Guidelines for the CONTROL OF STATIC ELECTRICITY IN INDUSTRY

OCCUPATIONAL SAFETY & HEALTH SERVICE

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1. INTRODUCTION

1.1 Static electricity is generated by the contact and separation of materials, and clearly this generation often cannot be prevented in the industrial setting. We must therefore aim at control measures rather than expend energy, time and resources trying to prevent the inevitable.

1.2 To evaluate the possibility of hazards from static electricity existing in an industrial locality or in a particular process, it is necessary to understand the causes and effects of the static electricity phenomenon.

1.3 Matter is composed of atoms that consist of negatively charged electrons circulating about a positively charged nucleus. When the surface electrons of a material are disturbed, an imbalance of negative and positive charges arises between the inter-acting surfaces, and results in the phenomenon known as static electricity. A deficiency or surplus of a single electron among 100,000 atoms is sufficient to give a detectable static charge on a surface.

1.4 Surface disturbances leading to the formation of a static charge can be caused in several ways but they all involve some kind of movement. They can result from induction, from the friction between two surfaces, or from the firm contact and subsequent separation of two materials. One of the materials becomes positively charged and the other negatively charged in the manner noted above and an electrical force of attraction will exist between them since, of course, unlike charges attract.

1.5 On an earthed conducting material, the charge flows away so rapidly after separation that it cannot be detected. However, if the material is a non-conductor or a perfectly insulated conductor, the electric charge cannot leak away. As this charge is unable to flow, it is called static electricity. It is ironic that *static* electricity requires *movement* for generation.

2. GENERAL HAZARDS AND PROBLEMS

2.1 The major hazard posed by static electricity is the possible ignition of flammable vapours or powders and this problem is discussed in more detail in Section 2.4 below.

2.2 Additional hazards are the production of unexpected shocks in humans that might result in injury caused by involuntary reflex action, and the possibility that false readings will be induced in sensitive instruments where static is present, These hazards may be less significant when compared with the ignition problem but they should still be given consideration.

2.3 Static electricity may cause industrial handling problems such as unwanted adhesion or repulsion of sheet paper in the printing industry, damage to delicate integrated circuits by the presence of high static voltages, and the blocking of powders and dusts being conveyed in pipes. Each of these problems can be alleviated by careful attention to specific control measures as discussed later (see Sections 3.4.2, 3.4.3, and 3.4.4).

2.4 Returning to the problem of the ignition potential of static sparks, the following conditions are necessary to produce a fire or explosion:

(a) Combustible material, gas, vapour or dust, must be present in the flammable range of fuel-to-air ratios for ignition to be possible;

(b) A static electric charge must have built up on a non-conducting object, or a conducting object that is insulated from earth, and this charge must have sufficient potential to discharge a spark to a neighbouring, usually earthed object;

(c) The spark must have sufficient energy to ignite the surrounding flammable mixture.

Precautions taken against ignition must eliminate at least one of the above conditions.

3. STATIC ELECTRICITY IN THE INDUSTRIAL CONTEXT

3.1 Major Industrial Sources of Static

As noted earlier, static electricity is always present in the industrial environment. Examples of typical situations likely to produce static electricity are:

(a) The use of power, or conveyor belts in which non-conductive materials move over or between pulleys and rollers;

(b) Pulverised materials or dusts passing through chutes or being conveyed pneumatically;

(c) The flow of fluids through pipes or conduits, or from orifices into tanks or containers;

(d) The flow of gases from orifices;

(e) The use of rubber-tyred vehicles;

(f) The general accumulation of static charge on personnel in the work place, particularly when they wear overalls made of synthetic materials.

3.2 General Means of Control

3.2.1 The principal methods used in industry to prevent the build-up of static electric charges to dangerous levels are:

(a) Bonding and earthing of stationary conductive equipment;

(b) Increasing the conductance of floors, footwear, wheels and tyres;

(c) Increasing the conductivity of non-conductors by incorporating conductive additives, surface layers and films, and by humidification of the atmosphere;

(d) Increasing the conductivity of the atmosphere by ionizing the air.

Section 3.3 considers these measures in more detail.

3.2.2 The first task in static control procedures is to identify all conducting equipment that may be isolated from earth, insulating materials. As noted before, the build-up of static electricity on such objects could have dangerous consequences especially as the existence of insulated conductors may not be obvious. Thus even rotating metal shafts may fall into this category if a non-conductive film of oil separates the shaft from the supporting bearings.

3.2.3 The most desirable method of control – the prevention of static generation – is rarely attainable. The solution to the problem lies in preventing a charge from building up to a hazardous level.

3.2.4 A resistance to earth not exceeding I megohm is usually sufficient to prevent the build-up of dangerous static charges, but a lower resistance is necessary when sensitive explosives and unstable chemicals are handled.

3.2.5 Hazardous static conditions cannot always be avoided with certainty in some operations, and thus additional precautions must be taken in areas where ignitable mixtures may be present. Industries at particular risk in this respect are chemical and pharmaceutical plants using flammable fluids and combustible dusts.

3.2.6 To summarise, the object of most static control measures is to provide a means by which separated negative and positive charges may re-combine or flow harmlessly to earth before sparking potentials are reached.

3.3 Discussion of Specific Control Measures

3.3.1 Bonding and earthing metal components is generally the single most effective means of control.

Bonding is the process of connecting together two or more conductive objects by means of a conducting wire or strip to eliminate a difference in potential between these objects, e.g., bonding across flanges of a metallic pipe.

Earthing refers to the connecting of one or more objects *to the earth* by a conducting strip.

Permanent earthing and bonding conductors shall be attached by soldering, welding, or suitable screwed terminations. The conductors also shall possess adequate mechanical strength and be made of corrosion resistant metal.

Spring-loaded clips may be used to provide earthing connections for moveable containers such as metal drums, but must be capable of maintaining metal contact through any paint or surface rust. Earthing clips must be connected *prior* to the use of the equipment or the pumping of flammable liquids, and *not* during use.

The integrity of bonding and earthing connections should be tested periodically, and particularly after equipment has been maintained or painted.

Further information on bonding and earthing procedures is available in AS 1020 *The Control of Undesirable Static Electricity*, an endorsed New Zealand standard.

3.3.2 Artificial humidification of the atmosphere is useful in certain instances as a backup to other control measures. A permanent relative humidity of at least 65% produces a very thin film of moisture on an exposed surface and this provides a conductive path for the dissipation of accumulated charge.

The method is best incorporated as part of the air conditioning system. In relative terms, it represents an expensive control measure and may not be suitable for some processes.

Humidification is ineffective with petroleum products as the necessary conducting film cannot build up. In such cases, the conductivity of oils and related products can be increased by using antistatic additives.

3.3.3 The conductivity of the air may be increased by the production of electrically charged *ions* that then provide a path to earth for static charges on equipment. Ionization of the air can be accomplished by:

(a) Electrical static eliminators;

(b) Induction needle bars (comb-type eliminators);

(c) Bars employing radioactive sources, which emit ionizing radiation.

Powered and radioactive devices both introduce potential new hazards and should only be installed with caution after considering other methods. The Radiation Protection Act and accompanying Regulations, administered by the Department of Health, set out requirements for the handling and use of radioactive materials.

3.3.4 Conductive flooring and footwear should be provided wherever an easily ignitable atmosphere may exist. This is especially important in the case of gases and solvent vapours since the static charge that can accumulate on the human body can be up to 25 mJ, which is often sufficient to provide the ignition spark. The following floors are considered sufficiently conductive to dissipate static electricity:

- Metal;
- Concrete floors, clean unpainted and free from oil;
- Wooden floors that are untreated or simply waxed;
- Special conductive plastic flooring.

Besides providing the necessary means for the safe leakage to earth of the accumulated charge, items of clothing, especially those containing synthetic fibres should not be donned or removed within the area of potential hazard.

3.4 Materials Handling Problems

3.4.1 In Section 2.3 we mentioned the industrial nuisance potential of static electricity in certain contexts.

Typical control measures, which are necessary in these cases are now considered.

3.4.2 Besides bonding and earthing of machinery, the specific problems posed by static electricity in the production of synthetic fibres and plastic sheets and film, and the paper industry, may be overcome by ionizing the air using static comb devices backed up where practical by humidification of the atmosphere in areas of low humidity.

3.4.2 The manufacture of integrated circuits is an intricate procedure and static charges can easily damage the delicate componentry. Methods to eliminate this problem involve the provision of special anti-static work stations.

3.4.4 When powders are conveyed in pipes, the build-up of static electricity can produce dual problems of possible ignition by sparking and clogging due to the charged powdered material. Conveying dusts only in metal pipes that are bonded and earthed eliminates these problems. If plastic flexible couplings are essential, these should be kept as short as possible, preferably to less than 1 m.

Figure 1: Typical Construction for a Static Comb

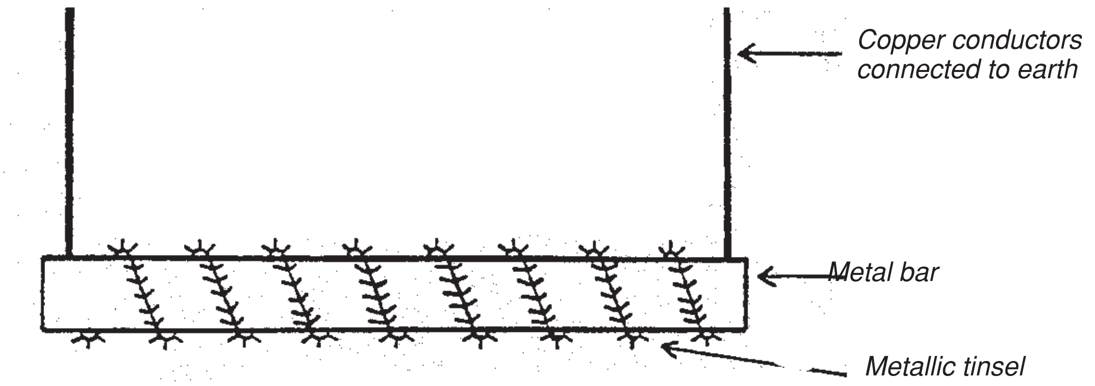


Fig.2 Filling a Tanker with a Flammable Liquid

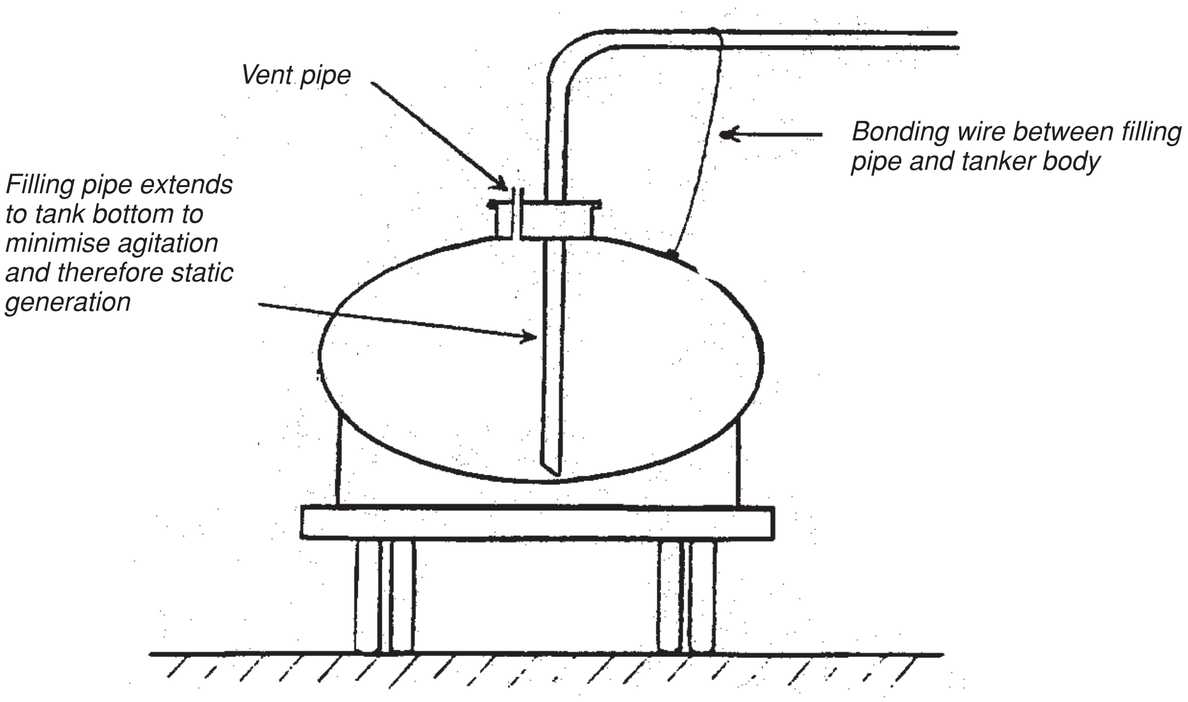


Fig.3 Location of Ionising Device for Dissipating Static Charge from Drive or Conveyor Belts

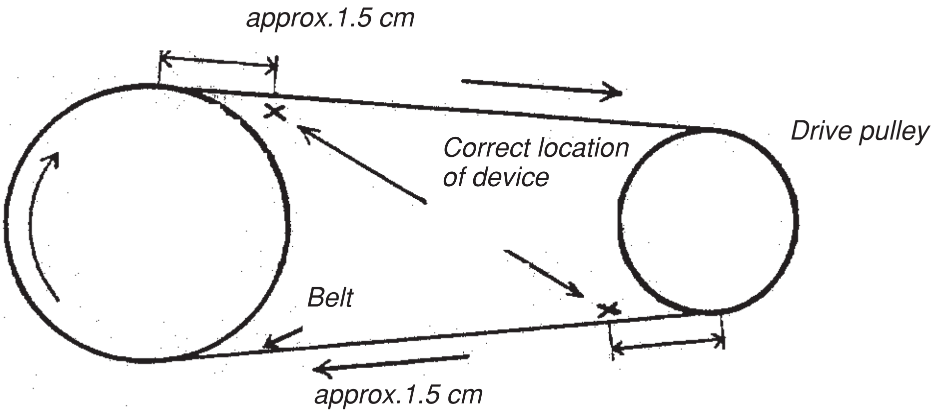
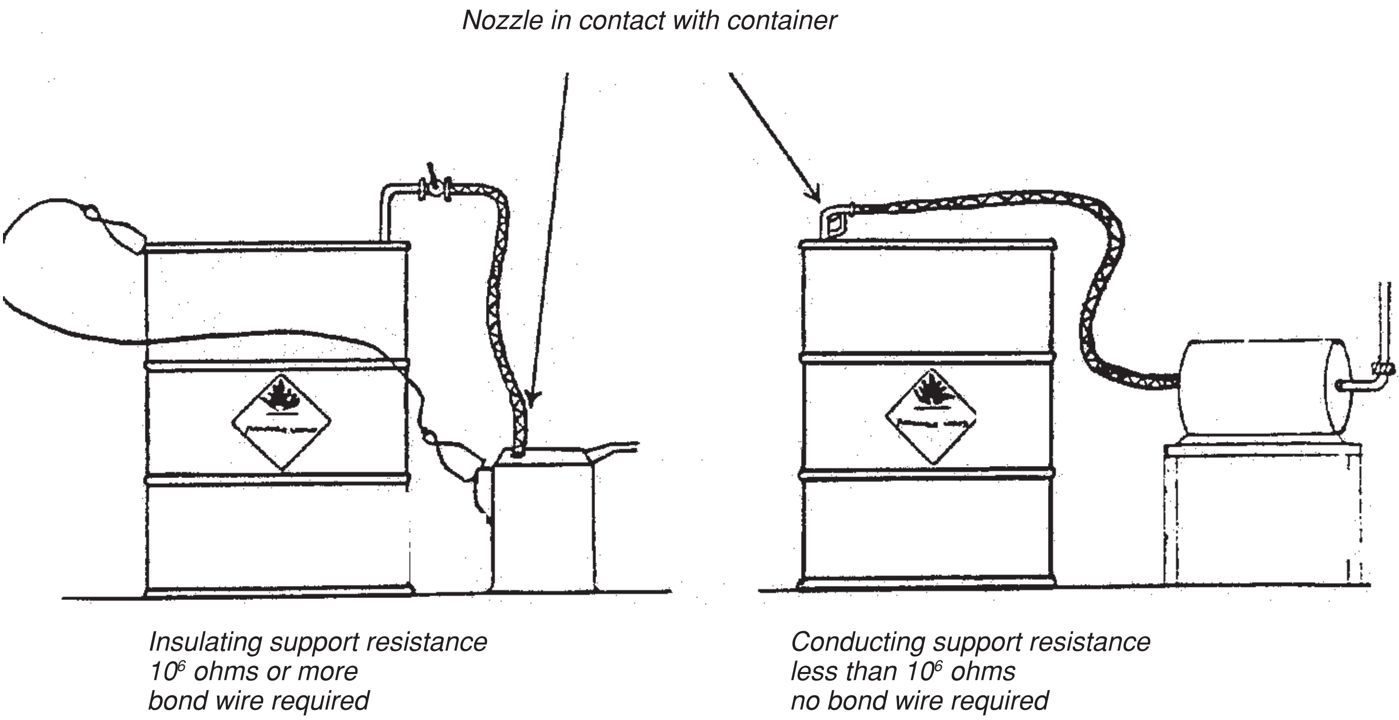


Fig. 4 Bonding During Container Filling



4. HAZARD CONTROL IN SPECIAL PROBLEM PROCESSES AND INDUSTRIES

4.1 Liquids in Motion

4.1.1 The generation of static charges within liquids occurs with movement in such operations as liquids flowing through pipes; the mixing of liquids; the pumping, filtering and agitating of liquids; or by pouring a liquid from one container to another. All liquids in motion can generate static electricity even though they flow or are contained in bonded and earthed pipes or vessels.

4.1.2 Under certain conditions, non-conducting liquids such as hydrocarbon solvents can accumulate high static charges. The production and accumulation of static electricity is especially serious if the liquid splashes and forms a mist inside a tank or other vessel.

4.1.3 To control the build-up of static electricity generated in flammable liquids, close attention must be given to the following procedures:

(a) Fill pipes should either extend almost to the bottom of the tank or enter from below to minimise mist formation.

(b) Use low-speed stirring or agitation to achieve mixing of materials; in particular do not pour powders from insulated bags or kegs with polythene liners directly into vessels containing flammable solvents. The static charges developed on the powder in these operations has resulted in spark discharges to the earthed vessel and a number of explosions overseas. Such additions should be added from a metal scoop by a worker wearing conductive footwear and standing on a conductive surface such as metal or concrete. An alternative solution to the problem would be for the manufacturers to supply the powder in conductive containers.

(c) Wherever possible, limit the velocity of liquids in pipelines to below 1 m/sec. This will generally reduce the formation of static electricity to non-hazardous levels.

(d) The manufacturers of hydrocarbon solvents generally add anti-static agents to assist the dissipation of any static charges formed. This information is not normally published and must be verified by contacting the manufacturer.

4.2 Moving Belts

4.2.1 As previously noted, the generation of static charges on moving belts cannot be prevented but the accumulation of the charge can be controlled by using conductive material in the belting and the use of metal rollers. This allows the charges to dissipate as fast as they are formed.

4.2.2 Belts may be made conductive by incorporating interwoven wires, or by the addition of carbon to the belt material during manufacture.

4.3 Gas Discharges

4.3.1 Pure gases discharged at high velocity through jets under conditions where neither liquid droplets nor solid particles are present seldom acquire sufficient static charge to result in ignition. However, when the gases contain liquid droplets or solid particles, or when these are formed during the discharge, sufficient charges can accumulate to ignite flammable vapours present. Several fires and explosions have been caused in this way.

4.3.2 The release of carbon dioxide gas from cylinders where it is stored under pressure is often accompanied by cooling. This results in the formation of charged solid particles of carbon dioxide, and ice may also be formed. A static charge may therefore build up during the discharge of carbon dioxide and the gas is thus not recommended for the rapid blanketing of flammable areas.

4.3.3 The situation described above for carbon dioxide may also apply to compressed air or steam escaping from an orifice. In each case, charged water droplets may impinge on the orifice or on a nearby insulated conductor with a consequent build-up of charge.

4.3.4 Carbon dioxide, steam or air are all examples of potential inerting or diluting agents for flammable atmospheres but clearly the ignition hazard noted above must be borne in mind. Thus the inlet nozzle, the tank, and any other surface that can accumulate a charge should be bonded and earthed. It must be stressed that, where applicable, it is safer to use water displacement to remove flammable vapours completely before carrying out hot work on tanks or containers.

4.3.5 If the gas discharging through an orifice is itself flammable, then clearly the hazards highlighted above for “inert” gases will be even greater. A particular example is Liquefied Petroleum Gas (LPG), which will readily produce charged droplets when released through an orifice. A static charge arising in this manner may represent an extreme hazard. Appendix 1 contains a list of minimum ignition energies for some common vapours and gases.

Other examples of flammable gases that can be ignited by a static discharge are hydrogen-air and acetylene-air mixtures.

4.4 Electrostatic Paint and Powder Application

4.4.1 Stricter rules are required for the application of paint by electrostatic methods than for powder. This is because flammable solvent vapours are much more easily ignited than are powders applied by electrostatic means. (Compare the minimum ignition energies tabled in Appendices 1 and 2).

4.4.2 The article being painted and all metallic equipment in and within 2 m of the booth must be adequately earthed.

4.4.3 In addition, for electrostatic paint spraying, it is imperative that the floor and soles of operators' footwear is conducting. This requirement also applies to other workers in the vicinity. For electrostatic powder coating applications, these provisions are only essential when the ignition energy of the powder in question is below 25 mJ.

4.4.4 Further information is available in the *Code of Practice for the Application of Coatings by Spraying of Electrostatic Powders,* published by the Occupational Safety and Health Service of the Department of Labour.

4.5 Combustible Dusts

4.5.1 Most industrial processes producing dusts, e.g. sieving, pouring, conveying and grinding, result in the build-up of static charges. Although dust clouds are often considerably more difficult to ignite than gas or vapour-air mixtures, this factor varies enormously and depends on the particle size and moisture content, as well as the chemical composition of the material.

4.5.2 Charged clouds of dust settling upon insulated surfaces can cause appreciable accumulations of static charge. In almost every major dust explosion initiated by a static discharge, the cause was traced to sparking between an insulated conductor charged by the dust and adjacent grounded equipment.

4.5.3 The energy in a static spark discharge from a large insulated machine may be about 50 mJ and that from a person up to 25 mJ under the most favourable conditions. Appendix 2 contains a list of dusts with their minimum ignition energies, from which can be judged the relative hazard from static charge accumulation in any particular situation.

4.5.4 All equipment producing, collecting and transporting dusts such as grinders, conveyors and hoppers should be constructed from metal and be bonded and earthed, If the dusts have ignition energies below 26 mJ, the flooring and operators' footwear must be conducting.

4.5.5 In addition to removing all sources of ignition including static discharges, industrial systems handling combustible dusts also must be protected against the possible effects of an explosion. The most commonly employed protection method is to fit explosion relief vents of adequate area. Other possible protection methods are the use of an inert gas in a closed system that enables recirculation, or the installation of a rapid-acting explosion suppression system. These alternative methods will normally be more expensive than relief venting.

4.6 Explosives

4.6.1 A static discharge spark will readily detonate primary explosives. Steps necessary to prevent accidents from static electricity in explosives manufacturing operations and storage areas vary considerably with the static sensitivity of the material being handled.

4.6.2 Wherever possible, the plant and equipment, including containers such as hoppers and scoops, should be constructed from conductive materials and bonded if applicable.

4.6.3 The accumulation of static can be prevented on any non-conductive part of the plant by application of conductive surface coatings, or by maintaining a sufficiently humid atmosphere.

4.6.4 Woollen and flame-resistant cotton garments are most suitable where sensitive primary explosives are handled. Clothing containing nylon, polyester or other synthetics should not be worn since these may accumulate a static charge of sufficient energy to cause ignition. Footwear and flooring should be conductive.

5. ELECTROSTATIC CHARGE DETECTION

5.1 The presence of static electricity can be crudely detected by sensory perception or by the attraction or repulsion of light objects. However, the extent of static charge accumulation should generally be estimated by instruments. A qualitative or at best semi-quantitative measure can be obtained using the classic gold leaf electroscope or a neon glow tube.

5.2 More quantitative measurements will require the use of either a vacuum tube electrometer, or preferably an electrostatic voltmeter.

5.3 Periodic surveys of static control measures using instruments of the type discussed above are recommended in situations where the handling of ignition-sensitive materials is carried out.

APPENDIX 1

MINIMUM IGNITION ENERGIES FOR SOME COMMON COMBUSTIBLE VAPOURS AND GASES

Vapour	mJ	Vapour	mJ
acetone	1.15	isopropanol	0.65
carbon disulphide	0.01	acetylene	0.02
diethyl ether	0.19	butane	0.25
ethyl acetate	1.42	propane	0.25
heptane	0.24	ethylene	0.07
hexane	0.24	ethylene oxide	0.06
methanol	0.14	hydrogen	0.02
methyl ethyl ketone (MEK)	0.53	methane	0.28

APPENDIX 2

MINIMUM IGNITION ENERGIES FOR SOME COMBUSTIBLE DUST CLOUDS

material	mJ	material	mJ
aluminium powder	10	phthalic anhydride	15
aspirin	16	pitch	20
benzoic acid	12	polycarbonate	25
calcium stearate	15	polyethylene	10
caprolactam	60	polypropylene	30
cellulose	40	polystyrene	15
coal	varies between 50-120	rice	50
cocoa	120	rubber	50
cork	35	sodium acetate	35
epoxy resin	9	stearic acid	25
lignin	20	sugar	30
lignite	30	sulphur	15
magnesium	40	thorium	5
nitrocellulose	30	titanium	15
nylon	20	urea formaldehyde resin	34
paper	60	vitamin C	60
perspex	15	wheat flour	50
phenol formaldehyde	10	wood flour	20
p-phenylene diamine	30	zinc stearate	10
		zirconium	5

Data taken from *Dust Explosions and Fires,* by K N Palmer, Chapman and Hall, 1973.