Generic Basis of Design

CO_2 Capture – BOD & Tender Specifications

AEB Amsterdam

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Abbreviations

Abbreviation	Definition
AEC	Afval Energie Centrale / Waste to Energy Plant
ALARP	As Low As Reasonably Practicable
ARA	Abwasser Reinigungsanlage / (existing) Wastewater Treatment Unit
AWP	Advanced Work Packaging
BFD	Block Flow Diagram
BL	Battery Limit
BOD	Basis of Design
CCR	Central Control Room
CW	Cooling Water
CWR	Cooling Water Return
CWS	Cooling Water Supply
CWA	Construction Work Areas
DCC	Direct Contact Cooler
DCS	Distributed Control System
DHSE	Design Health, Safety & Environmental
DWU	Demineralized water unit
ELV	Emission Limit Value
EPC	Engineering, Procurement and Construction
EQL	Equipment List
ESD	Emergency Shutdown
FEED	Front End Engineering Design
FG	Flue Gas
FGC	Flue Gas Conditioning
FGCTP	Flue Gas condensate treatment plant
HAZID	Hazard Identification
HAZOP	Hazard and Operability Study
HMB	Heat and Material Balance
HSE	Health, Safety & Environmental

Abbreviation	Definition
HRC	Hoog Rendement Centrale / High Efficiency (Power) Station
I&C	Instrumentation and Control
ICW	Internal Cooling Water
ICWS	Internal Cooling Water Supply
ICWR	Internal Cooling Water Return
I/O	Input/Output
IPS	Intrusion Prevention System
ISBL	Inside Battery Limits
IUTA	Institut für Energie- und Umwelttechnik e.V.
kt	kilotons
kV	Kilovolt
kW	Kilowatt
LP	Low Pressure
LPS	Low Pressure Steam
MSD	Material Selection Diagram
MTO	Material Take-off
MTPA	Million tonnes per annum
MWWT	Municipal Wastewater Treatment
OCAP	Organic CO_2 for Assimilation by Plants
O&M	Operation & Maintenance
OSBL	Outside Battery Limits
P&ID	Process & Instrumentation Diagram
PCC	Post Combustion Capture
PCDD/F	Polychlorinated dibenzo-p-dioxins/Furans
PCW	Primary Cooling Water
PCWS	Primary Cooling Water Supply
PCWR	Primary Cooling Water Return
PED	Pressure Equipment Directive
PFAS	Per- en polyfluoralkylstoffen / Per- & polyfluoroalkyl substances
PFD	Process Flow Diagram

Abbreviation	Definition
PMA	Particular material appraisal
PORTHOS	Port of Rotterdam CO_2 Transport Hub and Offshore Storage
RU	Reclaimer Unit
SCIP	Substance of Concern In Product
SME	Subject Matter Expert
STG	Steam Turbine Generator
SVHC	Substances of Very High Concern
TAUW	Technisch Adviesbureau van de Unie van Waterschappen
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
UFD	Utility Flow Diagram
ZZS	Zeer Zorgwekkende Stof – see also SVHC

Units of Measurement

The system of measurements shall generally be SI. Particular deviations are listed below.

Property	Units
CO_2 capacity	Million tonnes per annum (MTPA) or t/h
Composition (trace)	ppm or ppmv
Piping Diameter	DN
Electrical Power	kW or MW
Gas content/Particulates	mg/Nm^3
Higher/Lower Heating Value	MJ/kg
Pressure	bara – for flue gas/stack barg – for all other systems
Temperature	°C
Voltage	kV

Reference Documents

Document Number	Document Title
416041-47990/P.03/002	Battery Limit/Interface List
416041-47990/B.06/006	O&M Strategy
416041-47990/G.06/004	Project Safety Strategy
416041-47990/G.06/005	DHSE Plan & File
416041-47990/K.06/001	Constructability Review
416041-47990/J.06/002	I&C Philosophy
416041-47990/E.06/002	Electrical Philosophy
416041-47990/C.06/002	Civil & Structural Philosophy

1 Introduction

The purpose of this Generic Basis of Design document is to define overall and key project design data and requirements for the AURORA project to realize a new post combustion CO_2 capture (PCC) plant (excl. CO_2 liquefaction plant) at AEB's premises in Amsterdam, The Netherlands.

1.1 Project AURORA Definition

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 units namely the AEC (Afval Energie Centrale) and the HRC (Hoog-Rendement Centrale) with 6 incineration lines in operation. Waste is incinerated in these two facilities to combinedly generate electric power and heat to be supplied to the electrical grid and the district heating network respectively. The flue gases resulting from the incineration process are at present exhausted to atmosphere by the AEC main stack (4 joint flue gas line lines) after flue gas treatment and HRC main stack (2 joint flue gas lines).

AEB Amsterdam has the ambition to realize a post-combustion CO_2 capture (incl. CO_2 conditioning) plant (PCC Plant) as part of the AURORA project to capture 507 kt (kilotons) of CO_2 annually from about 38% (mass basis) of the total flue gases of the HRC and AEC units.

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

The captured CO_2 shall be in principle delivered in gaseous form to a backbone (OCAP) for further transport and possible storage/utilization. However, an additional CO_2 liquefaction plant could also be installed to deliver liquid CO_2 to nearby greenhouses. For the previous phase of project development, various pre-FEED activities have been completed for the CO_2 capture project and AEB Amsterdam is currently in the tendering process for a FEED/EPC contract.

The key elements of the AURORA project:

- CO_2 Capture Plant and a CO_2 Conditioning Unit, overall called *PCC plant* to deliver gaseous CO_2 to the OCAP Grid (backbone) or to a potential onsite CO_2 Liquefaction Plant.
- Potential CO_2 Liquefaction Plant including Liquefaction, Storage, Truck Loading and Evaporation to deliver either liquefied CO_2 to Greenhouses or gaseous CO_2 (regasification) back to the OCAP Grid.
- All physical interfaces between the new CO_2 Capture Plant, CO_2 Conditioning Unit, CO_2 Liquefaction Plant, and the existing AEC and HRC installations. This includes utility interfaces, connection to OCAP Grid and wastewater discharge (sewage system, cooling water system and harbor).

1.2 Plot Location/Layout

The AEB Amsterdam waste incineration plant is located in the Westpoort area of Amsterdam, The Netherlands (Coordinates: 52° 24´01" N, 4° 47´27" E). The site mean elevation is +1.4 m above NAP (Nieuw Amsterdam Peil).

Figure 1-2 below shows the location of the existing HRC, AEC units and the proposed area for the PCC plant at the existing AEB Amsterdam site. The main 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.

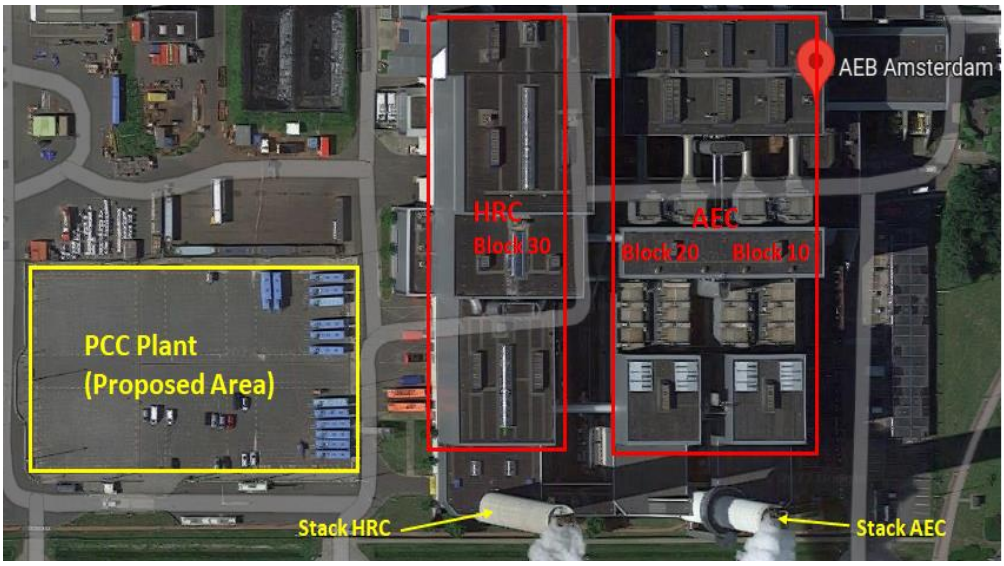


Figure 1-2 Plot Layout HRC, AEC and PCC plant

1.3 Block Flow Diagram

The overall high-level block flow diagram (BFD) for project AURORA is shown below.

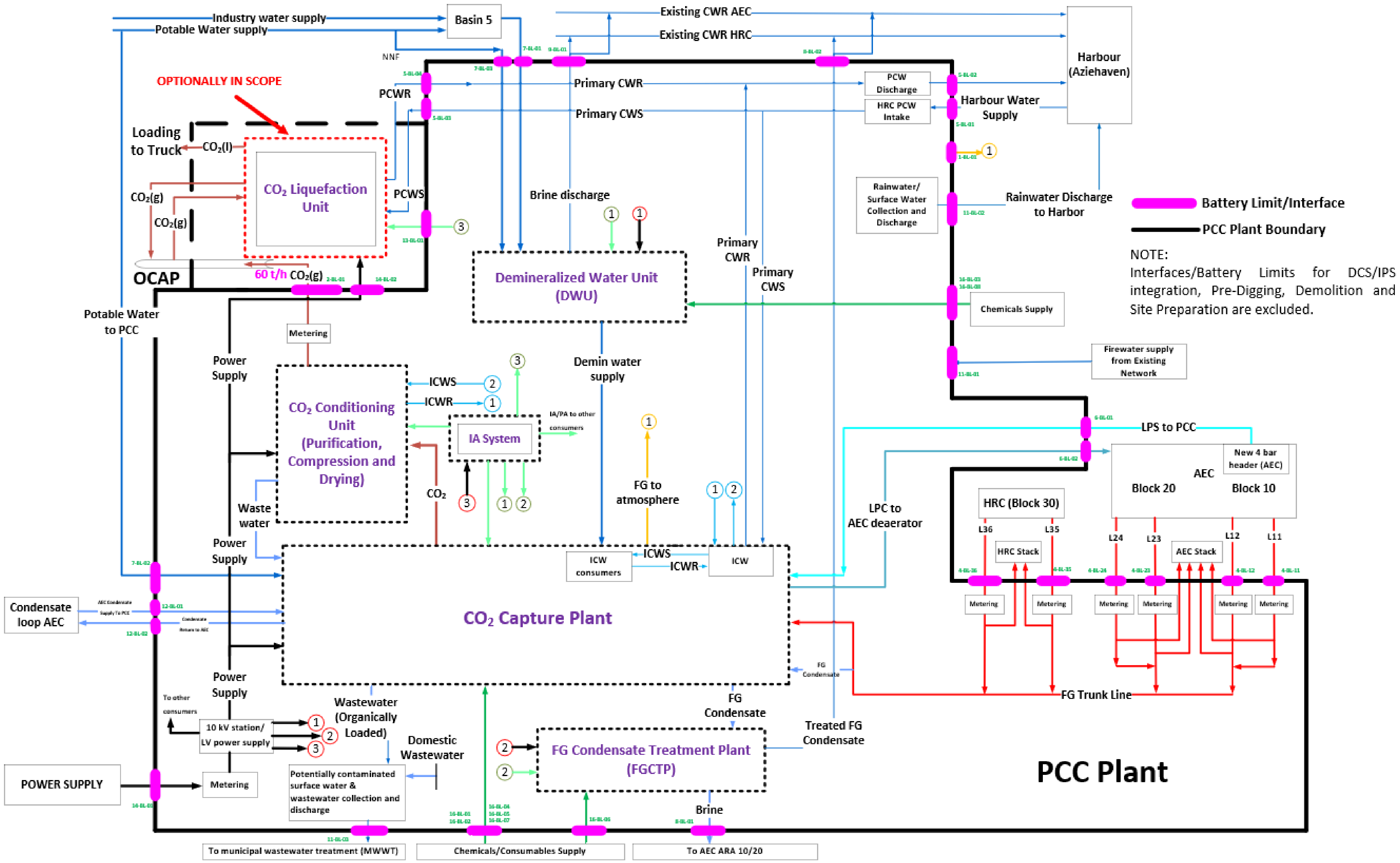


Figure 1-3 Block Flow Diagram - AURORA

The key process areas of the PCC plant consist of the flue gas stack tie-ins, CO_2 capture and CO_2 conditioning (purification, compression and drying) units. The design, manufacturing, testing at works, supply, delivery, erection, testing, commissioning of the CO_2 liquefaction plant is considered to be an optional scope for this project and hence for now excluded from this design basis. Note that related tie-ins are to be provided. Flue gas from the existing facilities (HRC and AEC units) shall be delivered to the PCC plant using a new flue gas trunk line; the FG trunk line is used to collect the required amount of flue gases from 2 or more of the 6 existing FG lines and feed it to the PCC plant to capture 60 t/h (nominal capacity) of CO_2. Refer to section 2.1 for the Design capacity and section 4 for the Operating Envelope.

Electrical power shall be supplied to the PCC plant consumers through two redundant 10 kV power feeders (Outside Battery Limits).

Primary cooling water (PCW) shall be obtained from the harbor located north of the plot to meet cooling demands of the potential CO_2 liquefaction plant and a dedicated closed loop cooling water system (called the internal cooling water (ICW) system). The ICW system shall be used to meet the main[1] cooling demands of the CO_2 capture and CO_2 conditioning units.

Steam required for the CO_2 capture plant shall be provided by the existing AEC unit whilst the generated steam condensate shall be returned to the existing deaerators of the AEC unit. A back up option[2] for steam supply to be also provided from the existing HRC unit.

A dedicated demineralized water unit (DWU) shall be installed to produce demineralized water which shall be used as make-up water for the main process area of the PCC plant. FG condensate shall be collected from the trunk line and CO_2 capture plant and sent to a dedicated FG Condensate Treatment Plant (FGCTP). The FGCTP shall be designed to mainly eliminate mercury and ammonia in the FG condensate prior to discharging the clean condensate to the harbor and/or reutilizing it within the PCC plant (e.g., as DWU feed water).

Wastewater produced in the process area and potentially contaminated surface water/rainwater shall be collected and appropriately discharged to the nearby municipal wastewater treatment (MWWT) plant. Provisions shall also be made to collect non-contaminated rainwater and discharge appropriately to the harbor. Re-use of non-contaminated rainwater from the roofs shall be investigated[3].

Chemicals/consumables (like caustic, acids etc.) shall be provided using tie-ins to the existing chemical storage facilities. Design shall include suitable storage facilities for amine solvent and other consumables (as applicable).

[1] Cooling Strategy to be confirmed and further developed in the next project phase
[2] To be further confirmed in the next project phase.
[3] This is not a mandatory requirement; it is a potential upside from the business case point of view

2 Basic Design Data

2.1 Design Capacity

The overall CO_2 capture facility shall be designed to produce and deliver a nominal capacity 60 t/h (1440 tpd) of gaseous, purified, compressed and dried CO_2 product. The nominal capacity is not a mandatory requirement from the environmental permit point of view; the nominal capacity of 60 t/h is an outcome from the business case point of view. Contractor to reevaluate and confirm the nominal capacity in the next project phase.

2.1.1 Design Margin – Capacity

Design margins to be considered for the CO_2 production capacity are listed in the table below:

Item	Design Margin[4]	Description/Remarks
CO_2 production (Maximum, t/h)	+8.0%	To be confirmed in FEED phase
CO_2 production (Minimum, t/h)	up to 30% minimum turndown	To be confirmed in FEED phase

2.2 Plant Life

The PCC plant shall be designed considering a lifetime of 16 years (for all units) coinciding with the anticipated CO_2 capture subsidy period.

2.3 Energy Efficiency & Heat Integration

The PCC plant shall be designed for maximum energy efficiency by incorporating suitable heat recovery/energy optimization techniques to maximize energy efficiency. One of the heat recovery options to be considered is to use heat from the regenerator condenser to pre-heat main condensate in the steam-water cycle of the AEC unit.

Stream	Flow (kg/hr)		Temperature (°C)
	Normal	Maximum	
AEC Condensate Supply to CO_2 capture plant	210,500	300,000	40-60
Heated Condensate Return to AEC	210,500	300,000	90 (maximum)

In the next project phase, all potential options to maximum plant efficiency and heat integration are to be considered.

[4] applied over nominal value

2.4 CO_2 Capture Rate

The PCC plant shall be capable of delivering a nominal capacity of 60 t/h gaseous CO_2. To achieve this, the CO_2 capture unit shall be designed for an average/design capture efficiency of 90% (mass basis) which is to be optimized for maximum energy efficiency. For the complete Operating Envelope (Refer to section 4) & variation in flue gas quality (Refer to section 3.1), the CO_2 capture efficiency shall be optimized for maximum CO_2 production and maximum energy efficiency. Under all circumstances, product CO_2 from the PCC plant shall comply and shall be delivered with the required CO_2 specification (Refer to section 3.2).

2.5 Ambient Conditions

2.5.1 Ambient Temperature

Temperature	Unit	Annual Average	Hot Month Mean	Hot Day	Summer Extreme	Winter Extreme
Dry Bulb Temperature	ºC	10.8	23.0	30.0	35.0	-20.0
Wet Bulb Temperature[5]	ºC	8.8	20.5	27.2	32.0	-20.8

2.5.2 Barometric Pressure

Pressure	Unit	Min	Mean	Max
Barometric pressure (average)	mbara	976.8	1013.0	1046.9

2.5.3 Relative Humidity of Air

Humidity	Unit	Min	Mean	Max
Relative Humidity average	%	33.0	80.8	100.0

[5] Estimated from Dry Bulb Temperature using an average relative humidity of 80.8%

2.5.1 Wind

Parameter	Value
Wind Zone (according to NEN 6702)	2
Wind Load	1.1

2.5.2 Precipitation

Parameter	Unit	Value
Rainfall: average month	mm/month	72.7
Rainfall: hourly max	mm/h	28.1
Snow Load (according to NEN 6702)	kg/m^2	150

2.6 Reference Design Conditions

The design reference conditions for the PCC plant are shown in the table below.

Property	Units	Value
Ambient Pressure	bara	1.013
Dry bulb Temperature	ºC	10.8
Wet bulb Temperature	ºC	8.8
Relative Humidity	%	80.8
Site elevation	m	+1.4m above NAP
Grid frequency	Hz	50
Power Factor		0.8 (lagging)

2.7 Site Conditions

Refer to Civil & Structural Philosophy, doc. no. 416041-47990/C.06/002.

2.8 Noise Limits

Refer to Project Safety Strategy, doc. no. 416041-47990/B.06/006.

2.9 Interfaces & Battery Limit

The existing facilities (AEC & HRC) shall be retrofitted to enable capturing CO_2 from the flue gases presently fully emitted to the atmosphere. Furthermore, multiple utilities/consumables like steam, chemicals, cooling water etc. shall be provided from/via the existing installations. Hence there are multiple interfaces expected for the new PCC plant with either existing installations, third parties and/or out of site areas. All envisaged interfaces or battery limit points for the new PCC plant are shown in the block flow diagram (see Figure 1-3). The PCC plant consists of the following interfaces/battery limit locations:

Interface Tag	Interface description	Medium
4-BL-11	Flue Gas from flue gas line L11	Flue Gas
4-BL-12	Flue Gas from flue gas line L12	Flue Gas
4-BL-23	Flue Gas from flue gas line L23	Flue Gas
4-BL-24	Flue Gas from flue gas line L24	Flue Gas
4-BL-35	Flue Gas from flue gas line L35	Flue Gas
4-BL-36	Flue Gas from flue gas line L36	Flue Gas
6-BL-01	LP steam from AEC LP steam header	LP steam
6-BL-02	LP condensate from PCC plant to AEC[6]	LP condensate
11-BL-01	Firewater from existing network	Firewater
11-BL-02	Clean Rainwater/Surface water discharge to harbor	Rainwater/Surface water
11-BL-03	Wastewater/Contaminated Rainwater or surface water discharge to MWWT	Wastewater/Rainwater/Surface water
1-BL-01	Treated Flue Gas to atmosphere	Treated Flue Gas
5-BL-01	Harbor water supply to PCW intake	Cooling Water
5-BL-02	PCW return to PCW discharge line to harbor	Cooling Water
5-BL-03	PCW supply to CO_2 liquefaction plant	Cooling Water
5-BL-04	PCW return from CO_2 liquefaction plant	Cooling Water
13-BL-01	Instrument/Plant Air supply to CO_2 liquefaction plant	Instrument/Plant Air
14-BL-01	Power supply to 10kV station	Electrical Power
14-BL-02	Power supply to CO_2 liquefaction plant	Electrical Power
2-BL-01	Product CO_2 export to OCAP	Product CO_2 (gaseous)
7-BL-01	Feed water supply to DWU from Basin 5	Industry water/Potable water
7-BL-02	Potable water supply to CO_2 capture plant	Potable water
7-BL-03	Potable water direct supply to DWU	Potable water
12-BL-01	AEC Condensate Supply To PCC	Condensate
12-BL-02	Heated Condensate Return to AEC	Condensate

[6] Back up option from HRC

Interface Tag	Interface description	Medium
8-BL-01	Brine/Effluent from FGCTP to AEC ARA 10/20	Effluent from FGCTP
8-BL-02	Treated FG condensate to existing CWR line of HRC/AEC	FG condensate
9-BL-01	Brine/Effluent from DWU to existing CWR line of HRC/AEC	Effluent from DWU
16-BL-01	Amine solvent to CO_2 capture plant	Amine solvent
16-BL-02	Caustic (NaOH) supply from existing tank(s) AEC/HRC	Caustic (NaOH)
16-BL-03	HCl supply from existing tank(s) AEC/HRC to DWU	Hydrochloric acid (HCl)
16-BL-04	Sulphuric acid (H_2SO_4) supply	Sulphuric acid (H_2SO_4)
16-BL-05	Anti-foaming agent	Anti-foaming agent
16-BL-06	Anti-scalant for FGCTP	Anti-scalant
16-BL-07	Lube oil supply to storage	Lube oil
16-BL-08	N_2 supply to DWU	Nitrogen

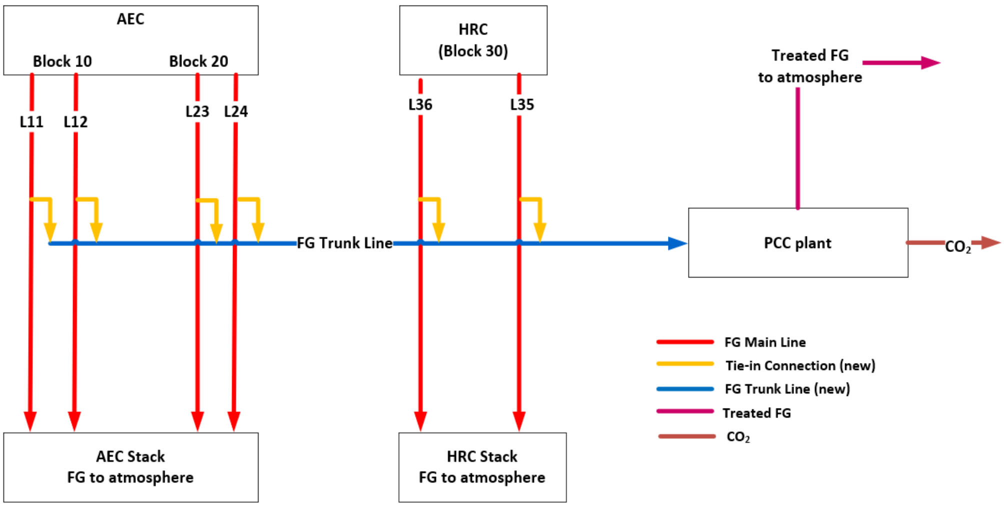
The battery limit/interface list above excludes DCS/IPS integration, Pre-Digging, Demolition and Site Preparation.

For associated battery limit process conditions, please refer to the Battery Limit/Interface List, doc. no. 416041-47990/P.03/002.

3 Feed Flue Gas and Product CO_2 Specifications

3.1 Feed Flue Gas

Flue gas will be fed to the PCC plant through a new dedicated FG trunk line; the FG trunk line will collect FG from six (6) incineration lines in the AEC and HRC units. The four (4) FG lines of the AEC (L11, L12, L23 and L24) need to be rerouted to comply with design requirements for upstream flow/emission measurements before routing the flue gas to the PCC plant. The existing emission measurements on the four (4) AEC lines in the AEC stack are to be relocated on the horizontal section of the duct before entering the stack. No changes are envisioned in this respect to the emission measurements on the two (2) HRC lines (L35 and L36).



The tie-in connections for the six (6) FG lines in the HRC and AEC are to be located just before entering the respective main stacks. The routing (tie-in connections) to the PCC plant shall be downstream the emission/flow measurement sections and thus the total (100%) combined flue gas flow from all six (6) lines (HRC & AEC) will pass through the measurement section before being routed to either the main stack (HRC or AEC) and/or PCC. The tie-in connections will feed the main trunk line to the PCC plant. FG (CO_2 free flue gas) shall be released to the atmosphere from a new stack in the PCC plant and hence no return flow of flue gases is anticipated from the PCC plant to the AEC/HRC stacks.

3.1.1 Feed Flue Gas Specification (Average)

Parameter	Unit	Design
Feed FG to PCC Plant	t/h	585
Battery Limit FG Pressure	bara	atm
Battery Limit FG Temperature	ºC	66

The nominal FG flow (38% of total flue gas flow per line) in all the six (6) tie-in connections is shown in the table below.

Description	Flow[7] (max) kg/h	Operating Pressure (bara)	Operating Temperature (°C)
Flue gas from AEC (L11 Tie-in Connection)	93,780	atm	66
Flue gas from AEC (L12 Tie-in Connection)	93,780	atm	66
Flue gas from AEC (L23 Tie-in Connection)	93,780	atm	66
Flue gas from AEC (L24 Tie-in Connection)	93,780	atm	66
Flue gas from HRC (L35 Tie-in Connection)	104,940	atm	66
Flue gas from HRC (L36 Tie-in Connection)	104,940	atm	66

3.1.2 Feed Flue Gas Quality (Average[8])

Component	Unit	Design Value
Bulk Components		
H_2O	vol % wet	22.76
CO_2	vol % wet	7.05
O_2	vol % wet	7.06
N_2	vol % wet	balance
Ar	vol % wet	0.74
Trace Components		
Dust	mg/Nm^3	0.94[9]

[7] 38% (mass basis) of the total flue gas flow per FG line

[8] Average from 4-year AEB measurement data (2018-2021)

[9] For particle size distribution, measurement of ultra-fine and fine particles in the flue gas, please refer to two reports (Attachment 1 & Attachment 2) by IUTA;

1. *Measurement of ultrafine and fine particles in flue gas of two waste incinerator lines after passing the full flue gas treatment system and after blower just before the flue gases enter the stack during a measurement period of 3 days (Report No: UN2-181106-T5595900-130B)*
2. *Measurement of ultrafine and fine particles in flue gas of four waste incinerator lines during a measurement period of 3 days (Report No: F2-220713-T5595900-086B)*

Component	Unit	Design Value
CxHy[10]	ppmv wet	0.11
HCl	ppmv wet	0.44
CO	ppmv wet	7.83
SO_2	ppmv wet	1.00
NO_x	ppmv wet	51.59
NH_3	ppmv wet	2.26
N_2O	ppmv wet	2.16
Ne	ppmv wet	14.38
He	ppmv wet	4.15
Kr	ppmv wet	0.80
Xe	ppmv wet	0.64
HF	ppmv wet	1.04E-02
Sb	ppmv wet	1.93E-04
As	ppmv wet	3.36E-05
Cr	ppmv wet	8.50E-04
Co	ppmv wet	0.00
Cu	ppmv wet	6.34E-04
Pb	ppmv wet	3.10E-04
Mn	ppmv wet	1.83E-04
Ni	ppmv wet	1.41E-04
V	ppmv wet	8.13E-05
Cd	ppmv wet	2.46E-05
Tl	ppmv wet	1.47E-05
Hg	ppmv wet	2.00E-05
Zn	ppmv wet	7.78E-03

To avoid poisoning of the amine solvent and to guarantee CO_2 product quality specifications (mainly based on dioxins, PFAS, mercury and other SVHC)) certain KPI's for the flue gas feed shall be met:

- Quality based on online monitoring of contaminants in the FG
- Process like operating envelope (e.g., not during incinerator unit start-up and shut down), minimum boiler temperature, minimum steam production, others.

The flue gas specification listed above is an average flue gas specification (measured over a 5- year period). It is possible that the actual flue gas composition varies during operation; also considering the cleaning schedules of the AEC and HRC boilers. The flue gas quality can get significantly impacted during this cleaning procedure of the HRC/AEC boilers. This

[10] Represented as CH4

should be taken into account by the Contractor during the design phase. Independent shut-off dampers shall be used to admit or close flue gas flow from the 6 lines to the FG trunk line. AEB's objective is to avoid PCC bypass operation during these boiler cleaning operations to minimize shut-off damper movements thus minimizing damper fatigue and maintenance. Contractor is to advise on the potential impact of the temporary upset of flue gas ash loads on amine degradation & entrainment and on all possible trace components that could cause amine degradation or excessive amine losses.

3.1.3 Flue Gas Stack Tie-in Design Requirements

- The PCC plant shall be designed to operate on full load (100% load) or reduced load[11] if only three (3) or lower number of FG lines are operational to supply FG to the FG trunk line.
- There will be a balanced suction from all operating flue gas lines, i,e., an equal amount of flue gas is extracted from the flue gas lines both in base case operation of the PCC plant and other additional operating cases (see below) without compromising the guaranteed performance values.
- The main FG lines to the main AEC and HRC stacks shall be always open, and no restriction/control device shall be placed in the main FG line to the central stacks.
- A minimum FG flow of about 10% of the average FG flow (at full load) should be maintained in the FG stack at all times to keep maintain the stack temperature. This is to make sure that in case of sudden process changes/trip of the PCC plant, natural draft in the stack is ensured.
- The total (100%) combined flue gas flow from all six (6) lines (HRC & AEC) will pass through the measurement section before being routed to either the main stack (HRC or AEC) and/or PCC plant. Specification & requirements for the flue gas measurement section can be found in Appendix B.
- Base operating case (See section 4) for the PCC plant is considered when flue gas from all six (6) FG lines (four (4x) from AEC and two (2x) from HRC) is available to be routed to the PCC plant (via the FG trunk line) coinciding with 38% (mass basis) of the combined flue gas flows. During operation, some of the FG lines will be out of operation for a temporary period throughout the year either according to scheduled maintenance, planned shutdown or unplanned shutdowns. This is expected to result in the following additional operating cases[12]:
  - 5 lines in operation (1x AEC line down)
  - 5 lines in operation (1x HRC line down)
  - 4 lines in operation (2x AEC lines down)
  - 4 lines in operation (2x HRC lines down)
  - 4 lines in operation (1x AEC line and 1x HRC line down)
  - 3 lines in operation (2x AEC lines down, 1x HRC line down)
  - 3 lines in operation (2x HRC lines down, 1x AEC line down)
  - 3 lines in operation (3x AEC lines down)
  - 2 lines in operation (4x AEC lines down)
  - 2 lines in operation (3x AEC line and 1x HRC line down)

[11] Reduced load of the PCC plant might be required to ensure there is sufficient FG flow to the central stacks and to prevent back flow when only three (3) or lower number of FG lines are in operation.
[12] The frequency of these additional operating cases to confirmed in FEED phase.

  - 2 lines in operation (2x AEC line and 2x HRC line down)
  - 1 line in operation (1x AEC line or 1x HRC line is in operation)
  - Insufficient/Poor combustion in boiler(s) upstream one or more FG lines (poor quality FG)
- Design Margins for the Flue gas flow rate (t/h) and CO_2 concentration (%vol) in the feed FG are listed in the table below:

Item	Design Margin (applied over nominal value)	Description/Remarks
CO_2 concentration in FG feed (Maximum, %vol)	+20.0%	Based on 2023 annual measurement data considering 5% - 95% percentile. To be confirmed in FEED phase.
CO_2 concentration in FG feed (Minimum, %vol)	-15.0%	Based on 2023 annual measurement data considering 5% - 95% percentile. To be confirmed in FEED phase.
Flue Gas Maximum Flow Rate (t/h)	+20%	Availability of excess flue gas (upto 20% over nominal capacity) is possible. In the base case, about 40% (mass basis) of the total flue gas flow per FG line is sent to the PCC plant); optimal capture efficiency and possible variation in CO_2 concentration in FG to be considered.
Flue Gas Minimum Flow Rate (t/h)	Up to 30% minimum turndown	To be confirmed in FEED phase. Optimal capture efficiency and possible variation in CO_2 concentration in FG to be considered.

3.2 CO_2 Product

The main product from the PCC plant is clean, pure, compressed CO_2 gas which will be fed to the pipeline (OCAP infrastructure), then to the backbone (PORTHOS) and eventually for permanent storage (via Aramis) or for potential use in greenhouses. Another option is to send the gaseous CO_2 product to the CO_2 liquefaction plant to liquefy the CO_2 for further truck transport to off takers/greenhouses.

3.2.1 Product CO_2 Specification

Parameter	Unit	Value
Fluid Condition	-	Gaseous CO_2
Mass flow	kg/h	60,000
Pressure	barg	21
Temperature	°C	<40

3.2.2 Product CO_2 Quality[13]

Product CO_2 specifications are based on potential use in greenhouses. In addition to the product CO_2 specifications listed below, additional attention is required to ensure that there are no SVHCs in the CO_2 product to secure food security (in greenhouses). Furthermore, special focus is to be assigned to PFAS, PCDD/F, Hg and other heavy metals. It is the responsibility of the technology provider to make sure that levels of PFAS, PCDD/F, Hg and other heavy metals in the final product CO_2 is as low as possible. Detailed description and requirements for these special focus items shall be provided as required at a later/design stage.

Class	Composition	Constraint	Unit	Value
-	CO_2	larger than	mol%	95
-	H_2O	less than	ppmmol	40[14]
Inerts	N_2	less than	mol%	2.4
	O2	less than	ppmmol	40
	H_2	less than	ppmmol	7500
	Argon	less than	mol%	0.4
	CH_4	less than	mol%	1
	CO	less than	ppmmol	750
	$O_2+N_2+H_2+Ar+CH_4+CO$	sum less than	ppmmol	40000
-	NO_x	sum less than	ppmmol	2.5
Sulphur	SO_x	sum less than	ppmmol	-
	H_2S	less than	ppmmol	5
	COS (Carbolnyl Sulphide)	less than	ppmmol	0.1
	DMS (Dimethyl Sulphide)	less than	ppmmol	1.1
	H_2S + COS + SO_x + DMS	sum less than	ppmmol	20
VOC	Amine	less than	ppmmol	1

[13] Based on Aramis CO_2 specification for OCAP infrastructure
[14] Emitters connected via OCAP infrastructure will comply with water content of 40 ppmmol instead of 70 ppmmol

Class	Composition	Constraint	Unit	Value
	Formaldehyde	less than	ppmmol	-
	Acetaldehyde	less than	ppmmol	0.2
	Aldehydes	sum less than	ppmmol	10
	Carbolylic acids & amides	sum less than	ppmmol	1
	Phosphorus-containing compounds	sum less than	ppmmol	1
	NH_3	less than	ppmmol	3
	Ethylene (C_2H_4)	sum less than	ppmmol	1
	H-Cyanide (HCN)	less than	ppmmol	2
	Total volatile organic compounds (excl. MeOH, EtOH, aldehydes)	sum less than	ppmmol	10
	Methanol	less than	ppmmol	620
	Ethanol	less than	ppmmol	20
Heavies	Glycols (TEG)	sum less than	ppmmol	Follow dewpoint specification below
	C2+ (aliphatic hydrocarbons)	sum less than	ppmmol	1200
	Aromatic Hydrocarbons	sum less than	ppmmol	0.1
Metals	Hg	less than	ppbmol	-
	Cadmium + Thallium	sum less than	ppbmol	-
Dew Point	Dew point (any liquid phase)	sum less than	ºC (@20 bar)	-10
Solids	Full removal cut-off diameter	less than	micron	1[15]

[15] This is the entry solids / dust specification for the Aramis stores.

4 Operating Envelope

The PCC plant shall in principle operate in two modes: Abated mode or Unabated mode. Abated mode means when the PCC plant is operational while Unabated mode means when the PCC plant is non-operational (or in stand-by). The operating envelop for the PCC plant has been shown in the table below:

Case	Operating Mode	Design Case	Description/Remarks	CO_2 production (t/h)	Expected Frequency
A	**Abated**	Base	All 6 FG lines (AEC, HRC) available; possible variation in CO_2 concentration in FG to be considered	60 (Nominal)	345 days/ year; 20[16] days downtime anticipated (to be further confirmed in FEED phase)
B	**Abated**	Reduced FG lines	4 or 5 FG lines (AEC, HRC) available; possible variation in CO_2 concentration in FG to be considered	60 (Nominal)	
C	**Abated**	Turndown	Reduced load operation, reasons can be: 1. 3 or lower number of FG lines are available 2. High energy prices (Electricity sales is higher priority) 3. CO_2 compressor is out of operation (depending on configuration/RAM study; for eg; 3x50%, turndown may be required) 4. Reduced LP steam availability for PCC plant Possible variation in CO_2 concentration in FG to be considered	CO_2 production to be maximized (Minimum Turndown 30%	
D	**Unabated**	Maximum contaminant/ Poor Flue gas Quality	Due to upstream process conditions & poor FG quality (Poor combustion in boiler(s)/boiler (s) cleaning/high dust content in FG etc.) PCC plant to be shutdown	0	15 days/ year
E	**Unabated**	Steam/Utility Unavailable	Due to high heat demand by the district heating system (Heat sales is higher priority), PCC plant to be shutdown	0	4-5 days/ year
F	**Unabated**	Poor product CO_2 quality	Product CO_2 quality does not comply with CO_2 specification	0	To be confirmed in FEED
G	**Unabated**	OCAP backbone unavailable	In case OCAP backbone is down, PCC plant to be shutdown.	0[17]	To be confirmed in FEED

4.1.1 Availability, Flexibility & Turndown

Refer to O&M Strategy, doc. no. 416041-47990/G.06/004 & Section above.

[16] 10 days planned downtime and 10 days unplanned downtime

[17] OCAP backbone has some buffer CO_2 capacity. It is expected that AEB (PCC plant operator) will receive a signal from OCAP to shut down the PCC plant in case of OCAP downtime. Operating Philosophy of the PCC plant in case the OCAP backbone is unavailable to be further developed during FEED phase.

5 Effluent & Emission Specifications

5.1 Depleted Flue Gas Quality

For the design operating case, AEB has estimated the treated/depleted flue gas flow from top of the absorber column to be 377,000 Nm^3/h (standard 11% O_2), which corresponds to an actual flow of 435,000 m^3/h.

Amine losses through the depleted flue gas should be kept as low as possible (ALARP).

The maximum ammonia (NH_3) concentration in this stream is set to be 2.6[18] mg/ Nm^3 (dry) (or 5 mg/Nm^3: dry FG, 11% O_2), corresponding to 0.97 kg/h.

For emissions, Substances of Very High Concern (SVHC, also referred as ZZS[19]) to public health were also investigated due to regulatory requirement. The permissible concentrations for some of the main SVHC components are listed below. Please refer to the full list of regulatory requirements on the RIVM[20] website.

Component	Concentration (mg/Nm^3, 11% O_2)	Component Description
Acetaldehyde	< 0.30	Acetaldehyde (ZZS)
Formaldehyde	< 0.40	Formaldehyde (ZZS)
Benzaldehyde	< 0.02	Benzaldehyde (Potential ZZS)
NDMA	< 1.00E-05	N-nitrosodimethylamine (NDMA) (ZZS)
NMOR	< 1.00E-05	N-nitrosomorpholine (NMOR) (Potential ZZS)
NDIPA	< 1.00E-05	N-nitrosodiisopropylamine (NDIPA) (ZZS)
NPYR	< 1.00E-05	N-nitrosopyrrolidine (NPYR) (ZZS)
NPIP	< 1.00E-05	N-nitrosopiperidine (NPIP) (ZZS)
NDPA	< 1.00E-05	N-Nitrosodipropylamine (NDPA) (ZZS)

Other SVHC's might be present depending on the chosen technology/solvent, it is the responsibility for the technology provider to make sure that no other SVHC components will be emitted.

The depleted flue gas shall be metered periodically.

5.2 Effluents & Wastewater

This section lists requirements/specifications for key effluent, and other waste & return streams.

[18] A final check on this figure and basis is still pending
[19] Zeer Zorgwekkende Stoffen
[20] https://rvszoeksysteem.rivm.nl/ZZSlijst/TotaleLijst

5.2.1 Flue Gas Condensate

FG condensate collected from the FG trunk line and the DCC column shall be routed to the new FG condensate treatment plant (FGCTP) to remove potential contaminants & pollutants (like mercury, ammonium (NH_4+) etc.). Treated water from the FGCTP shall be routed to the harbor through the existing AEC/HRC primary cooling water return line. Brine (effluent stream) from the FGCTP shall be routed to the existing AEC plant (ARA 10/20).

5.2.1.1 FG Condensate Specifications

Parameter	Unit	Value		
		Minimum	Average	Maximum
pH	-	3.6	4.9	6.7
Suspended solids	mg/l	-	-	<1.0
Hg	µg/L	-	0.17	3.10
As	µg/L	-	-	<50
Cd	µg/L	-	-	<5
Co	µg/L	-	-	<5
Cr	µg/L	-	-	<5
Cu	µg/L	-	-	<50
Fe	µg/L	-	14.3	540
Mn	µg/L	-	1.2	20
Mo	µg/L	-	-	<5
Ni	µg/L	-	-	<50
Pb	µg/L	-	-	<50
Sb	µg/L	-	-	<50
Sn	µg/L	-	-	<50
Ti	µg/L	-	-	<5
V	µg/L	-	1.0	5.8
Zn	µg/L	-	3.9	84
Mg	µg/L	-	-	<5
NH_4	mg/l	-	5	19
Na	mg/l	-	0.77	6.5
Ca	mg/l	-	0.47	8.8
Cl	mg/l	-	2.5	67
SO_4	mg/l	-	5.3	21
TOC	mg C/l	-	0.63	8.6
N-NO_3	mg N/l	-	0.21	0.6
N-NO_2	mg N/l	-	0.15	0.6

5.2.1.2 Discharge Emission Limits for Treated FG Condensate[21]

Parameter	Unit	Value		
		Minimum	Yearly Average	Maximum
pH	-	6.0	-	9.0
Hg	µg/L	-	-	2.0
NH3	mg/l	-	3.0	5.60
N-Total	mg/l	-	-	10

5.2.2 Wastewater from Process

Contaminated wastewater from the CO_2 capture and CO_2 conditioning unit shall be routed to dedicated retention tank(s) for collection (together with domestic wastewater) and appropriately discharged to the nearby Municipal Wastewater Treatment (MWWT) Plant.

5.2.3 Brine from Demineralized Water Unit (DWU)

Brine (effluent stream) from the DWU shall be routed to the existing AEC/HRC primary cooling water return line or to the primary cooling water line of the PCC plant.

5.2.4 Rainwater, Firewater & Spills

- **Contaminated surface water:** Potentially contaminated surface water shall be routed (together with process condensate) to the MWWT plant. Retention tank(s) to avoid peak discharge (for instance after heavy rainfall) and/or undesired disposal of contaminated surface water is required within the PCC plant.
- **Non-contaminated surface water:** Rainwater shall be collected and routed to the harbor (Aziëhaven) after passing through oil separator. Harbor water specifications are described in section 6.1.1. Re-use of uncontaminated rainwater shall be investigated in next project phase.
- **Spills, fire water retention and terrain water retention (only potentially contaminated water):** Retention tank(s) shall be used for collection and controlled discharge of potentially contaminated water, used firewater and any other spills. Retention tanks(s) to contain major onsite and avoid discharge of chemical/material spills to the sewer system is required within the PCC plant.

[21] Considerations for other substances might be required. To be further evaluated during FEED phase.

6 Utility Specifications

6.1 Primary Cooling Water Intake, Supply and Return

The maximum amount of primary cooling water (PCW) for the PCC plant (excluding the CO_2 liquefaction plant) is anticipated at 8,391 m^3/h (~8,391 t/h) continuously. The maximum amount of primary cooling water for the PCC plant (including the CO_2 liquefaction plant) is anticipated at 9191 m^3/h. This is for cooling the PCC plant based on a once-through cooling water system principle i.e., without considering alternatives like air cooling or cooling tower systems. In order to accomplish such, the present once-through based PCW system is to be expanded. A conceptual design study has been performed to expand the present PCW intake thus catering for the additional PCW demand by the PCC plant (refer to Attachment 3 in Appendix A).

In the next project phase, the PCC Plant's cooling demand and system expansion design (civil & process) of the existing PCW intake shall be confirmed to meet the same.

The primary cooling water intake flux (intake velocity at any point of the intake plane) at the harbor shall not exceed 0.3 m/s (regulatory requirement).

Description	Flow (max) kg/h	Operating Pressure[22] (barg)	Temperature (operating) (°C)	Temperature (maximum) (°C)
PCW intake (without CO_2 liquefaction)	8,391,000	4.0	23.5	25
PCW intake (with CO_2 liquefaction)	9,191,000	4.0	23.5	25
PCW return (without CO_2 liquefaction plant)	8,391,000	3.3 / 3.0 (min)	33.2	35
PCW return (with CO_2 liquefaction plant)	9,191,000	3.3 / 3.0 (min)	33.2	35

An internal cooling water (ICW) system shall be used to supply CW to (most of the) consumers in the CO_2 capture plant. The process waste heat will be rejected from the ICW to the PCW through a dedicated interchanger(s). The ICW system shall be integrated in the design of the CO_2 capture and CO_2 conditioning unit.

6.1.1 Primary Cooling Water (or Harbor Water) specifications

Key primary cooling water specifications are listed below:

[22] Vendor to advise on design values for pressure drop.

Property	Units	Value
Ca	mg/l	160
Mg	mg/l	280
Total hardness	meq/l	31
Total dissolved solids (TDS)	mg/l	8192.66
Total Organic Carbon (TOC)	mg C/l	10
Total Alkalinity	mmol/l	3.5
Salinity	mg Cl/l	2500-6500 3500 (average)

6.1.2 Other Requirements

- Emission limit value (ELV) for cooling water return: active chloride content lower than 0.5 mg/l (independent of the discharge point).
- Discharge point for cooling water return from PCC towards the harbor should be designed to avoid turbulence in harbor water and stirring[23] up of sludge deposits on the bottom of the harbor.

6.2 Steam Supply and Condensate Return

Steam required for the PCC plant will be extracted from an existing steam turbine generator (STG) of the AEC unit and fed into a new LP steam header at the AEC unit. LP steam shall be provided to the PCC plant primarily from the new LP steam header. A back-up option is to provide LP steam to the PCC plant from the HRC LP steam header. An alternative/back-up option currently also under consideration is to utilize a new back-pressure STG when there is no steam availability from the AEC STG. The LP condensate from the PCC plant shall be routed to the existing deaerator(s) at the AEC unit.

Description	Flow (max) kg/h	Operating Pressure[24] (barg)	Operating Temperature (°C)
LP steam intake	72,000	3.00	160-170
LP condensate return	72,000	3.00	140

It is important to note that steam supply will be shut off at alarm level AL3, and this will be considered a responsibility for the contractor. Other steam requirements (if any) to be investigated in the next project phase.

[23] Turbulence can induce stirring up such that sludge deposits on the bottom of the harbor can increase suspended solid content (>100 mg/l) in the water at the harbor (Aziëhaven).
[24] Lowest operating point: 2.2 barg, 136°C (saturated). Normal operating point: 3.0 barg, 164°C (20K above saturation); Highest operating point: 6.0 barg, 185°C (20K above saturation).

6.2.1 Steam & Steam Condensate Quality

The quality of the supplied steam and return condensate shall comply with quality requirements[25] as shown in the table below.

Parameter	Unit	Steam Quality		Condensate Quality	
		Minimum	Maximum	Minimum	Maximum
Conductivity	µS/cm	4.3	-	4.3	-
Acid conductivity	µS/cm	-	0.2	-	0.2
Silica (SiO_2)	µg/l	-	20	-	20
pH	-	9.2	-	9.2	-
Ammonium (NH_4+)	µg/l	500	2000	-	-
Oxygen (O_2)	µg/l	-	50	-	100
Suspended solids	µg/l	-	10	-	100
Total organic Carbon (TOC)	µg/l	-	10	-	100
Sodium (Na)	µg/l	-	5	-	5
Potassium (K)	µg/l	-	5	-	5
Sulfate (SO_4)	µg/l	-	10	-	20
Total hardness (Mg + Ca)	µmol/l	-	5	-	5
Iron (Fe total)	µg/l	-	10	-	20
Copper (Cu)	µg/l	-	3	-	3
Other heavy metals	µg/l	-	5	-	5

6.3 Industry Water and Potable Water Supply

Industry water from Basin 5 (existing tank) shall be used as feed (default option) to the new demineralized water unit. As a back-up option, potable water shall be used to feed Basin 5. An alternative is to use flue gas 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 project phase. Potable water shall also be supplied for safety showers, eyewash, & sanitary use.

Maximum design flow for industry water supply and potable water supply is 15 m^3/hr.

[25] For more details and escalation levels refer to Stoom- en condensaatkwaliteit, Stoomnet, Afval Energie Bedrijf (Doc no. 08.Q600.i.22361)

6.3.1 Industry Water Specification

Component	Unit	Values (Measured)		
		Minimum	Average	Maximum
Electrical conductivity (at 20 ºC)	mS/m	42.1	56.3	62.9
Temperature	ºC	6	13.4	23.5
Oxygen, lab measurement	mg/l	5.9	8.9	11.1
Turbidity level	FTE	<0.03	0.08	0.45
Saturation index	pH	0.01	0.08	0.36
Saturation index (actual temperature)	pH	0.01	0.02	0.32
Acidity	pH	7.49	7.73	7.94
Acidity (actual temperature)	pH	7.34	7.68	7.96
Suspended substances	mg/l	<0.2	<0.2	<0.2
Inorganic Macro Components				
Hydrogen carbonate	mg/l	134	159	184
Carbonate	mg/l	<5	<5	<5
Chloride	mg/l	57	81	92
Sulfate	mg/l	43	56	68
Potassium	mg/l	3.27	4.31	5.02
Sodium	mg/l	29.4	41.4	50.0
Calcium	mg/l	53.2	62.4	70.1
Magnesium	mg/l	8.2	10.6	12.8
Total hardness	mmol/l	1.67	2.00	2.25
Total hardness in ºD	ºD	9.3	11.2	12.6
Ammonium	mg/l NH_4	<0.02	<0.02	<0.02
Ammonium	mg/l N	<0.02	<0.02	<0.02
Total Kjeldahl nitrogen as N	mg/l N	<1.0	<1.0	1.3
Total Nitrogen, calculated as N	mg/l N	0.8	2.2	4.7
Nitrite	mg/l N	<0.002	<0.002	<0.002
Nitrite	mg/l NO_2	<0.007	<0.007	<0.007
Nitrate	mg/l N	0.82	2.01	3.42
Nitrate	mg/l NO_3	3.62	8.89	15.12
Orthophosphate	mg/l P	<0.02	<0.02	<0.02
Orthophosphate	mg/l PO_4	<0.06	<0.06	<0.06
Total Phosphate	mg/l P	<0.02	<0.02	<0.02
Total Phosphate	mg/l PO_4	<0.06	<0.06	<0.06
Silicate	mg/l Si	0.5	1.8	3.3
Silicate	mg/l SiO_2	1.1	3.8	7.0
CO_2 calculated	mg/l	3.8	5.3	7.2
Corrosion-index		0.93	1.27	1.46
Total Alkalinity Content (TAC)	mmol/l	2.5	2.7	3.0

More detailed specifications for other inorganic and organic micro/biological components are available (if necessary).

6.3.2 Potable Water Specification

Component	Unit	Values (Measured)		
		Minimum	Average	Maximum
Electrical conductivity at 20 ºC	mS/m	51.8	54.1	56.8
Temperature	ºC	8.3	13.6	20.6
Oxygen, lab measurement	mg/l	5.4	8.3	10.9
Turbidity level	FTE	<0.03	<0.03	0.195
Total Alpha-Radioactivity	Bq/l	<0.05	<0.05	<0.05
Rest Beta-Radioactivity	Bq/l	<0.2	<0.2	<0.2
Total Beta-Radioactivity	Bq/l	<0.2	<0.2	<0.2
Tritium	Bq/l	<5.0	<5.0	<5.0
Saturation index	pH	0.18	0.36	0.51
Saturation index (actual temperature)	pH	0.20	0.32	0.42
Acidity	pH	8.07	8.16	8.25
Acidity (actual temperature)	pH	8.00	8.12	8.20
Inorganic Macro Components				
Ion balance	%	0.8	3.1	5.4
Ion balance anions	meq/l	5.81	5.94	6.14
Ion balance cations	meq/l	5.57	5.75	5.96
Hydrogen carbonate	mg/l	169	177	199
Carbonate	mg/l	<5	<5	<5
Chloride	mg/l	69	73	78
Sulfate	mg/l	42	45	48
Potassium	mg/l	3.42	3.80	4.17
Sodium	mg/l	59.1	66.4	73.5
Calcium	mg/l	37.2	40.1	44.2
Magnesium	mg/l	8.36	9.25	10.56
Total hardness	mmol/l	1.29	1.38	1.51
Total hardness in ºD	ºD	7.23	7.72	8.43
Ammonium	mg/l NH_4	<0.02	<0.02	<0.02
Ammonium	mg/l N	<0.02	<0.02	<0.02
Nitrite	mg/l N	<0.002	<0.002	<0.002
Nitrite	mg/l NO_2	<0.007	<0.007	0.007
Nitrate	mg/l N	0.41	0.81	1.29
Nitrate	mg/l NO_3	1.82	3.61	5.71
Orthophosphate	mg/l P	<0.02	<0.02	0.0207
Orthophosphate	mg/l PO_4	<0.06	<0.06	0.0635

Component	Unit	Values (Measured)		
		Minimum	Average	Maximum
Total Phosphate	mg/l P	<0.02	<0.02	<0.02
Total Phosphate	mg/l PO_4	<0.06	<0.06	<0.06
Silicate	mg/l Si	2.06	3.08	4.07
Silicate	mg/l SiO_2	4.4	6.6	8.7
CO_2 calculated	mg/l	1.75	2.34	2.97
Corrosion-index		0.95	1.02	1.08
Total Alkalinity Content (TAC)	mmol/l	2.8	2.9	3.1

6.4 Demineralized Water

The dedicated demineralized water unit for the PCC plant shall be designed for a nominal capacity of 12 m^3/h.

6.4.1 Demineralized Water Specification

The main specifications for demineralized water are listed below:

Parameter	Unit	Value
Conductivity @ 25 °C	µS/cm	< 0.1
pH	-	8.4 – 9.5
Oxygen	µg/L	< 10
Silica (SiO_2)	µg/L	< 5
Iron (Fe), Total	µg/L	< 5
Copper (Cu)	µg/L	< 1
Sodium (Na)	µg/L	< 2
TOC	ppb	<10

6.5 Fire Water Supply

There is an extensive firewater distribution network around the existing installation at the AEB site. It is envisaged that the PCC plant will be connected to the existing firewater network. Potable water is used as firewater and suitable modifications shall be made in the existing firewater network to ensure adequate capacity and smooth plant operation for the PCC plant. A maximum firewater capacity of about 480 m^3 is envisaged for the PCC plant.

6.6 Instrument Air Supply

A dedicated instrument air package for the PCC plant (incl. CO_2 liquefaction plant) shall be part of the design. Key specifications for the instrument air package are listed below:

Parameter	Unit	Value		
		Minimum	Average	Maximum
Airflow	m^3/h	1020	1190	1360
Air pressure	barg	6	7	8
Air Temperature	ºC	20	22	25
Relative Humidity	%	50	55	60

6.7 Electrical Power Supply

Power Supply shall be available at the battery limit through two redundant 10 kV power feeders (Outside Battery Limits) directly from the public grid or AEB's potential new 50/10 kV station.

Parameter	Unit	Value	Remark
Supply Voltage	kV	10	3-phases
Supply frequency	Hz	50	
Power Feed Line		2×100%	2 redundant incoming feeders at 10 kV
Distribution Voltage	kV	0.69	For motors ranging from 200 to 450 kW
Distribution Voltage	kV	0.4	For motors below 200 kW
General loads and lighting	V	230	1-phase
DC supply	VDC	110	

Efficient electrical motors (minimum IC-4) shall be appliable in the design.

Other electrical requirements are included in the Electrical Philosophy, doc. no. 416041-47990/E.06/002.

6.8 Chemicals & Other Consumables

The following chemicals/consumables are anticipated to be utilized in the PCC plant:

- Amine/Chemical solvent – to be utilized in the CO_2 capture plant. Supplied through trucks and loaded into dedicated solvent storage tank(s) on PCC plant site.

- Caustic/NaOH – to be utilized for dosing in the CO_2 capture plant, DWU and FGCTP. Supplied from existing caustic tanks in HRC/AEC units
- Anti-foaming agent – to be utilized in the CO_2 capture plant.
- Hydrochloric Acid (HCl) – to be used in the DWU, supplied from existing tanks in HRC/AEC units.
- Sulphuric Acid (H_2SO_4) – expected to be used to acidify quench water in the acid wash section on top of the absorber column in the CO_2 capture plant, this will be supplied though trucks and loaded into dedicated storage tank(s) on the PCC plant site.
- Anti-scalant – to be used in the FGCTP.
- Lube and hydraulic oil – for mechanical equipment like the CO_2 Compressor
- Hypochlorite (biocide) – to be used as oxidizing biocide to treat primary cooling water before supplying to the PCC plant

Appropriate storage options/tank(s) and access are to be provided for all above listed chemicals/consumables required for smooth operation of the PCC plant.

Chemical/Consumable	Expected Consumption
Amine solvent (CO_2 capture plant)	150 t/yr (normal 200 t/yr (max)
Caustic (NaOH)	18-20 t/yr
Hydrochloric acid (HCl)	25.5 t/yr
Sulphuric acid (H_2SO_4) supply	169 t/yr
Anti-foaming agent (CO_2 capture plant)	150 kg/yr
Anti-scalant (FGCTP)	2.4 t/yr
Lube oil (Mechanical equipment)	To be determined
N_2 (DWU)	80.1 t/yr
Hypochlorite (Biocide)	225 t/yr

7 Process & Emission Limits

The complete PCC plant shall be designed to comply with all process and emission limits as summarized in the table below:

Item	Units	Value	Remarks
LP steam Consumption	t/h	72	Maximum Consumption
Electricity Consumption (Total)	MW_e	8.9	Maximum Consumption
Cooling Water Intake & Return	See Section 6.1. Cooling based on cooling water. No air cooling or cooling tower.		
Absorber Stack Height	m	102	Maximum
Amine Solvent Consumption	t/yr	195	Maximum
PCC Plot Area	m^2	5500	Maximum
Surface Area - Non-contaminated surface water	m^2	3300	Minimum
Surface Area - Contaminated rainwater	m^2	2200	Maximum
Wastewater Discharge from Process to MWWT Plant[26]			
Flow	m^3/h	10	Maximum Discharge to MWWT plant
Temperature	°C	30	Maximum
Sulphate	mg/l	300	Maximum
Suspended solids	mg/l	300	Maximum
Mineral oil	mg/l	200	Maximum
pH	-	8.5	Maximum
ammonia	mg/l	61	Maximum
Acetaldehyde	mg/l	12	Maximum
Amine	mg/l	174	Maximum
Discharge Emission Limits for Treated Flue Gas Condensate	See Section 5.2.1.2		

[26] Further considerations & requirements for wastewater discharge to be confirmed in FEED phase.

8 Health, Safety & Environmental (HSE) Standards

HSE standards and minimum requirements for the AURORA project can be found in the Project Safety Strategy (doc. no. 416041-47990/G.06/004) and DHSE Plan & File (doc. no. 416041-47990/G.06/004).

9 Plant Control & Safeguarding

With respect to the control, operation, automation, and safeguarding, the PCC plant and supporting utilities shall be considered as one installation. The control, operation, automation, and safeguarding shall be through a new ABB 800xA system (system which can communicate and has the same look/feel as the existing ABB 800xA system) from the existing Central Control Room. The new system must be able to communicate with ABB 800xA HMI within normal speed boundaries and this communication must be proven in use in other similar facilities.

However, the existing AEC/HRC unit monitoring, and control will remain independent from the PCC plant through the existing ABB Procontrol P14 system for the waste incinerator plant(s). Potentially, the latter may be replaced by an ABB 800xA DCS system as well (out of PCC scope).

The PCC plant's proposed DCS control visualization shall be in accordance with existing AEC/HRC plant philosophy and shall be interfaced with the existing or new ABB control system of the waste incineration plant(s). Process alarms shall be always clearly observable for responsible personnel.

Key Instrumentation & Control requirements for the project can be found in the I&C Philosophy, doc. no. 416041-47990/J.06/002.

10 Construction Aspects

- The PCC plant in principle will be an outdoor installation. Some equipment (e.g. CO_2 compressor) might require acoustical enclosures considering noise/other requirements
- Construction of the PCC plant will occur during normal plant operations in AEB. Construction methodology shall reduce the impact on current operations to a minimum and shall be coordinated with AEB Operations.
- Construction traffic to/from the construction site shall not interfere with the current traffic (high volume of waste/dump trucks and train offloading) close to the site.
- Crane / heavy lift operations shall be safe for surrounding facilities.
- Other requirements can be found in the Constructability Review report, doc. no. 416041-47990/K.06/001.

11 Code and Standards

Industry standards shall be applied as default. Specific AEB standards are applied only if necessary (with prior approval from AEB).

Appendix A
List of Attachments

No.	Document Number	Document Title
1	UN2-181106-T5595900-130B (IUTA)	Measurement of ultrafine and fine particles in flue gas of two waste incinerator lines after passing the full flue gas treatment system and after blower just before the flue gases enter the stack during a measurement period of 3 days
2	F2-220713-T5595900-086B (IUTA)	Measurement of ultrafine and fine particles in flue gas of four waste incinerator lines during a measurement period of 3 days
3	210112-16001-0 (Iv-Water) WAPA210112-16001-01 (AEB)	Post Combustion Capture Plant - Cooling Water (OSBL)

Appendix B
Design Requirements (TAUW) – Flue Gas Measurements

This section is a description from TAUW of what a flue gas measuring surface must meet in order to be able to carry out the measurements safely and according to the standard. For this purpose, requirements are included in the NEN-EN 15259: 2017. This standard contains recommendations and requirements regarding:
- Positioning of the measuring surface
- Number and positioning of the measuring openings in the measuring surface
- Space around the measuring surface

B.1 Principles

- The new measuring surfaces for L11, L12, L23 and L24 will be installed in new horizontal pipes to be realised
- The flue gas duct is round
- The diameter of the new flue gas channels of L11, L12, L23 and L24 are(probably) 2.6 m.
- There will be tie-ins on the flue gas ducts of L35 and L36.
- The flue gas ducts for the tie-ins will not be adjusted. The new tie-ins can affect the existing
- measuring surface of the AMS measurements
- The diameter of the existing channels remains 2.8 m

B.2 Recommendations

With regard to the distances of the measuring surface in relation to disturbances, recommendations are included in the standard (section 6.2.1).
- The distance between a disturbance and the measuring surface is at least 5 x hydraulic diameter
- The distance between the measuring surface and a disturbance is at least 2 x hydraulic diameter

The hydraulic diameter is equal to the diameter for a round flue gas duct.

A disruption may include:
- Bend
- Inflow of an additional waste gas flow
- Outflow or drain point of a (partial) current
- Valves, changes in diameter or shape
- Outlet

These are recommendations. If this is not met, this does not necessarily mean that the measuring surface does not comply with the standard. This is determined by means of control measurements. These control measurements shall test whether the measuring surface meets the criteria mentioned in section B.4.

B.3 Requirements for the number and positioning of the measuring openings

Below are the requirements with regard to the number and positioning of the measuring openings.
- The measuring surface of L11, L12, L23 and L24 has a diameter of 2.60 m. At least two measuring openings must be fitted here at an angle of 90° to each other.

- The space around the measuring surface must be sufficient to safely insert the measuring lances into the flue gas duct. The measuring lances must be long enough to reach all traverse points (see Figure 11-1). Section 8.2 of the standard contains the following table:

Table 2 — Minimum number of sampling points for circular ducts

Range of sampling plane areas m^2	Range of ducts diameters m	Minimum number of sampling lines (diameters)	Minimum number of sampling points per plane
< 0,1	< 0,35	–	1 [a]
0,1 to 1,0	0,35 to 1,1	2	4
1,1 to 2,0	>1,1 to 1,6	2	8
> 2,0	> 1,6	2	at least 12 and 4 per m^2 [b]

a Using only one sampling point can give rise to errors greater than those specified in this European Standard.

b For large ducts, 20 sampling points are generally sufficient.

A channel of 2.60 m has an area of 5.31 m^2. There should be 4 traverse points per m^2. This corresponds to 10.6 traverse points. This is rounded up to an even number. In the same way, a channel with a diameter of 2.80 m can also be calculated.

- With a channel diameter of 2.60 m, the traverse points are located at the following distances from the wall:
  - 6, 17, 31, 46, 65, 92, 168, 195, 214, 229, 243 and 254 cm

- With a channel diameter of 2.80 m, the traverse points are located at the following distances from the wall:
  - 5, 15, 28, 41, 56, 75, 103, 177, 205, 224, 239, 252, 264, 275 cm

Remark

The NEN-EN 15259 states that the traverse points near the wall are at least 3% of the axis length or 5 cm (whichever is larger). In this case, the first and last traverse points would not participate during the measurements.

In the case of a measuring surface in a horizontal pipe, TAUW advises to install the measuring openings in such a way that they are placed diagonally on the flue gas duct.

Explanation of space around the measuring surface

In this case, the diameter of the flue gas duct is 2.6 m. The effective length of the lance should_then be about 2.6 m. Since there is still a piece on the back of the lance and is applied, the free_space for the measuring surface must be at least the diameter + 1.5 m. For example, diameter 2.6m + 1.5 m is 4.1 m.

From a practical point of view of the execution of official measurements by an accredited measurement institute, there are a number of practical points of attention. It is more convenient to insert the lance from top to bottom because:

- The lance cannot fall out 'spontaneously', at most can sink into the channel
- It is easier to lower a lance from above than to have to insert it upwards
- With an out-stack dust measurement, any formed droplets do not fall on the filter and thus let the filter 'close'

These points don't have to be showstoppers.

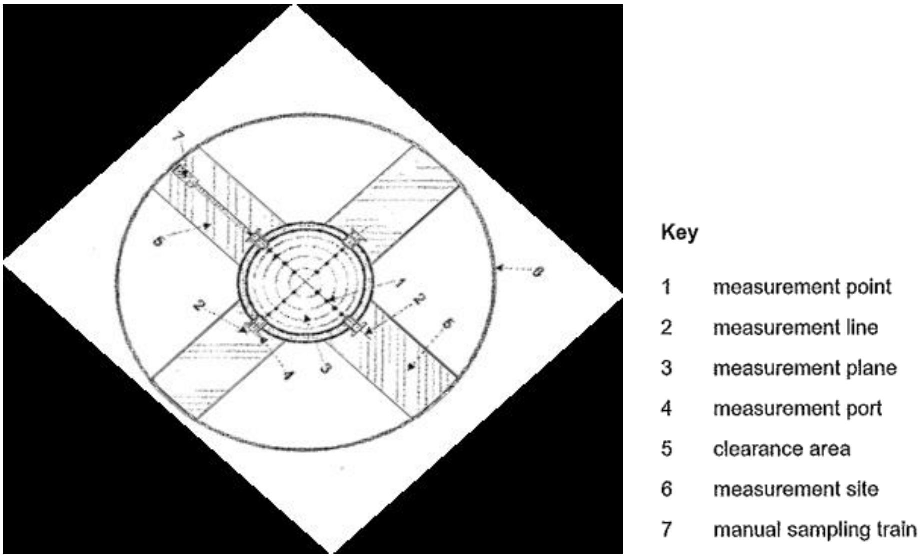


Figure 11-1 Positioning of measuring openings (axes) in the channel (source: NEN-EN 15259:2017)

The diameter of the measuring openings must be such that the measuring lances can be inserted well into the duct. In general, measuring openings with a diameter of 3" are sufficient. TAUW makes extensive use of so-called shortcuts (see Figure 11-2)

Figure 11-2 CAM lock coupling with cap

In addition to the required measuring openings, TAUW advises to install additional measuring openings (at least 2 per channel) for measuring supporting parameters such as oxygen. This measuring aperture can be placed in the same measuring surface as the required measuring apertures. Preference is given to a measuring opening with a diameter of 3", horizontal. This is a standard size that is used by many measurement institutes, including TAUW.

B.4 Test criteria measuring surface per traverse point

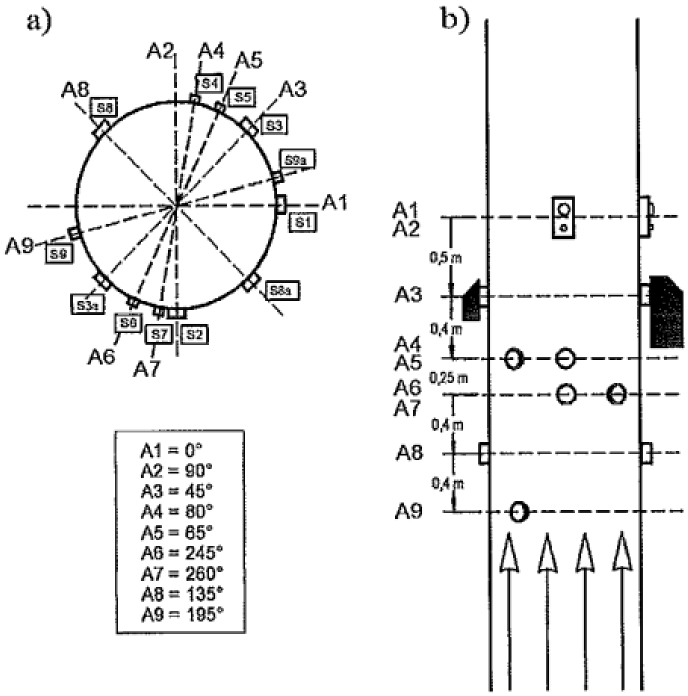
Prior to the measurements, and level measurement shall be carried out and flow and velocity shall be assessed on the basis of the following criteria (section 6.2.1(c)):

- The angle of the flow to the channel axis shall be less than 15°

- There must be no negative flow (backflow)
- The ratio between the minimum and maximum measured speed shall be less than 3:1
- The minimum speed expressed in differential pressure using a pitot shall be greater than 5 Pa

B.5 Measurement location SRM (our measuring location) in relation to the AMS

The NEN-EN 15259 contains an example of how the measuring locations can be situated in relation to each other (see Figure 11-3). The standard is based on a vertical channel.



Key

a)	top view	b)	front view
A	measurement line, measurement plane		
S	measurement port		
S1	reference method	S6	HCl, total carbon, water-vapour AMS
S2	reference method	S7	reference method
S3	dust AMS (optical head)	S8	volume flow AMS (transmitter)
S3a	dust AMS (reflector)	S8a	volume flow AMS (receiver)
S4	SO_2, NO, O_2 AMS	S9	temperature
S5	reference method	S9a	pressure

Figure 11-3 Example positions various measuring locations (source: NEN-EN 15259:2017)