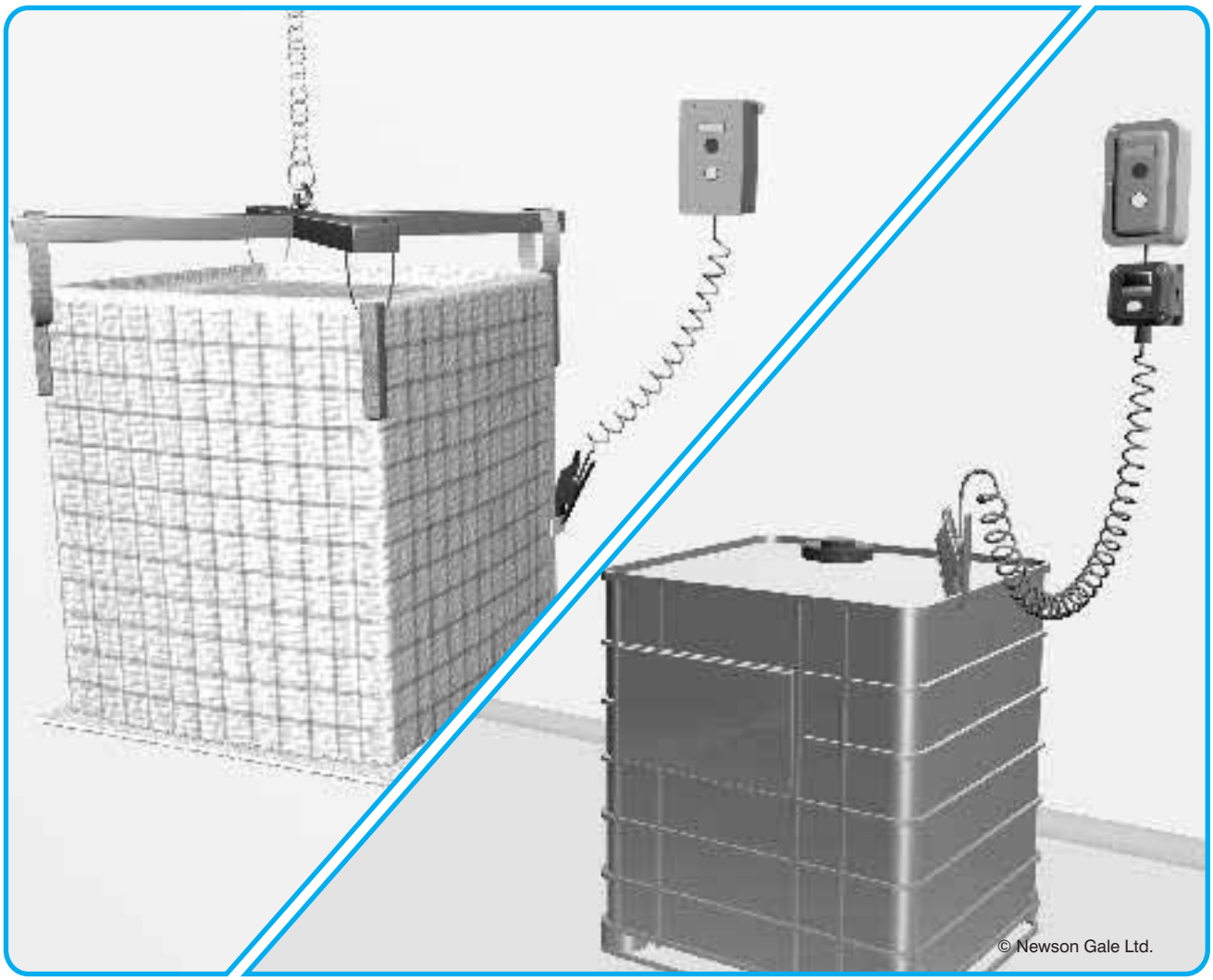
Earth-Rite FIBC
EMUF01 (standard version)

Earth-Rite PLUS Single Mode IIB T5
EMUE91

CA10 - Grounding of flexible & rigid IBCs

using appropriate ground monitoring / interlock systems



When filling or emptying either rigid or flexible intermediate bulk containers, ground monitoring systems may be employed to prevent product transfer unless the grounding cable is in place. A system with a monitoring range appropriate to the type of container should be selected. This will normally be up to 10 ohms for rigid IBCs or drums and up to 1 x 10^8 ohms (100 megohm) for Type 'C' FIBCs or static-dissipative liners.

CLC/TR 50404 states that: the conductive fabric and the conductive threads (including the handles) shall have a resistance to the grounding point on the FIBC of less than 1 x 10^8 ohms…..In order to prevent spark discharges, the FIBC Type C shall be properly grounded whenever being filled or emptied. (7.2.6.8.3).

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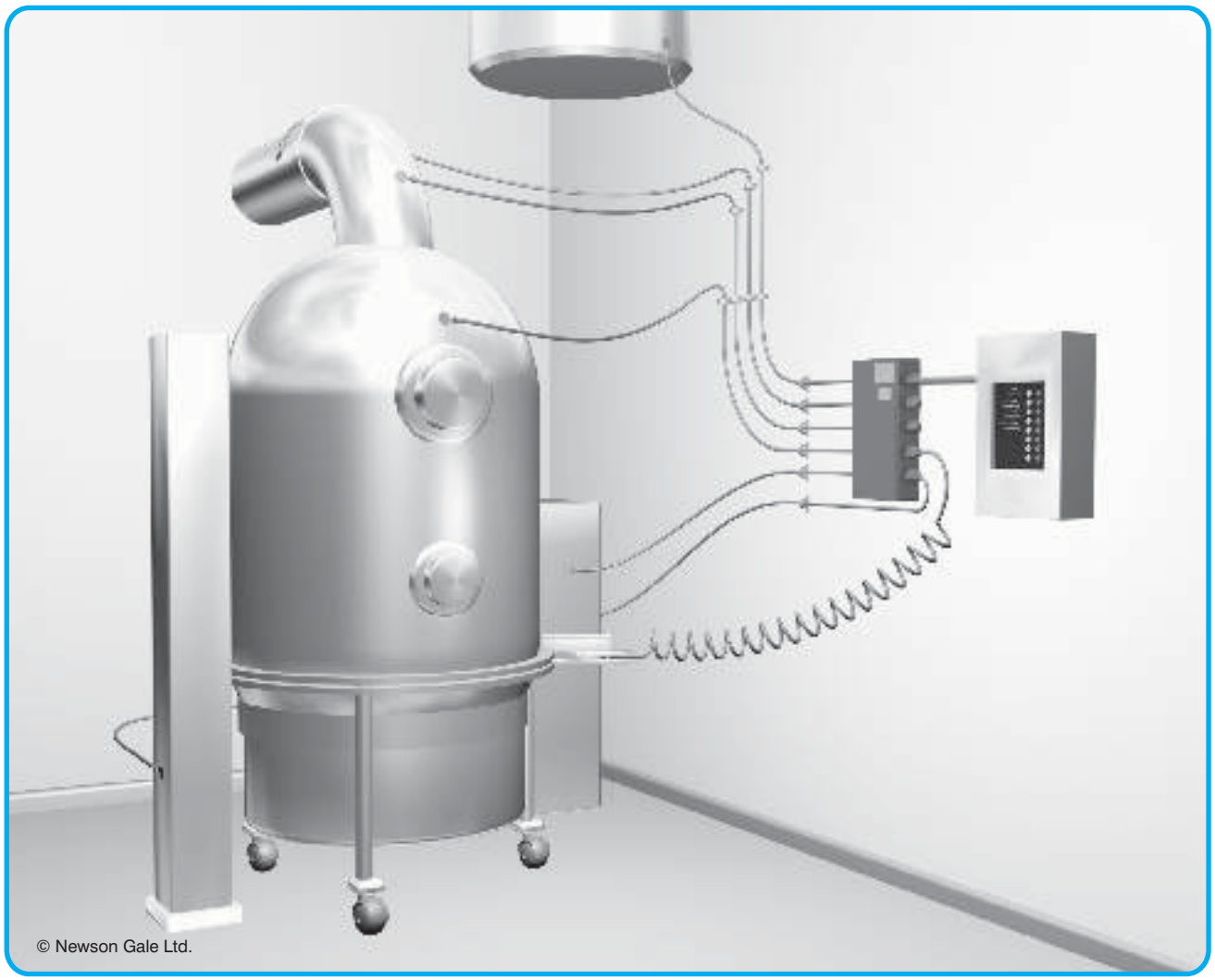
CA11 - Grounding of fluid bed drier & its components

Earth-Rite MULTIPOINT
with up to 8 channels
Based on EMUM50

Stainless steel Dual Circuit
clamp & 5m cable
VESR20

using a multi-channel ground monitoring / interlock system



There are many items of plant that have interconnected metallic parts. Large scale driers, such as fluid bed or spray driers, as used in the pharmaceutical or food processing industries, have a product bowl, filters or ducting that are often disconnected in everyday operation.

These parts may have insulating gaskets etc between them and could be isolated from ground if they are not properly reconnected using their bonding straps etc. As it is time-consuming to test these connections after each reassembly, many sites choose to actively monitor the ground condition of such separate sections.

BS5958 states that: All metallic parts... should be connected to each other and to ground, so that the resistance to ground at all points is less than 10 ohms (16.2.1).

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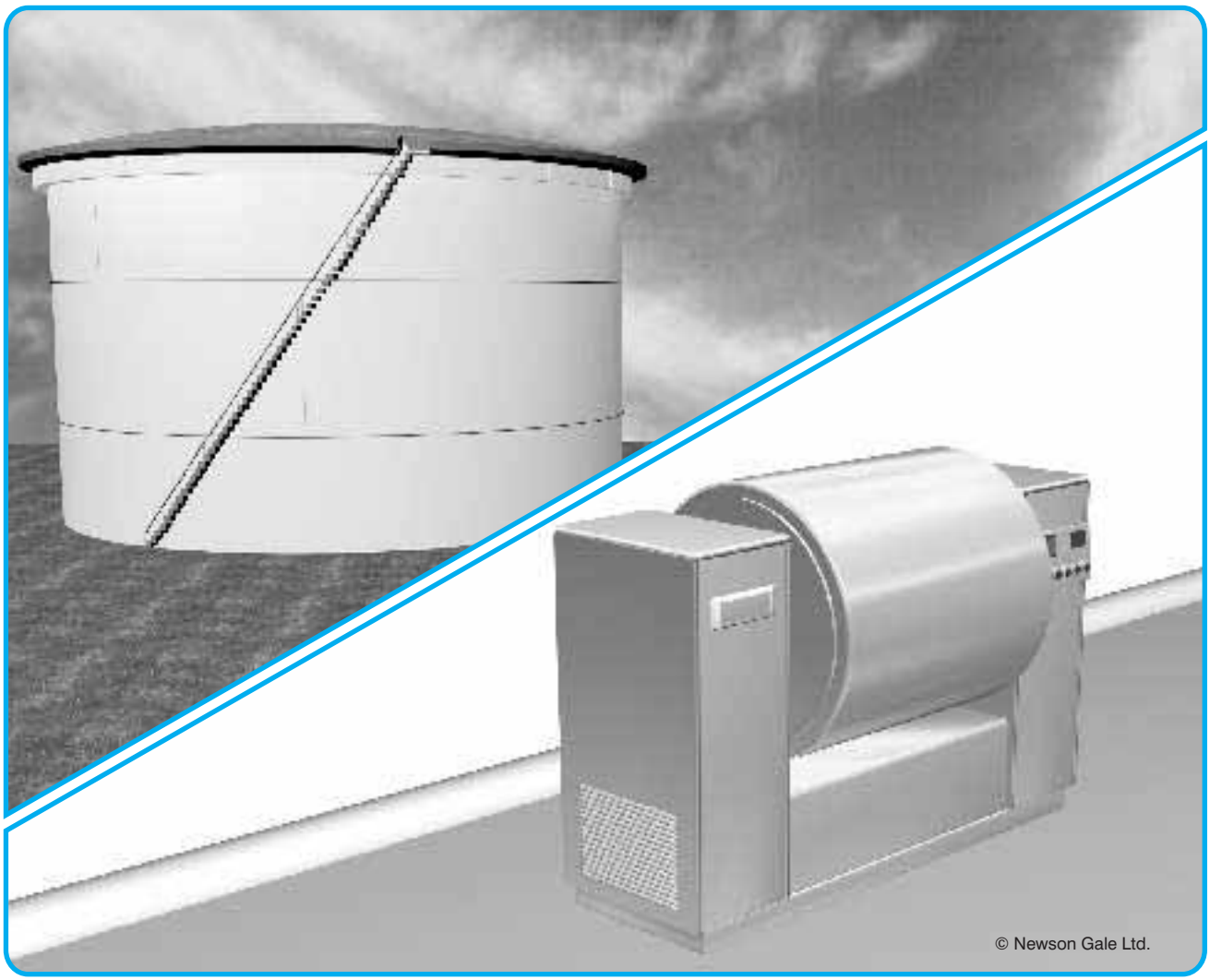
CA12 - Grounding of rotating vessel & fixed container

Earth-Rite OMEGA module VESF70

4 Earth-Rite OMEGA modules DIN rail mounted

using dedicated ground monitoring / interlock modules



Ensuring that a rotating drum or impeller is correctly grounded may be difficult as it is not always possible to rely on the connection made from its shaft to the body of the machine, owing to the design of bearings, etc. A popular method of guaranteeing ground continuity is to use a ground monitoring module to test the ground connection to the drum or impeller via a pair of carbon brushes or a slip ring, acting on the shaft.

Such modules may also be used to test the ground connection to key items of fixed plants, such as large storage vessels for flammable liquids.

NFPA 77, when discussing the static dissipation path through bearings (in this case, in rail car wheel assemblies) states that: resistance to ground….might not be low enough to prevent the accumulation of static electric charge (7.8).

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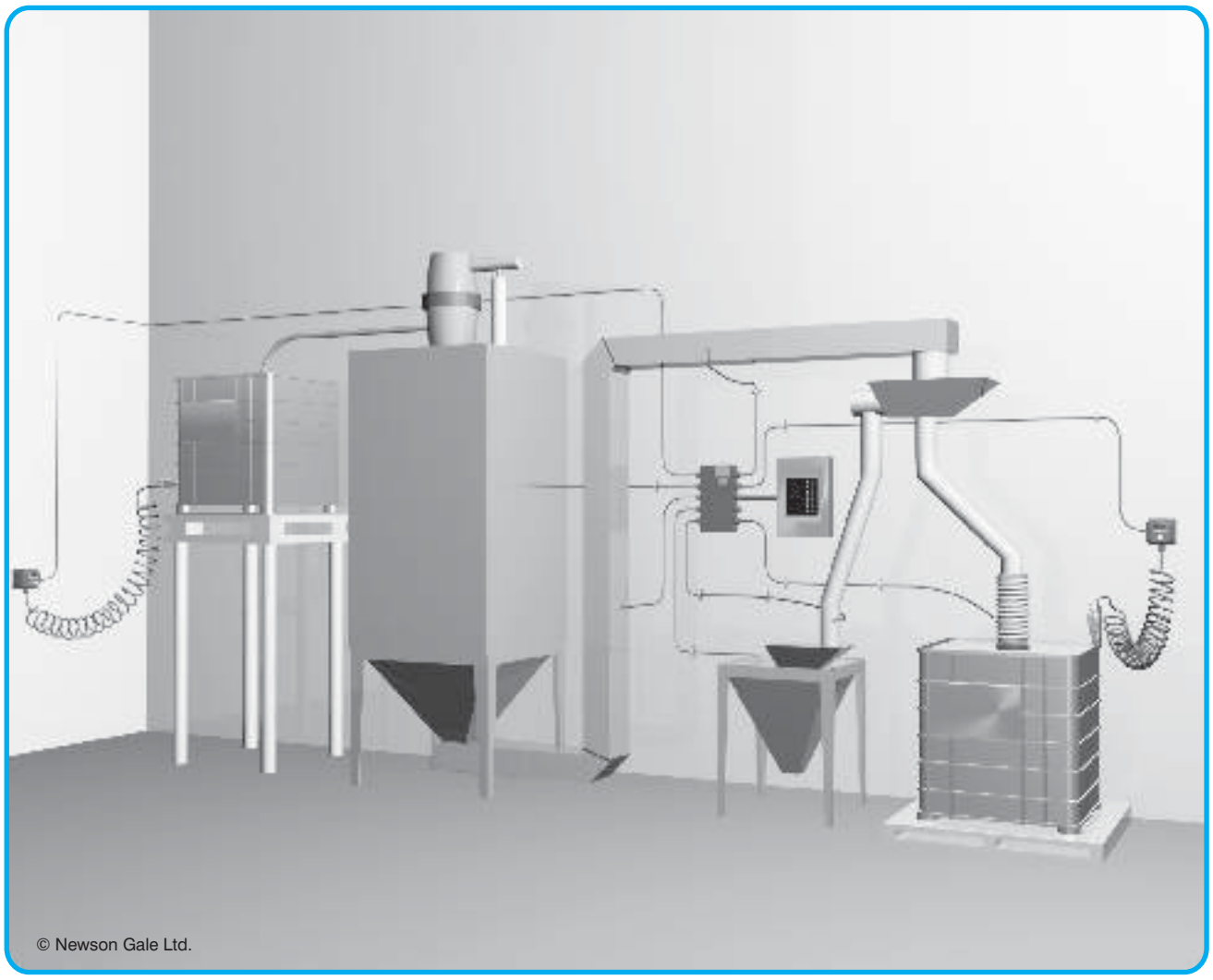
CA13 - Grounding of Interconnected plant Items & pipes / ducting

Earth-Rite MULTIPOINT
With up to 8 channels
Based on EMUM50

Plug & Socket Connector
VESF30 & VESF31

using a multi-channel ground monitoring / interlock system



Ground monitoring of individual plant sections is common, as interconnected process items must be kept at the same electrical potential and bonded to a ground connection. Ungrounded transfer pipes and ducting are prone to static build up and are often ground monitored, particularly when they are disassembled regularly for cleaning etc.

It is very important to ensure that the monitoring equipment selected will not allow the sum of circulating currents from the various channels to exceed permitted levels for Intrinsic Safety.

NFPA 77 states that: Resistance in continuous paths will typically be less than 10 ohms. Greater resistance usually indicates the metal path is not continuous, usually because of loose connections or corrosion (6.4.1.3).

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CA14 - Grounding of personnel & testing condition of footwear

Sole-Mate footwear tester
VESF50

Sole-Mate calibration unit
VESF59

using static-dissipative footwear / footwear tester

As with plant, it is equally important to ensure that personnel in hazardous areas are suitably earthed at all times. The most practical way to achieve this is to ensure that static dissipative footwear is worn and that floors have a suitable level of conductivity.

Several standards are in use, the most commonly adopted being the safety footwear standards, EN345 (Europe) and ANSI Z41 SD Type II (USA). Both recommend an upper limit for static dissipation of $1x10^9$ ohms. The alternative level of $1x10^8$ ohms, as described in CLC/TR 50404, BS5958 and ANSI Z41 SD Type I are occasionally used; however, it is more difficult to obtain this type of footwear.

In order to comply with the recommendations, a footwear tester should be used. It is vital to ensure that the tester selected monitors to the same level as the footwear in use on site. Testers monitoring to the levels recommended for use in the electronics industry (ESD) should not be used for testing the integrity of EN ISO 20345 or ANSI Z41 SD Type II footwear.

EN ISO 20345 states that the footwear…should normally have an electrical resistance of less than 1000 megohm ($1x10^9$ ohms) at any time throughout its useful life. The user is recommended to establish an in-house test for electrical resistance and use it at regular and frequent intervals (7.2).

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Guide to European Hazardous Area Equipment Coding

All ATEX Approved equipment (both electrical and mechanical) suitable for use in potentially explosive atmospheres carries the following type of marking:

⟨Ex⟩	European Community Ex mark
II	Equipment Group (Surface Industries = II, Mining Industry = I)
1, 2 or 3	Equipment Category
G	Suitable for use in a Gas / Vapour atmosphere or
D	Suitable for use in a Dust atmosphere or both (GD)
Example	⟨Ex⟩ **II 1 GD**
Note	The Equipment Categories 1, 2 and 3 approximate to the Hazardous Area Zones 0, 1 and 2 respectively (see table opposite)
Additionally	The temperature classification and gas (or apparatus) group needs to be known and in the case of electrical equipment, also the method of protection (see appropriate tables)

Methods of Ex Protection

Code	Method of protection	Cenelec standard	Equipment category	Description of protection
Ex o	Oil Immersion	EN 50015	2	flammable atmosphere excluded
Ex p	Pressurised	EN 50016	2	flammable atmosphere excluded / diluted
Ex q	Powder Filled	EN 50017	2	quenching of flame
Ex d	Flameproof	EN 50018	2	explosion contained within enclosure
Ex e	Increased Safety	EN 50019	2	explosion prevention by electrical design
Ex ia	Intrinsic Safety	EN 50020	1	low energy, safe with two operational faults
Ex ib	Intrinsic Safety	EN 50020	2	low energy, safe with one operational fault
Ex n	Non-Incendive	EN 50021	3	non-sparking in normal operation
Ex m	Encapsulated	EN 50028	2	flammable atmosphere excluded

Ex equipment may use more than one method of protection. For example, a ground monitoring system may use a flameproof enclosure (Ex d - Category 2, suitable for mounting in Zone 1) containing an associated intrinsically safe circuit (Ex ia - Category 1, suitable for use in Zone 0). In this case the associated equipment category will be shown in brackets, eg:

⟨Ex⟩ **II 2 (1) GD EEx d [ia]**	the additional “E” (EEx) denotes certified to Cenelec (ie. European) standards
⟨Ex⟩ **II 2 (1) GD EEx d [ia] IIB T5**	to complete the code, the gas group and temperature class are included

Temperature Class (Europe)

The hazardous materials are classed by their auto-ignition temperature and the T rating is the maximum surface temperature that the certified equipment can reach (measured at 40°C ambient).

T1	450°C
T2	300°C
T3	200°C
T4	135°C
T5	100°C
T6	85°C

Note that equipment approved for use in Gas or Gas and Dust zones usually has the temperature rating expressed as the T Class (eg T6), however equipment approved for use in Dust zones only, usually shows the actual temperature (eg T85°C).

Temperature Class (USA)

Note that Temperature Class subdivisions are used in the USA.

T1	450°C				
T2	300°C	T2A 280°C	T2B 260°C	T2C 230°C	T2D 215°C
T3	200°C	T3A 180°C	T3B 165°C	T3C 160°C	
T4	135°C	T4A 120°C			
T5	100°C				
T6	85°C				

Comparison of European (Cenelec), American (NEC) and International (IEC) Hazardous Area Classification

	Explosive atmospheres present continuously, for long periods or frequently	**Explosive atmospheres are likely to occur in normal operation**	**Explosive atmospheres are unlikely to occur, or be present only infrequently or for a short period only**
CENELEC / IEC	ZONE 0 (Gas / Vapour) ZONE 20 (Dust)	ZONE 1 (Gas / Vapour) ZONE 21 (Dust)	ZONE 2 (Gas / Vapour) ZONE 22 (Dust)
USA / NEC505 Class I (Gas)	ZONE 0	ZONE 1	ZONE 2
	Explosive atmospheres can exist all of the time or some of the time under normal operating conditions		**Explosive atmospheres are not likely to exist under normal operating conditions**
USA / NEC500 Class I (Gas) Class II (Dust) Class III (Fibres)	Division 1		Division 2

Two classification systems are used in the USA: NEC500 (Class / Division) and NEC505 (Class / Zone). NEC505 is similar to the CENELEC / IEC Zone system.

Comparison of European and American Gas (apparatus) Groups

Groups according to CENELEC, IEC and NEC505	
Gas Group	**Representative Gas**
I (Mining)	Methane
IIA	Propane
IIB	Ethylene
IIC	Hydrogen

Groups according to NEC 500					
Group		**Representative Gas**	**Group**		**Representative Dust / Fibre**
Class I	Group A	Acetylene	Class II	Group E	Metal Dust
Class I	Group B	Hydrogen	Class II	Group F	Coal Dust
Class I	Group C	Ethylene	Class II	Group G	Grain Dust
Class I	Group D	Propane	Class III		Fibres

Ingress Protection

It is generally accepted that ingress protection for Ex equipment starts at IP54:

IP54	protection against dust and water splashed from any direction (inc. rain)
IP55	protection against dust and low pressure water jets / hosing
IP65	completely dust tight and protected against low pressure water jets / hosing
IP66	completely dust tight and protected against heavy seas
IP67	completely dust tight and protected against periods of immersion in water

The American NEMA ingress ratings are difficult to equate to the IEC IP ratings, but the popular NEMA 4 rating approximates to IP55, with NEMA 4X having additional protection against corrosion.

On-Going Maintenance of Static Control Procedures and Equipment

Once appropriate static control procedures and equipment have been put in place, it is vital that a high level of static awareness is maintained. The three principles of a successful, on-going static control policy are:

i. Regular testing of the equipment used including logging of results.

ii. Frequent awareness training for operators and staff, particularly new employees.

iii. Reference to the standards when changes take place, such as the introduction of new types of plant or materials.

Generally, there are two main elements to the physical side of the static grounding system. These are firstly, the fixed grounding network. This may take the form of a copper strip or bar running along the walls and connected to a number of grounding rods, pits or grids, driven into the ground. This network should be tested periodically, with respect to ground, to ensure that it is maintaining a low (typically less than ten ohm) resistance to ground. These tests are fairly specialist, and may be carried out by an outside contractor, often in conjunction with tests on lightning protection equipment. A typical test period would be every 11 or 13 months (so that over a period of time, the tests cycle through the seasons). A main point to look out for when testing the network, is any significant variation with previous tests, which could show deterioration. This also highlights the need for keeping good records. If the grounding network meets the necessary low resistance, then any metal object connected to it will also be grounded.

The second part of the physical system is the devices used to connect plant and equipment to the grounding network. If a piece of plant is fixed, such as the body of a mixing machine, then a simple strong bonding cable can be used to permanently attach it to the grounding network. However, movable plant, such as the mixer's product bowl, or a 200 litre drum is harder to ground, and the standards recommend that a cable with strong mechanical strength and a “designed for purpose” clamp are used to make a temporary connection when the item is in use. These connections can be tested using an intrinsically safe ground lead tester or ohm meter and the results for each lead recorded. The tester or meter will be used to complete a circuit between the grounding point and the plant item to be grounded; for the purpose of testing clamps and their cables or reels, this may take the form of a clean piece of metal placed in the clamp jaw. The tester or meter leads may then be connected between the piece of metal and the grounding point in order to complete the circuit and obtain a reading.

These types of flexible connector should be tested more frequently than fixed ones; typically once every three months in the case of ground leads and after every re-assembly, in the case of bonds on removable ducting sections. A bond to a fixed piece of plant may be tested on an annual or six-monthly basis.

The on-going training of personnel may be more difficult to maintain, partly because of disruption to production, and also, as it can be difficult to keep things interesting. Training today need not just take the form of a classroom lecture; new learning media such as interactive CD-ROM provides flexible training solutions to accommodate the varying needs of production schedules, shifts and locations. Team leaders can quickly assess the knowledge level of existing or new operators and programme one or two hours per week to bring knowledge levels up.

Today, it is common for companies to use continuous monitoring of ground connections and systems incorporating interlocks that prevent a static-generating operation from taking place unless the ground is made. Such systems mean that the frequency of lead testing can be reduced, as the systems are providing a continuous test to a pre-determined resistance level. They also mean that the grounding measures are more likely to be remembered during operation, as a visual indication of ground condition, such as the LED in a self-testing clamp, act as a strong reminder to use the device.

Typical time intervals between tests:

Fixed grounding	Every 11 or 13 months
Fixed plant and equipment	Annually
Ground Monitoring systems and devices	Annually
Non-monitored grounding leads & clamps	Every 3 months
Removable plant sections	After every re-assembly
Footwear	Weekly or daily, depending on conditions

This information is intended for guidance only, as every situation is different and suitable periods between tests may vary depending on individual plant, processes, etc. Of course, any defects in grounding and bonding devices, noticed by staff between maintenance periods, should be reported immediately.

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Safety-Checklist

Maximise Safety in the Area

- Ensure all operators and managers are trained in safe working with flammable products. It is vital that they understand the characteristics and dangers of flammable products and the principles of static control.
- Ensure all electrical equipment is appropriate for use in the designated flammable atmosphere.
- Ensure lift trucks and other vehicles used in the vicinity are explosion protected to the appropriate standard.
- Ensure **"No Smoking"**, **"Static Hazard"** and **"Ex"** warning signs are clearly posted.

Minimise Charge Generation and Accumulation

- Ensure operators are supplied with static-dissipative / anti-static footwear. Gloves, if worn, should also be static-dissipative.
- Ensure floors are adequately conductive and are well grounded.
- Ensure static-dissipative footwear is always worn and remains in good condition by use of resistance testing before entry into the flammable area.
- Ensure all containers, pipework, hoses, plant, etc., are conductive or static-dissipative, bonded together and grounded.
- Ensure that sufficient, suitable grounding leads and clamps are provided to enable movable containers to be grounded prior to product transfer or mixing.
- Where practical, pipe liquids directly from storage to the point of use.
- Eliminate or minimise product free-fall distances.
- Where practical, keep pumping speeds low.
- When using plastic materials, such as drums, kegs, liners and hoses in flammable areas, they should be static-dissipative and suitably grounded.
- When using FIBCs (Big Bags) in flammable areas or with potentially combustible dusts or powders, they should be "Type C" static-dissipative and suitably grounded.
- The use of anti-static additives should be considered in low conductivity liquids if they do not harm the product.

Maintain Safe Working Practises

- Ensure all new operators, managers and maintenance staff are trained in safe working with flammable products.
- Develop a written "safe system of working" for the handling of flammable products.
- Ensure all grounding straps, clamps, wires and monitoring systems are regularly inspected and maintained. The results of inspections should be recorded. Intrinsically safe equipment should be used to test continuity.
- Ensure static-dissipative floors remain non-insulating.
- Ensure all contractors are controlled by strict "permit-to-work" systems.
- Where large, conductive, movable equipment, such as stainless steel IBCs, road tankers or "Type C" FIBCs could become isolated from earth, the use of ground monitoring systems, with suitable interlocks to process equipment, pumps or valves is recommended, to ensure that they cannot pose a static hazard.

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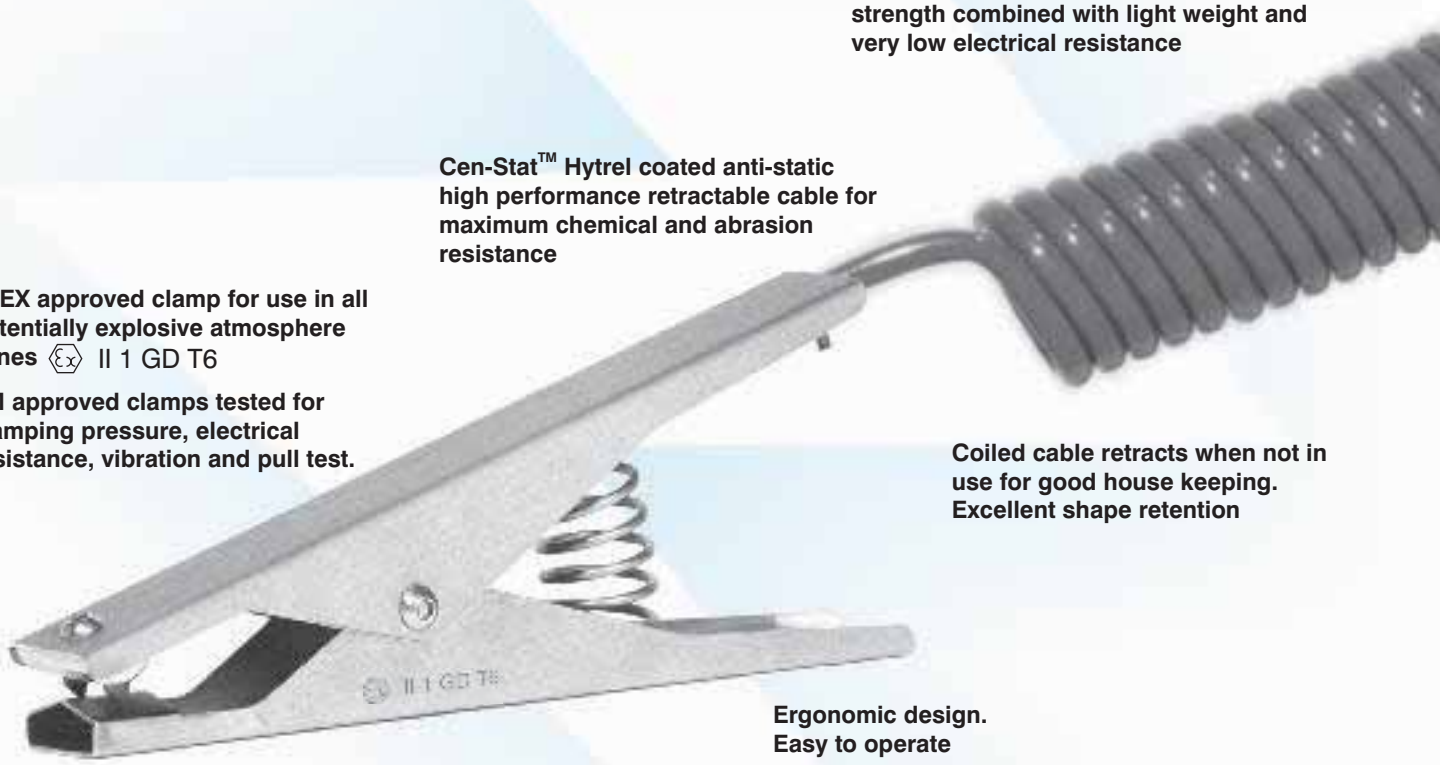
Anatomy of a Cenelectrex® Clamp & Cable

Steel core cable for maximum mechanical strength combined with light weight and very low electrical resistance

Cen-Stat™ Hytrel coated anti-static high performance retractable cable for maximum chemical and abrasion resistance

ATEX approved clamp for use in all potentially explosive atmosphere zones Ⓔx II 1 GD T6

FM approved clamps tested for clamping pressure, electrical resistance, vibration and pull test.



Coiled cable retracts when not in use for good house keeping. Excellent shape retention

Ergonomic design. Easy to operate

Powerful clamping action

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