Guidelines
on
Basic Safety Requirements
in
Aerosol Manufacturing

Third Edition: October 2013

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Foreword

It is a real pleasure, as President of the European Aerosol Federation, to introduce the third edition of this useful FEA Guidelines on Basic Safety Requirements in Aerosol Manufacturing which has been developed by dedicated experts from the aerosol industry.

Aerosol manufacture generally involves the use of flammable ingredients and propellants. The safe handling and processing of these flammable materials are basic requirements for our industry. FEA has taken the responsibility and the lead to continuously update a guide that provides clear and practical directions to achieve this goal.

Generally, legislation exists in EU Member States and candidate countries covering safe handling of flammable products and propellants in manufacturing facilities; and the new Seveso III Directive will apply from the 1st of June 2015.

The aim of these guidelines is, of course, not to replace the legislation, but to supplement it and provide helpful guidance to the industry.

Our ambition is to promote and support a global roll-out of this guideline to achieve one high level of safety standards globally.

I am convinced this excellent guide will be helpful for you in implementing safe industrial processes and practices.

Rolf Bayersdörfer
FEA President
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Chapter 1

Purpose of this Manual

The purpose of this manual is to provide basic safety recommendations for aerosol production with flammable/dangerous products and propellants in agreement with current and in anticipation of European legislation.

Notes:

a. National and European legislation, in particular the ATEX Directives, has ALWAYS to be respected and takes priority over these guidelines.
b. The use of substances and mixtures needs to comply with the REACH Regulation.
c. The design and construction of machinery, installations and buildings should always be in line with the appropriate CEN standards.

Limitations:

a. These guidelines only cover aerosol filling, propellant storage and finished product storage on site.
b. Excluded is transport and handling of flammable liquids and gases before delivery to the manufacturing site.

These guidelines are to be used as supplement to legislation and local regulations, and do <u>not</u> replace them.

Chapter 2

Flammable Propellant Safety System

The handling and storage of dangerous substances is regulated by the Directive 96/82/EC on the control of Major Accident Hazards involving Dangerous Substances (Seveso II Directive). This Directive will be repealed and replaced by Directive 2012/18/EU (Seveso III Directive[1]) on the 1st of June 2015.

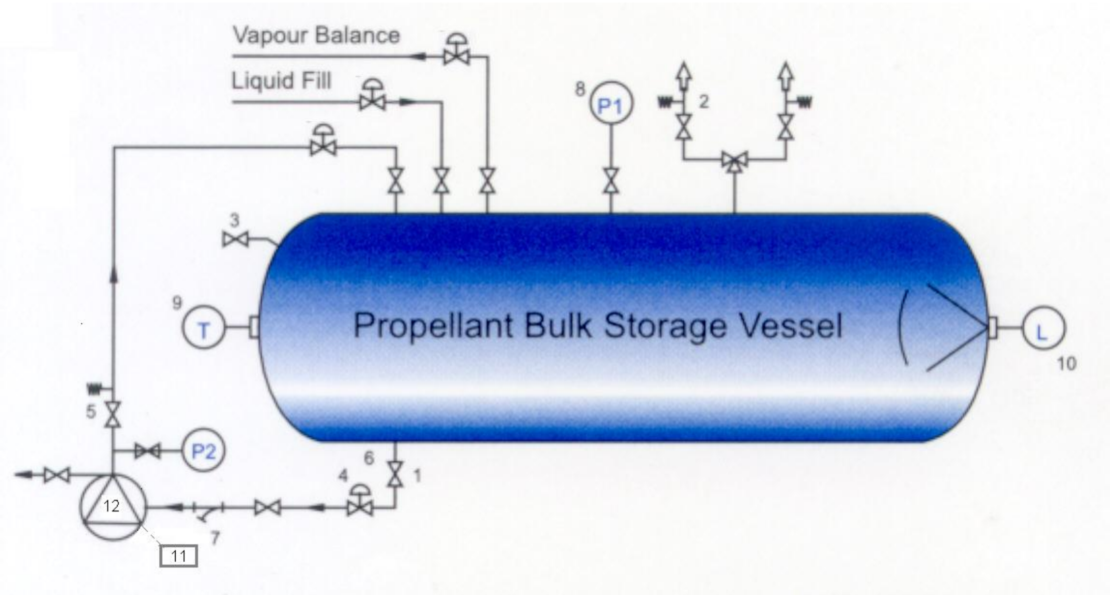
Flammable propellants and aerosols are covered by this Directive

2.1. Propellant Storage

The distances Tank to Factory and Loading Station are covered in national legislation, and will depend on the tank-size and the layout situation.

2.2. Propellant Handling

Figure 1: Propellant Bulk Storage Vessel.



[1] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2012:197:0001:0037:EN:PDF

The propellant storage vessels should be fitted with:

- a shut-off valve **(1.)** preferably automatic;
- a pressure relief system **(2.)**;
- a manual level check **(3.)**;
- a remotely operated shut-off valve **(4.)**.

The following should be considered:

- automatic level control to prevent overfill;
- deluge system for protection in case of nearby fire or for cooling in general;
- to protect the propellant bulk storage from a nearby fire, it is recommended to install a fire detection system.

ALWAYS

➲ BEFORE connecting any tanker/contain ensure proper connection with earth has been established and potential charge has been released. For more information ***see § 9.6.8.1.***

➲ Check contents to ensure adequate capacity to receive the delivered load BEFORE commencing discharge from tankers.

➲ Check that the correct tank-manifold connections are made.

➲ Ensure that filling is not above the SAFE maximum.

➲ Follow suppliers recommended discharge and sampling principles.

➲ Remember that propellants are usually difficult to detect by smell, because most propellants are de-odorised.

Unless the pump has a by-pass for overpressure protection, the pump pressure relief valves **(5.)** should return propellant to the same tank and not into the pump suction pipe.

In the case of hydrocarbon/DME propellant bulk storage vessels an excess flow valve **(6.)** should also be fitted in the liquid off-take.

If DME is used as a propellant, beware of the fact that DME is soluble in water. Potential spillage should be watched carefully.

Additional ancillary fittings which may be desirable and which are commonly found on propellant bulk storage installations are:

- a filter **(7.)** on the liquid outlet to protect the pump **(12.)**;
- a pressure indicator **(8.)** to indicate vapour pressure;
- a temperature indicator **(9.)**;
- a level indicator **(10.)**;
- a gas detector **(11.)** in the vicinity of the pump.

Chapter 3

Processing and Bulk Tanks System

3.1. Introduction

This section is not exclusive to aerosols but is product-related.

Past accidents have shown the danger of Static Electricity (***see § 9***).

- Location of processing/mixing should be separated from filling by fire resistant floors/walls as required by national legislation.
- Zoning requirements should depend on the product formulation.
- Calamity/catchment tank to be appropriately installed.
- Transport of batch container to filling machines only if CLOSED!
- Ensure that suitable PPE (Personal Protective Equipment) are available to any operator and they are used whenever necessary or useful.
- **Trucks and other mobile equipment must be appropriately specified according to area classification, as e.g. explosion-proof.**
- If batch containers are used, a larger ATEX zone (***see § 4***) should be made around the filling machines to include the location of the container.
- Pumps have to be explosion-proof and the system should be fail-safe.
- Special care to be given to the collection of product spillage.
- Proper grounding of container and pump.
- Check whether a flame-arrester is required between tank and piping, or tank and atmosphere.
- Ensure that all manufacturing vessels, pipework and ancillary equipment are suitable for, and compatible with, the materials they will come in contact with.
- Before starting the pump, ensure that the vessel may vent in a safe manner.

3.2. Electrical Equipment

- Electrical equipment should be suitably explosion-proof and conform to national standards (***see § 12.2.***).
- It is recommended to have control equipment positioned away from ground level to avoid being damaged.
- Permanent electrical installations should be used wherever possible and the use of flexible electrical leads reduced to a minimum.

- Flexible lines should be kept to a minimum length and their application should be considered with care. Flexibles in general are sensitive to mechanical and chemical damage and may form a hazard to operators and a source of ignition once damaged. Flexibles should be checked frequently, preferably on a timed-maintenance programme.

3.3. Ventilation

Provide adequate low and/or high level ventilation and extraction where toxic, flammable or dangerous materials are being used in the mixing process; ensure they are collected and treated as applicable.

Note: Solvent vapours are heavier than air!

3.4. Construction

- Construct the mixing area with a sill or ramp to contain any liquid spillage.
- Ensure, where possible by automatic level controls, that vessels cannot be overfilled.
- Where pipes are taken through the floor from upstairs mixing rooms, install a ramp or flange to prevent spillage to lower floor.
- Holes through floors/walls must be sealed with fire-resistant material to maintain integrity between floors/rooms as required by national legislation.
- Ensure that exits are kept clear at all times.

3.5. Processing Operations

- Take particular care when liquids with low boiling points are used as solvents or diluents during concentrate manufacture.
- Minimise evaporation losses to ensure that localised concentrations in the atmosphere do not exceed the permitted Occupational Exposure Limits.
- Follow Operational Conditions and Risk Management Measures provided in the suppliers' safety data sheet supporting REACH.
- All processing vessels shall be designed to prevent liquid losses/spill/splash by the incorporation of flanged and/or sealed lids and seals around heating/cooling coils and stirrer shafts.
- Ensure that explosion-proof conditions are in place whenever flammable liquids are being processed for example apply rotary dispensing valves, explosion-proof chutes for adding ingredients, ...
- ***When powders or non-polar solvents are used, be aware of their potential to build up static electricity and of dust or solvent / hybrid mixture explosions, and take appropriate measures!***
- Where powders are being handled, ensure there is adequate dust extraction and if necessary provide appropriate respirators.
- ***Do not carry open buckets or bins of liquids uncovered.***
- Where possible, pump liquids rather than use transport containers around the mixing rooms and/or into the filling room. Where this is not practical, use a purpose designed safety container and keep it covered.

- Only use connections to earth that are certified for electrostatic conductivity (resistance < 1 MΩ (megaohm)).

3.6. Cleaning Down Procedures

- The use of solvents in cleaning can give rise to increased toxicity and/or flammability hazards.
- Wherever possible avoid using flammable or toxic solvents, for example, as part of cleaning procedure. Avoid using solvents as a spray particularly in enclosed spaces.
- Disposal of cleaning solvents should be to an effluent tank and not down the drains. Waste rags (which could include material liable to spontaneous ignition) should be disposed of safely.

3.7. Storage

- Store only the minimum required amount of flammable raw materials in the processing area, and never more than is allowed by local regulations.
- Storage of raw materials and (intermediate) mixtures should be appropriate for the physical (e.g., flammable) or health (e.g., toxic or corrosive) or environmental hazards. Flammable and toxic materials should be stored separately.
- Ensure that they are properly identified, safely stored and used in compliance to Safety Data Sheets and, if available, to pertinent Exposure Scenarios.
- Keep and update Risk Assessment.
- Ensure that exits are kept clear at all times.

Chapter 4

Aerosol Gas-filling

4.1. Production – Zoning

Definition of Zoning[2]:

ZONE 0	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.
ZONE 1	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.
ZONE 2	A place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

In summary:

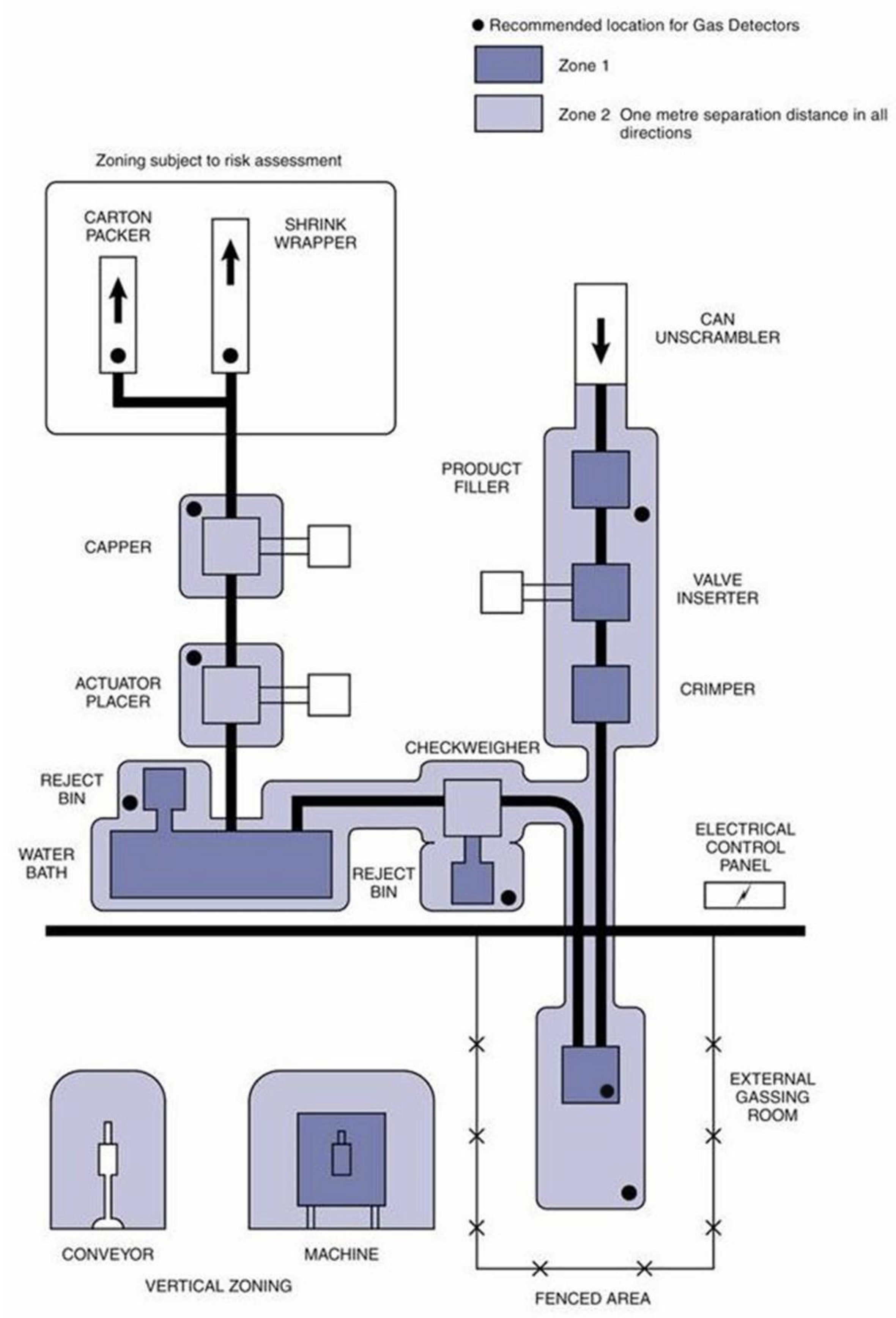
ZONE 0	100% of time explosive atmosphere
ZONE 1	Possible explosive atmosphere (permitted)
ZONE 2	Possible explosive atmosphere can only occur in faulty or abnormal conditions

All parts of the aerosol filling line should be addressed by risk assessment to determine the proper zoning.
The primary enclosure of the gas-filling room is generally Zone 1.

ZONING is generally + 1 meter around the machine, except when extract ventilation is used in the zoned area.

[2] Source: ATEX Directive 1999/92/EC, Annex I

Figure 2: Zone classification for typical aerosol filling line.

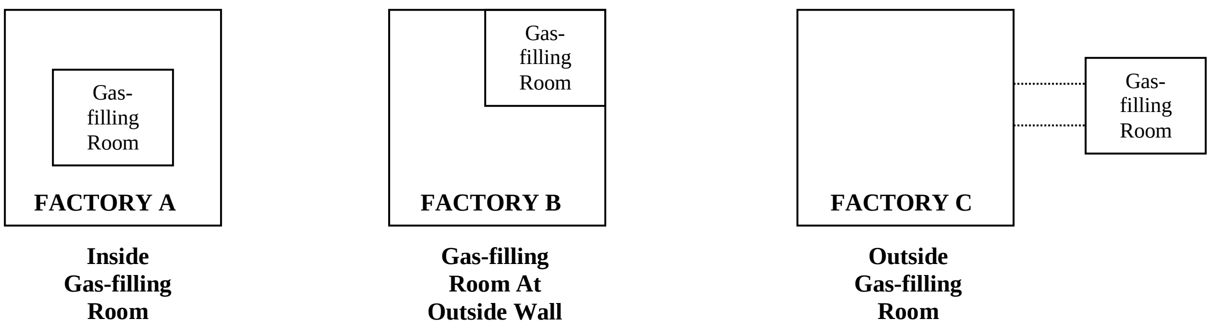


4.2. Gas-filling Room Building Requirements

The gas-filling room is the enclosure, indoor or outdoor where the machine that puts propellant into the aerosol is located, also known as the gas house, gassing room or gassing booth.

- Gas-filling room to be separated from packaging area, mixing room and warehouse.
- Gas-filling room to be Low Pressure (lower pressure than surrounding space).
- Floor to be gas-tight and anti-static.
- No drains within 15 meters outside of the gas-filling room.
- Walls and doors to be fire-resistant.
- Room needs blow-out wall or roof – Size and construction to be determined by experts.
- The gas house shall be designed to withstand an internal over-pressure. Typically designs should be able to withstand an instantaneous pressure rise of 1400 kg/m^2.
- The gas house shall have a pressure relief system which vents to a safe place. Pressure relief should be constructed so that at least one wall or, preferably the roof of the gas house, will relieve the explosion pressure to a safe area in a direction away from the usual position of all employees. A relief pressure of 140 kg/m^2 is recommended as the normal safety margin.

Figure 3: Examples of possible layouts.



If possible, preference to be given to Option C: outside gas-filling room.

4.3. Gas-detection

- A minimum of 2 gas-detectors need to be operational and located close to the gas-filling machine(s) (one in the primary enclosure and the other in the secondary enclosure), with due consideration to extract flow.
- Consult with supplier on type of sensor to be used and most effective location (catalytic detectors are poisoned by silicones; infra-red detectors are not poisoned and are fail-safe).
- Gas-detectors need to be checked on a regular basis according to supplier's validated system.

4.4. *Ventilation / Extraction*

- Automatic control function: ventilation has to be running before the machinery starts and propellants valves are to be opened.
- The primary system (inside the enclosure of gas filling machine) generally requires an extraction rate of minimum 50 times per hour. Additionally, a calculation for dilution and capture velocity must be made following Appendix 1 ***(§ 12.1.***).
- The secondary area needs an extraction of minimum 5 times per hour if the gas concentration is between 0 % - 20 % LEL[3.]
- When the 20 % LEL is reached, an acoustical and/or optical alarm should be activated. The ventilation will double the extraction rate, both in the primary and secondary area.
- If concentration is above 40 % LEL, extraction continues at maximum speed, the line must stop and the gas supply needs to be closed automatically; personnel who are at risk should be evacuated.
- Actual extraction rate calculations are listed in ***§ 12.1.*** and should be related to the above minimum extraction rate. The higher of the two numbers should be used.
- The design philosophy is based on maintaining the LEL level as low as possible with a first level response at 20 % LEL.

4.5. *Changing of Propellants*

- Minimise number of people in the gas-filling room during changeover.
- During changeover increase ventilation.
- Shut-off supply-line. Use position monitored spring loaded automatic shut-off valves.
- Minimise venting of propellants. Venting in a closed system directly connected to the exhaust stack.
- Empty machine and cylinder.
- The last step is to open new supply-line.

4.6. *General recommendations*

- Permanent operators in the gas-filling room must be avoided.
- If people enter the gas-filling room, their safety needs to be assured; an explosion suppression system could be considered as a possible solution.
- For overload pressure, safety valve needs to exhaust into safe area.
- The use of a checkweigher is recommended for the detection of overfilled cans (***see § 7.1.***).
- Heating system by hot-water heat exchanger or hot air through special ducting (***see § 12.1.***); ensure the avoidance of a naked flame or electrical heating.

[3] LEL = Lower Explosion Limit

Elimination of spark sources:

- Conductive conveyor is recommended for the entire line.
- Machines need to be Explosion Proof – ATEX or equivalent (***see § 12.2. , and also § 9***).
- Use non-sparking impact tools per supplier's recommendation.
- Apply anti-static floor & earth bonding.
- Check the total filling line for proper grounding at least once per year.
- When filling aerosols with powders or non-polar solvents consider using anti-static agents and/or components to reduce their potential as an ignition source.
- Ensure the exclusion of isolated parts made of conductive material.
- Special clothing and shoes should also be worn on the rest of the production area.

Experience has shown that static electricity is a key cause of fire accidents. In ***§ 9*** more background on static electricity is available.

4.7. Electrical Requirements

Special attention is required for all equipment in Zone 1 and 2.
For details – please refer to ***§ 12.2.***

Chapter 5

Disposal of Faulty Aerosols

5.1. On-line Removal and Storage

Faulty cans are by definition a highly hazardous situation and are typically detected and removed at the checkweigher and waterbath.

- If possible, store rejected aerosols externally.
- Use a ventilated waste container, adequately grounded.
- Use a reject system designed and operated so to prevent further can damage (air expulsion, soft collection and removal system).

5.2. Transport

Transport of rejected cans to a waste-compartment should be made in a special container in accordance to the ADR (Special Provision SP 327).

If transport of rejected cans is to be made to an external waste handling facility, the transport method needs to be in accordance with the agreement of the carrier and the regulator.

5.3. Guidelines for On-Site Destruction

Follow national legislation, please find additionally some safety recommendations:

Please note that local authorisation permit is required for this!

LOCATION:	- As far as possible from other buildings.
BUILDING:	- One room for the can infeed. - One room for the actual can-crusher. - Consideration of weather conditions (below 0°C n-butane is liquid) should be taken into account because of the density of the propellants. - In general it is not recommended to operate the equipment near or below 0°C (approaching 0°C, solubility of butane in solvents increases sharply and viscosity of liquid contents is higher).

TRANSPORT:	-	Transport of the cans to the crusher on an antistatic conveyor belt.
	-	Any waste solvent collected after crushing should be adequately vented before off-site transport. This transport must be made in accordance with ADR and local legislation. Consideration should be given to avoid the potential pressurisation of the transport container from residual flammable gases due to agitation during handling.
EXTRACTION:	-	Spot ventilation above storage and press and extract externally.
	-	Extraction rate to be sized according to ***§ 12.1.***
GAS DETECTION:	-	- In and outside the building.

All electrical equipment according to ATEX and conform to national standards (***see § 12.2.***).

Collection of residual liquids must be handled safely and appropriately in accordance with their composition. It is the responsibility of the waste producer to ensure proper and safe handling and treatment.

5.3.1 Safety Devices

- Crushing room fitted with a deluge sprinkler system actuated by:

  - thermal safety device;

  - emergency stop, outside the building.

- Waterless fire suppression systems (including CO_2 and Nitrogen) above conveyor belt and press actuated by:

  - thermal safety device;

  - remote activation device outside the building, in case of emergency.

- Foam or BC-Powder extinguishers installed in and outside the building.

5.3.2 Electrical Safety Devices

- Total electrical power shut off after:

  - activating the fire alarm;

  - sprinkler pressure drops;

  - extinguisher pressure drops.

- Can Crushing *__not possible__* after:

  - activating the Emergency stop;
  - opening of one of the doors;
  - not enough ventilation, measured by flow detectors in the ventilation duct;
  - high gas alarm (≥ 20 % LEL).

The ventilation must be activated some minutes prior to starting the crushing operation.

5.4. BREF document related to Waste Treatment Industries[4]

A Best Available Techniques (BAT) reference document, also called BREF, has been drawn for the waste treatment industries as part of the exchange of information carried out in the framework of Article 13(1) of the Industrial Emissions Directive (IED) 2010/75/EU.
This BREF covers the installations of a number of waste (hazardous and non-hazardous) treatments, and deals with *inter alia*:

- common waste treatments such as the temporary storage of waste, blending and mixing, repackaging, waste reception, sampling, checking and analysis, waste transfer and handling installations, and waste transfer stations;
- treatments to recover mainly waste material such as the regeneration of organic solvents;
- treatments to produce mainly solid and liquid fuels from hazardous and non-hazardous waste.

The document also deals with aerosol dispensers treatment.

[4] More information: http://eippcb.jrc.es/reference/wt.html

Chapter 6

Water Bath Test and its Alternatives

Please refer to the FEA *Guide on Hot Water Bath Testing and Its Alternatives*.

Chapter 7

Other Equipment on the Line

7.1. Checkweigher

The purpose of a checkweigher is detection of overfilled containers which are potentially hazardous. It is also meant for detection of underfilled containers, which do not meet the fill-weight declaration and can be hazardous in case of leakages.

Continuous, automatic checkweighing is recommended from a safety point of view. The checkweigher should be frequently calibrated.

Containers which are light in weight, due to a low or omitted product concentrate fill, can still be high in pressure and potentially dangerous.

Faulty compressed gas aerosols can usually not be detected by checkweigher and an alternative measurement system is required (e.g. pressure detection).

7.2. Actuator Placing and Capping

Manual or automatic placement of actuators or caps may, in some cases, cause spray off of the contents of the aerosol.

If the active ingredient, solvent or propellant is flammable, or hazardous to health, adequate extraction should be provided at the point of application of actuator buttons or actuator caps.

In the case of manual placement, advise all operators to direct the spray nozzle AWAY from them and use specialised tool when tapping.

7.3. End of Line Packaging

The presence of large quantities of packaging components or finished goods in a production area can result in congestion, blockage of emergency exit routes and an unnecessary fire hazard.
Industry experience has shown that a close control and organisation of the supply of packaging components to the filling line are both a major contribution to safety and to line efficiencies.

7.3.1 Boxing

Boxes need to be constructed and closed to protect aerosols from damages and loss of contents during storage and transport, in accordance to the transport of dangerous goods legislation.

Box and carton machines shall be subject to a risk assessment of potential malfunctions, which could result in punctured or crushed aerosols.

The hazards to consider are the release of flammable gases or vapours that might be exposed to a source of ignition and the missile hazard of flying aerosols if they are punctured and ignited.

The operation should be covered by the emergency plan for the aerosol filling operation.

A gas detector should be installed in carton (case) packers at a low position at the most likely location for any flammable vapour to accumulate with appropriate action to alert operators and automatically stopping the machinery safely in the event of a gas alarm.

Box and carton machines shall be fitted with a device to prevent excessive temperatures if hot melt glue is used.

The device should activate an alarm and both cut power to the heaters and stop the machine when excessive temperatures are detected.

The excessive temperature device shall be calibrated or checked at regular intervals and the results recorded.

7.3.2 Shrink-wrapping (including sleeving)

The shrink-wrap machine design shall ensure that individual aerosols and collations are prevented from being trapped in the heating tunnel by built-in obstructions.

Main concern is an ignition source due to high surface temperatures!

- Ensure that there are no obstructions, which can result in either packs or individual containers being trapped in the tunnel. In order to detect fallen cans in the tunnel, photoelectric beams can be used.
- An alarm should be arranged to sound in the event of an **unforeseen stoppage**. A fan at the side of the tunnel, or even air-blasts through the tunnel, are most unlikely to be effective in preventing explosion and should not be relied upon to do so.
- Air-driven conveyors should form a backup in the event of power failure to ensure evacuation of all aerosols from the tunnel.
- Ensure that adequate fire extinguishers are at hand and that they are suitable for the machine. It is advisable to have a built-in fire extinguishing system, with remote activation on both hands. Portable fire extinguishers should be of CO_2 type.
- Check temperature on a regular basis.

Chapter 8

Transport and Storage of Finished Goods on Site

Depending on the stored quantity, the storage of finished goods can fall in the scope of the Seveso Directives.

A general guideline on storage of finished goods in- and outside the manufacturing site has been developed. It also covers loading and unloading instructions.

8.1. Transport

The operator has to be familiar with the established technology in order to be able to judge the safety conditions of his transport facility.
Forklift / pallet truck drivers should be licensed and trained regularly to operate.

Hazards have to be identified in order to stipulate preventive measures and rules of conduct. The following conditions may cause hazards:

- general leakages of can or valve;
- bursting of can caused by external influences such as being run over, dropping, damaging by forklift truck;
- bursting of can caused by excessive temperatures;
- cans flying about after having burst.

It is important to avoid the defined identified hazards by taking the measures specified below:

- only transport pallets which have been secured;
- mark the transport route and keep it free of obstruction;
- sufficient manoeuvre spaces;
- installation of a fire extinguisher on forklift truck and along the transport route;
- setting up of operating instructions for transport.

If a fire breaks out in spite of all the precautions mentioned above having been taken, the operators have to be instructed that they have to respond promptly, but with regard to their own safety.

When aerosols are exposed to fire, cans will burst after a short period of time (about 1 minute) and there is the danger that the cans will be flying around. Besides the potential for injury to people, they can become further sources of fire.

8.2. Storage

Storage of filled aerosols requires careful consideration of the hazards associated with flammable propellants and liquids.
Several instances of very destructive warehouse fires have been recorded and there is a need to take safety very seriously in this respect.

It is therefore important to ensure that the finished aerosols are stored where they can be isolated from the production area and in a manner that reduces risk of accidents resulting in a fire:

- Finished aerosols should not be stored or be allowed to accumulate in the production area other than the quantity required to make up a single transport unit.
- All transport units shall be removed to a specified staging area or to the finished product storage area immediately after completion of any required *in situ* quality checks.

Ideally the finished aerosol storage area should be in a different building to the aerosol filling line.

In cases where the finished aerosol storage is adjacent to, or in the same building as, the aerosol filling line, then the following requirements also apply:

- The finished aerosol storage area should be separated from the production area in accordance with local legislation or by a 2 hours fireproof division.
- There should be a sliding door between the production and the finished aerosol storage areas, held open by a fusible link, magnetic clamp or other 'fail safe' device, which allows the door to close in the event of a fire or other specified emergency.
- Fire doors and shutters should provide the same level of fire resistance as the wall in which they are installed. Gravity or spring operated devices such as a combination of a loaded pulley system and inclined runners with fusible link, which fails at a given temperature, are suitable in this respect.
- A fire shutter should be installed between the production and finished product storage areas. This fire shutter should be activated by an appropriate detection system.
- Emergency exits for personnel should always be present.

Please also refer to the FEA *Guidelines on Basic Safety Requirements in Aerosol Storage*.

Chapter 9

Static Electricity

This section provides an aid for preventing and controlling electrostatic discharges[5] in aerosol production operations. The measures taken for preventing and controlling static electricity are additional to local regulations and recommendations by authorities.

9.1. Introduction

Practically all movements of persons, machinery, solids, liquids and gases generate static electricity. It is a fact that the generation of static electricity is inherent to the process itself.

For new installations, the problems created by static electricity should be taken into account at the design stage. All plant equipment and operating methods should be designed to provide an unimpeded path to earth for static charges as they are generated.

Control measures should therefore be directed at:

- preventing the accumulation of static electricity from materials by ensuring that any charge is dissipated as quickly as it is generated;
- (where this cannot be done) allowing adequate relaxation intervals between operations to permit the charge to dissipate to earth.

9.2. Methods of Controlling Static Electricity

In order to control the hazards of static electricity the following should be ensured:

- equipment and installations are comprised of conductive materials;
- potentially isolated equipment parts are grounded and bonded.

These measures cannot fully prevent charging of the medium inside the equipment. Therefore, additional measures are needed depending on the nature of the materials being used, processed, or transported.
Detailed descriptions of earthing and bonding, of additives and of specific measures with certain equipment, personnel, and processes, are given in ***§ 9.6.***

[5] See also: CLC/TR 50404:2003 Electrostatics – Code of practice for the avoidance of hazards due to static electricity

To avoid static electricity building up, the following should be applied:

9.2.1 Liquids

- Keep flow rates as low as possible for liquids with low electric conductivity, e.g. below 1 m/s for conductivity < 1000 pS/m.
- Avoid violent agitation.
- Avoid two-phase flow (liquid/liquid, liquid/gas, liquid/solid, gas/solid).
- Consider the use of anti-static dopes for solvents with conductivity < 1000 pS/m.
- Prevent particle/droplet formation or spraying (especially for liquids with low conductivity).
- Avoid free fall of liquids (e.g. > 1 m).
- Avoid suspensions (liquid/liquid phase separations).

9.2.2 Powders/Non-conducting Solids

- Avoid violent agitation and turbulence.
- Keep flow rates low, e.g. below 25 tons per hour for powders with particle sizes between 100 and 1000 µm, or 4 tons per hour for granular material.
- Increase the relative humidity.
- Consider the use of anti-static additives (during raw material preparation).
- Introduce or weave in conducting material (filaments) into packaging material and filter bags. Inparticular use flexible IBCs type B for combustible dust and type D for flammable vapour zoned areas.

9.2.3 Gases

- Avoid the presence of liquid or solid particles.
- Avoid high velocity of the gas through pipes. In general a gas velocity > 10 m/s should be avoided when ignitable/flammable mixtures could be present

9.2.4 Insulated Conductors

- Increase the relative humidity of ambient air, e.g. above 65 % (Note: not adequate in Zone 0 area).
- Wrap with wire gauze.

- Ionise the air (Passive/active ionisers provide sufficient safeguard when using insulating materials in Zone 1 areas. Active ionisers incorporated in air blowers are suitable for both Zone 1 and Zone 0 areas).
- Apply a conductive coating.
- For the use of plastic components see standard CLC/TR 50404:2003 for maximum surface areas.

In a number of operations where these conditions cannot be fulfilled and static electricity is built up as a consequence, measures such as earthing and bonding and operation procedures are a prerequisite to guarantee safe operation.

9.3. Maintenance and Inspection

9.3.1 Equipment

Earthing and bonding equipment should be checked before operation.
Additionally, a qualified electrician should carry out regular inspections and testing for mechanical integrity.

A labelling system giving the period of the inspection and the state of repair is recommended. An example of an inspection scheme is given below:

- **Daily inspections**
  All operating employees should visually inspect grounding cables and clamps. Poor equipment should not be used!

- **Monthly inspections**
  Since flexible earthing leads and hoses are subject to wear and tear, they should be inspected monthly and labelled to reflect the retest date. Particular attention should be paid to the condition of the earthing clips or clamps.

- **Quarterly inspections**
  Supervising personnel together with an authorised maintenance employee shall inspect earthing and bonding equipment.

- **Annual inspections**
  It is recommended that independent maintenance staff or an authorised external inspectorate should inspect the complete earthing system. Measurement of the electric resistance should be below 10 Ω (ohm); in combination with lightning protection, below 2.5 Ω.

9.3.2 Housekeeping

Because of the nature of paints, resins and powder deposits, insulating deposits can accumulate on equipment and clamps. Proper metal-to-metal contact is essential to maintain effective bonding

and earthing and therefore both earthing clips or clamps and the equipment to which they are attached should be kept clean.
Deposits on floors and equipment, which may act as insulators, should be regularly removed.

9.4. Training

Personnel should be provided with adequate training and instructions on the potential hazards of static electricity, and the precautions to be used.

9.5. Responsibilities

Supervisors should be instructed on their responsibilities to ensure that safe methods of work are used.

In areas where anti-static precautions are required supervisors/line managers should ensure the following:

- access is limited to personnel adequately trained and wearing the proper personal protective equipment, e.g. fire- resistant overalls, conducting safety shoes, etc.;
- equipment is suitable for use in this area;
- equipment is properly maintained;
- adequate records of the above are maintained.

9.6. Considerations

In this paragraph the various measures of controlling static electricity are described in more detail.

9.6.1 Earthing and bonding

Earthing and bonding very effectively reduce the risks of static accumulation. Appropriate combinations of bonding and earthing control the build-up of charge or a potential difference between parts of equipment and supporting structures.

It is important that the design and installation of an earthing system should be correct.

The system should be of adequate mechanical strength to avoid accidental damage and designed to ensure a resistive path to earth not higher than 10 Ω.
If lightning protection is also required, the resistance should be lower than 2.5 Ω.

Fixed equipment should be permanently connected to the earthing system.

Sufficient flexible earthing leads should be attached to the main earthing system at one end and attached with a large spring crocodile clip or welding clamp at the other end to mobile equipment before use.

In dust filters, all conductive parts, conductive filter cloth support baskets, clamps, straps, etc. should be grounded.

9.6.2 Anti-static Additives

Because of their poor conductivity, solvents like non-polar hydrocarbons are particularly liable to accumulate static charges. In such cases conductivity should be increased, e.g.:

- Consider the use of an anti-static additive where possible. If such additives are used they must be present in all insulating hydrocarbon solvents so as to avoid dilution by blending. A procedure should be established to ensure their addition and appropriate concentration. The supplier's specification should be strictly adhered to.
- Pre-mixing polar solvents with hydrocarbon solvents before use. Since water can reduce the efficiency of anti-static additives, tanks should be clean and dry before use. Specifications of the raw materials should be checked for water presence. Contamination of the raw materials with water during the various processes should be avoided.

9.6.3 Piping Systems

Static electricity is generated when liquids flow through pipelines. To reduce the rates of static generation effectively, the following should be observed:

- Keep flow rates as low as possible by controlling pipe sizes and pump speeds. An acceptable maximum velocity is 1 m/s for solvents with low conductivity.
- Check for electrical continuity in pipelines containing certain joints and flange gasket materials that may insulate piping sections. In such cases it is necessary to bond across flanges and joints.
- Ball valves with PTFE[6] seals may present a special problem. Design should be in accordance with CLC/TR 50404:2003.
- Filters, gauges, or other obstructions in pipelines accentuate the generation of static charge. It is good practice to use larger bore piping after the final obstruction to allow relaxation.
- Where flexible hoses are used, they should be constructed of solvent resistant materials appropriate for the liquid carried and designed to ensure electrical continuity. Proper "wiring" can also enhance the conductivity. Biannual checks of hose conductivity should be performed.

9.6.4 Free Fall of Liquids

In the design of new equipment, the free fall of solvents with low conductivity (< 1000 pS/m) and low flash point (< 55°C) should be avoided since this gives rise to the generation of static electricity. Liquids should not be permitted a fall more than 1 meter.

[6] PTFE: polytetrafluoroethylene.

The risks associated with the loading of tanks can be reduced by using closed systems, reducing filling rates, directing the flow down the sides of the vessels and extending the discharge ends of the delivery lines into the tank as reasonably practicable.
This recommendation also applies to conducting flammable liquids in large tanks (greater than 2.5 m diameter) to prevent the risk of flammable charged mist formation.

9.6.5 Plastic Materials

The growing use of plastic linings for bags, drums and aerosol valves, and the plastic containers and aerosol cans themselves has increased the hazard of static build-up on the surface of these components. For example problems have been experienced with certain polymer coatings when used with powder formulations. Wherever possible anti-static grades of plastic should be used. The following should be observed:

- If reasonably practicable, raw materials should be removed from plastic or plastic lined containers and bags outside areas where highly flammable liquids are being used. The contents should be transferred to paper bags or metal containers before being brought into production areas that are likely to contain highly flammable liquids or vapours. The generation of powder clouds in solvent vapour/air mixtures should be avoided as far as reasonably practicable.
- Similarly, the use and removal of plastic materials for stretch and shrink-wrapping on bags of raw materials and empty containers can increase the risk of static generation. The wrappings should be removed before the materials or containers are transferred into production areas where flammable vapours are present.
- Plastic liners in mobile mixing vessels should be removed from the vessel outside areas where highly flammable liquids are being processed.
- Use of plastic tote bins for flammable solvents should be avoided.

9.6.6 Personal Protection Equipment

Static charges can be generated and accumulated by human beings. To avoid excessive build-up and to ensure that they cannot be a source of risk in areas where flammable concentrations of vapour may occur, the following should be considered:

- Operators should not wear 100 % synthetic overalls. The approved overalls for use in an anti-static environment is made of a fibre containing a blend of at least 60 % cotton. Suppliers of such overalls should be asked to confirm the anti-static properties of their products. While there is no evidence that the wearing of synthetic underwear may cause static electricity, problems of that nature may be minimised if cotton overalls are worn.
- Overalls, pullovers, etc. should not be removed in areas where flammable vapours may be present.
- An operator may accumulate a dangerous electrostatic charge, if insulated, particularly in conditions of low humidity. Static electricity discharges from a person can be minimised through the provision of conducting footwear, clothing, etc. and by a conductive floor.
- If appropriate anti-static or conductive footwear, clothing and flooring should be specified.

9.6.7 Discharge of Pressurized Gases

The discharge of pressurised gases may cause static charge. This situation may occur in production areas when steam or compressed gas and airlines develop leaks. Steam, air or gas leaks in hazardous areas should be repaired as quickly as possible.

9.6.8 Process Operations

9.6.8.1. Tanker Deliveries

The movement of tank wagons on roads and the flowing of liquids in the tanks during such movement may generate static charges both on the chassis of the vehicle and in the liquids being carried.

As soon as a tank wagon arrives at a loading or discharge station and before any other **operation is carried out, the chassis should be grounded by means of a flexible earthing lead** to the static earthing system connected to the chassis of the vehicle. The use of a so-called "Electrostatic Earth Proving Unit" for proving the continuity of this connection is recommended.

Flexible tubing used for charging or discharging the tankers should be constructed of materials appropriate for the liquid to be transferred and designed to ensure electrical continuity.

9.6.8.2. Loading via Chutes, Hoppers, etc.

Loading chutes used for charging solids and liquids to ball mills, tanks, reactors, etc. should be grounded and bonded. Ball mills, chutes and hoppers must be designed to provide a separation distance above the grinding media of no less than 10 cm to avoid spark discharge and the minimum practicable height to avoid excessive free fall and, thus, static generation. The loading chute diameters should be as wide as practicable.

9.6.8.3. Operation of Belt Drives, Conveyer Belts, etc.

Belt drives, conveyer belts, high-speed rotating shafts, etc. may generate static charges. Wherever practicable, they should be constructed of conductive materials or treated to dissipate static charges.

9.6.8.4. Loading of Bulk Containers

In addition to the precautions outlined in ***§ 9.6.4*** , the following principles should be followed:

1) Avoid high flows during unloading.

2) Ensure all equipment is fully bonded and grounded, especially the filling equipment.

3) Ensure that the container being filled is not isolated from the filling equipment.

9.6.8.5. Vessel Cleaning

1) If hydrocarbon solvents are used for cleaning, either by running the mixer blade or by a spray technique, then conductivity should be increased by treating the solvents (***see § 9.6.2***). The same precautions for bonding and earthing tanks, pipelines, mobile containers, cans, and drums, and for the avoidance of free fall should be taken.

2) Where flammable solvents are sprayed under pressure (e.g. high-pressure solvent cleaning), the hazard of creating an explosive mixture (solvent and air) should be recognised and appropriate precautions taken to prevent static discharge.

3) Where aqueous cleaning solutions are sprayed in the presence of flammable vapours appropriate precautions should also be taken as mentioned above (multi-phase solvents should not be allowed!).

Chapter 10

Emergency Plan

- There should always be an emergency plan. If the Seveso Directive is applicable, the plan needs to be developed according to its provisions. Particular attention should be given to auditing and training of the emergency plan.

- It is recommended to have the emergency plan agreed upon by local authorities (e.g. Fire brigade) for lower tier Seveso sites. Upper tier sites always need to have the plan agreed[7].

- All Personnel need to be trained on this plan.

- Written instruction-cards in case of emergency should be readily available throughout the buildings.

- At each telephone there needs to be a list with emergency numbers and responsibilities of the persons at these emergency numbers.

- It is recommended that once per year a live emergency exercise is performed and the plan is reviewed.

[7] From 1 June 2015 the calculation for identifying lower and upper tier sites will change with respect to the treatment of filled aerosols.

Chapter 11

Training and Maintenance

- The need for Equipment/Machinery training is described in the Machinery Directive, 2006/42/EC.
- The equipment supplier should provide manuals on:
  - adequate operating procedures training;
  - system of work;
  - maintenance.
- The operator-training manual needs to be in the language of the user.
- Point of reference for responsibility on site:
  - **qualified competent person to set-up and implement a program for training**;
  - document the training process (due diligence).
- Training should be given to all employees on a regular basis, and employees should sign to acknowledge having received the training.
- Training should be provided on reacting to outbreaks of fire.
- Training is both a MANAGEMENT as well as an EMPLOYEE responsibility.
- The operator, supervisory and maintenance staff should be familiar with the basic properties and hazards of the materials they are working with.
- In accordance with Directive 89/391/EEC[8], all temporary workers and visitors should obtain appropriate instructions before entering the site premises.
- Inspection and Maintenance of all Safety Devices should be included in a programme (***see Table 1***).

[8] Council Directive 89/391/EEC of 12 June 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work.

Table 1: Inspection programme of safety device

The following devices should be taken into a regular safety inspection programme:

Devices	Safety inspection programme
Earth Continuity / Static Electricity	Every 6 months
Gas Detectors	Every 2 months or as recommended by the supplier
Ventilation rates	Every 6 months
Automatic valves	Every 6 months
Emergency stops	Every month
Flexible hoses/couplings/pipework and seals from bulk supply through filling	Continuously
Total Safety System Programme	Every year

- It is recommended to perform an annual safety audit by a third party.

Specific Processing Training:

- Exercise care in handling solvents in processing operations, particularly in respect of TOXIC and FLAMMABLE HAZARDS, giving due attention to ventilation and extraction.

- Whenever materials are transferred from one container to another LABEL CLEARLY.

- When chemical drums are being re-used remove or paint out the old label thoroughly and again LABEL CLEARLY.

- Always clean out thoroughly to avoid unintentional mixtures and cross-contamination.

Whenever a flanged joint pipeline which contains flammable/hazardous material is disconnected, a "PERMIT TO WORK" must be instigated.

IMPLEMENT THE USE OF “PERMITS TO WORK”.

Appendices

12.1. Appendix 1: Airflow Rate Calculation

12.1.1 Aerosol Gas Filling – Ventilation

In practice, the primary enclosure air changes are usually much higher than 50 times per hour, the accepted industry standard.

Remember this figure is only relevant in some cases of large enclosures and rooms.

It is common practice to find that a higher ventilation rate needs to be used when calculating air changes based on capture velocity and dilution.

IMPORTANT: Do not base calculation on enclosure or room air changes alone. The two important parameters to consider are ***Dilution*** and ***Capture Velocity***.

12.1.1.1. Dilution

It is necessary to have a sufficient airflow to dilute the flammable propellant vapour within the primary enclosure and the secondary area, so that its concentration is always well below the Lower Explosive Limit (approx. 1.8 % vapour/air mixture, valid for butane/propane mixtures) (***see Table 2***).

It is recommended that the concentration is kept below 20 % of this 1.8 % by providing sufficient airflow.

This airflow must be calculated by taking the anticipated loss of liquefied propellant per filling operation per can, multiplied by the maximum output (cans per minute) multiplied by the expansion ratio of liquid to vapour of the propellant (***see Table 3***).

This will give the volume of vapour released per minute during normal working.

Table 2: Mixture hydrocarbons/air or DME/air and risk of explosion

Scale		
Up to 100 % hydrocarbon	Gas i.e. liquid	
90		
80		
70		
60	Too rich	
50		
40		
30		
20		
18 %	Higher Explosive Limit (DME)	
10 %	Higher Explosive Limit (LPG)	
9		
8		
7	Explosive mixture DME/air	
6		
5	Explosive mixture LPG/air	
4		
3.4 %	Lower Explosive Limit (DME)	
3		
2		
1.8 %	Lower Explosive Limit (LPG)	
1.4 %	Lower Explosive Limit (iso-Butane)	
1		
0.72 %	40 % of LEL (LPG)	Recommended Gas-detector settings
0.36 %	20 % of LEL (LPG)	
0 % hydrocarbon		

For LPG propellant: Range 1.8 % to 10 % is the ideal mixture to ignite for an explosion.
Below 1.8 %, the mixture is too weak, too much oxygen.
Above 10 %, the mixture is too rich, too little oxygen.

For DME propellant: Range 3.4 % to 18 % is the ideal mixture to ignite for an explosion.
Below 3.4 %, the mixture is too weak, too much oxygen.
Above 18 %, the mixture is too rich, too little oxygen.

Table 3: Expansion rates

Substance	Approx. expansion rate (20°C, 1 bar)
Propane	1 : 273
iso-Butane	1 : 232
n-Butane	1 : 240
DME	1 : 349

For example, a rotary filling machine with 12 gassing heads using "through the valve" pressure technique will usually release up to 1 ml of liquefied propellant at the end of each filling cycle (when the nozzle lifts from the valve).

At a typical operating speed of 240 cpm (cans per minute), the total liquid gas released is up to 240 ml (i.e. 1 ml x 1 fill x 240 cpm).

By comparison indexing equipment operating at 80 cpm, but where the propellant fill is made up from 3 separate gas index operations; the total gas release could also be 240 ml (i.e. 1 ml x 3 fills x 80 cpm).

This volume of liquefied propellant generally expands approximately 250 times when released to atmosphere (***see Table 3***).

The gas loss can be calculated as follows:

$$\textbf{GL (m}^3\textbf{/h)} = \frac{LS \times LpC \times ER \times 60}{1{,}000{,}000}$$

where:	GL	=	Gas Loss (expressed in cubic metres per hour)
	LS	=	Line Speed (expressed in cans per minute)
	LpC	=	Loss per can (expressed in ml of liquefied propellant per can)
	ER	=	Propellant Expansion Ratio (liquid to vapour)

In order to ensure that operation always remains under 20%, and then in avoiding that the alarm activates, it is recommended to calculate the minimum airflow to dilute this gas loss to 15 % of the LEL[9]:

$$\textbf{Airflow (m}^3\textbf{/h)} = \frac{GL \times 100}{LEL \times 0.15}$$

where:	GL	=	Gas Loss (expressed in m^3 per hour)
	LEL		is expressed in %

To maintain this within 15 % of LEL (1.8 % for Butane/Propane), refer also to other ventilation parameters (***see § 12.1.1.2.***).
A safety factor of at least 20 % should be added to this result to cover for accidental discharge of propellant (multiply by 1.2 or more).

[9] LEL = Lower Explosive Limit

Example:

Line speed	240 cans per minute
Propellant fillers	Single stage rotary
Propellant	Butane/Propane (mixture where the expansion ratio equals 250 and LEL equals 1.8 %)
Gas loss per can	1 ml (typically between 0.2-1 ml. To be measured because it depends of the machine and the valve)

$$\textbf{Gas Loss} = \frac{240 \times 1 \times 250 \times 60}{1{,}000{,}000} = \textbf{3.6 m}^{\mathbf{3}}\textbf{/h}$$

If we consider a minimum safety factor of 20 %, the minimum airflow to dilute this gas loss to 15 % of the LEL is:

$$\textbf{Airflow} = \frac{3.6 \times 100 \times 1.2}{1.8 \times 0.15} = \textbf{1600 m}^{\mathbf{3}}\textbf{/h}$$

12.1.1.2. Capture Velocity

Primary ducts should be sized to provide the airflow calculated above at a velocity of 1 metre per second measured at the point the gassing nozzle disengages from the valve (not measured at the duct).

The base of the primary enclosure should also be ventilated to remove any accumulation of (heavier than air) vapour at a duct velocity of 0.76 metre per second.

12.1.2 Secondary Ventilation

Secondary ventilation should consider the same, again sizing by the highest extraction rate:

- Minimum air changes – 5 times per hour when gas concentration is below 20 % LEL and 10 per hour when the gas concentration is above 20 % LEL.

- Dilution levels – this must be adequate to dilute any normal escapes of gas (such as from leaking containers) to below 20 % LEL.

- Minimum air velocity – 0.76 metre per second at ducts and conveyor openings. This parameter usually has the effect of increasing the number of air changes per hour in current modular gassing rooms with small internal volumes.

12.1.2.1. Ventilation/ Extraction Capacity Calculation

$$\textbf{VR (m}^3\textbf{/h)} = \frac{(100 - LEL) \times R}{DL \times LEL}$$

where:
VR = Required Ventilation Rate (expressed in cubic metres per hour)
LEL = Lower explosive limit of propellant (expressed in %)
R = Estimated propellant loss (expressed in cubic meter per hour)
DL = Minimum Design Limit (generally 10 %)

Example:

Aerosol product filled with Butane as propellant (LEL = 1.8 %), a line speed of 120 cans per minute and a gas loss of 0.5 cm^3 per can. Chosen safety factor: 20 %.

$$\textbf{Gas Loss} = \frac{120 \times 0{,}5 \times 250 \times 60}{1{,}000{,}000} = \mathbf{0.9\ m^3/h}$$

$$\textbf{VR (m}^3\textbf{/h)} = \frac{(100 - 1.8) \times 0.9 \times 1.2}{0.1 \times 1.8} = \mathbf{589{,}2\ m^3/h}$$

12.2. Appendix 2: Electrical/Propellant Information

Product Classification			
Example	*CENELEC*	*North America Code*	*Ignition Temperature*
Propane	II A	D	470°C
Butane	II A	D	365°C
DME	II B	C	235°C
Ethanol	II A	D	425°C
Isopentane	II A	D	420°C

Protection Standards				
	Permitted Zone of Use	*IEC Standard*	*CENELEC EN 50 …*	*Code Letter IEC Ex … CENELEC EEx…*
Pressurization	1 or 2	2	016	p
Flame Proof	1 or 2	1	018	d
Increased Safety	1 or 2	7	019	e
Intrinsic Safety	0,1 or 2	11	020 (apparatus) 039 (system)	ia or ib

12.3. Appendix 3: Acronyms and Abbreviations

ADD	Aerosol Dispensers Directive 75/324/EEC
ADR	European Agreement concerning the International Carriage of Dangerous Goods by Road
ATEX	Potentially Explosive Atmospheres
BAT	Best Available Technique
BREF	Best Available Technique reference document
BS	British Standard
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardization
IEC	International Electrotechnical Commission
IED	Industrial Emissions Directive 2010/75/EU
LEL	Lower Explosion Limit
MAC	Maximum Allowed Concentration
PTFE	PolyTetraFluoroEthylene
RID	Regulations concerning the International Carriage of Dangerous Goods by Rail