



Resin dust explosion risks

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HARRPA

Hydrocarbon Resins, Rosin Resins and Pine Chemicals Producers Association

1. Introduction

1.1. HARRPA

HARRPA (Hydrocarbon Resins, Rosin Resins and Pine Chemicals Producers Association) is located in Brussels. HARRPA is a CEFIC (European Chemical Industry Council) sector group.

HARRPA represents the Europe based, hydrocarbon resins, rosin resins and pine chemicals producers. HARRPA has strong world wide connections to associations, like PCA (Pine Chemicals Association) in the USA, ANIPIN (Associação Nacional dos Industriais do Pinus) in South America, and with Asia-Pacific producers.

HARRPA represents the producers of resins based on natural raw materials (tall oil rosin and gum rosin) coming from pine trees, and resins derived from hydrocarbon feedstock from the petrochemical industry.

HARRPA's mission is to provide a forum for industry discussion, to share best practices with all stake holders, and to represent industry interests by interacting with the European Union authorities.

1.2. Products applications

After processing, the raw materials become resins. Depending on the starting materials and the nature of the reaction, the resins can range in colour from water white to dark yellow/brown and from liquid to solid at ambient temperature.

These resins find numerous applications amongst others paints, coatings, adhesives, hot melt adhesives, sealants, printing inks, rubber, tyres, paper, road construction, and also chewing gum, beverages including wine, cosmetics, fragrances and perfumes, etc...

To find out more about HARRPA, please visit our website <http://www.cefic.org/harrpa>.

1.3. Scope of the brochure

This brochure is designed to share information about the major risks associated with the handling of solid resins. (For definitions see § 2.1.)

The goal of this brochure is:

- to identify and collate the best practices in the industry
- to share those practices with safety professionals and others
- to reduce the risks related to handling of solid resins

This document is written on behalf of HARRPA.



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It is not intended to give answers to all safety aspects related to the handling of these solid resins. This document shares best practices and ideas from the companies that helped compile it.

It should be noted that circumstances may differ, and one should always study the local rules and legislation and take the appropriate measures related to that particular situation.

It is the responsibility of local management to make sure that all precautions are taken to safeguard people, equipment and the environment.

The information and advice in this brochure is given in good faith, but it is up to the user to check the suitability of equipment and operating procedures for their own particular situation and any relevant local laws or regulations.

Neither HARRPA nor Cefic shall be liable for any loss, damage or injury which may arise from the use of these guidelines, whether caused by negligence or otherwise.



2. Products covered

2.1. Definitions

In this brochure, the word **resin** is not limited to hydrocarbon resins, or rosin resins but includes: tall oil, wood, gum rosins and their derivatives.

The handling of these resins might create dusts. These dusts have certain explosion characteristics. Under adverse conditions explosions may occur.

Solid resins are delivered as prills, flakes, pellets, or in drums (cast solid). They are brittle materials prone to create dust during handling. These combustible dusts present a fire or explosion hazard when dispersed in air or other gaseous oxidiser. This may lead to violent explosions if ignited.

2.2. Clusters of rosin resins and rosin derivatives

- | | |
|------------|--|
| Cluster R1 | Rosin disproportionated, dehydrogenated, hydrogenated, dimerized, decarboxylated rosin |
| Cluster R2 | Glycerol - pentaerythritol esters from Cluster R1 |
| Cluster R3 | Rosin treated with maleic/fumaric acid or maleic anhydride |
| Cluster R4 | Glycerol, pentaerythritol esters from Cluster R3 and their salts like Li, Na, K, Mg, Ca, Zn, including aliphatic amine salts and ammonium salts |
| Cluster R5 | Rosin, condensed with formaldehyde, phenol, alkyl phenols, aryl phenols and if applicable esterified with polyvalent alcohols and if applicable their metal salts and if applicable modified with hydrocarbon resins on basis C5-C10 and if applicable fatty acids (like tall oil fatty acids, soy bean oil, coconut oil, linseed oil, castor oil) and if applicable their esters. |
| Cluster R6 | Rosin, treated with maleic/fumaric acid or maleic anhydride, condensed with formaldehyde, phenol, alkyl phenols, aryl phenols and if applicable esterified with polyvalent alcohols and if applicable their metal salts and if applicable modified with hydrocarbon resins on basis C5-C10 and if applicable fatty acids (like tall oil fatty acids, soy bean oil, coconut oil, linseed oil, castor oil) and if applicable their esters. |
| Cluster R7 | Rosin acids and resin acids condensed with formaldehyde. |

**2.3. Clusters of hydrocarbon resins and derivatives**

- Cluster H1 Aliphatic, alicyclic resins
Aliphatic unsaturated (C5 dienes, C4-C6 olefins), aliphatic cyclic (DCPD, terpene resins)
- Cluster H2 Terpene resins
 α -pinene, β -pinene, α/β -pinene, d-limonene, camphene, dipentene / β -phellandrene
- Cluster H3 Aromatic containing resins
Aliphatic/aromatic (pure monomers), aromatic (pure monomers), aromatic/cyclic, C9 aromatic, aliphatic/C9 aromatic
- Cluster H4 Hydrogenated resins
Aliphatic, aliphatic/aromatic, aliphatic/aromatic/cyclic (Terpene)
Aromatic: DCPD/indene/styrene/ α -methyl styrene/vinyl toluene/isobutylene, α -methyl styrene/styrene, α -methyl styrene/vinyl toluene, styrene, others
- Cluster H5 Polycyclopentadiene resins
- Cluster H6 Coumarone-indene resins
Coumarone indene, modified coumarone indene

2.4. Physico-chemical properties of solid resins

Typical range of measured dust characteristics of solid resins are given in the table below. (All the explosion characteristics given have been measured in accordance with International standard methods). As can be seen, a wide range of values are found, and protection can be problematic/expensive for some geometries for St 3 powders (fastest burning explosion class). Therefore protection will require testing of the powder at a recognized testing laboratory. (See references Section 8). For an expert to design a safe protection system (suppression of venting) the following data will be required vessel shape and volume, vessel strength (safe working pressure), the dust explosion characteristic value Kst or St Class. See glossary for definition of terms.

Minimum Ignition Energy	$\cong 1 - 3 \text{ mJ}$
Lower Explosion Limit (in air)	$\cong 15 \text{ g/m}^3$
K_{st} (explosion index)	$\cong 150 - 315 \text{ bar.m.s}^{-1}$
Electrical Resistivity	$> 10^{14} \text{ Ohms.m}$
Dust Auto Ignition Temperature	$\cong 360 \text{ }^\circ\text{C}$
Maximum Explosion Pressure	$\cong 8.8 \text{ bar}$
Hazard Class	= St 1 or St 2 or St 3
Layer Ignition Temperature	= Not measurable (product melts)



3. Hazards and precautionary measures

3.1. General remarks

Combustible dust when finely divided or suspended in air presents a fire or explosion hazard when ignited.

Minimize airborne dust and eliminate all ignition sources. Keep away from heat, hot surfaces, sparks, and flame. Control sources of static electricity at conveyors, ducts, piping, and mechanical and manual resin handling operations by installing and maintaining proper electrical bonding and grounding systems.

Establish good housekeeping practices. According to NFPA standard 654, dust layers 0.8 mm thick can be sufficient to warrant immediate cleaning of the area.

Do not use air hoses for cleaning. Minimize dry sweeping to avoid generation of dust clouds. Vacuum dust-accumulating surfaces and remove to a chemical disposal area. Vacuums with explosion-proof motors should be used.

Handle in accordance with good industrial hygiene and safety practices. These practices include avoiding unnecessary exposure to and removal of the material from eyes, skin and clothing. Wash thoroughly after handling. In particular suitable respiratory protection must be provided and worn.

Use continuous suction at points of dust generation to capture and minimize the accumulation of dust clouds. Always use appropriate Personal Protective Equipment (PPE).

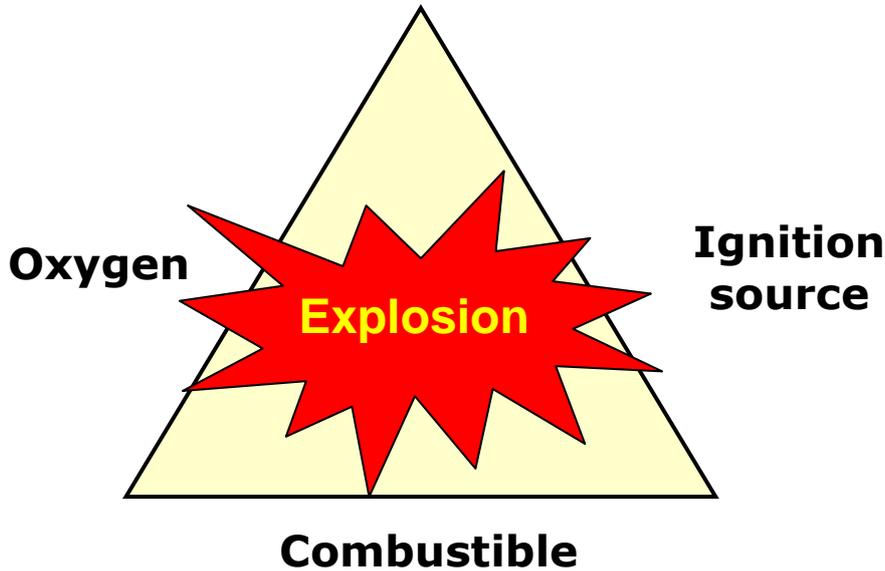
Train workers in the recognition and prevention of hazards associated with combustible dust in the plant.

Always read and understand the SDS (Safety Data Sheet) and label information before using the products.

3.2. Conditions leading to an explosion

Uncontrolled combustion may lead to an explosion and can take place provided three components are present simultaneously and in the right amount. The components are: combustible material (fuel), oxygen, source of ignition.

This can be illustrated by the well known fire triangle.



For combustion/explosion, the fuel/oxygen ratio must be within a specific range. Also, the ignition energy must be sufficiently high to initiate combustion. Additionally for dust explosions a source of energy is required to disperse the dust in air (e.g. draft, gravity or agitation).

Resins are flammable and the minimum ignition energy for resin dust is low. (See table §2.4. above).

Prevention of fires and explosions is generally accomplished by removing one or better two sides of the fire triangle.

The recommended preventive/mitigation measures are based on that principle.

3.3. Summary table

The table hereafter is a summary of the main hazards and possible related safety measures. Actual measure will depend on local conditions.

HAZARD	PRECAUTIONARY MEASURES
Ignitions sources	
• Flames: welding flame, cutting flame, combustion engine, cigarettes or smoking materials	→ Working methods: orders, procedures, work permits
• Electric spark: Motors, switches, fixed and portable instruments, cellular phone ...	→ Equipment selection and maintenance - ATEX regulation (area classification / adequate equipment selection)



<ul style="list-style-type: none">• Mechanic spark / hot spot: Hammer, sandblasting, frictions,	→ Equipment selection and maintenance - ATEX regulation (area classification / adequate equipment selection) work permits
<ul style="list-style-type: none">• Electrostatic spark: Charges generated by friction, contact... (Pouring product, product flow, machinery)	→ Grounding / bonding of conductive pieces, selection of anti-static materials (PE bags, operator clothes,), hygrometry (humidity) measurement and control.
<ul style="list-style-type: none">• Auto-ignition: Hot surfaces (steam line, machinery,...), self - heating due to product oxidation	→ Equipment and facilities design, dust accumulation prevention (design, housekeeping)
Flammable material	
<ul style="list-style-type: none">• Flammable dust in cloud	→ Minimize dust generation (design, equipment selection, oil/water pulverisation), avoid accumulation (dust collection system, housekeeping)
Oxygen/Air	
	→ Inerting
Explosion	
	→ Explosion mitigation: explosion vent, explosion suppression, secondary explosion risk prevention, explosion propagation prevention
Other risk: Health risk	
Suspended dust presents respiratory risks for the personnel exposed to it	→ Anti-dust mask

3.4. Equipment and facilities design

A few simple rules should be observed when designing a plant:

- Avoid the creation of dust.
- Use where possible equipment, which does not induce the formation of dust clouds.
- Surfaces should be smooth and easily cleaned. Sloped surfaces are to be preferred over horizontal.
- Access for inspection and cleaning should be made to all concealed areas such as, Equipment, Ducts, Pipes, Hoods, Ledges, Beams and Suspended Ceilings.



- Piping and cables that exit dusty areas through walls, floors or ceilings must be sealed and dust proof.
- Cleaning: only clean by suctioning in order not to disperse the dusts.
- Install dust collection equipment at the debagging station or at the product processing station.
- Do ensure that dust concentrations are below the explosive range.
- Create an inert (or oxygen-depleted) atmosphere in the equipment presenting risks when the presence of a dust cloud is inevitable, bearing in mind the process involved.
- Protect the equipment using discharge devices such as (e.g.):
 - explosion hatches
 - safety panels / rupture discs
 - automatic expansion devices
 - install explosion suppression system
- Connect the vents to a safe location outside of the plant.
- Ensure proper electrical grounding of all equipment.
- Plastic pipes or plastic lined pipes should not be used unless they are specially made to be conductive and earthed.
- Choose mechanical and electrical equipment complying with local regulation and not susceptible to generating heat or sparks (e.g. power break) leading to the ignition of the dust.
- Forklift trucks: use of specific types.

3.4.1. Electrical equipment

This equipment must necessarily be adapted to the ATEX classification of the zone concerned, and be designed to be operated in a dust-laden atmosphere.

Please note: If the equipment is dismantled while still live, or if protective casings are opened, safety can no longer be guaranteed. Seals must be maintained in good condition.

3.4.2. Explosion vent

For an expert to design a safe protection system (suppression or venting) the following data will be required, vessel shape and volume, vessel strength (safe working pressure), the dust explosion characteristic value Kst or St Class.





The following international guides are generally used in this regard:

NFPA-68: Guide for venting deflagration (National Fire Protection Association USA)

VDI 3673: Pressure relief of dust explosion (Verlag Düsseldorf Germany).

The vents should be ducted to a safe place outside the plant using a duct with suitable diameter and sturdiness. In addition to the venting arrangements, up-stream, down-stream and work areas will need to be protected by suitably specified rotary and/or fast acting valves.

Exhaust pipes should not have any sharp bends or be too long.

3.4.3. Explosion suppression

Another protection method consists of explosion suppression. This uses pressure measurement to detect an initiating explosion and then fires fire extinguishing agent into the vessel. As with venting, other areas of the plant will need to be protected by rotary or fast acting valves of suitable specification. Such systems must be designed, installed and maintained by experts.

3.4.4. Grounding/bounding

As a general rule: do remember that static electricity is always **present**. It is generated in varying degrees by the friction of the products against the walls of the equipment and pipes (by charging, agitation or pneumatic transport).

Sparks, resulting from a potential difference, can even appear between an operator moving closer to a piece of equipment and the equipment itself. The pulse energy in this specific case is of the order of 30 – 50 mJ.

The mere flow of solid particles down the slopes of a heap inside a silo causes a build-up of charge.

Therefore make sure that:

- Electrical continuity connections are present, and ducts and pipes connected to the various apparatus are earthed correctly.
- The foot-racks on metal platforms and the internal metal parts of the equipment are earthed.
- Pneumatic conveyor lines and sieves are earthed.
- Debagging hoppers and pipes connected to them are earthed.
- Flow velocities are kept as low as is practical.

Electrical continuity and equipotent bounding must be checked on a regular basis in accordance with the regulations in force in the country.

Regular cleaning of the metal floors also contributes to their proper electrical continuity.

Insulating materials which can impair proper electrical continuity must be banned.

Equipment that is liable to contain dust must not be allowed to act like a lightning rod.



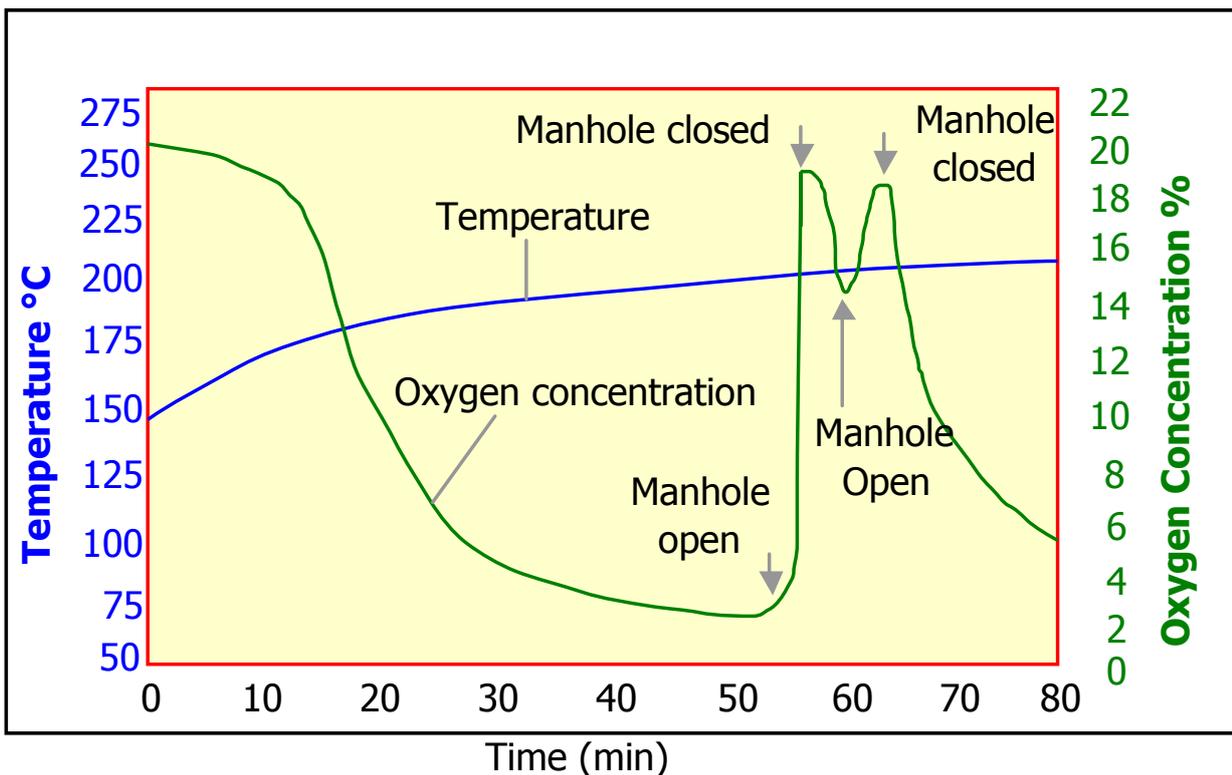
Please note: personnel must wear safety shoes with conductive soles on conductive floors.

3.4.5. Inerting

Inerting is the process of converting from flammable or reactive conditions into a safe non-flammable state by the addition of an inert gas (usually nitrogen, but also carbon dioxide, or others can be used).

An inert gas such as nitrogen can be used to lower the oxygen concentration inside the vessel. According to experts opinion, the maximum oxygen content should be as low as possible and, as a rule of thumb, should not exceed 4 %, but should be checked in any case.

The inerting system must be designed to prevent air ingress when loading the vessel. When equipment has been purged with inert gas, particular attention must be paid to the risk of asphyxiation for personnel operating the plant or entering the enclosures concerned for maintenance purposes. In such cases, access permits must be required in addition to work permits and testing that the air is 21% oxygen (i.e.) air is essential immediately prior to each entry.



Changes in oxygen levels during heating of raw materials to 200°C

Basic understanding of the chemistry of the manufacturing process and good engineering practices are necessary to determine the risks and the appropriate design of the process equipment. A study by T.J. Snee (T.J. Snee, 1985) shows that all steps in the production process should be considered. In this study T.J. Snee has shown that opening an inerted



vessel increases the oxygen concentration dramatically during warming up of the content of the vessel (see graph hereafter). The oxygen concentration increases to 21 % in a short time. The presence of an ignition source or sufficient heat may have serious consequences.

Pure nitrogen or carbon dioxide, or a mixture of air and nitrogen may be used for purging purposes.

In the latter case, adjusting the mixture can be achieved in a simple way by using an oxygen analyser after mixing at a sufficient distance from the nitrogen inlet point.

Operating outside the flammability limits is under all circumstances essential and inerting can help to achieve this. Suppliers of inert gases can help with design and delivery of the right equipment and gas for the specific production process.

Explosive atmospheres are not only created by resin dusts, but may include dusts from other raw materials leading to completely different explosion conditions.

Apart from dust explosions, be aware of other explosive atmospheres created by gas, liquids or mists.

When working with combustible or flammable materials, run risk analysis.

An article of G. Raykovitz, (Safety first for maximum benefits – Adhesive Technology , March 2001), describes the T.J. Snee study and the challenges created by relying on inerting alone.

3.4.6. Secondary explosion risk

A primary explosion can spread outside the zone in which it first occurred. An ensuing pressure wave can then scatter dust deposits into suspension (from steel structures, pipes, equipment or any horizontal surface.), and, through the energy released by the primary ignition, produce a secondary explosion. Hence good house-keeping is essential to prevent devastating secondary explosion and also to ensure hygienic conditions. All vessels, hoppers and dust containers must be kept with their hatches closed and sealed.

Example: ignition of coal-gas in a mine causing a secondary dust explosion.

**4. Product handling****4.1. Pouring product****4.1.1. Static charge generated when pouring resins**

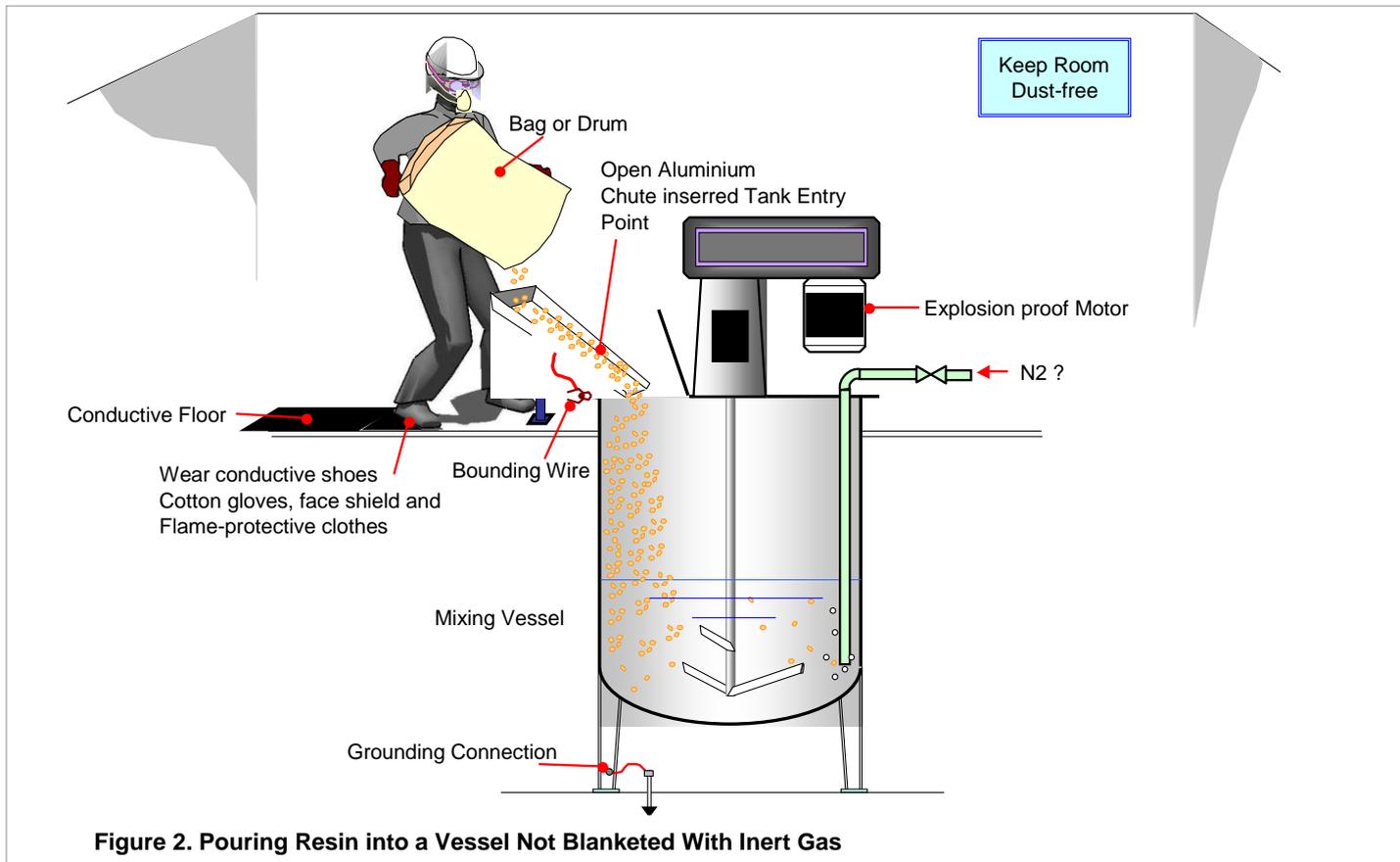
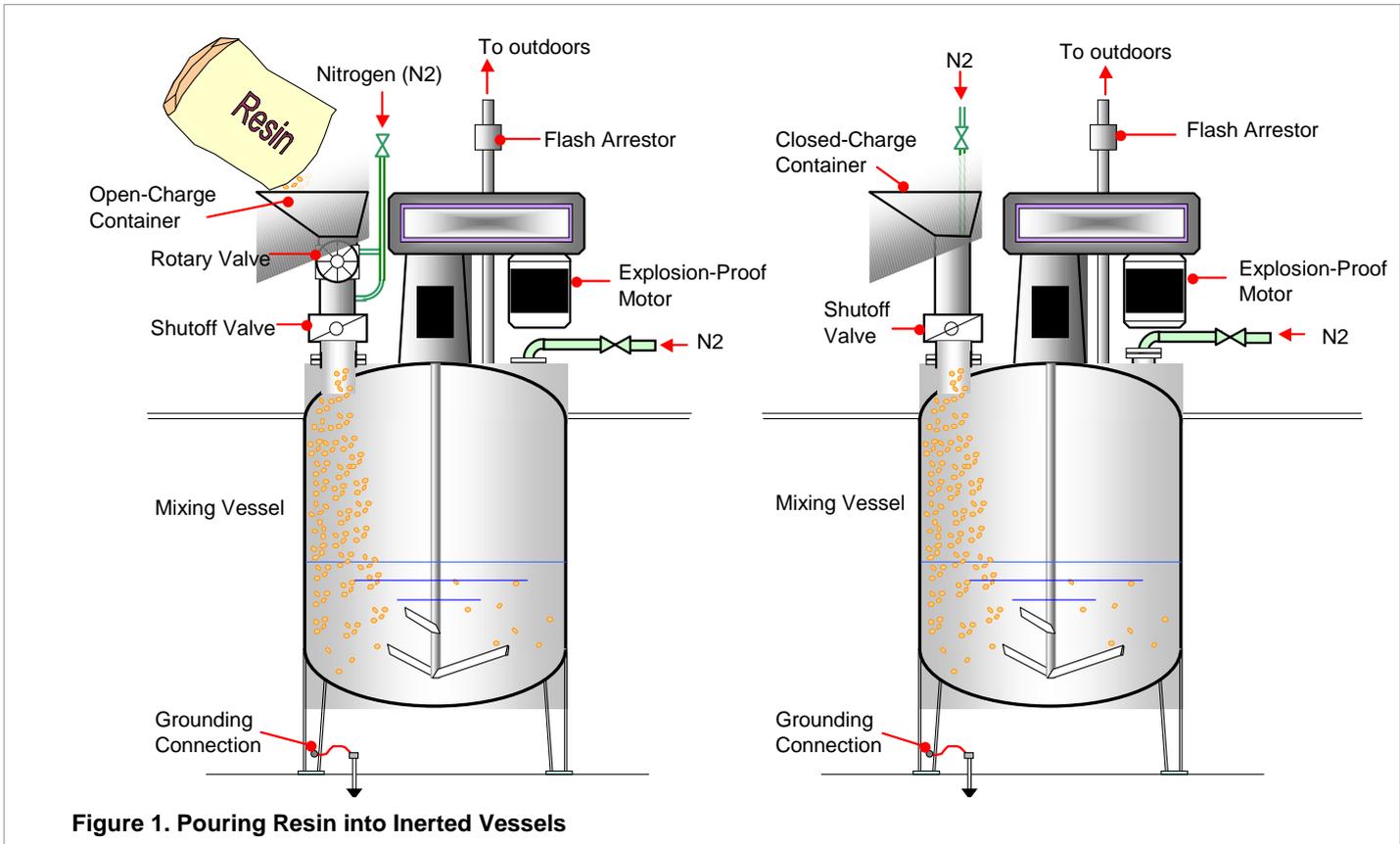
In the past, recognised institutes completed tests to determine the magnitude of static electricity generated when emptying bags of resins. Plain, plastic-lined, and plastic-coated kraft paper bags, as well as polyethylene plastic bags, were used in the tests. Although the testing was performed primarily for resins, finely divided polypropylene flake and sand were included for comparison. All were found to generate similar amounts of static electricity.

Consequently, we conclude that the potential to generate static electricity exists when dumping resins from any of these bags.

The static electricity generated (on the operator, bag, and equipment) while dumping the bags was, in several cases, found to have the potential to ignite flammable vapours, and some combustible dusts exhibiting low ignition energies. The information that follows will help to prevent electrostatic charge build up.

Since the build up of electrostatic electricity depends on many factors, (floor and operator shoes conductivity, hygrometry during operations, presence of dust, etc.) there is no guarantee our guidelines will prevent static charge build up. However, implementation of the following guidelines should minimize the potential for fire when pouring resins.

If pouring powders into highly flammable liquids (Flash point <40°C) or into liquids within 5°C of their actual Flash point use fully contained and inerted charging or seek expert advice.





In the above Figures (1 and 2) any metal drums used for charging resin must be earthed.

4.1.2. Suggestion for reducing dust when pouring bags

The following practice for minimizing dust has been found effective. However, it should not preclude the use of a metal chute or implementation of the aforementioned safety measures.



Step 1: Make a 10 to 15 cm slit at top rear of bag. (The slit will function as a vent and minimize turbulence to provide free - less dusty - flow.)



Step 2: Suspend end of bag over chute. Reach under bag and cut to make a flap.



Step 3: Empty bag slowly.

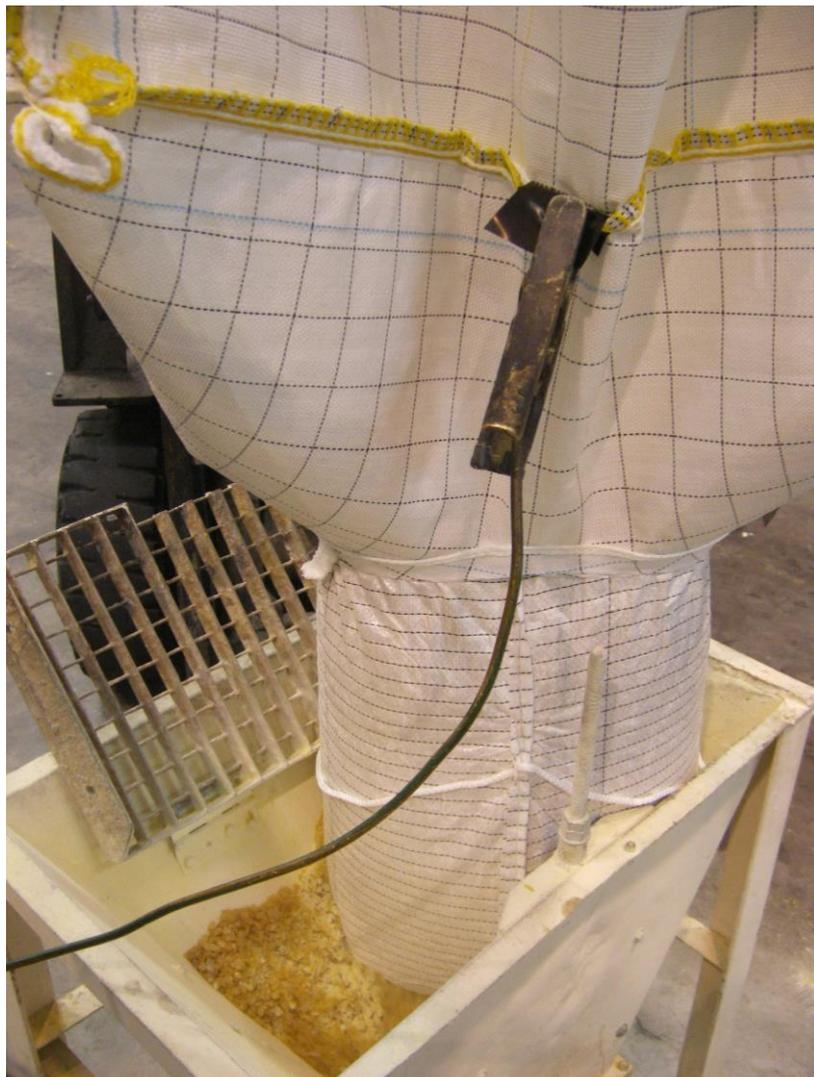


4.1.3. Use of flexible intermediate bulk containers (FIBCs)

When using FIBCs extra precautions should be taken. There are five types of FIBC currently available. These are Type A, Type B, Type C, Type D and Type D⁺. Only Type C, D and D⁺ may be used with resins. When emptying these bags large quantities of resin pour out. The warning label on the FIBC should be read before handling.

This flow of material can generate large electrostatic charge build-up, depending on flow rate, type of material, type of FIBC and equipment used. In general the discharge speed should not exceed the maximum of 2 kg/s. Consult the proper experts for further detail on maximum discharge speed and proper discharge equipment.

Avoid sparks by grounding all equipment and the FIBC if Type C (grounding cable must be connected to the marked bag ground connection).





5. Working methods

Four main points must be observed

- **A clean and tidy plant:** elimination of all secondary explosion risks.

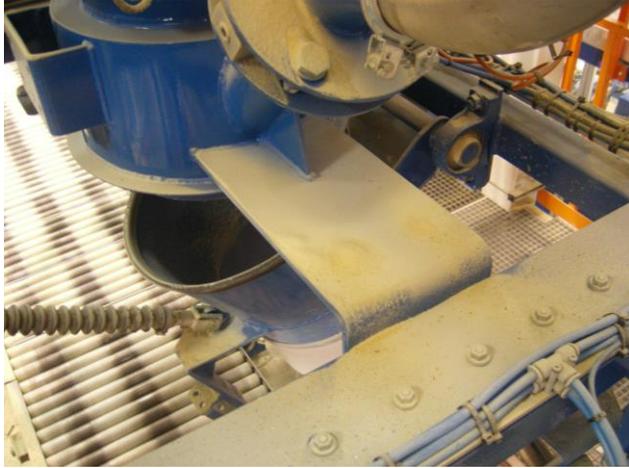
This must be ensured to prevent all risks of dust becoming airborne. Regular cleaning of the plant must be carried out with a vacuum cleaner complying with ATEX regulations based on the classification of the plant's zone. As a general rule, ensure good house keeping. The pictures below illustrate examples of dust accumulation which may lead to explosion risks.





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➤ **Elimination of hot spots:**

- Open flames and welding:

Operations generating flames (welding / cutting / « de-solidification » using a welding torch, etc.) should not, where possible, be carried out in a plant in operation. In all cases, a work permit and a fire permit must be issued beforehand.

- Defective equipment or electrical short circuit:

Repair defective equipment immediately, or replace if necessary.

- Mechanical friction and impacts:

- i. Tackifying powders tend to produce crusting which can induce stress in mechanical parts, and, as a result, overheating.
- ii. Ban the use of impact tools such as hammer, chisel, impact wrench, etc., not suitable for the work atmosphere.



Illustrative example:

Explosion at Blaye (France) – 1997

Explosion of wheat dust in a confined environment, purportedly due to overheating in a dust-extraction fan

11 fatalities – 1 injured



➤ **Maintenance of equipment**

Have preventive maintenance in place. Be aware of inerted equipment, and spreading of dust by opening of equipment. Use the right explosion proof tools.

➤ **Training of personnel:**

- i. Properties and hazards of the products
- ii. Operating instructions
- iii. Failure alerts
- iv. Emergency plans
- v. Hazards of inerted equipment

Notice:

Provide instructions for contractors and subcontractors on safety rules and work permits.

6. Health risks

Apart from the ignition/explosion hazards inherent to dusts, they also present genuine risks to human health through inhalation.

It is important to recall that particles with a size ranging from 5 µm to 30 µm are stopped by the upper respiratory tract (nose, mouth, pharynx). If the concentration of these particles is too high, they line the mucous membranes and cause real discomfort. This discomfort can be exacerbated by the tackifying nature of the product.

The smallest particles (1 µm and under) enter the lower respiratory system: from the trachea right down to the air sacs where they will be destroyed by macrophage. Any presence of powder exceeding the macrophage processing capacity will cause a build-up and, as a result, inflammation.

It is therefore important to protect the people working in an atmosphere laden with suspended fine powder in order to eliminate health risks.

Personal protective equipment:

Non-valve dust respirators and valve dust respirators (for high dust concentrations) are typical personal protective equipment, which should not replace collective protective equipment.



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They can be worn during short periods of time and in particularly dust-laden conditions.

It should be noted that standard EN149 dated 2001 provides for 3 effectiveness classes (FFP1...FFP3) measured on particles of 0.01 to 1 μm .

The appropriate class should be chosen on the basis of dust levels:

FFP1: stops 77 % of particles

FFP2: stops 92 % of particles

FFP3: stops 98 % of particles.

Operators should wear breathing masks marked **EN149 : 2001**.



Summary of the Personal Protection Equipment (PPE) which might be used

The following table is only given as a recommendation.
The choice of the PPE must be result of a formal analysis including risks assesment, hazard assesment ...

	HARRPA	PPE	 (*) ie.: Special maintenance works
	Normal work conditions Low Dusts concentration	Unusual work conditions (*) High Dusts concentration	
Helmet	✓	✓	
Gloves	✓	✓	
Working Suit anti-static	✓	✓	
Safety Shoes (with conductive soles)	✓	✓	
Safety Glasses	✓		
Dusts-proof Goggles		✓	
Special non-woven Suit Dusts proof (anti-static)		✓	
Hair cap		✓	
Anti-Dusts Mask FFP3		✓	



7. Definitions (glossary)

AIT	Auto Ignition Temperature	The lowest temperature at which a combustible material ignites in air without a spark or flame.												
CD	Combustible Dust	Any finely divided solid material, 500 µm (425 µm for US) or less in diameter (i.e., material passing through a U.S. No.40 standard sieve), that presents a fire or explosion hazard when dispersed and ignited in air or other gaseous oxidizer.												
Dust	Dust	Any finely divided solid material, 500 µm (425 µm for U.S.) or less in diameter (i.e., material passing through a U.S. No.40 standard sieve).												
EC	Electrical Conductivity	The reciprocal of resistivity expressed as Pico Siemens per meter. $\text{picoS} = 1 \times 10^{-12}$												
dP/dt	Maximum Rate of Explosion Pressure	An indicator of explosion severity.												
IG	Inert Gas	A non-flammable, non-reactive gas that reduces the available oxygen level in air to the point where a flammable mixture is no longer possible.												
K _{st}	Explosion Indices (St stands for Staub)	The maximum value for the material specific constant "K _{max} " that describes the rate of pressure rise, dP/dt as a function of vessel volume. Slow, faster, fastest burning St1-3.												
		<table border="1"> <thead> <tr> <th>Hazard Class</th> <th>K_{st} bar.m.s⁻¹</th> <th>P_{max} (bar)</th> </tr> </thead> <tbody> <tr> <td>St-1</td> <td>200</td> <td>10</td> </tr> <tr> <td>St-2</td> <td>201-300</td> <td>10</td> </tr> <tr> <td>St-3</td> <td>>300</td> <td>12</td> </tr> </tbody> </table>	Hazard Class	K _{st} bar.m.s ⁻¹	P _{max} (bar)	St-1	200	10	St-2	201-300	10	St-3	>300	12
		Hazard Class	K _{st} bar.m.s ⁻¹	P _{max} (bar)										
		St-1	200	10										
St-2	201-300	10												
St-3	>300	12												
LEL/MEC	Lower Explosion Limit Minimum Explosion Concentration	The lowest concentration of a combustible dust in air, expressed in grams per cubic meter, which will propagate a flame. (Specific to the PSD of the tested sample and is not an intrinsic material constant).												
LIT	Layer Ignition Temperature (smoulder temperature)	The smoulder temperature describes the flammability behaviour of a flat dust layer on a hot surface. It is defined as the lowest temperature of a heated, free-standing surface which is capable of igniting a 5 mm thick dust layer.												
MIE	Minimum Ignition Energy	Lowest energy required, which upon discharge is sufficient to ignite the most ignitable mixture of air and dust, under specific test conditions.												
MIT	Minimum Ignition Temperature	The minimum temperature at which a dust cloud can be ignited.												
MOC	Minimum Oxygen Concentration	The lowest molar (or volume) gas-phase concentration of oxidant (usually oxygen) at												



		which a specified fuel (dust) can propagate a flame. (For most organic dusts <12 vol % O ₂ , paraformaldehyde <4 vol %)
PSD	Particle Size Distribution	Explosive properties are usually measured at a dust fraction of ≤63 μm.
ZONING	Zone 20	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is present continuously, or for long periods or frequency.
	Zone 21	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is likely to occur in normal operation occasionally.
	Zone 22	A place in which an explosive atmosphere in the form of a cloud of combustible dust in air is not likely to occur in normal operation but, if it does occur, will persist for a short period only.



8. References

Documentation on risks of flammable mixtures, measures and engineering practices can be found on the HSE UK website where a brochure titled "Guidance and Codes of Practice relating to inerting" is published.

[HS\(G\)140 Safe use and handling of flammable liquids](#), HSE, 1996.

Paragraph 36 gives guidance on the transfer of flammable liquids using gas pressure.

[HS\(G\)158 Flame arresters : preventing the spread of fires and explosions in equipment that contains flammable gases and vapors](#), HSE, 1996.

Paragraph 35 gives guidance on the use of inert gas blanket within vessels as alternative to flame arresters, where explosions may occur in emergency vents.

[HS\(G\)103 Safe handling of combustible dusts : precautions against explosions](#), HSE, 1994.

Paragraphs 35 to 36 give guidance on the use inerting to prevent dust explosions.

GS5 Entry into confined spaces, HSE, 1994.

Gives guidance on vessel entry where inert gases are used.

[BS 5908 : 1990](#) Code of Practice For Fire Precautions in the Chemical and Allied Industries, British Standards Institution. General. Section 10, Paragraph 58.5 provides guidance on the flammability of powders and measures to protect against ignition including inerting.

F.P. Lees, 'Loss Prevention in the Process Industries: Hazard Identification, Assessment and Control', Second Edition, 1996.

G. Raykovitz, Safety first for maximum benefit, Adhesive Technology, March 2001.

T.J. Snee, An instrument for measuring the concentration of combustible airborne material, Ann. occup. Hyg. Vol. 29, No. 1, pp. 81-90, 1985, © 1985 British Occupational Hygiene Society, Published by Oxford University Press.

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NFPA 654 Standard for the prevention of fire and dust explosions from the manufacturing, processing, and handling of combustible particulate solids 2006 edition.

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