



Project Safety Strategy

CO₂ Capture – BOD & Tender Specifications

AEB Amsterdam

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Abbreviations

Abbreviation	Definition
AEC	Afval Energie Centrale (Amsterdam) / Waste to Energy Plant
AFB	Active Fire Protection
AIT	Auto Ignition Temperature
ALARP	As Low As Reasonably Practicable
API	American Petroleum Institute (US)
ATEX	Atmosphères Explosibles
BLEVE	Boiling Liquid Expanding Vapor Explosion
CCR	Central Control Room
CCTV	Closed Circuit Television
DHSE	Design Health, Safety & Environment
DWU	Demineralised Water Unit
EDP	Emergency Depressurisation
EER	Evacuation, Escape and Rescue
EERS	Evacuation, Escape and Rescue Strategy (ISO 13702)
EN	European Standard (given the status of a national standard)
ENVID	Environmental Impact Identification
EPC	Engineering, Procurement and Construction
ESD	Emergency Shutdown
ESDV	Emergency Shutdown Valve
FEED	Front End Engineering Design
F&G	Fire & Gas
GRP	Glass Reinforced Plastic
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HMI	Human-Machine Interface
HRC	Hoog Rendement Centrale / High Efficiency (Power) Station
HVAC	Heating, Ventilation and Air Conditioning
LOPC	Loss of Primary Containment

Abbreviation	Definition
MSDS	Material Safety Data Sheet
MWWT	Municipal Wastewater Treatment
OCAP	Organic CO ₂ for Assimilation by Plants
PAGA	Public Address General Alarm
PCC	Post Combustion Capture
PED	Pressure Equipment Directive
PFP	Passive Fire Protection
PS	Performance Standard
PSD	Process Shut Down
PSV	Pressure Safety Valve
QRA	Quantitative Risk Analysis
SIL	Safety Integrity Level
SIS	Safety Instrumented System
VESDA	Very Early Smoke Detection Apparatus
UPS	Uninterrupted Power Supply
VDU	Visual Display Unit (operator station)

1 Introduction

Technical Safety Management in project development and design processes comprises activities to identify risks, develop safety strategies and performance requirements for safety systems and barriers.

This document will set the Safety Strategy to be pursued for AEB's Post Combustion Capture (PCC) "Aurora" Project, based on the identification and evaluation of the hazards and effects that have been identified so far in the project development.

It is intended to be a high-level document that will be expanded and revised as the project develops.

The Safety Strategy is the outcome of a systematic identification and evaluation of the hazards and effects which may arise in the plant.

The Safety Strategy shall outline the design principles for layout, arrangement and the selection, design, location, and role of safety barriers to be implemented to manage risk. Emergency preparedness and operational aspects are also addressed in the Safety Strategy.

2 Objective

The objectives of the Safety Strategy are, in order of priority:

- Safety of people.
- Protection of the environment.
- Protection of assets and minimization of financial consequences of incidents, including fire and explosions.
- Minimum interference with normal operations, including transport. and no trips of the existing installations (AEC/HRC).
- Minimization of reputational consequences of incidents, including fire and explosions.

3 Scope

This Safety Strategy applies to the facilities involved in the Post Combustion CO₂ Capture Project (excl. CO₂ liquefaction plant) at AEB Amsterdam.

AEB Amsterdam is a waste processing company located in the Netherlands and currently owned by the City of Amsterdam. AEB is one of the largest waste processing plants in Western Europe processing over 1.4 million tonnes of waste every year. The AEB Amsterdam site has two (2) waste incineration plants namely the AEC (Afval Energie Centrale) and the HRC (Hoog-Rendement Centrale). Waste is incinerated in these two plants to combinedly generate electric power and heat to be supplied to the public grid and the district heating network respectively. The flue gases resulting from the incineration process are at present directly exhausted to atmosphere through 6 flue gas lines by the AEC (4 joint flue gas line lines) and HRC (2 joint flue gas lines) main stacks.

AEB Amsterdam has the ambition to realize a post-combustion CO₂ capture (incl. CO₂ conditioning) plant (PCC Plant) to capture about 0.5 Mton of CO₂ annually from the flue gases of the HRC and AEC units. A CO₂ liquefaction plant could also be installed to deliver liquid CO₂ to nearby greenhouses. For the previous phase of project development, various pre-FEED activities have been completed for the CO₂ capture project and AEB Amsterdam now would like to start the tendering process for a FEED/EPC contract.



Figure 1-1 AEB waste incineration plant (source: internet/public domain)

The key elements of the complete CO₂ capture (incl. CO₂ conditioning) and liquefaction project consists of:

- CO₂ Capture Plant and a CO₂ Conditioning Unit, overall called PCC plant to deliver gaseous CO₂ to the OCAP Grid (backbone) or to the CO₂ Liquefaction Plant.

- CO₂ Liquefaction Plant including Liquefaction, Storage, Truck Loading and Evaporation to deliver either liquefied CO₂ to Greenhouses or gaseous CO₂ to the OCAP Grid.
- All physical interfaces between the new CO₂ Capture Plant and a CO₂ Conditioning Unit and the existing AEC and HRC installations.

The CO₂ liquefaction plant is a separate (outside) scope element in this project and hence excluded from this document.

The Safety Strategy reflects the plant's specific conditions on e.g., environment and climate, competence of staff, cultural elements, infrastructure such as transport, external emergency preparedness resources, telecommunications, health care, availability of supplies of water and electricity, etc.

3.1 Plot Location/Layout

Figure 3-1 below shows the location of the HRC, AEC and proposed area for the PCC plant. The flue gas stacks for the HRC and AEC plants are also shown. Layouts of flue gas lines in Block 10 (L11, L12) and Block 20 (L23, L24) are in principle mirror of each other.

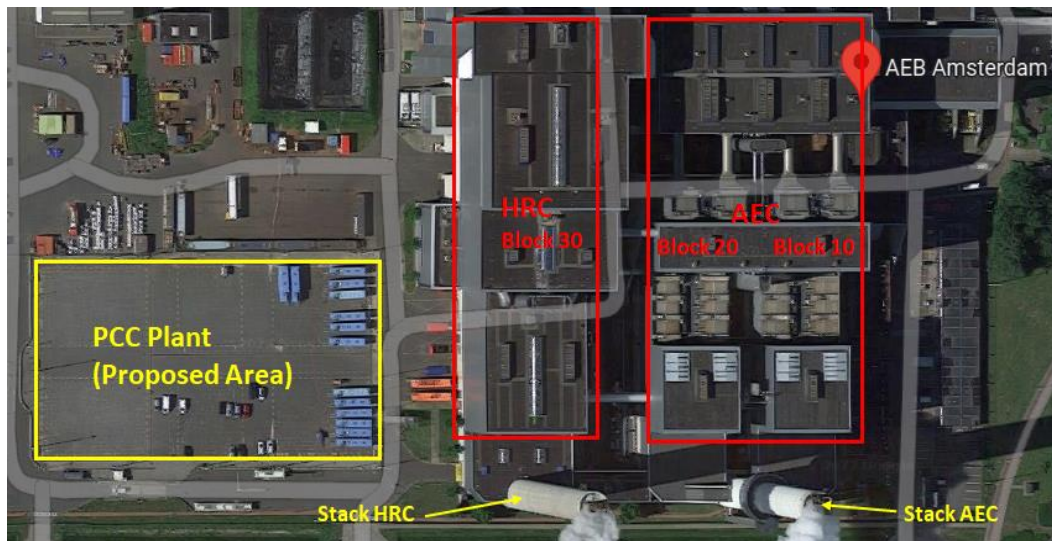


Figure 3-1 Plot Layout HRC, AEC and PCC plant

3.2 Scope

3.2.1 Project Scope

The scope for the AURORA project covers the design, manufacture, testing at works, supply, delivery, erection, testing, commissioning of the CO₂ capture plant and the CO₂ conditioning unit. In addition, utility provisions for the CO₂ liquefaction plant and connections to the existing installations (AEC/HRC) are also considered within the scope of AURORA.

3.2.2 Optional Project Scope

Apart from the CO₂ liquefaction plant, a pilot project with an objective to reduce operational and permitting risks is also considered optional project scope and this is for further consideration by FEED/EPC Contractor.

3.2.3 Scope of this Document

This document provides the **minimum** Safety requirements for the AURORA project which shall be adhered to.

4 References

The documents that have been taken as a basis for this Safety Strategy are the following:

4.1 Codes and Standards

Code or Standard No.	Title
2015/830/EC	Material Safety Datasheet
2008/1272/EC	Classification, Packaging and Labelling of substances and mixtures
2014/34/EC	ATEX Directive
2014/68/EC	Pressure Equipment Directive (PED)
2006/42/EC	Machinery Directive
2008/1/EC	Integrated Pollution Prevention and Control
2008/98/EC	Waste Framework Directive
IEC 60079	Hazardous Area Classification requirements
IEC 61511	Functional Safety – Safety Instrumented Systems for the Process Sector
IEC 61285	Industrial-process control – Safety of analyser houses
ISO 14122-1	Safety of Machinery - Permanent means of access to machinery Part 1: Choice of fixed means of access between two levels
ISO 14122-3	Safety of Machinery - Permanent means of access to machinery Part 3: Stairs, stepladders, and guardrails
EN 1005-2	Safety of machinery - Human physical performance Part 2: Manual handling of machinery and component parts of machinery
EN 1005-3	Safety of machinery - Human physical performance Part 3: Recommended force limits for machinery operation
EN 15154-1 & 2	Emergency safety showers- Part1: Plumbed-in body showers & eye wash
ISO-11064-series	Ergonomic design of control centres
EN 378-1/4	Refrigerating systems and heat pumps – Safety and environmental requirements
EN 626-series	Safety of machinery - Reduction of risks to health from hazardous substances emitted by machinery
EN 563	Safety of machinery - Temperatures of touchable surfaces - Ergonomics data to establish temperature limit values for hot surfaces
EN 16798-3	Energy performance of buildings - Ventilation for buildings - Part 3: For non-residential buildings - Performance requirements for ventilation and room-conditioning systems

Code or Standard No.	Title
PGS Standards	Publicatierreeks Gevaarlijke Stoffen standards
EIGA Standards	EIGA Standards
A-TS-IAL-006	AEB Noise Limits Standard

4.2 Project Documentation

Document No.	Title
Specific Tender Documents	
416041-47990/B.01/001	Block Flow Diagram
416041-47990/B.02/002	Generic Basis of Design
416041-47990/B.06/001	Project Scoping Document
416041-47990/G.06/005	DHSE Plan & File
416041-47990/G.06/006	Overall HAZID Report
416041-47990/G.06/007	DHSE Risk Register
416041-47990/L.01/001	Overall Plot Plan
416041-47990/P.06/002.	User Requirement Specification
Related AEB Documents	
68774-G-1305-0003-002 rev 0.1	HAZID Rapport -PCC
&AE-S-RX 1010 (EN)	HAZID Review Report - PCC of CO ₂ from Waste Incineration Plant
&AE-S-ZA 1001 (EN)	Hazardous Area Classification Plot Plan- PCC of CO ₂ from Waste Incineration Plant
&AE-S-PC 1003 (EN)	Overall Process Safety and Environmental Protection Concept- PCC of CO ₂ from Waste Incineration Plant
60001/ WAPA210112	HAZID Report - Koel Watervoorziening PCC

5 Plant's Hazardous Substances

The following hazardous substances are expected to be on site as part of the project's scope. For most of them, their MSDS should be provided by the licensor(s) and/or vendor(s). This list is to be revisited and updated if needed in later stages of the project.

5.1 Generic Hazardous Substances

CO₂

Although CO₂ is not classified as toxic, it however has a neurological impact on humans. CO₂, like nitrogen, will displace oxygen but unlike nitrogen, people would be at severe threat from increasing CO₂ concentrations well before they were from the reducing oxygen concentrations. Concentrations in the range of 10% to 15% will lead to dizziness, drowsiness, severe muscle twitching and unconsciousness within a minute to several minutes. Concentrations from 17% to 30% will quickly result in loss of controlled and purposeful activity, unconsciousness, coma, convulsions, and death.

In addition, CO₂ released at high pressure can form dry ice. Dry ice is extremely cold (-78.5 °C) and can cause frost injuries to exposed personnel.

Steam

A steam release could lead to severe burns and asphyxiation.

Lube/hydraulic and transformer oil

Lube/hydraulic oil for compressors and other rotating equipment, and transformer oil could cause a fire and cause environmental pollution.

Other chemicals

Refrigerant (NH₃), Anti foam Agent etc.

5.2 Specific Hazardous Substances

Amine-based absorber solution

There are health and environmental effects related to amine emissions. Amines can react to form other dangerous substances, as well. In high concentrations, amines can burn and create a fire hazard. Amines are corrosive to all body tissues, and they are detrimental for reproductive capability and for the unborn child.

Amine in storage tanks can burn if heated e.g., by a fire, depending on the concentration in the amine-water mixture. More information about the hazards posed by the specific amines used shall be referred from its material safety datasheet(s).

Ammonia

Ammonia is a toxic compound that could be released to the air and to the water. It can cause odour nuisances. Furthermore, depending on the concentration it can lead to an explosive atmosphere.

More detailed evaluation about the possible scenarios related to ammonia release shall be performed during the next phase of the project as it is required to be verified whether processes can be designed such to reduce the ammonia emissions.

Reclaimer chemical, NaOH

Corrosive. Water-Reactive. Harmful if swallowed. Causes severe eye and skin burns. Causes severe digestive and respiratory tract burns.

Acid wash chemical, H₂SO₄

Extremely corrosive to all body tissues, highly toxic to aquatic organisms and terrestrial plant life.

Other

Other hazardous substances include Nitrogen (see section 7.2) & Gasoline (Emergency Generator)

6 Defined Situations of Hazards and Accidents

The Safety Strategy for the Aurora Project is based on the defined situations of hazards and accidents identified and assessed so far during the project's HAZID session and earlier safety studies performed captured in the documents listed in Chapter 4.2.

The PCC plant in principle is expected to have lower potential risk than the present plant's processing facilities:

- The PCC plant will primarily handle non-flammable liquids and gases.
- The PCC plant will be operated at moderate temperatures and low pressure.

However, the PCC plant will introduce new and demanding risk elements:

- Potential health and environmental effects from loss of chemicals into air, like amines amine degradation products, and ammonia
- Handling of large volumes of CO₂, with a risk of leakage and gas dispersion at ground level.
- Generating EX-atmosphere/introducing new ATEX areas.

The main HSE hazards associated with the PCC plant are mentioned in the paragraphs below.

6.1 Emissions to Atmosphere and Associated Health Effects

- 1) Emissions to atmosphere at normal operation (predicted emissions including start-up/shut-down operation and maintenance):
 - From the amine-based process: there will be amine emissions (trace quantities) from the absorption process. There can be amine emissions (trace quantities) via the treated flue gas on top of the absorber column. Amines may form other substances, by reactions in the process and / or in the atmosphere.
 - Main emission component/concern in the treated flue gas is ammonia other concerns are carcinogenic nitrosamines, nitramines, amides, aldehydes, and volatile acids.
 - Insufficient knowledge presently, to be detailed in further project phase(s):
 - Exposure concentration
 - Exposure limits (accept criteria) and consequential emission limits
 - From a chilled ammonia refrigeration process there are HSE risks related to emissions of ammonia
- 2) Accidental releases to atmosphere
 - Insufficient knowledge presently, to be detailed in further project phase(s).
 - LOPC of steam of nitrogen and steam can lead to asphyxiation and will create an inert atmosphere in which gas detection will not be reliable.

6.2 CO₂ Exposure to Personnel

Personnel could be exposed to high(er) concentrations of CO₂ due to emissions and leakages. CO₂ detectors and O₂ detectors, if relevant, must be installed in all parts of the facility where leakages of hazardous concentrations of CO₂ can occur.

A more detailed study including dispersion calculations, number and type of detectors, alarm limits and required measures such as shutdown and evacuation of areas shall be performed in a later stage.

6.3 Frost Injuries

In the event of a pressure relief or a gaseous leakage in the system, CO₂ will change into a solid state and form dry ice. This will create a visible dense white fog of solid CO₂ particles in the form of powder and vapour. Dry ice can cause frost injuries to exposed personnel. Furthermore, dry ice can clog equipment and valves and/or embrittle sealings ultimately leading to pressure rise and possible leakages respectively.

CO₂ in liquid form will be transferred under high pressure in the area proposed for the CO₂ Liquefaction Unit (not part of current project scope).

The above-mentioned frost injury hazards are also applicable for Nitrogen being used for the project.

6.4 Static Electricity

Dry ice may create static electricity becoming a potential ignition source. Also, as a result of fast flowing fluids, static electricity can build up in pipelines too.

6.5 CO₂ Pressure Relief

Pressure relieves for high pressure CO₂ will be provided. Their design and (vent) location shall be safe, based on dispersion modelling. A rapid vent of CO₂ might create dry ice, possibly leading to blockage of the vent itself. Valve sealing material shall be selected adequately to avoid embrittlement and consequential leakages.

6.6 BLEVE

A Boiling Liquid Expanding Vapor Explosion (BLEVE) can occur if a liquid CO₂ container/storage tank (not part of the current project scope) is heated by a fire in the vicinity, causing its pressure and temperature to increase until the container eventually bursts, resulting in an overpressure wave and flying objects. Other causes include corrosion and material failure, tank overfilling, faulty valves, or incorrect operation of valves. The BLEVE risk can be managed by implementing measures that will reduce the probability and consequences of a BLEVE. The most important measures will be locating the tank of liquid

CO₂ such that it is not exposed to any fires in the surrounding area, ensuring high-quality materials and quality in the production of tanks, and safeguarding tanks against overfilling. In addition, the liquid CO₂ export area shall be situated 2.5 metres lower than the surrounding facilities which will reduce the consequences should a BLEVE occur.

6.7 Fire and Explosion

No major fire scenario has been identified for the project as the products used are mostly non-flammables, however following points shall be further looked into to confirm their applicability for the project:

- Unburned hydrocarbons could be carried through the flue gas to the PCC plant, potentially leading to a fire or an explosion.
- Transformer oil and lube/hydraulic oil can cause a fire under certain conditions.
- Amine in storage tanks can burn if heated, e.g., by a fire. The fire risk will vary according to the type of amine chosen and the concentration in the amine-water mixture.
- Ammonia is also a flammable substance and represents a significant fire hazard.
- Accidental flammable releases from facility might lead to a fire or explosion that has an impact on the PCC plant.
- Hot work near GRP equipment/lines. Use of alternative construction materials like Lined Steel could be considered.
- Hot work near all forms of plastic is a fire hazard, especially during a major outage

6.8 Construction and Operation Next to a Live Plant

The risks associated with construction and/or operation next to a live plant relate to possible accidents at the facility part which might have an influence on the design, construction, or operation of the PCC plant:

- Design and construction of a plant within the existing facility boundaries, i.e., within the influence area of e.g., gas leaks etc. Risk zones of existing, nearby facilities defined in the respective QRAs shall be reviewed, more specifically, the QRAs of Waternet & BEN. Their production facilities could impact the PCC plant's safety e.g., through a biogas tank explosion and wood gasifier factory fire respectively. The imposed risk zones must be considered to anticipate for adequate plant/equipment design and adhering appropriate safety distances.
- Measures related to ignition source control in the Construction phase shall be implemented, also taking into account the possibility of flammable gas releases from the existing, nearby facilities. This also will require a good communication procedure with the facility (Control-room and Emergency procedures).
- Additionally, the typical risks associated to Construction works shall be minimized. The safeguards to be considered during Construction works will not be discussed in this Safety Strategy.

- Ergonomics and maintenance facilities will be considered in each phase of the project, including equipment to be foreseen to carry out the works, required space and implementation of safety provisions.

6.9 Flooding

Considering the plant location (Netherlands) which is a low-lying location, there exist a potential risk due to flooding. This is to be considered in the design & operations as per applicable local norms.

6.10 Noise

New noisy pieces of equipment (blowers, compressors, pumps, vents...) will be installed. This implies general emission of operational noise to personnel and to the environment.

80 dB is the maximum permitted noise exposure limit to workers in a 12-hour shift.

6.11 Chemical Handling

Several chemicals (e.g., Amine) are corrosive or have other hazards.

First a complete overview of all used chemicals with its specific hazards must be compiled, followed by designing a safe installation. Furthermore, soil contamination shall be prevented.

The design shall be based on the following working environment strategy as per Arbeids Hygienische strategie in order of priority:

- 1) Substitution
- 2) Prevention (e.g., use of hazardous chemicals);
- 3) Minimization (e.g., use of hazardous chemicals);
- 4) Collective measures to reduce risk (e.g., separation, ventilation);
- 5) Individual measures to reduce risk (e.g., minimize manual handling)
- 6) Minimize the need for personal protective equipment.
- 7) Ensure safety equipment such as eyewash/safety showers, gas detection, alarms

6.12 Waste Handling

Waste streams will be generated by the CO₂ capture process. There are two types of effluent streams – one is wastewater generated by the CO₂ capture plant and CO₂ conditioning unit, and the second is the flue gas condensate collected in the DCC column. Wastewater shall be collected and sent to the municipal wastewater treatment plant. Flue Gas Condensate shall be treated in a dedicated Flue Gas Condensate Treatment Plant (FGCTP) to remove mercury and ammonia. The treated Flue Gas Condensate shall eventually be discharged to the harbor. An alternative is to use FG condensate as feed water for the DWU. This is currently under investigation by AEB, and this is to be further investigated/confirmed in the

next phase. In case FG condensate is utilized as feed water for the DWU, suitable discharge philosophy for the brine stream from the DWU needs to be developed in the next phase to meet the environmental permit requirements.

Waste production shall be as low as possible, and the environmental impact shall be minimized according to the following priority:

- Prevention
- Re-use
- Material recycling
- Energy recycling (waste-to-energy)
- Biological treatment
- Incineration / Landfill

For the key requirements related to the effluent, other waste and return streams, refer to section 2.8 "Effluents/Waste Discharge Requirements" of the User Requirement Specification (Rev B) document number 416041-47990-P.06-002 for details.

Other waste streams such activated carbon, silica gel, spent amine solvent will be processed at site through incineration. Note that the waste streams concerned must be formally approved by AEB's Acceptation Teams.

6.13 Road Tankers

It is foreseen that a relatively high number of road tankers will be supplying the new facilities. Means to reduce numbers and frequency shall be focused on. Risk related to busy traffic situations and loading/unloading activities are:

Traffic accidents (including road passing personnel);

- Collisions.
- Leaks during filling/unloading operations.

Accordingly, Design, Handling (loading/unloading) and Operation requirements related to handling of Sulphuric acid, ammonia and amine including storage and transport is to be reviewed in the HAZOP session. Also, the use of quick release couplings for Loading/Unloading operation should be reviewed.

A dedicated Logistics Plan shall be developed focusing on proper lining, safety signs, vehicle routing and lighting around the roads for low visibility conditions.

7 Performance Standards for Safety System and Barriers

Based on the hazards identified in the previous chapter, safety systems and barriers are listed for implantation in this section to minimize risks in the Aurora Project.

Performance Standards describing the role and design strategy for each barrier are specified into design requirements with respect to technical safety systems.

7.1 Containment

All equipment and piping related to prevent release of any flammables, and/or harmful fluids (chemicals, toxic gases, etc.) should be designed according to proven industrial standards whilst following recognized design codes (ASME, ANSI, etc.). The systems concerned shall be constructed, maintained, and operated with the aim to avoid leaks to occur.

The use of flexible hose connections in processing systems should be minimised.

Use of welded connections has the preference over bolted flange connections. Principal of double block and bleed (to safe location)

No overhead piping over walkways without protection.

The overall goal is to minimize the likelihood of a loss of containment for the dangerous substances listed in Chapter 5.

7.2 Natural Ventilation and HVAC

Natural ventilation is the preferred solution for the PCC plant, if possible. For open spaces, optimum natural ventilation shall be provided by means of a proper lay-out and proper spacing among the different pieces of equipment.

Buildings critical for safe operation or safety at the plant (e.g., enclosures, E&I Rooms etc.) shall be mechanically ventilated with redundant fans and have an overpressure relative to surrounding areas to avoid ingress of gas. The air inlet must be located outside the hazardous area and secured with measurements.

Buildings with batteries shall have redundant mechanical ventilation to ensure sufficient and reliable ventilation to dilute possible gas concentrations based on calculations or simulations.

Compressor houses, emergency shower and operator shelters shall preferably be naturally ventilated, having sufficient air changes to avoid accumulation of gas and/or explosive

atmosphere. If sufficient air changes cannot be obtained by natural ventilation, e.g., where a certain temperature is required, mechanical ventilation shall be evaluated.

Building indoor areas which can have confirmed spaces where leakages from the use and storage of asphyxiating gases such as Nitrogen & Carbon Dioxide is a possibility should be covered under a permit to work and special precautions like use of personal protection oxygen detectors should be considered.

7.3 Fire and Gas Detection

A Fire & Gas detection system shall be installed to detect, alert and initiate actions in case of leakage with release of flammable, toxic or asphyxiating gases and in case of fires. The fire and gas detection system shall be supplemented with the use of adequate numbers of flashing beacons and audible alarms in the field. The locations of these flashing beacons and audible alarms should be such that these are clearly visible and audible than the surrounding area.

The Fire and Gas detection system requirements shall be further developed and finalized in the next phase of the project based on the finalization of the products and their properties which will be used in the PCC plant. As a minimum based on the requirements at the new PCC plant following is foreseen:

7.3.1 Gas Detection System

The gas detection system shall provide reliable and fast detection by installation of adequate type, number, and location of gas detectors.

The gas detection system should be supplemented by other measures like portable gas detector and personal portable gas monitors as well e.g., for entering less ventilated areas like compressor houses or lower areas like pits or trenches. Personal portable gas monitors measuring the concentration of Oxygen are especially recommended for areas handling toxic / noxious gases. In general, following type of gas detection is applicable:

- Flammable Gas Detectors (Point Type) for detecting any flammable cloud for areas handling flammable/combustible products such as Ammonia & Amine. Also, it should be reviewed whether analyser houses will require any flammable gas detectors based on review of the properties of the products which will be analyzed. Requirement of Hydrogen detectors should also be checked for battery rooms based on the battery type which will be used in the project as charging of certain battery types releases hydrogen. Accumulation of hydrogen with an ignition can cause hazardous atmosphere.
- Toxic Gas Detectors for detecting any presence of toxic components above the concentration which could become danger to the health of personnel. This toxic gas detection shall be designed to detect the presence of such components like Ammonia, Carbon Dioxide etc. for the PCC plant. The alarms should be setup up for values which determine any immediate or long-term impact of human life such as ERPG_{1,2,3} values provided by the authorities.

- Oxygen detectors for detecting any deficiency of oxygen in an area resulting from accumulation of gases such as nitrogen replacing oxygen and causing health effects due to poor availability of oxygen in the human body.

7.3.2 Fire Detection and Evacuation System

The goal of the fire detection system is:

- 1) To comply with the building law to make it safe for people
- 2) To have an acceptable risk for AEB assets (AEB Risk Matrix available upon request).

The fire detection system shall monitor continuously for the presence of a fire to alert personnel and allow control actions to be initiated manually or automatically to minimize the likelihood of fire escalation and probability of personnel exposure.

The fire detection system shall provide reliable and fast detection of a fire. Installation of fire detectors of adequate type and number and in adequate location shall alert to take relevant action for the related area.

The exact number and location of the detectors and their associated equipment shall be determined during next engineering phase based on local standards. This should depend on typical factors like type of fire, equipment arrangement, national regulations, and installation requirements from fire detector manufacturer. Detectors should be located where the early stages of fire will be detected

As a minimum the following type of detectors are foreseen as a minimum:

- a) Heat Detectors for locations such as substations, switchgear rooms, workshop, warehouse etc. where any fire can lead to increase in temperature above a predetermined limit of the detector hence resulting in fire detection.
- b) Flame detectors for locations where hydrocarbon pool fire is a real scenario such as compressor & pumps lube oil skids.
- c) Smoke detectors should be provided in buildings such as substation rooms. Also, use of early warning and aspirating type smoke detections systems like VESDA should be reviewed for locations such as instrumentation and electrical panels, cable rooms etc which are not manned continuously and where fire can develop instantly, and an early warning is required.
- d) Manual Push Buttons should be provided along the process areas and buildings walkways and escape routes where operator presence and quick response to any hazardous situation is required.

During later stages of the project, further assessments on flammable and toxic gas detection (for volatile fluids or solutions with toxic components) shall be performed based on dispersion calculations.

The actions to take upon gas detection and the voting principle to be applied shall be in accordance with the existing fire and gas philosophy at site. Fire and gas control panels shall be provided to detect all changes in status of monitored points, provide event annunciation. The location of these panels should be finalized based on client input.

7.4 Emergency Shut Down

The PCC unit shall have a separate ESD system, and shall normally be manually activated based on confirmed emergency situations.

ESD systems shall be established to reduce the leakage of flammable or toxic material to atmosphere. This is done by:

- Isolating feed and product to/from each process unit, including stopping of rotating equipment.
- Sectioning parts of process units containing large volumes of toxic material.

Activation of ESD shall be possible from the control suites for the relevant process units in the CCR. This should be evaluated for other strategic locations such as:

- CO₂ export pipeline
- E&I Rooms

Depressurisation as part of the shutdown should normally be done by manual activation from the control room. Only if this implies too much delay, it can be done automatically. This shall be determined in later stages.

Manual activation points will be considered along main escape routes. The amount of these will be defined considering the minimum distance among them.

ESD valves shall have either spring return or local accumulators to ensure fail-safe function. Spring return types of valves are preferred and shall be used when required size is available. The position shall be indicated both locally and in the control room

ESD system status shall continuously be available in the CCR, and the system shall raise alarms for operator awareness or actions, considering:

- ESD initiated.
- ESD function failure to execute actions upon demand.
- ESD function (sensor, logic solver or final element) defect or failure.

7.5 Open Drain

Hazardous and non-hazardous open drains shall be physically separated to prevent backflow of hydrocarbons (lube and transformer oil) or dangerous substances from a hazardous area to a non-hazardous area.

Paved areas will be provided to collect possible spills: caustic, acid, chemicals, amines, etc. Separate intermediate containment shall be designed before releasing them for water treatment. When possible, those different spillages will be routed separately to the Flue Gas Condensate Treatment Plant (FGCTP) or otherwise be handled outside the unit.

Storage tanks (solvent, acids, chemicals etc.) shall be located in tank yards, having sufficient capacity to collect possible leakages from the tanks. Draining from the tank yards shall normally be closed. However, the tank yards shall be drained at a regular basis. It shall be possible to route the draining from the tank yards to the treatment plant.

7.6 Ignition Source Control

7.6.1 Hazardous Area Requirements

The hazardous areas at the PCC plant will be very limited (if at all) due to very limited amounts of flammable gases and chemicals. Loss of containment could cause the presence of hydrocarbons and the formation of an explosive atmosphere, so a review of the existing Products with respect to the area classification requirements should be performed as per IEC 60079-10-1, 60079-10-2 and area classification layouts established.

7.6.2 Equipment in Hazardous Areas

The overall safety philosophy to prevent ignition in the event of a (flammable) gas leakage is to apply ATEX certified equipment in areas where gas exposure is likely. Area classification shall be established in accordance with IEC 60079-10-1, 60079-10-2 etc, and equipment shall be constructed, installed, operated, and maintained in accordance with requirements of recognized industry standards such as IEC60079 and EN13463.

7.6.3 Hot Surfaces

The surface temperature of equipment, piping, and exhaust ducts etc that can be exposed to leaks from flammable mediums shall not exceed auto-ignition temperatures (AIT). Only in open air a higher maximum surface temperature may be accepted.

7.6.4 Static Electricity

Objects that may be electrostatically charged shall be bonded i.e., a separate connection to earth. Particular precautions will be required if non-conductive materials (including surface coating) are applied, i.e. connection to earth may not be sufficient.

Particular attention will be given to the fuelling and loading/unloading operations.

Attention shall be given to the potential of static electricity caused by formation of dry ice. Equipment and material shall be protected from collecting electric charge by bonding and design.

7.6.5 Radio Frequency Energy

Portable equipment (e.g., radios, gas detectors, test and measuring equipment) shall be ATEX certified.

7.6.6 Traffic

Traffic shall not act as an ignition source and shall be controlled by driving permissions and procedures. In hazardous areas, traffic shall be restricted to a minimum.

7.6.7 Hot Works

Hot works shall not act as an ignition source. This shall be ensured by work permit system and the hot works are ended upon confirmed gas detection. This is to not to be considered limitative.

7.7 Emergency De-Pressurization and Vent System

The CO₂ vent system of the PCC plant is venting from a system with gaseous CO₂.

The releases of these vents shall be located to a safe area to be determined by dispersion modelling. Those vent systems shall be reviewed and further optimized during the next phase of the project.

As a rule, or design starting point, the EDP times (after activation) should not exceed 15 minutes down to 7 bar or 50 % of the design pressure, whichever is the lower.

7.8 Active Fire Protection

The application of active fire protection shall be based on risk assessment to be performed during the next phase.

A distinction can be made between active fire protection required for the plant area and for the buildings.

Specific active fire protection for fire hazards within the PCC plant will have to be investigated in more detail during the next project phase.

Permanent hydrants shall be located in strategic positions. Hydrants shall be readily accessible from roads and be located in such a way that possible damage by road traffic will be minimised.

Equipment shall have adequate frost protection in accordance with project specifications, which could include min. water flow, heat tracing and/or drains at low points. Release of firewater shall normally be manual.

General

A fire brigade of the harbour area (Gemeenschappelijke Brandweer Amsterdam) of which AEB is a member is available. In addition, trained, dedicated, operational personnel shall also contribute in case of fire. The dimensioning of resources shall be based on the emergency preparedness analysis.

Arrangement of isolation valves shall be such that not more than 50% of the firewater to water hoses and hydrants for one area is affected if one segment of the firewater ring main is unavailable.

7.9 Passive Fire Protection

The use of PFP materials shall as far as possible be avoided due to maintenance issues and corrosion problems. Use of passive fire protection shall be evaluated in areas defined as fire proofing zones.

Manned buildings and buildings with important safety critical equipment shall be separated from process areas by adequate distance or fire divisions.

7.10 Emergency Power and Lighting

In the next phase of the project a black out philosophy should be made and based on that a design should be made which should as a minimum contain:

- The goal to achieve
- The implications of the goal on the design of the plant
- Different blackout scenario's
- Guidelines on powering redundant pumps
- Preferred ways of delivering emergency power

The UPS shall provide emergency power for the various safety systems (Fire and Gas, Firefighting control, alarms, ESD etc.) & DCS system as minimum for 30 minutes. During the next project phase, it shall be defined whether this time is enough, or it is necessary to consider longer back-up times, depending on the actual need and the risk assessed for PCC project.

Shut down of ventilation in rooms where UPS is located shall not cause temperatures above vulnerable components' tolerance within 30 minutes.

A reliable emergency power supply, independent of the plant's main power supply, shall be done by means of generators, and should be available for a minimum 18 h at full load or as per AEB philosophy and should be checked in the next phase of the project.

The emergency generator(s) (if required) shall provide emergency and essential power via emergency switch boards to following equipment:

- HVAC equipment
- Emergency lighting at ground level
- UPS in process areas
- Seal oil pumps
- Lubricating oil pumps and heaters
- Defined process equipment
- Electrical heat tracing of e.g., emergency showers and fire protection equipment

Emergency lighting along escape route at work locations and at assembly points shall be provided with local self-contained batteries or central uninterruptible power supplies.

At ground level emergency lighting shall be supplied from UPS, emergency generator, or local self-contained batteries.

At main roads, the general lighting shall provide emergency lighting. Fixtures shall be ATEX-certified, and a sufficient number of fixtures supplied from UPS or emergency generator.

7.11 Process Safety

Process safety systems and equipment, typically PSD, PSV, heat-off and local instrumented safety functions shall ensure that the process conditions do not exceed specified process safety limits. The aim of the process safety systems is to control any abnormal operating conditions to prevent and/or minimize possible hazardous chemicals or gases releases.

Overpressure protection shall include PSV as the ultimate protection and consist of two independent barriers. The instrumented barrier shall be designed from IPF/LOPA analysis and shall as a minimum be SIL1.

Storage tanks shall have a system protecting against overfilling.

Alarms shall warn operators to act before abnormal situations arise.

Response time for process safety functions shall be within the process safety time.

Process transmitters should be used instead of switches in safety instrumented functions, and this should be further checked and confirmed in next phase.

7.12 PAGA / Alarm and Communication System for Use in Emergency Situations

PAGA/Alarm and communication system for use in emergency situations shall alert, inform, and guide personnel as quickly as possible in the event of a hazardous or emergency.

It will provide communication of requirements for emergency action to all personnel and allow two-way communication between the emergency controller and the emergency response team.

The alarm system shall distribute audio alarms, visual alarms, and emergency messages, and shall be interfaced with the Fire & Gas system for alarm input.

Signal types, visual colour codes and alarm types shall be according to local requirements and practice.

Facilities for charging of batteries on Portable radios/ Porta phones used for emergency communications shall be provided.

Equipment for external communication shall be powered from dedicated battery supplies and/ or powered from plant UPS system.

7.13 Escape, Evacuation and Rescue (EER)

Number, size, and location of evacuation means shall be established based on manning, risk/EER analysis and hence the Safety Strategy.

There shall be at least two escape exits from permanently or intermittently manned areas outside offices, situated as far apart from each other as possible

There shall be no dead-end corridors within buildings exceeding 5 m in length.

All doors shall be constructed so that one person can easily open them from either side. Inside of doors to be equipped with push bars. They shall open in the direction of escape without blocking the outside route and be self-closing. This requirement should consider the effect of wind.

Safety signs and markings shall be in accordance with relevant international standards, e.g., ISO 3864 and ISO 17398. The types, number and location of safety signs/markings shall be defined during detailed design.

The Muster areas shall be located outdoors with free access to surrounding areas or in a protected area with easy access to such areas.

The possibility for an indoors temporary refuge shall be considered to protect the personnel against toxic releases or large CO₂ releases.

Emergency communication systems to be considered for all muster stations.

Eyewashes and safety showers are expected in the CO₂ capture unit area including mitigating measures to prevent legionella.

Emergency preparedness for the PCC project will be based on the existing emergency preparedness plan and Organisation at AEB facility.

The capture facilities will be physically integrated into existing facilities. Security and emergency response must follow the same principles and standards as the rest of the area and must be coordinated by the area operator.

Risk analyses as basis for revision of existing plans and Organisation will be carried out in due time before any construction activities.

7.14 Layout Design Principles and Explosion Barriers

The PCC plant including internal process pipelines should be oriented with respect to the prevailing wind direction and the terrain to minimize the likelihood of a gas release or smoke drifting towards the office/administration area, workshop/storage areas and areas with third party activities. It is to be noted that there are public roads and pedestrian routes alongside the project area.

In plant areas with uneven terrain, particular attention is required to ensure that a leak at one location does not allow escaped fluids to flow by gravity to other areas where it may cause an escalation of the accident scenario.

Substations containing electrical equipment and controls for a process unit located in enclosed buildings or weatherproof housings shall be at least 30 m or as per AEB's requirements from the unit they are serving.

Roads within the plant area shall be arranged for use by vehicles in emergencies. Walkways will be designed to allow passage with stretcher.

At least two entrances to the plant shall be arranged for emergency vehicles to prevent these from being blocked during an incident.