Ammonia Refrigeration
Risk Assessment and Safety Management

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• Why is it needed
• Current legislation
• Safety management programme
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- Safe
- Efficient
- Eco-friendly
- Tried & Trusted
- Self-alarming
- Hazardous
Ammonia is a hazardous substance -toxic and explosive-

• The risk attributable to this hazard must be assessed and managed
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- 0.0001% to 0.005% (1ppm to 50ppm) odour threshold
- 0.0025% (25ppm) LTEL 8hr time, ERPG-1
- 0.0035% (35ppm) STEL 10min
- 0.015% (150ppm) ERPG-2
- 0.02% (200ppm) eye and nose irritation
- 0.04% (400ppm) throat irritation
- 0.05% (500ppm) EN378 stage 1 level
- 0.075% (750ppm) ERPG-3
- 0.17% (1,700ppm) cough
- 0.24% (2,400ppm) threat to life after 30 minutes
- 0.5% to 1.0% (5,000ppm to 10,000ppm) prob. of death with short exp.
- 3.0% (30,000ppm) EN378 stage 2 level
- 3.75% (37,500ppm) controlled max. level (25%LFL)
- 15% (150,000ppm) lower flammability limit (LFL)
- 28% (280,000ppm) upper flammability limit (UFL)
• Ammonia is flammable in air at concentrations of 15% to 28% by volume, requiring a temperature of 450 - 500ºC.

• Auto-ignition will occur above 630ºC.
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- HSE
- COSHH
- ATEX/DSEAR
- PSSR
- EN 378
- Institute of Refrig
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HSE

- H & S at Work Act
- Man. of H&S at Work Regs
- PM 81 ("Safe management of ammonia refrigeration systems")
- IIAR R1-UK version 2007
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COSHH

• Assess the risks
• Develop precautions
• Control exposure
• Use procedures
• Monitor exposure
• Emergency response
• Training
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ATEX/DSEAR

- Assess the risks
- Control risk
- Emergency response
- Training
- Zoning
- Avoid ignition sources
- Control access
- Explosion protection
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PSSR

• Procedures
• Preventive maintenance
• Management of Change
• Incident investigation
• Relief valve venting
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• RIDDOR
• BS EN 378
• Institute of Refrigeration
• International Institute of Refrigeration
• Insurance company
A 14 point plan for ensuring safety is managed.
Mercury Technologies has modified the plan to ensure UK and EU legislation is met, while adding a Safety System Review and an Offsite Consequence Analysis.
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
6. Precomm. review
7. Employee participation
8. Reviews
9. Incident investigation
10. Permit to work
11. Contractors
12. Management systems
13. Safety systems review
14. Offsite consequence
15. Emergency response
16. Hazard analysis
1. System Information

- MSDS
- Flow diagrams
- Drawings
- Press / temp limits
- Test certificates
- Manuals
- Load and charge calculations
## Chemical Safety Data: Ammonia (gas)

<table>
<thead>
<tr>
<th>Common synonyms</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Formula</td>
<td>NH₃</td>
</tr>
</tbody>
</table>
| Physical properties | Form: colourless gas  
Stability: Stable, flammable  
Melting point: -77 °C  
Boiling point: -33 °C  
Vapour density: 0.89 g/l  
Flash point: 11 °C  
Explosion limits: 16% - 25% |
| Principal hazards | *** Ammonia gas is very harmful, and may be fatal, if you inhale it. A level of just 500 ppm (that is, 1 part in 2,000) of ammonia in air is potentially fatal.  
*** Ammonia dissolves readily in water to give a very corrosive solution. This solution can cause serious burns to the skin or eyes.  
*** Ammonia is an environmental pollutant.  
*** Ammonia has a high reactivity, and may react enthusiastically or violently with some materials, including acids and aldehydes. |
| Safe handling | Wear safety glasses. It is essential that you work in a well ventilated area, normally a fume cupboard. Ammonia is extremely soluble in water (you may have come across the "ammonia fountain" demonstration that illustrates this), so care must be taken to avoid the problem of water sucking back into the source of the gas. |
| Emergency | Eye contact: Immediately flush the eye with water. Exposure to ammonia vapour may cause serious eye damage, so call for medical help.  
Skin contact: Wash off with soap and water. If there are any signs of skin damage, call for first aid.  
If inhaled: Call for immediate medical help. |
| Disposal | Where practical, ammonia should be dissolved in water and neutralized before disposal. |
| Protective equipment | Safety glasses. |
| Further information | Ammonia (gas)  
Chemicals in the HSci database  
More extensive safety data |
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15. Emergency response
16. Hazard analysis
2. Operating procedures

- Start & Stop, normal / emerg.
- Oil & Refrig drain / charge
- Lockout tagout
- Confined space
- Opening
- Ammonia Leak
- First aid
1. System Information
2. Operating procedures
3. Training
   4. Mechanical Integrity
   5. Management of change
   6. Precomm. review
   7. Employee participation
   8. Reviews
9. Incident investigation
10. Permit to work
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13. Safety systems review
14. Offsite consequence
15. Emergency response
16. Hazard analysis
3. Training

- Ammonia awareness
- Refreshers for ALL
- Records kept?
- Evacuation
- Use of safety equipment
- Operation & maintenance
- Spills
1. System Information
2. Operating procedures
3. Training
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4. Mechanical Integrity

- Inspections
- Daily log
- PM
- PSSR
- Calibrations
- Manuals up to date
Ammonia Refrigeration Safety Inspection Checklist
Pressure Vessels

Inspected by: --- Date: ---

Pressure Vessel No:
Pressure Vessel Location:
Pressure Vessel ID:

Application
☐ High pressure receiver ☐ Intercooler ☐ Accumulator ☐ Oil Pot
☐ Pump receiver, Low temp ☐ Pump receiver ☐ Other (Describe)

Application Data:
Normal Operating Pressure: [ ]
Temperature:
Vessel Size: [ ]
Normal Liquid Level: HLA: [ ] HLCO: [ ]
LIA: [ ] LLIQ: [ ]

Normal Ammonia Inventory:
Design Capacity (Specify: pump down, surge vol. kW, etc.):

Vessel Nameplate Data
Manufacturer, Name, Model, Serial #: [ ]
Year Manufactured:

Max. Allowable Pres: [ ] @ °C
Max. Design Working Pressure: [ ] @ °C

Minimum Design Metal Temp [ ] @ °C

Test pressure applied
Stress Relief: ☐ Yes ☐ No
Certification stamp?: ☐ Yes ☐ No Certification No:

Safety Relief Valve Data
Type: ☐ Dual ☐ Single ☐ None
Manufacturer, Name, Model, Serial #: [ ]
Year Manuf. or re-certified:
Seal unbroken?: ☐ Yes ☐ No
Pressure Setting:
Capacity:
Valve Connections: ☐ Inlet ☐ Outlet / Pipe Size ☐ Inlet ☐ Outlet

Is valve properly installed & piped to termination?: ☐ Yes ☐ No

If NO, explain:

Visual Liquid Level Indicator
☐ Tubular ☐ Flat Armored ☐ Armored Bull's Eye ☐ High Pressure Industrial ☐ None

Level switches
☐ HLCO ☐ HLA ☐ OL ☐ LLA ☐ Other ☐ Electronic

What protection do these controls give:
☐ Liquid to compressors ☐ Flooding vessel ☐ Pump cavitation

Are cutouts hard wired ☐ Yes ☐ No
### Ammonia Refrigeration Safety Inspection Checklist

**Jus-rol**

**Pressure Vessels**

<table>
<thead>
<tr>
<th>Conforms</th>
<th>Yes</th>
<th>No</th>
<th>Recommended Actions</th>
<th>Safety Status</th>
<th>Target Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Nameplate legible &amp; complete?</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>b) Suitable for ammonia?</td>
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<tr>
<td>c) Operating within limits?</td>
<td></td>
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<tr>
<td>1. Minimum Pressure</td>
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<tr>
<td>2. Minimum temperature</td>
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<td>d) Stamp legible?</td>
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<tr>
<td>e) Certification drawings on file?</td>
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<td>f) Manufacturer report on file?</td>
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<tr>
<td>g) Does vessel have known alterations or modifications?</td>
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<tr>
<td>1. If yes, was vessel recertified?</td>
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<tr>
<td>2. Is revised data report on file?</td>
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<tr>
<td>h) Safety relief &amp; hydrostatic relief valves</td>
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<tr>
<td>1. Proper type?</td>
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<tr>
<td>2. Pressure setting correct?</td>
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<td>3. Capacity correct?</td>
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<td>4. Installation correct?</td>
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<td>5. Piping to termination correct?</td>
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<tr>
<td>6. Relief valves replaced or recertified within last 5 years?</td>
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<td>7. Seal unbroken?</td>
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<td>8. Above liquid level?</td>
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<tr>
<td>i) Tubular linear liquid level indicator (light gauge)</td>
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<tr>
<td>1. Protected from traffic hazards?</td>
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<td>2. 360° guards?</td>
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<td>3. Internal check shut off valves?</td>
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<tr>
<td>j) Vessel properly identified &amp; marked</td>
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<tr>
<td>k) Vessel and components adequately protected from impact?</td>
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<tr>
<td>l) Is the vessel adequately supported?</td>
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<tr>
<td>m) Is the vessel free from excessive vibration?</td>
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<tr>
<td>n) Are critical valves accessible?</td>
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<td>o) Is there adequate oil draining capability?</td>
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<td>p) Vessel condition?</td>
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<tr>
<td>q) Insulation condition</td>
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<tr>
<td>r) Relief valve condition</td>
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</tbody>
</table>

Are there any other conditions that might negatively affect safe vessel operation? [ ] Yes  [ ] No
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
6. Precomm. review
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14. Offsite consequence
15. Emergency response
16. Hazard analysis
5. Management of Change

- Changes approved?
- Time enough for change?
- H & S impact investigated?
- Procedures modified?
- PM modified?
- Training modified?
- Safety hardware modified?
<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>System Information</td>
</tr>
<tr>
<td>2.</td>
<td>Operating procedures</td>
</tr>
<tr>
<td>3.</td>
<td>Training</td>
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<tr>
<td>4.</td>
<td>Mechanical Integrity</td>
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<td>5.</td>
<td>Management of change</td>
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<tr>
<td><strong>6.</strong></td>
<td>Precomm. review</td>
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<td>7.</td>
<td>Employee participation</td>
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<td>8.</td>
<td>Reviews</td>
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<td>9.</td>
<td>Incident investigation</td>
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<td>Permit to work</td>
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<td>12.</td>
<td>Management systems</td>
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<td>13.</td>
<td>Safety systems review</td>
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<td>14.</td>
<td>Offsite consequence</td>
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<tr>
<td>15.</td>
<td>Emergency response</td>
</tr>
<tr>
<td>16.</td>
<td>Hazard analysis</td>
</tr>
</tbody>
</table>
6. Pre-commissioning review

• Similar to Management of Change
• Clean/disinfect condenser(s)
• Construction matches drawings and specs?
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
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15. Emergency response
16. Hazard analysis
7. Employee participation

- Is a plan in place to safely manage the ammonia risk?
- Are all levels of employees involved in safety management?
- Is information readily available to all employees?
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
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16. Hazard analysis
8. Reviews

• 1yr – 2yr – 3yr?
• Significant changes
• Procedures used / relevant
• Significant events
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
6. Precomm. review
7. Employee participation
8. Reviews
9. Incident investigation
10. Permit to work
11. Contractors
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13. Safety systems review
14. Offsite consequence
15. Emergency response
16. Hazard analysis
9. Incident Investigation

- System in place?
- Start in a timely manner?
- Team make-up
- Report
- Review report
- Implement recommendations
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
6. Precomm. review
7. Employee participation
8. Reviews
9. Incident investigation
10. Permit to work
11. Contractors
12. Management systems
13. Safety systems review
14. Offsite consequence
15. Emergency response
16. Hazard analysis
10. Permit to work

- System in place?
- Relevant to ammonia?
- Hot work
- Fire prevention
- Define time, date and place
- Keep records
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
6. Precomm. review
7. Employee participation
8. Reviews
9. Incident investigation
10. Permit to work
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14. Offsite consequence
15. Emergency response
16. Hazard analysis
11. Control of Contractors

- H & S responsibilities
- Can it be verified?
- Does he train his employees?
- Is he aware of site rules?
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
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14. Offsite consequence
15. Emergency response
16. Hazard analysis
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12. Management System

• Defined team
• Defined roles
• Regular meetings
• Review programme
• Refresher training
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1. System Information
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14. Offsite consequence
15. Emergency response
16. Hazard analysis
13. Safety Systems Review

- Ventilation
- Ammonia detection
- Pressure relief valves
- PPE
- Building layout and lighting
- Labelling and signage
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
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14. Offsite Consequence Analysis

- Plant room leak
- Pressure relief valve release
- Pressure vessel rupture
Vapour plume
SIMPLE TERRAIN INPUTS:

SOURCE TYPE = POINT
EMISSION RATE (G/S) = 1139.00
STACK HEIGHT (M) = 5.2300
STK INSIDE DIAM (M) = .5130
STK EXIT VELOCITY (M/S) = 7.8860
STK GAS EXIT TEMP (K) = 303.0000
AMBIENT AIR TEMP (K) = 293.0000
RECEPTOR HEIGHT (M) = .0000
URBAN/RURAL OPTION = URBAN
BUILDING HEIGHT (M) = .0000
MIN HORIZ BLDG DIM (M) = .0000
MAX HORIZ BLDG DIM (M) = .0000

BUOY. FLUX = .168 M**4/S**3; MOM. FLUX = 3.957 M**4/S**2.

*** FULL METEOROLOGY ***

*** TERRAIN HEIGHT OF 0. M ABOVE STACK BASE USED FOR FOLLOWING DISTANCES

<table>
<thead>
<tr>
<th>DIST (M)</th>
<th>CONC (UG/M**3)</th>
<th>U10M (M/S)</th>
<th>USTK (M/S)</th>
<th>MIX HT (M)</th>
<th>PLUME HT (M)</th>
<th>SIGMA Y (M)</th>
<th>SIGMA Z (M)</th>
<th>DWASH</th>
</tr>
</thead>
<tbody>
<tr>
<td>100.</td>
<td>7.528E+06</td>
<td>4</td>
<td>1.0</td>
<td>1.0</td>
<td>320.0</td>
<td>17.37</td>
<td>16.07</td>
<td>14.22</td>
</tr>
<tr>
<td>200.</td>
<td>5010E+06</td>
<td>6</td>
<td>1.0</td>
<td>1.0</td>
<td>10000.0</td>
<td>18.84</td>
<td>21.52</td>
<td>14.56</td>
</tr>
<tr>
<td>300.</td>
<td>3695E+06</td>
<td>6</td>
<td>1.0</td>
<td>1.0</td>
<td>10000.0</td>
<td>18.84</td>
<td>31.42</td>
<td>20.31</td>
</tr>
</tbody>
</table>

MAXIMUM 1-HR CONCENTRATION AT OR BEYOND 100. M:

100. 7.528E+06  4  1.0  1.0  320.0  17.37  16.07  14.22  NO
<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>Machinery room leak</td>
<td>Level D to 200m radius</td>
</tr>
<tr>
<td>b)</td>
<td>Pressure relief valve venting</td>
<td>Level D to 1,800m radius</td>
</tr>
<tr>
<td>c)</td>
<td>HP receiver rupture (worse-case)</td>
<td>Level C to 1,400m radius Level D to 7,000m radius</td>
</tr>
</tbody>
</table>
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1. System Information
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15. Emergency Response

- Is there a plan?
- Is there a team?
- Instructions
- Communication
- Training
- First aid
- Coordination
Emergency Response Planning Guideline (ERPG) Values

<table>
<thead>
<tr>
<th></th>
<th>Listed value (ppm)</th>
<th>Calculated value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ERPG-1</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>ERPG-2</td>
<td>150</td>
<td>105</td>
</tr>
<tr>
<td>ERPG-3</td>
<td>750</td>
<td>525</td>
</tr>
</tbody>
</table>
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**Workplace Exposure Limits (WEL)**

<table>
<thead>
<tr>
<th></th>
<th>Listed value (ppm)</th>
<th>Calculated value (mg/m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTEL</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>STEL</td>
<td>35</td>
<td>25</td>
</tr>
</tbody>
</table>
# Acute Exposure Guideline Levels (AEGLs)

<table>
<thead>
<tr>
<th></th>
<th>10 min</th>
<th>30 min</th>
<th>60 min</th>
<th>4 hr</th>
<th>8 hr</th>
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<tr>
<td>AEGL-1</td>
<td>39</td>
<td>30</td>
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<tr>
<td>AEGL-2</td>
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<td>220</td>
<td>160</td>
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<tr>
<td>AEGL-3</td>
<td>2700</td>
<td>1600</td>
<td>1100</td>
<td>550</td>
<td>390</td>
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</tbody>
</table>
1. System Information
2. Operating procedures
3. Training
4. Mechanical Integrity
5. Management of change
6. Precomm. review
7. Employee participation
8. Reviews
9. Incident investigation
10. Permit to work
11. Contractors
12. Management systems
13. Safety systems review
14. Offsite consequence
15. Emergency response
16. Hazard analysis
16. Hazard Analysis

• Each major item of equipment
• Human factors
• Site issues
• Instrumentation
• Shutdown/Startup
• Emergency situations
## Compressors

<table>
<thead>
<tr>
<th>Item</th>
<th>Question</th>
<th>Scenario</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Equipment/Activity – Generic compressor</strong></td>
<td><strong>Consequences/Hazards</strong></td>
</tr>
<tr>
<td>10</td>
<td>What if a PSV discharges into piping/system that is not vented to atmosphere</td>
<td>A PSV discharges into piping/system that is not vented to atmosphere. There is a rise in pressure downstream of the PSV. This causes a rise in the set point of the PSV. An overpressure develops, resulting in a leak/rupture and an NH₃ release.</td>
</tr>
<tr>
<td>11</td>
<td>What if a sealing component (packing, O-rings, gaskets, Mechanical seal, flange) fails</td>
<td>A sealing component fails and a leak develops, resulting in NH₃ release.</td>
</tr>
<tr>
<td>12</td>
<td>What if a compressor discharge valve is closed</td>
<td>A compressor discharge valve is closed. An over-pressure condition develops. The over-pressure lifts PRVs and/or causes an equipment leak/rupture, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>13</td>
<td>What if a compressor suction valve is closed</td>
<td>A compressor suction valve is closed. Starved compressor overheats and fails one or more sealing components. Leaks develop in the equipment, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>14</td>
<td>What if there is insufficient flow of cooling medium to the compressor</td>
<td>Insufficient flow of cooling medium overheats compressor oil, mechanical seals, etc. The excessive heat fails one or more sealing components. Leaks develop on the equipment, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>Item</td>
<td>Question</td>
<td>Scenario</td>
</tr>
<tr>
<td>------</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>What if the condenser structural supports and enclosure are weakened</td>
<td>Corrosion/vibration weakens a structural component. The component fails and impacts tube causing a leak resulting in an NH₃ release.</td>
</tr>
<tr>
<td>14</td>
<td>What if plugs/caps or blind flanges are missing on purge or drain valves</td>
<td>A valve is inadvertently opened or leaks. There is no plug, cap or blind flange, resulting in an NH₃ release.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>What if a condenser is impacted by a vehicle</td>
<td>A condenser is impacted by a vehicle, causing a rupture, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>16</td>
<td>What if valves are not accessible</td>
<td>A valve is not accessible. Attempts by employees to access a valve causes a leak/rupture. A valve is not accessed quickly enough in an emergency situation, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>Item</td>
<td>Question</td>
<td>Scenario</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------------------------------------------------</td>
<td>---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td><strong>Equipment/Activity – Human factors : operator/process interface</strong></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>What if an employee strikes equipment, piping or valves with a hammer, spanner, etc.</td>
<td>An employee strikes equipment, piping or valves with a hammer, spanner, etc. This causes a crack or rupture, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>14</td>
<td>What if an employee applies external heat to equipment, piping, valves</td>
<td>An employee applies external heat (e.g., steam hose, torch, hot water hose, heat lamp) to equipment (e.g., oil pot), piping, valves, etc. This causes an overpressure and leak/rupture, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>15</td>
<td>What if there are unexplained system noises and no subsequent reporting or response</td>
<td>There are unexplained system noises and no subsequent reporting or response. The unexplained noises are indicative of a system problem. The non-reporting and non-response results in an NH₃ release.</td>
</tr>
<tr>
<td>16</td>
<td>What if an employee changes a set point</td>
<td>A set point is incorrectly changed (e.g., shortening hot gas defrost times, changing compressor cut-outs, hot gas relief, etc.). This causes an overpressure, liquid slugging, hammer or excessive mechanical wear, resulting in an NH₃ release.</td>
</tr>
<tr>
<td>Item</td>
<td>Question</td>
<td>Scenario</td>
</tr>
<tr>
<td>------</td>
<td>--------------------------------------------------------------------------</td>
<td>-------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>Consequences/Hazards</td>
<td>E/A Controls</td>
</tr>
<tr>
<td>9</td>
<td>Equipment/Activity – Facility siting : HVAC equipment</td>
<td>An NH₃ release. Is drawn back into the facility by HVAC equipment. This increases the exposure of employees to hazardous consequences</td>
</tr>
<tr>
<td>10</td>
<td>Equipment/Activity – Facility siting : siting of machinery room</td>
<td>The machinery is sited adjacent to a large employee population. There is an NH₃ release, resulting in increased exposure of employees to hazardous consequences</td>
</tr>
<tr>
<td>11</td>
<td>Equipment/Activity – Facility siting : control room</td>
<td>The control room is sited adjacent to the control room. There is an NH₃ release, resulting in increased exposure of employees to hazardous consequences</td>
</tr>
<tr>
<td>12</td>
<td>Equipment/Activity – Facility siting : access/egress</td>
<td>What if there is insufficient access or egress (especially elevated locations) for maintenance or emergencies.</td>
</tr>
<tr>
<td>Item</td>
<td>Question</td>
<td>Scenario</td>
</tr>
<tr>
<td>------</td>
<td>----------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Consequences/Hazards</td>
<td>E/A Controls</td>
</tr>
<tr>
<td>5</td>
<td>What if the facility has not planned for loss of facility water</td>
<td>The facility has not planned for loss of facility water. A loss of facility water occurs. There is refrigeration system upset and pressure increase, causing a leak/rupture and resulting in an NH₃ release.</td>
</tr>
<tr>
<td>6</td>
<td>What if there are no assigned responsibilities in the event of an emergency situation</td>
<td>There are no assigned responsibilities in the event of an emergency situation. There is a refrigeration system upset and pressure increase, causing a leak/rupture and resulting in an NH₃ release.</td>
</tr>
<tr>
<td>7</td>
<td>What if there are no isolation valves for securing the system in the event of an emergency situation</td>
<td>There are no isolation valves for securing the system in the event of an emergency situation. This prevents control and management of the emergency situation, increasing the exposure to hazardous consequences.</td>
</tr>
<tr>
<td>8</td>
<td>What if the emergency ventilation system is non-existent, inadequate or inoperable during and emergency situation</td>
<td>The emergency ventilation system is non-existent, inadequate or inoperable during and emergency situation, increasing the exposure to hazardous consequences.</td>
</tr>
</tbody>
</table>
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- Air coolers, pressure vessels
- Instrumentation/controls
- Piping/valves
- Charging
- Commissioning/shutdown
- Modifications
- Past incidents
<table>
<thead>
<tr>
<th>Frequency range</th>
<th>Qualitative frequency criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 4</td>
<td>Events expected to occur yearly with respect to the refrigeration system. Examples include single instrument or valve error, hose leaks or a human error</td>
</tr>
<tr>
<td>Level 3</td>
<td>Events expected to occur several times during the lifetime of the refrigeration system. Examples include dual instrument or valve failure, hose ruptures or piping leaks</td>
</tr>
<tr>
<td>Level 2</td>
<td>Events expected to occur no more than a few times during the lifetime of the refrigeration system. Examples include combinations of instrument failures and human errors, or full-bore failures of small lines or fittings</td>
</tr>
<tr>
<td>Level 1</td>
<td>Events expected to occur at most once during the lifetime of the refrigeration system. Examples include multiple instrument or valve failures or human errors, or spontaneous failures of tanks or vessels</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Consequence range</th>
<th>Qualitative safety consequence criteria</th>
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</thead>
<tbody>
<tr>
<td>Level 4</td>
<td>Potential for multiple, life-threatening injuries or fatalities</td>
</tr>
<tr>
<td>Level 3</td>
<td>Potential for a single life-threatening injury or fatality</td>
</tr>
<tr>
<td>Level 2</td>
<td>Potential for an injury requiring a physician’s care</td>
</tr>
<tr>
<td>Level 1</td>
<td>Potential to local vicinity, with potential injuries requiring no more than first aid</td>
</tr>
</tbody>
</table>
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Summary of Risks
<table>
<thead>
<tr>
<th>No.</th>
<th>Scenario</th>
<th>Section</th>
<th>Risk</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>4.1 Possible undersized relief valve</td>
<td>Haz. An/Safety Sys.</td>
<td>Level B</td>
</tr>
<tr>
<td>2</td>
<td>4.23/8.2/13.1 Action item tracking system</td>
<td>Haz An/Man Sys/Audit</td>
<td>Level B</td>
</tr>
<tr>
<td>3</td>
<td>9.2 Lock out / tag out procedure</td>
<td>Oper. Proc.</td>
<td>Level B</td>
</tr>
<tr>
<td>4</td>
<td>16.1 Reference to procedures</td>
<td>Hot work permits</td>
<td>Level B</td>
</tr>
<tr>
<td>5</td>
<td>17.1 Minimal control of contractor safety</td>
<td>Contractors</td>
<td>Level B</td>
</tr>
<tr>
<td>6</td>
<td>18.1 Fire brigade shutdown instructions</td>
<td>Emerg. resp. prog.</td>
<td>Level B</td>
</tr>
<tr>
<td>7</td>
<td>4.2 Condenser/Receiver vandalism risk</td>
<td>Haz. An.</td>
<td>Level C</td>
</tr>
<tr>
<td>8</td>
<td>4.3 Pressure vessel information</td>
<td>Haz. An.</td>
<td>Level C</td>
</tr>
<tr>
<td>9</td>
<td>4.4 Security at condenser/receivers</td>
<td>Haz. An.</td>
<td>Level C</td>
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<tr>
<td>10</td>
<td>4.5 RS/5 site glass failure</td>
<td>Haz. An.</td>
<td>Level C</td>
</tr>
<tr>
<td>11</td>
<td>4.15 Pipe, valve and insulation inspections</td>
<td>Haz. An.</td>
<td>Level C</td>
</tr>
<tr>
<td>12</td>
<td>4.16 Replace plugs and caps</td>
<td>Haz. An.</td>
<td>Level C</td>
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<tr>
<td>13</td>
<td>4.17 Ammonia awareness training</td>
<td>Haz. An.</td>
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<tr>
<td>14</td>
<td>4.18 Charging procedure</td>
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<td>15</td>
<td>4.19 Ventilation sail switches</td>
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<td>4.22 Oil charging procedure</td>
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<td>Level C</td>
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<td>4.24 Operator training</td>
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<td>Level C</td>
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<td>18</td>
<td>5.1 Vulnerability to traffic</td>
<td>Mech. Int.</td>
<td>Level C</td>
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<td>5.11 Pipe inspections</td>
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<td>Level C</td>
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<td>6.1 Personal protective equipment</td>
<td>Safety Sys.</td>
<td>Level C</td>
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<tr>
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<td>6.2 Emergency lighting</td>
<td>Safety Sys.</td>
<td>Level C</td>
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</table>
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• Ammonia is efficient & “green”
• Ammonia is hazardous
• Risk must be mitigated
• Mercury Technologies can assist
Mark Roxburgh
Office   +44 (0)1429 867 000
Mobile   +44 (0)7754 308 561
roxburgh@mercurytechnologiesltd.co.uk
www.mercurytechnologiesltd.co.uk