Applying ATEX - Directive

A practical approach to the Explosion Protection Document

case study “ARENBERG“
The explosion protection document

“In carrying out the obligations [Assessments of explosion risks], the employer shall ensure that a document, hereinafter referred to as the “explosion protection document“ is drawn up and kept up to date”
Explosion risk assessment

“The employer shall assess the specific risks arising from explosive atmospheres, taking account at least of:

- The likelihood that explosive atmospheres will occur and their persistence
- The likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective
- The installations, substances used, processes, and their possible interactions
- The scale of the anticipated effects
Explosion protection document

Operating instructions → Material Properties

Ignition Sources

Explosion Risk Assessment → Zoning

Process Conditions

Explosion Protection Document
Explosion protection document

Operating instructions

Material Properties

Ignition Sources

Explosion Risk Assessment

Zoning

Process Conditions

Explosion Protection Document
Explosion risk assessment

Assessment for each area and each installation:

- **Availability of combustible/flammable materials? Y/N**
  - All materials that can generate exothermic oxidation reactions
    - Ref. MSDS, Bretherick, …
  - Risk sentences R10/R11/R12/R15/R17
  - As raw material, intermediate substance or process effluent
  - Substantial quantities

- **Dispersion of combustible/flammable materials to concentrations within explosion limits?**
  - Within explosion limits in air (max. concentrations for all circumstances)
  - Leaking pressurized lines

-> Y&Y : Explosive atmosphere !!!
Can explosive atmosphere be prevented or reduced in size?

- **Replacement of combustible products?**
  - Flammable solvents replaced by aqueous solutions (process of replacement may be triggered by financial motives)

- **Reduction of concentrations?**
  - Retaining temperature of flammable liquids within confined volumes min. 15°C below FP

- **Inertization?**
  - (IMEC internal standard: dilution below 25% LEL)
  - Dilution of oxygen concentration

- **Encapsulation of installations?**

- **Adequate ventilation?**
  - For distribution bunkers ventilated with outside air often burden on distribution of gases with low vapour pressure
Can explosive atmosphere be prevented or reduced in size?

Adequate ventilation?
Explosion risk assessment

Can explosive atmosphere be prevented or reduced in size?
Explosion risk assessment

Can explosive atmosphere be prevented or reduced in size?

- Limiting use of explosion detectors – interlocking flow of combustible material
  - Detection points to be separated from possible ignition sources
  - Activation time of interlock
Reducing explosion impact

- Locating zoned installations at remote places (whenever possible)

  - Building blast resisting structures

  - Damage limiting constructions
Explosion protection document

Operating instructions  Material Properties

Ignition Sources

Explosion Risk Assessment

Zoning

Process Conditions

Explosion Protection Document
Zoning

=> Y&Y : Explosive atmosphere !!!
=> Prevention impossible = zoning

Zoning = “defining the extent of explosive atmosphere on the basis of the frequency and duration of occurrence of an explosive atmosphere”

- Defining:
  - Frequency and duration of the occurrence
  - Extent of explosive atmosphere
Zoning

Classification of a zoned area defined by frequency and duration of occurrence of explosive atmosphere:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Occurrence of explosive atmosphere</th>
<th>Duration of explosive atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 0</td>
<td>Continuously</td>
<td>Long periods</td>
</tr>
<tr>
<td>Zone 1</td>
<td>Likely</td>
<td>In normal operation occasionally</td>
</tr>
<tr>
<td>Zone 2</td>
<td>Not likely</td>
<td>Short period only</td>
</tr>
</tbody>
</table>
Zoning

Examples:

<table>
<thead>
<tr>
<th>Zone</th>
<th>Occurrence of explosive atmosphere</th>
<th>Duration of explosive atmosphere</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone 0</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Zone 1</td>
<td>Pyrophoric exhaust, vent lines hydrogen</td>
<td>In normal operation occasionally</td>
</tr>
<tr>
<td>Zone 2</td>
<td>Solvent exhaust, storage/distribution of gases</td>
<td>Short period only</td>
</tr>
</tbody>
</table>
Zoning

- Extent of a zoned area defined by characteristics of combustible/flammable material:
  - Specific gravity in air (most gases heavier than air, except hydrogen)
  - Evaporation rate of flammable liquids
  - Size of evaporation area
  - Working temperature
  - Working pressure
  - Upper/lower explosion limits
  - Extent defined in collaboration with authorized body based upon local and international (NFPA) standards
Explosion protection document

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Process Conditions

Explosion Protection Document
“The employer shall assess the specific risks arising from explosive atmospheres, taking account at least of:

- The likelihood that ignition sources, including electrostatic discharges, will be present and become active and effective “
Ignition sources

Prevent ignition from active ignition sources

- When is an ignition source active and effective or where does the “exploration” for ignition sources stop?
  - Zone 1: normal operation (when installations are used within their design parameters) & anticipated failures of installations
  - Zone 2: normal operation
Ignition sources

- Possible ignition sources:
  - Hot surfaces
    - Heating devices, electrical devices & appliances, hot water pipes, overheated bearings
    - Ignition temperature diborane: 38-53 °C
  - Flames, hot gases
    - Open flames during maintenance works, smoking, hot air blowers, …
  - Mechanical sparks
    - Metal/metal contacts during maintenance works
    - Grinding works
    - Intrusion of metal parts in ducts
Ignition sources

- Heat generated by exothermic reactions
  Heat generation > cooling
  Self-heating: increase of temperature leads to increased reaction velocity / other influencing parameters: surface/volume – ambient temperature – contact time

- Electrical installations
  - Electrical sparks when opening and closing switches
  - Heated contacts
  - Ex-proof equipment

- Static Electricity
  Electrostatic discharges – teflon coating in ductwork?
Explosion protection document

Operating instructions  Material Properties

Ignition Sources

Explosion Risk Assessment  Zoning

Process Conditions

Explosion Protection Document
# Process Hazard Assessment

## Process Definition Sheet

The information below will be treated with the utmost confidentiality.

<table>
<thead>
<tr>
<th>Name and type of equipment</th>
<th>IMEC n°:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supplier of information</td>
<td>Pump Manufacturer:</td>
</tr>
<tr>
<td>Date</td>
<td>Pump type:</td>
</tr>
<tr>
<td>Process responsible</td>
<td>Pump Purge (l/h):</td>
</tr>
<tr>
<td>Maintenance responsible</td>
<td>Atmosphere: Pressure Process? Y/N?</td>
</tr>
</tbody>
</table>

## Process Specifications: Process Chamber A

<table>
<thead>
<tr>
<th>Name of Recipe</th>
<th>Gas species (mixing pattern/scheme)</th>
<th>Gas 1</th>
<th>Gas 2</th>
<th>Gas 3</th>
<th>Gas 4</th>
<th>Gas 5</th>
<th>Gas 6</th>
<th>Gas 7</th>
<th>Gas 8</th>
<th>Gas 9</th>
<th>Gas 10</th>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Step</th>
<th>0-Naime (sec)</th>
<th>Typical Gasflow Rate (l sec^-1 / min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
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</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Process conditions

Process Hazard Assessment on all processes:

- Multidisciplinary approach chaired by ES&H–manager, attended by:
  - Equipment (hardware) engineers
  - Process engineer
  - Equipment supplier
  - Hook-up team (at later stage)

- Process hazard assessment results in Process safety document
  - Hook up of drains, exhausts
  - Gas monitoring equipment
  - Abatement installation
  - Process safety measures such as interlocks on tools and utilities
Process conditions

- Process hazard assessment (upstream/downstream):
  - Identification of process effluents:
    - Anticipated process flows and "gas on times" (Min/Max/Typical)
    - Bypass flows / calibration flows
    - Working temperature
    - Working pressure
    - Properties of process effluents
    - Identification of possible hazardous reactions between process effluents (Chamber-Platform)
Internal process safety standards – downstream:

- Effluent dilution: process emissions < 25 % LEL, unless in Pyrophoric exhaust

- Effluent treatment for harmful, toxic or reactive gases including abatement for explosive mixtures

- Separation of process gas flows (after local abatement if applied)
  - Caustic Exhaust
  - Acid Exhaust
  - General Exhaust ( = Heat Exhaust )
  - Pyrophoric Exhaust

- Pyrophoric exhausts for explosive effluents below environmental air emission standards

- Explosion monitoring in exhaust of some (MOCVD) processes interlocking MFC’s (unknown byproducts)
Process conditions

- Process Hazard Assessment – Upstream:
  - Identification of process precursor properties
  - Identification of hazardous reactions of process precursors
  - Appointing
    - purge groups (compatible gases within same purge gas group)
    - storage locations
    - gas cabinets
    - gas distribution bunker
  - Utilities:
    - Bulk distribution
    - Warehousing of chemicals / gases
Explosion protection document

Operating instructions → Material Properties

Ignition Sources → Explosion Risk Assessment → Zoning

Process Conditions

Explosion Protection Document
Operating instructions
Operating instructions

- Safe Work Permits / Instructions for maintenance works
  - Working in zoned areas/ installations = critical task

- Qualification of maintenance workers

- Measurement of occurrence of explosive atmosphere

- Signposting
VEILIG-WERKVERGUNNING

1. Aanvrager/Opdrachtgever: .................................................................
2. Omschrijving van de werken: ......................................................................................................................
3. Uitvoerder: ...........................................................................................................................................
4. Duur van de werken: .................................................................................................................................
5. Geldigheidsduur van de vergunning: ........................................................................................................

<table>
<thead>
<tr>
<th>Werkzaamheden/Af te sluiten toestellen en/of infrastructuur</th>
<th>Te specifiëren</th>
<th>Vergunning af te leveren door:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Γ Proceestoel ...................................................................</td>
<td></td>
<td>Onderhoudsverantwoordelijke toestel</td>
</tr>
<tr>
<td>Γ Afzuiging .....................................................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Koelwater ....................................................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ DI-water ......................................................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Elektriciteit Supp. Area ..........................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Elektriciteit Cleanroom ...... ....................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Gasleidingen/Gasfles ...............................................</td>
<td>HU</td>
<td></td>
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<tr>
<td>Γ Gassetekstie ..................................................................</td>
<td>T/D - Veiligheid - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Gezoneerde ruimtes ...................................................</td>
<td>T/D - Veiligheid</td>
<td></td>
</tr>
<tr>
<td>Γ Opvang CAW/Solventen ..............................................</td>
<td>HU - T/D</td>
<td></td>
</tr>
<tr>
<td>Γ Opvang AW ....................................................................</td>
<td>HU - T/D</td>
<td></td>
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<tr>
<td>Γ Perslucht/Vacuum ....................................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Stikstof/Zuurstof/Waterstof .....................................</td>
<td>T/D - HU</td>
<td></td>
</tr>
<tr>
<td>Γ Las- en slijpwerk ....................................................</td>
<td>HU - Veiligheid - T/D</td>
<td></td>
</tr>
<tr>
<td>Γ Andere ..........................................................................</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

VRIJGAVE VOOR VEILIG WERK

<table>
<thead>
<tr>
<th>Verantwoordelijke</th>
<th>Naam + Handtekening + Datum</th>
<th>Veiligheidsmaatregelen</th>
</tr>
</thead>
<tbody>
<tr>
<td>Opdrachtgever</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uitvoerder</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Onderhoudsverantwoordelijke toestel/Toestelnummer(s)
Onderhoudsverantwoordelijke
Operating instructions

- Work instructions for maintenance tasks

  - Safe work permit when working in zoned areas
    Information on safe work permit:
    - Nature of works, location of works, timing of works
    - Nature of explosion hazard / hazard identification
    - Safety measures, to be signed off by person responsible for taking safety measures
    - Personal Protective Equipment
    - Instructions for alerting including use of explosion detector
    - Start Time / time of completion of works
    - Inspection / control instructions

- Dispatching of works in central control room

- Ad hoc instructions for maintenance works
Operating instructions

- Ad hoc instructions following a risk assessment on site:
  - Removing explosive atmosphere by:
    - Removing combustible material (steam purging of solvent drains)
    - Closing fuel supply
    - Stopping process equipment
    - Discharging combustible compounds
  - De-activation of ignition sources by:
    - De-energizing electrical installations
    - Use of explosion proof tools
  - Explosion Monitoring of explosive atmosphere with quantimeter
Operating instructions

- Qualification of maintenance workers

  - Explosion protection document used as reference manual explaining for each zoned area/installation:
    - Nature of explosion risk
    - Safety measures
    - Correct use of equipment and installations
    - Meaning of signs / signposting
    - Safety measures when executing maintenance works

  - External contractors always under close supervision of IMEC engineer when executing “critical works”

  - Entire utility maintenance staff
Explosion protection document

Operating instructions → Material Properties

Ignition Sources → Explosion Risk Assessment → Zoning

Process Conditions

Explosion Protection Document
The explosion protection document

- Separate sheet for each area/installation where explosion risk has been assessed
  - Distribution bunker for flammable/toxic gases
  - Storage bunker for flammable/toxic gases
  - Waste park
  - Exhaust of chemical storage and distribution bunkers
  - Room with loading stations for forklifts
  - Exhaust of loading station for forklifts
  - Exhaust of UPS – battery supply
  - Exhaust pyrophoric gas rooms
  - UPS–battery room
  - Bottle stores (day storages)
  - Low value storage containers
  - Hydrogen pad (distribution & storage)
The explosion protection document

- Calamity exhaust for gas storage and distribution bunkers
- Pyrophoric exhaust FAB
- Stack outlets roof FAB
- Solvent distribution bunker
- Solvent storage bunker
- Solvent collection room
- ...

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The explosion protection document

Data sections in the explosion protection document:

- Purpose of the room/installation and - for rooms- brief description of manipulations
- Characteristics of combustible/flammable material (referring to other documents)
- Description of the nature of the explosion risk
- Classification and dimension of zoned area
- Technical and organizational safety measures including summary of the risk assessment
- Risk assessment for some ignition sources (under normal operational conditions)
The explosion protection document

- Purpose of the room/installation and -for rooms- brief description of manipulations

  - Description of manipulations with gases/solvents
  - Purpose of the installation
  - Max. contents of combustible/flammable equipment
  - Relevant technical information of rooms and installation
  - Design spec's (if relevant)
The explosion protection document

- Characteristics of combustible/flammable material
  (referring to other document)
  - Molecular weight
  - Density
  - Relative vapor density (vs.air)
  - Boiling point
  - Flash point
  - Max. working conditions: pressure / temperature
  - LEL / UEL
  - Temperature group (T1-T6)
  - Explosion group

- Gas mixtures: properties of bulk unless more accurate information available
  - (MSDS of specific mixture)
The explosion protection document

- Description of the nature of the explosion risk in combination with ignition sources

- Purging/venting of installations
- Leaking recipients
- Hydrogen (and oxygen !) formation when charging battery packs
- Formation of unwanted or unexpected by-products
- Leaking conveying lines
- Leaks during manipulation of products
The explosion protection document

- Classification and dimension of zoned area
  - By authorized body according to international standards

- Technical and organizational safety measures including summary of the risk assessment
  - Technical measures
    - Flow shut off valves (function/activation)
    - Flow limiting devices
    - Gas detection systems
    - Pressure monitoring
    - Leak detecting devices
    - Function of ventilation / AC flows / Ventilation flows
The explosion protection document

- Risk assessment for some ignition sources (under normal operational conditions and anticipated failures)
  - Flames / hot gases
  - Hot surfaces
  - Electrical installations
  - Electrostatic discharges
  - Lightning
  - Sparks (mechanical operations/welding/grinding)
  - Chemical reactions
  - Adiabetic compression & shock waves
<table>
<thead>
<tr>
<th>Ref. locatie:</th>
<th>CU/09.0.017</th>
<th>SOLVENTOPVANG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functie/handelingen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reagentia:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risico</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lek tijdens het leegmaken van de tank. Open-tankontluchting</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# The explosion protection document

<table>
<thead>
<tr>
<th>Beheersingsmaatregelen</th>
<th>Zone: Zone 2: ganse ruimte</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technische en organisatorische maatregelen</td>
</tr>
<tr>
<td></td>
<td>Natuurlijke ventilatieopeningen</td>
</tr>
</tbody>
</table>
The explosion protection document

<table>
<thead>
<tr>
<th>Ontstekingsbron</th>
<th>Normale werking</th>
<th>Te verwachten abnormale werking</th>
<th>Onderhoud</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vlammen &amp; hete gassen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hete oppervlakten</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elektrische installaties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statische elektriciteit</td>
<td></td>
<td></td>
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<tr>
<td>Bliksem</td>
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<tr>
<td>Mechanische vonken en lasvonken</td>
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<tr>
<td>Chemische reacties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adiabatische compressie &amp; schokgolven</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(ontstekingsbronnen die niet met voldoende intensiteit om dampen en gassen te kunnen ontsteken in de infrastructuur aanwezig zijn: straling in het optische gebied, hoogfrequente elektromagnetische straling, ioniserende straling, ultrasoon geluid en zwerfs)
# The explosion protection document

## Functie/handelingen

### Zone: Zone 2: gans ruimte

**Technische en organisatorische maatregelen**

- Natuurlijke ventilatieopeningen

## Reagentia:

### Risico

Lek tijdens het leegmaken van de tank. Open-tankontluchting

## Basiselementen

<table>
<thead>
<tr>
<th>Zone</th>
<th>Beheersingsmaatregelen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 2: gans ruimte</td>
</tr>
<tr>
<td></td>
<td>Technische en organisatorische maatregelen</td>
</tr>
<tr>
<td></td>
<td>Natuurlijke ventilatieopeningen</td>
</tr>
</tbody>
</table>

### Ontstekingsbron

- Vlammen & hete gassen
- Hete oppervlakten
- Elektrische installaties & materiaal
- Statische elektriciteit
- Bliksem
- Mechanische vonken en lasvonken
- Chemische reacties
- Adiabatische compressie & schokgolven

### Te verwachten abnormale

<table>
<thead>
<tr>
<th>Zone</th>
<th>Beheersingsmaatregelen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 2: gans ruimte</td>
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</tr>
<tr>
<td></td>
<td>Natuurlijke ventilatieopeningen</td>
</tr>
</tbody>
</table>

### Onderhoud

<table>
<thead>
<tr>
<th>Zone</th>
<th>Beheersingsmaatregelen</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Zone 2: gans ruimte</td>
</tr>
<tr>
<td></td>
<td>Technische en organisatorische maatregelen</td>
</tr>
<tr>
<td></td>
<td>Natuurlijke ventilatieopeningen</td>
</tr>
</tbody>
</table>
Processing tools

- Processing tools?

- Procurement specs:
  - All tools acquired by or placed or operated within IMEC facilities need to comply with:
    - Machinery Directive
    - Low Voltage Directive
    - EMC–Directive
    - Pressure Directive
    - ATEX–Directive

- Certificate of compliance required, signed by vendor before commissioning

- NO other certification accepted (SEMI S2/ NFPA, TUV, …)