B03i
Base of Design

Plant Description	**Carbon Capture Storage Plant, Sluiskil**
Linde Project No. **3710 A3T8**	Client Project No. **16471**
Linde Project Code **Sluiskil**	Client Project Code **CACTUS**
Linde Doc. No. **&AE-0000-N-SP 1001 (EN)**	Client Doc. No. **16471-Y85-00001** / Client Revision **00**

Steel Structure and Civil design basis & general description

Status	Issue	Date	Prepared	Reviewed	Approved	Remarks
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IFD	3.0	12.10.2022	5.1.2.e	5.1.2.e 5.1.2.e	5.1.2.e	
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IFD	1.0	10.09.2021	5.1.2.e	5.1.2.e 5.1.2.e	5.1.2.e	

CONTENT

1 Scope

The specification defines scope, general requirements, applicable codes, and standards that are taken as basis for the civil & steel structure design.

2 Codes & Standards

2.1 Eurocodes

The most relevant Eurocodes for this specification are listed:

EN 206	Concrete - Specification, performance, production, and conformity
EN 10080	Steel for the reinforcement of concrete - Weldable reinforcing steel - General
EN 1504-6	Grouts
EN 1090	Execution of steel structures
EN 13670	Execution of concrete structures
EN 1990	Basis of structural design
EN 1991	Eurocode 1 - Actions on structures
EN 1992	Eurocode 2 - Design of concrete structures
EN 1993	Eurocode 3 - Design of steel structures
EN 1997	Eurocode 7 - Geotechnical design
EN 1998	Eurocode 8 - Design of structures for earthquake resistance

The Euro Codes shall be supplemented by the National Annexes of the Netherland for their own areas of jurisdiction.

2.2 Client Design Specification

CSA related client specifications are listed as follows. Exceptions will be applied after having client approval.

10000-Y50-00026 Rev. 5.0	SPECIFICATION FOR CIVIL AND STRUCTURAL DESIGN
10000-Y50-00029 Rev. 7.0	Specification for deep foundations
10000-Y50-00032 Rev. 5.0	Specification for Acid Proofing
10000-Y50-00033 Rev. 4.0	SPECIFICATION for ANCHORING in Concrete
10000-Y50-00034 Rev. 11.0	Specification for Cladding
10000-Y50-00035 Rev. 9.0	Specification for Concrete Works
10000-Y50-00036 Rev. 10.0	Specification of GRP grating, ladders, and handrails
10000-Y50-00038 Rev. 6.0	SPECIFICATION for STRUCTURAL STEEL
10000-Y50-00044 Rev. 3.0	YPO Specification of Fire Proofing for steel structures and equipment skirts
16471-B45-00121 Rev. 1.0	Appendix E22 - Specific Requirements to Buildings EPC 2022
16471-B45-00122 Rev. 1.0	APPENDIX E25: GENERAL REQUIREMENTS FOR CIVIL WORKS and STRUCTURAL EPC 2022
16471-B45-00123 Rev. 1.0	GENERAL REQUIREMENTS TO CONCRETE WORKS EPC 2022
16471-B45-00113 Rev. 1.0	Appendix E14 - Heating, Ventilation and Air Conditioning Specification EPC 2022

16471-C50-00001	Site Specification
20_271-Explosie contouren	Explosion contour map provided on 12.09.2022
inm infra CCS 21-06-22	Topographical survey sewers around project area
210533	Report geotechnical soil investigation
Project 23210574	Report exploratory soil investigation for C.C.S. project
16471-Y56-00010.dwg	Known underground facilities at site area

2.3 Linde Documents

&AE 2000-TSS 2301 (EN)	Specification on corrosion protection

In case that using of GFK material for grating, railings and ladders is not possible, following Linde standards will be applied:

LS 511-02:	Railing
LS 513-02:	Ladders
LS 514-02:	Self-closing gate of platform exits at ladders
LS 515-02:	Grating
LS 516-02:	Grating step

3 Site Conditions

All related data to site conditions like location, weather conditions and soil information will be considered according to client information.

4 General deign principles

Basis for design of structures are good engineering practice and general accepted rules of technique.

All structures shall be designed with safety as the primary consideration.

All work shall be realized in accordance with all relevant and applicable project specifications, standards, and codes.

This applies also to building material, employed for these kinds of work. In connection with any materials used for civil work and buildings, requirements of the project specifications have to be fulfilled.

Types of main bearing systems of structures described in this section are preliminary.

Technical description of General Civil Works and Buildings describes the current status of preliminary planning and has to be adjusted during engineering. Construction methods shall be finally determined during Detail engineering stage in accordance with safety requirements to meet an optimum regarding construction duration, aspects of utilization and construction costs.

All Civil/Structural works within the PLANT PLOT LIMITS shall be part of civil engineering.

5 Structural Steel design principles

All safety requirements, like escape ways, door sizes, operation spaces and operation accessibility will be according to related YARA specifications. Ladder, railing, and grating are made of GRP material.

Manual driven hoists with maintenance platforms will be foreseen on cases where mobile devices are not possible.

Circular platforms on columns are not foreseen.

Checker plates will be used only in case of special requirements.

Structural steel shall be designed in accordance with DIN EN 1993 (EC3). Execution and fabrication of structural steel shall be in accordance with DIN EN 1090.

Execution class is EXC 2 and partly EXC 3 according to DIN EN 1090-2.

European section tables shall be used.

Mainly used material grade is S235 according to DIN EN 10025.

All structural calculations are in line with Eurocode EN 1090 and EN 1091.

Corrosion protection method for steel elements is a workshop applied 3-layer coating system C5.01 according to specification &AE 2000-TSS 2301(EN).

On-site connections shall be bolted (stainless material), welding on-site should be avoided.

6 Civil design principles

6.1 Site Clearance

It is assumed that the site is handed over with a natural ground level of approximately +1.40m as shown in sounding diagrams of the geotechnical report. A more detailed topographical survey is currently not available and shall be carried out at the latest prior start of construction work.

The site is to be cleared of vegetation and be roughly levelled and compacted for construction works. A safe working platform for piling rigs shall be achieved by a structural backfill layer according to a recommendation of the geotechnical consultant.

The construction area will be assured to be free of underground structures except for the area identified by hand-digging surveys by YARA in September 2022 (16471-Y56-00010.dwg).

Pre-existing contamination of the site being identified by the geotechnical survey will require decontamination to be agreed upon with Dutch authorities by YARA and shall be disposed of at YARA's cost.

Any delays due to unknown underground structures and contamination to the schedule must be fairly assessed.

The construction area will be munitions-free as well as free of the rights of third parties.

Linde will be responsible for setting out the construction site from set-out points identified by YARA.

An additional and more detailed geotechnical investigation of the construction area shall be carried out.

6.2 Plant Level / Earthworks / Excavation

Elevation of final plant surface:	+1.70 m NAP (HPFS = High Point Finishing Surface)
Elevation of existing plant roads:	ca. +1,50m NAP
Maximum ground water level:	+1,00 m NAP +/- 0,5 m variations (to be verified!)
Frost depth:	0,7m below grade

Based on available geotechnical investigations (CPT data only) done by VAN DER STAATEN company in July 2021, LINDE involved Geotechnical Consultant BAUGRUND DRESDEN (BGD) for further evaluation of soil conditions during the FEED phase. BGD report (refer to 0542FA5740 2000 C-RT 1001 (EN)) will determine

the bearing capacities of piles and provide further geotechnical recommendations as a basis for FEED calculations.

For a complete assessment of soil conditions on site further geotechnical investigations are required connected to a more detailed report by geotechnical expertise prior start of Detail design.

CPT values on site indicate soft soil layers (clay, silt…) in the upper circa 10m of soundings. Down drag is an effect up to the first solid sand layer of min. 250 mm thickness with a min. qc = 10 MPa average. Site Specification (16471-B45-00103, cl. 2.5.1) defines a maximum soil bearing capacity of 50 kN/m^2 which needs further confirmation. Until the results of further geotechnical investigations are available, it will be assumed that the plant will require piled foundations.

Dewatering measures will have to be considered for site execution. A functional description of dewatering measures shall be provided by Geotechnical Consultant.

Backfilling shall be carried out according to recommendations given in the geotechnical reports and will be differentiated by structural fill and general fill. Test (mainly for compaction) as required in the specifications shall be carried out during backfill, layer by layer.

Flooding scenarios up to 2.1 m NAP as forecasted in report “Bepaling gemiddelde waterdiepte tijdens overstroming Yara Sluiskil B.V.” (2016) will cause transient load conditions for lightweight objects exposed to buoyancy.

6.3 Foundations/Soil Improvement

The deep foundation design shall follow the results of geotechnical investigations and regulatory requirements stated above.

Displacement piles (e.g., type FUNDEX) are to be considered for deep foundation design. Currently FUNDEX pile types 38/46 and 46/ 56 are considered with 15m length in process area and 26m length in tank area.

The bottom of pile capes or single foundations shall be ca. 800mm below grade.

Protective coating of foundations shall be applied as specified in the project specifications.

Foundation design shall comply with the appropriate project specifications and must consider demand on settlements. Total settlements shall be limited up to 25mm and differential settlements to half of the total.

6.4 Concrete/Reinforcement

The design and calculations of reinforced concrete structures shall be based on the relevant Design of Concrete Structure Specification.

Most concrete parts are to be cast in situ. Prefabricated elements are to be applied depending on project requirements and local availability.

Reinforced structural concrete is to be used with cylinder strength (compression) of 35 N/mm2 as required in the project specifications. Lean concrete and blinding for non-reinforced concrete are in the strength of 12 N/mm2 (after 28 days).

Concrete mix design and related Exposure Categories shall be in accordance with Eurocode. Furthermore, the concrete mix shall be designed for durability taking full account of the environment to which it will be subjected; the chemical composition of the soil and the corrosiveness of the atmosphere and/or atmospheric pollution.

Supply is from local ready-mix subcontractors with local aggregate and cement.

Reinforcement shall be with a yield/ultimate strength of 500/550 N/mm2.

Supply of anchoring facilities will be an integral part of foundations, setting of anchor bolts and grouting of equipment bases, base plates, etc. Design and material definition of these parts to follow project specifications.

Normal non-shrink cement grout with general technical approval will be used for steel structures and equipment grouting. Epoxy grout might be required by a machine vendor.

6.5 Underground Constructions

Underground installations for surface run-off water drainage shall be provided. A sewer system for Process water is not needed for the CCS plant.

ISBL gravity drainage systems for surface run-off water from roofs and paved areas shall be by means of concrete channels and underground piping. Road inlets, catch basins, manholes/inspection shafts will be parts of the system.

Dewatering elements like gutter and downspouts are made of stainless steel according to YARA specifications.

The ISBL run-off water systems of the process plant area will tie in the existing plant drainage line (BØ400) at the plant's Northern side in between MH 22215 and MH22214 at an invert elevation not higher than +0,25 NAP (according to YARA's sewer survey done in October 2022). The small, paved area around the CO2 pumps of the storage area shall be drained into MH22408.

Stormwater in gravel areas will percolate into the ground.

The contractor will provide maximum flow rates to be expected from new drainage facilities for YARA's own capacity check of the existing sewer system.

ISBL sewer system shall be able to discharge the assumed fire water supply rate by 2 x 96m3/h by the two hydrants close to new process area. Firewater coming from the water mist skid inside the machine hall with a supply rate of 46m3/h for 20min shall be retained inside the building.

Further plant safety demands require the retention of oil leakages and water-glycol spillage in ISBL sewer system for manual disposal. Design of building parts of such accidentally contaminated run-off systems or liquid-retaining structures shall avoid any hazardous impact on the environment.

For that reason, drainage lines coming out from Machine Hall or oil retention pits below oil transformers (85TR05, 85TR06) will be blocked by a normally closed control valve (N.C. valve). Any retained contaminated water upstream shall be disposed of manually. If probes of retained water do not indicate contamination, valves must be opened manually by an operator for further discharge via an oil separator. The oil separator shall be equipped with a sedimentation device (2500l), and retention volume of hydrocarbons (690l) using a wear-free coalescence device with automatic closure. The first manhole joining the separator downstream shall be used as the sampling shaft.

The calculation of rainwater amount to be retained in bonded areas shall be based on 24-hour rainfall.

Underground cable distribution, if needed, shall be done via conduits (6" Ø). Conduits at crossing points with plant traffic routes shall be encased by concrete (duct bank).

Underground grounding facilities, inside and outside of concrete foundations, are part of electrical design work.

6.6 Paving and Roads

Paving is foreseen for all areas of equipment where spillages are anticipated during normal operating conditions and for areas where access for operation and maintenance is required.

The tank storage area shall not be paved, except the area around CO2 pumps where maintenance is anticipated.

All paved areas shall slope away from equipment/pipe ways and drain to the appropriate system. Curbed areas shall be provided where potentially contaminated liquids are to be retained. Retained stormwater shall be probed after each rain event and if there is no contamination the operator shall drain off the retained stormwater by means of a sluice gates or gate valve.

Structural concrete is to be used for paving with minimum cylinder strength (compression) of 25 N/mm2.

Unless they are not part of foundation base slabs/beams, other paved areas shall also be reinforced concrete slabs. The remaining unpaved areas are to be finished by a 15cm gravel layer on geotextile to avoid future vegetation.

Unless the pending Lifting and Maintainability study does not require higher loads, the paving design shall consider forklift traffic with 5 t lifting weights and corresponding wheel loads of 7 t.

The access road to the machine compressor house is exposed to heavy traffic loads and shall have an asphalt finish. Road design shall consider truck loads up to 60t with corresponding wheel loads of 10 t.

All operational/maintenance loads above the traffic loads considered in design will be distributed by spreader plates/ beams during the time of transport/operation.

Subbase definition of roads and paved areas shall consider the load level above and shall be non-frost material.

Slope conditions of paved areas shall follow project specifications.

1.2 m wide walkways to access points of buildings shall be paved with concrete cobblestones and be bordered with a curbstone.

7 Object description

New plant contains three construction areas in an existing chemical industrial complex. Process area (chapter 7.1), Tank area (chapter 7.2) and ship loading area (chapter 7.3).

7.1 Process Area

To process area belong following main objects: Machine Hall; Area with equipment structures, Pipe rack, Air cooler Area, E&I Container Area, and Transformer Area. These areas are described in following sub-chapter 7.1.1; 7.1.2; 7.1.3; 7.1.4.; 7.1.5, and 7.1.6.

7.1.1 Machine hall

Machine hall is a metal building consisting of a framing system with braces for stability of the structure. It is a one-story-building with a double pitch roof. Load bearing structure will be founded on reinforced concrete pile caps supported on piles.

Preliminary dimensions for machine hall are:

Eaves Height: 13 m

Width (CL): 16 m

Length (CL): 45 m

Main loadbearing elements are executed in EXC 3.

Insulated cladding acc. to YARA specification of the machine hall provide protection against sun, wind, and rain as well noise protection (33 dB). Parts of the cladding are designed as explosion release panels. One gate (roll-up door) and four escape metal doors are foreseen. Windows are not planned. Openings for cable entries, ventilation system with air inlet and air outlet will be designed in walls and roof.

Current design of Machine house considers one special sized (5 m x 5 m) gate (likely roll-up door) and four escape metal doors. Windows are not planned. Translucent elements will be foreseen according to YARA specification. Access to roof will be given via ladder access. Fall prevention system is foreseen.

All material used for wall and roof covering shall be flame resistant or non-flammable. Any further passive fire protection to steel structure elements is not planned. The machine house will have a fire and gas detection system.

For erection case, a part of the roof structure is designed as an erection opening.

Cable- and pipe supports will be connected outside and also inside of the hall.

One Overhead non-ex crane is foreseen. Lifting capacity ~ 40 t. Crane beam (EXC 3) with crane rail (S355).

Machine foundations for CO2 and NH3 compressors are exposed to dynamic vibrations and are therefore separated from the foundations of the Machine Hall and floor slab by sealed expansion joints. Compressor foundations are table foundations consisting of R.C. base slabs supported on piles, columns, and elevated

slabs. Foundation design for heavy machinery shall ensure natural frequencies are out of the range of 0,8 to 1,2 times of operating frequency and vibration amplitudes/velocities are within acceptable limits of requirements by machine vendor and definitions of project specifications.

The floor slab shall be structured in concrete beamed slabs supported on piles. The entire floor area will provide the required retention volume for fire water released by the water mist system (ca. 16m^3 resulting from 48m^3/h for 20min) or accidentally oil leakages from machinery. Therefore, a curb wall at the floor perimeter line shall be installed and the threshold elevation of access gates and doors is to be 5cm higher than the floor level inside and grade level outside. Ramps are to be provided for easy accessibility at doors and gates. Floor washing requirements by YARA require disposal of wash water via a sloped floor slab to drain gutters and an oil separator. The underground drainage line out of the building shall have a normally closed control valve that shall be manually opened for floor-washing purposes.

Floor finishing of the machine hall shall be done by steel trowelling with a hardening additive and will have an epoxy coating. The area of escape ways inside the building shall get an anti-slip finishing (slip resistance R12, V4 according to BGR 181).

Lay down area of the overhead crane between to compressor foundations shall be designed with the same traffic loads considered for road access outside the building.

To prevent damage from mechanical impact by plant operation the 1.5m high bottom part of exterior walls is to be protected by reinforced concrete sandwich panels.

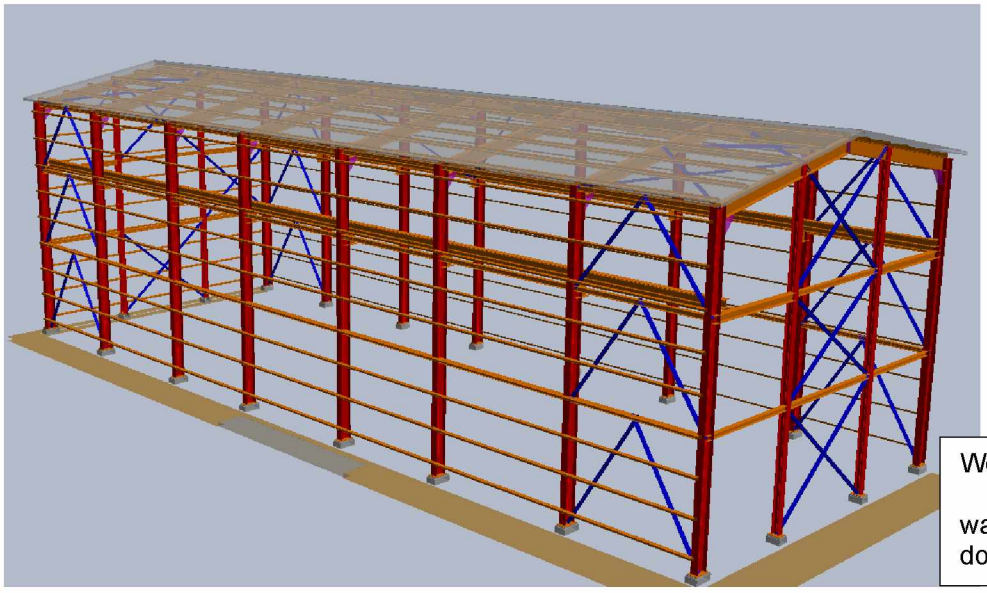
Gutters and pipes for the discharge of storm water will be designed based on the local regulations and prevailing weather conditions.

The building shall be equipped with a lightning protector. On each corner column a clip for earthing connection shall be provided.

Mechanical forced ventilation system provides the required air exchange rate and compensate the heat emission generated by the installed equipment. Fresh air will be sucked in via silencers. All air intakes and outlets of the buildings shall be placed at high level. Exhaust air will be extracted by roof fans. The fan housing is made of seawater-resistant aluminium. The base frame and built-in bird protection grille of the fan are made of galvanized sheet steel, the inlet nozzle is made of copper.

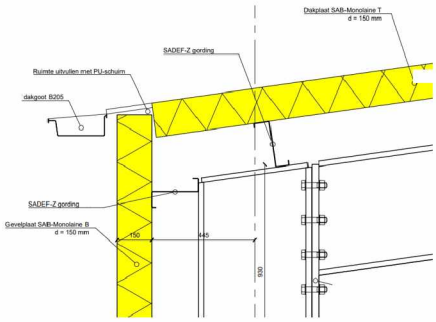
Acc. to &AE-S-PC 1003, at least 3 air changes per hour are to be provided. The emergency air exchange rate is “15” as per EN378-3.

According to the Site Specification (doc. no. 16471-C50-00001), the ventilation system is designed to keep the room temperature at +40°C at an outside temperature of +30°C (equivalent to +45°C inside @ambient +35°C) with plant in operation. Heating is foreseen to ensure minimum temperature of 5°C in case of plant shutdown. Air conditioning components are not provided.



Working status, not detailed

wall cladding, gates and doors not shown



Example of roof to wall connection from authority drawing

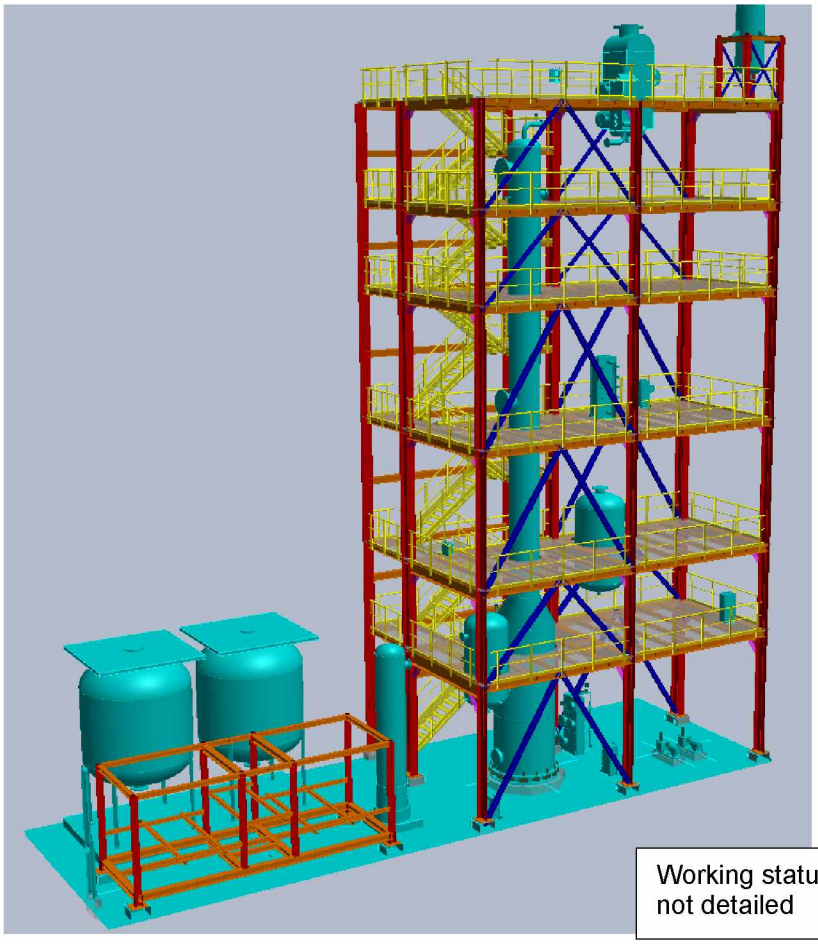
7.1.2 Equipment Structures, Top-Platforms on vessels

Main equipment structure for vessels- and pipe supports has six levels and is designed as a combination of rigid frames and truss-braces as stabilizing elements. Structure is reachable by staircase and a second ladder escape way. Accessible areas will be covered with grating and are equipped with railing.

Preliminary dimensions of the equipment structure are:

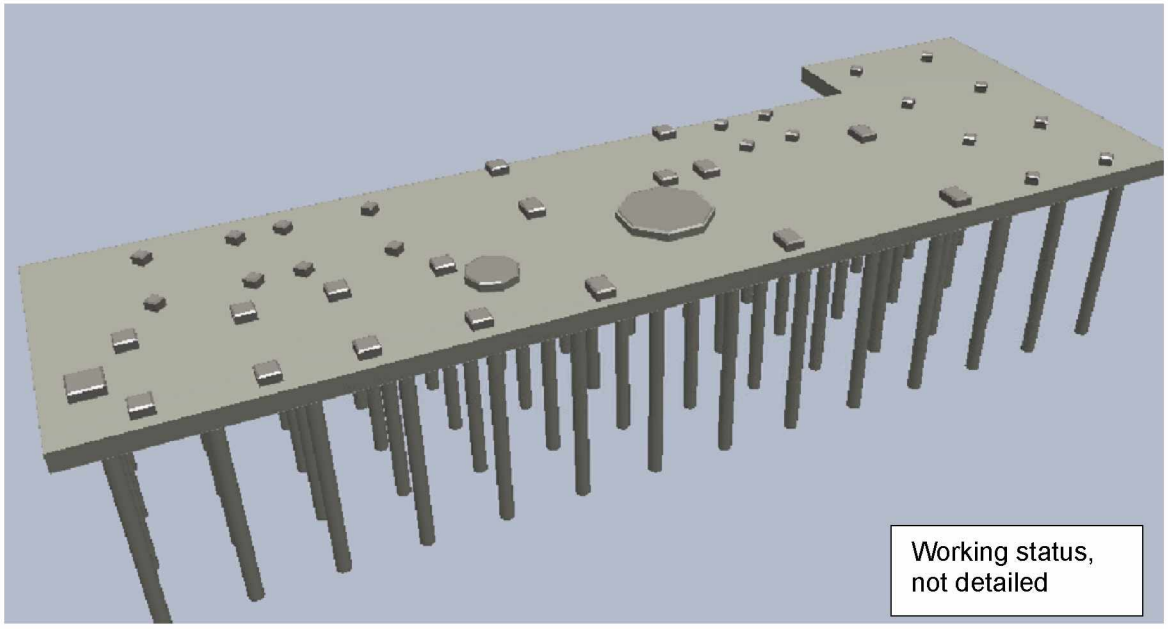
Height: 24 m
Width (CL): 5 m (+ staircase)
Length (CL): 12 m

Next to the equipment structure are top platforms on two vessels with ladder access and a small process structure. A transition walkway to air cooler platform shall be foreseen.



Working status, not detailed

The central part of CCS plant with steel structures, staircase, equipment and interconnecting piping and cabling shall be founded on a big R.C. raft foundation supported on piles. Bottom of raft foundation shall be -1,0m below grade level. Upper surface of raft foundation will serve as paving slab and shall be sloped towards the road inlet point at plant North side. Several pedestal on top of foundation will be required for steel structure and equipment supports.

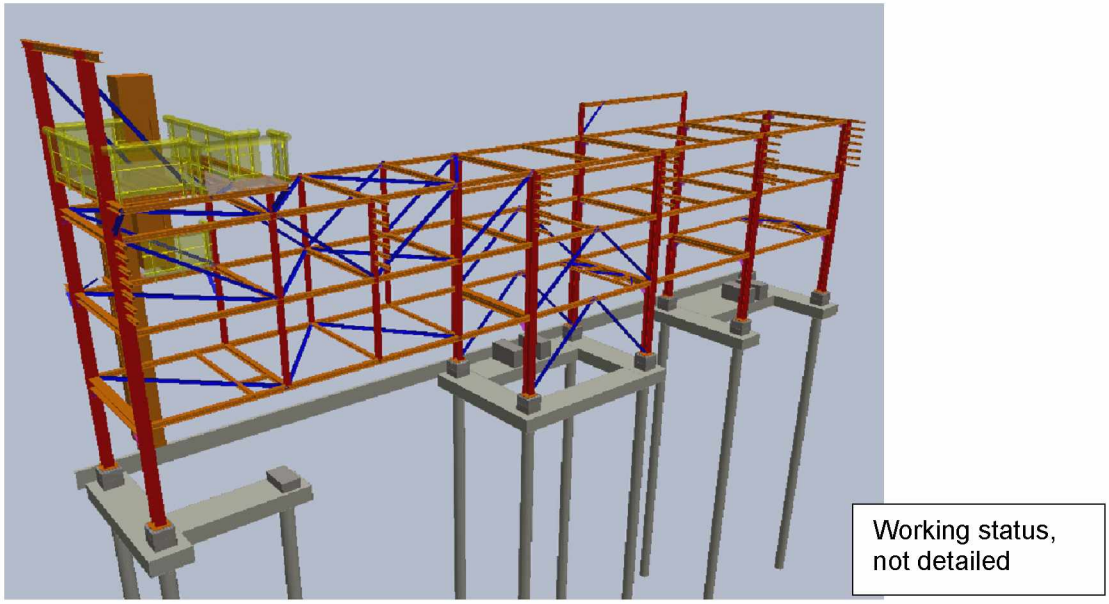


7.1.3 Piperack

Main-pipe rack for the plant has three levels, it is 4 m width, 8 m high and approximately 32 m long. It is a combination of rigid frames and truss-braces as stabilizing elements. Piperack has an operation platform accessible by ladder and covered with grating and equipped with railing.

Piperack do not have a connection to YARA piperack. This possibility will be investigated during detail design.

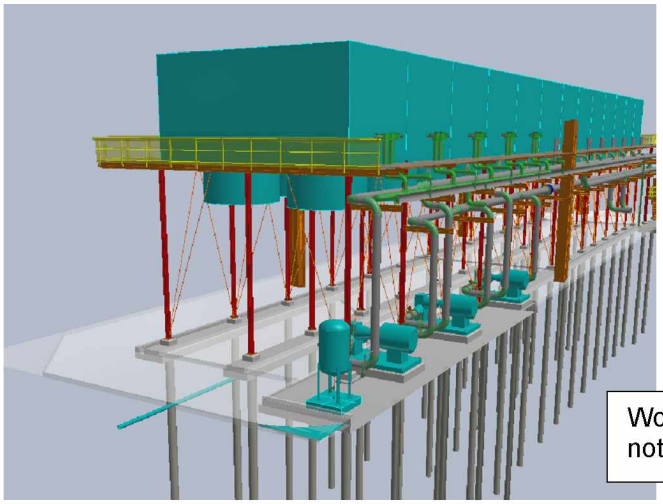
Steel columns of pipe rack are supported by pile caps resting on piles. Additional foundation beams for pumps or pipe supports are connected to pile caps.



7.1.4 Air cooler Area

Air coolers (E613 & E605) shall be supported via foundation beams on piles. Foundation beams will provide brackets to support paving slabs in between. The Foundation beam on the plant North side of air coolers shall have an integrated drainage trench to collect run-off. The top of the foundation beams will also serve as sloped plant paving and require proper surface finishing (steel trowelling). In the area of Cooling Water pumps foundation beam is enlarged to provide the same support conditions to minimise without any differential settlements. In addition, several concrete pedestals for steel columns of equipment are to be installed on top of the foundation beams.

According to “Overall Process and Environmental Safety Concept” (&AE-S-PC 1003 (EN)) process areas in which substances hazardous to water will be used (e.g., water-glycol-mixture or lube oil of machinery) shall be paved and diked. Therefore, area of cooling water pumps and air coolers serving cooling water (E605) will have to be paved and curbed. Disposal of retained water shall be done via slide gate valve to be manually opened in case no contamination has been probed.



Working status, not detailed

7.1.5 E&I Container Area

Supports of E&I containers consist of an upper R.C. columns (T.O.C. +2,0m above grade) supported on the foundation ring beams on piles.
Concrete slabs shall pave the floor of the cable basement below containers. Access platforms are made of steel with stair access, grating and railing.

7.1.6 Transformer Area

Dry transformers (MV/LV) are installed on a foundation base slab supported on piles. A half-open shelter covered with non-insulated cladding protects the compressors, open sides get metal fence with two doors (see following picture as an example).
Concrete pedestals on the slab support the steel shelter. Small curb walls are to be installed at the closed side walls of the shelter.

Oil transformers (MV/MV) shall rest on a concrete pedestal located within an oil retention pit made from concrete. The sloped foundation base slab is supported on piles. The pit shall be equipped with a floor drain and an N.C. control valve (Normally Closed) downstream to catch potential oil leakages. But also, stormwater will be retained inside pits and need to be manually disposed of by opening the N.C. valve. Concrete walls (2h fire resistant, ca. 6 to 8m high) will enclose 3 sides of transformer boxes.

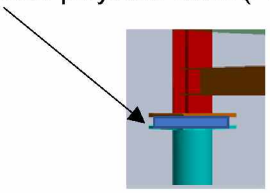
The pedestal shall be surrounded by a painted structural steel substructure on which stainless steel gratings are resting.

On top of these gratings course, gravel shall be placed. The pit shall be coated on the inside with an oil resistant coating.

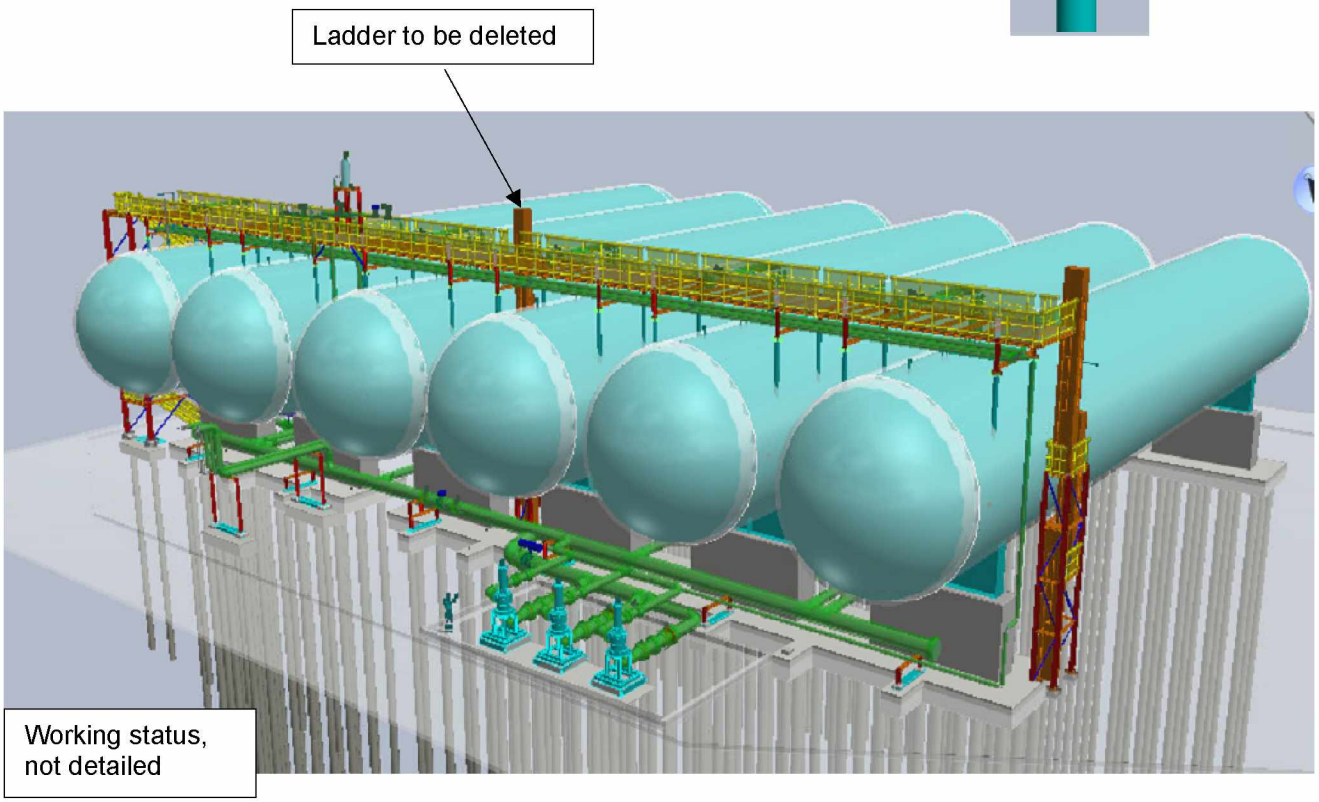
7.2 Storage Tanks Area

On six storage tanks an operation walkway is located above the tanks and is supported by the tanks. It is accessible by one stair staircase and two escape ladders ways. Walkway is in a height of approximate 14 m; it is 3 m wide and 64 m long.

To avoid thermal bridges insulation pads, made of hardwood or fibre-reinforced polyester resin (FRP), will be installed at the interface between tank and platform.



In addition, pipe supports are foreseen in this area.



CO2 storage tanks are supported on two saddles (fixed and sliding saddle). Saddles are supported by large concrete pedestals on common foundation beam and on piles.

Due to high equipment loads under operation larger displacement piles then in process area are expected. Minor equipment, like CO2 pumps, and sleeper for pipe supports are also supported on piles to avoid unacceptable differential settlements in between these building parts.

Existing underground installations between storage tanks SR602 and SR603 shall be considered in foundation design.